

***Programme of Exploiting Heating and Cooling
Efficiency Potential for 2016-2030***

**Ministry of the Economy
November 2015.**

TABLE OF CONTENTS

TABLE OF CONTENTS	2
LIST OF ABBREVIATIONS	10
SUMMARY	12
1. POTENTIAL FOR THE DEVELOPMENT OF DISTRICT HEATING AND COOLING THERMAL SYSTEMS BASED ON INCREASE IN ENERGY CONSUMPTION	14
1.1. AIDE-MEMOIRE ON THE CROATIAN DISTRICT HEATING SECTOR.....	14
1.2. ANALYSIS OF THE CURRENT SITUATION IN THERMAL ENERGY GENERATION, DISTRIBUTION AND SUPPLY.....	16
1.2.1. HEP Toplinarstvo d.o.o., Zagreb	17
1.2.2. Gradska Toplana d.o.o., Karlovac	18
1.2.3. Tehnostan d.o.o., Vukovar	19
1.2.4. Grijanje Varaždin d.o.o./Vartop d.o.o./Grijanje Univerzal d.o.o., Varaždin	20
1.2.5. Plin VTC d.o.o., Virovitica	20
1.2.6. Stambeno Komunalno Gospodarstvo d.o.o., Ogulin	21
1.2.7. Energo d.o.o., Rijeka	22
1.2.8. Brod-Plin d.o.o., Slavonski Brod	23
1.2.9. GTG Vinkovci d.o.o., Vinkovci	24
1.2.10. Termalna Voda d.o.o./Top-Terme d.o.o., Topusko	24
1.3. ANALYSIS OF THERMAL ENERGY CONSUMPTION	25
1.4. OPPORTUNITIES AND CHALLENGES FOR FURTHER DISTRICT HEATING SYSTEM DEVELOPMENT .	27
1.5. USE OF NEW TECHNOLOGIES IN HEAT GENERATION FOR DISTRICT HEATING SYSTEMS.....	28
1.6. ANALYSIS OF DISTRICT COOLING SYSTEMS	29
2. FORECAST CHANGES IN ENERGY CONSUMPTION FOR HEATING AND COOLING UNTIL 2030	30
2.1. FINAL ENERGY CONSUMPTION IN THE REPUBLIC OF CROATIA.....	30
2.2. STARTING POINTS.....	30
2.3. ANALYSIS OF HOUSEHOLD SECTOR ENERGY CONSUMPTION	32
2.4. PROJECTED FUTURE USEFUL THERMAL ENERGY CONSUMPTION IN THE HOUSEHOLD SECTOR....	34
2.5. ANALYSIS OF SERVICE SECTOR ENERGY CONSUMPTION	39
2.6. PROJECTED FUTURE USEFUL THERMAL ENERGY CONSUMPTION IN THE SERVICES SECTOR	40
2.7. ANALYSIS OF INDUSTRY SECTOR ENERGY CONSUMPTION	41
2.8. PROJECTED FUTURE USEFUL THERMAL ENERGY CONSUMPTION IN THE INDUSTRY SECTOR	44
2.9. THERMAL ENERGY AND COOLING ENERGY CONSUMPTION MONITORING	45

2.9.1.	Energy consumption monitoring at the level of Croatia.....	45
2.9.2.	Energy efficiency monitoring at the level of counties, municipalities and cities	46

3. MAP OF CROATIA SHOWING THE LOCATIONS OF THERMAL ENERGY CONSUMPTION _____ 47

3.1.	CARTOGRAPHIC DATA	47
3.2.	CARTOGRAPHIC REPRESENTATIONS.....	47

4. DETERMINING THERMAL ENERGY DEMAND WHICH CAN BE MET THROUGH HIGH-EFFICIENCY COGENERATION _____ 70

4.1.	OVERVIEW OF TECHNOLOGIES ACCEPTABLE FOR USE IN DISTRICT HEATING AND DISTRICT COOLING SYSTEMS	70
4.1.1.	Levels of thermal supply centralisation.....	70
4.1.1.1.	General.....	70
4.1.1.2.	Centralisation at the residential building level	71
4.1.1.3.	Group of buildings level.....	71
4.1.1.4.	Settlements and city districts	71
4.1.1.5.	Multi-settlement network.....	72
4.1.1.6.	DHS at city level.....	72
4.1.1.7.	DHS of city and surrounding settlements.....	73
4.1.1.8.	Further characteristics	73
4.1.2.	DHS and cogeneration	73
4.1.2.1.	Basic characteristics of cogeneration	73
4.1.2.2.	Types of cogeneration installations	75
4.1.2.3.	Special cases of cogeneration processes.....	79
4.1.3.	Characteristics of district cooling	81
4.1.3.1.	DHS district cooling	81
4.1.3.2.	Characteristics of district cooling using cooling water distribution ...	83
4.1.3.3.	Application of DHS – DH and DC – suitable building types	83
4.2.	PROJECTIONS OF HEATING CONSUMPTION DEVELOPMENT, AND DETERMINING HIGH-EFFICIENCY COGENERATION POTENTIAL	83
4.2.1.	Definitions.....	83
4.2.2.	Heat consumption development until 2030	84
4.2.2.1.	Characteristics of settlements	84
4.2.2.2.	Household projections.....	85
4.2.2.3.	Industry projections.....	85
4.2.2.4.	Service sector projections.....	85
4.2.2.5.	Position of district cooling capacities	85
4.2.2.6.	Potential by the year 2030.....	86

5. IMPACT OF ELECTRICITY, GAS, THERMAL ENERGY AND RENEWABLE ENERGY SOURCE MARKETS _____ 87

5.1.	INTRODUCTION TO THE ENERGY MARKET IMPACT.....	87
5.2.	ELECTRICITY IMPACT	87
5.2.1.	Impact of electricity price on thermal energy production	87

5.2.2.	Impact of electricity price on the choice of centralised system	87
5.3.	IMPACT OF NATURAL GAS PRICE	87
5.3.1.	Impact of natural gas price on thermal energy production	87
5.3.2.	Impact of gas price on the choice and use of district heating systems	88
5.4.	IMPACT OF RENEWABLE ENERGY SOURCES, BIODEGRADABLE AND MUNICIPAL WASTE	89
5.4.1.	Impact of renewable sources, biodegradable and municipal waste on thermal energy production	89
5.4.2.	Impact of renewable sources on the choice of district heating system	90
5.5.	THERMAL ENERGY MARKET	90
5.6.	CONCLUSION	90
6.	<i>DETERMINING THE POTENTIAL FOR ADDITIONAL HIGH-EFFICIENCY COGENERATION</i>	<i>91</i>
6.1.	INTRODUCTION	91
6.2.	CURRENT CONDITION OF THERMAL ENERGY FACILITIES AND INDUSTRIAL POWER PLANTS	92
6.2.1.	Zagreb electricity/heating plant (EL-TO Zagreb).....	92
6.2.1.1.	Block A	93
6.2.1.2.	Block B	93
6.2.1.3.	Blocks H and J	94
6.2.1.4.	Auxiliary units.....	95
6.2.1.5.	Planned replacement of existing units in EL-TO Zagreb	96
6.2.2.	Zagreb thermal power/heating plant (TE-TO Zagreb).....	96
6.2.2.1.	Block C	97
6.2.2.2.	Block K	98
6.2.2.3.	Block L.....	99
6.2.2.4.	Auxiliary units.....	100
6.2.2.5.	Planned replacement of existing units in TE-TO Zagreb	100
6.2.3.	Osijek thermal power/heating plant (TE-TO Osijek)	101
6.2.3.1.	GPP block	101
6.2.3.2.	45 MW block	102
6.2.3.3.	SBK block.....	104
6.2.4.	Sisak Thermal Power Plant (TE Sisak)	104
6.2.4.1.	Blocks A and B.....	104
6.2.4.2.	Block C – under construction.....	104
6.2.5.	Belišće d.o.o. Belišće	105
6.2.5.1.	Cogeneration facility	107
6.2.5.2.	Process steam generation facility.....	108
6.2.5.3.	Power plant	108
6.2.5.4.	Water management	108
6.2.5.5.	Potential for further development	109
6.2.6.	Petrokemija d.d. Kutina	109
6.2.6.1.	Cogeneration facility	110
6.2.6.2.	Water management	112
6.2.6.3.	Potential for further development	113
6.2.7.	INA Rijeka Oil Refinery.....	114

6.2.7.1.	Cogeneration facility	115
6.2.7.2.	Water management	118
6.2.7.3.	Potential for further development	118
6.3.	ANALYSIS OF THE APPLICATION OF HIGH-EFFICIENCY COGENERATION IN THE EXISTING THERMAL ENERGY FACILITIES AND INDUSTRIAL POWER PLANTS	119
6.3.1.	Existing thermal energy facilities	120
6.3.1.1.	EL-TO Zagreb	120
6.3.1.2.	TE-TO Zagreb	121
6.3.1.3.	TE-TO Osijek	122
6.3.2.	Existing industrial power plants	124
6.3.2.1.	Belišće d.o.o. Belišće	124
6.3.2.2.	Petrokemija d.d. Kutina	124
6.3.2.3.	Rijeka Oil Refinery	125
6.4.	ANALYSIS OF POTENTIAL NEW LOCATIONS FOR HIGH-EFFICIENCY COGENERATION	126
7.	DETERMINING THE POTENTIAL TO INCREASE INFRASTRUCTURE ENERGY EFFICIENCY	129
7.1.	INTRODUCTION	129
7.2.	ANALYSIS OF THE CURRENT CONDITION OF ENERGY INFRASTRUCTURE	129
7.2.1.	Samobor	130
7.2.2.	Zaprešić	130
7.2.3.	Velika Gorica	130
7.2.4.	Sisak	130
7.2.5.	Kutina	130
7.2.6.	Karlovac	131
7.2.7.	Ogulin	131
7.2.8.	Varaždin	131
7.2.9.	Rijeka	131
7.2.10.	Virovitica	132
7.2.11.	Slavonski Brod	132
7.2.12.	Osijek	132
7.2.13.	Belišće	132
7.2.14.	Vukovar	133
7.2.15.	Zagreb	133
7.3.	COMMENT ON ENERGY EFFICIENCY	136
7.4.	COMMENT ON THE TECHNICAL AND TECHNOLOGY CHARACTERISTICS OF INSTALLATIONS AND HEATING NETWORKS	136
7.1.	COMMENT ON THE POTENTIAL TO INCREASE ENERGY EFFICIENCY OF THE EXISTING INFRASTRUCTURE	143
7.2.	IN LIEU OF A CONCLUSION	144
8.	STRATEGY, POLICIES AND MEASURES	145
8.1.	INTRODUCTION	145
8.2.	ACQUIS COMMUNAUTAIRE	145

8.2.1.	Directive 2004/8/EC on the promotion of cogeneration based on useful heat demand in the internal energy market	145
8.2.2.	Directive 2012/27/EU on energy efficiency	145
8.2.3.	Directive 2010/31/EU on the energy performance of buildings	146
8.2.4.	Directive 2009/28/EC on the promotion of the use of energy from renewable sources	146
8.2.5.	Directive 2010/30/EU concerning the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products.....	146
8.2.6.	Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control).....	146
8.3.	LEGAL FRAMEWORK OF THE REPUBLIC OF CROATIA.....	147
8.3.1.	Thermal Energy Market Act	147
8.3.2.	General Terms and Conditions of Thermal Energy Supply	148
8.3.3.	General Terms and Conditions of Thermal Energy Delivery	149
8.3.4.	Network Rules of Thermal Energy Distribution	149
8.3.5.	Rules on the method of cost allocation and billing for thermal energy delivered	149
8.3.6.	Decree on the amount and method of payment of a concession fee for heat distribution and a concession fee for the construction of heat distribution energy facilities.....	149
8.3.7.	Methodology for determining tariff item amounts for thermal energy production	150
8.3.8.	Methodology for determining tariff item amounts for thermal energy distribution.....	150
8.3.9.	Energy Act	150
8.3.10.	Tariff system for electricity generation from renewable energy resources and cogeneration	151
8.3.11.	Decree on incentive fee for electricity generation from renewable energy resources and cogeneration.....	152
8.3.12.	Rules governing the use of renewable energy resources and cogeneration...	152
8.3.13.	Rules governing the grant of eligible electricity producer status	152
8.3.14.	Renewable Energy Sources and High-Efficiency Cogeneration Act.....	152
8.3.15.	Environmental Protection and Energy Efficiency Fund Act	153
8.3.16.	Energy Sector and Investment Monitoring Centre Act	153
8.3.17.	Energy Efficiency Act	153
8.3.18.	Decree on contracting and implementation of public sector energy service ..	155
8.3.19.	Rules of systematic public sector energy management.....	155
8.4.	STRATEGY AND PLANNING DOCUMENTS	155
8.4.1.	Sustainable Development Strategy	155
8.4.2.	Energy Development Strategy	155
8.4.3.	Croatia's Low-Emission Development Strategy – in the making	156
8.4.4.	National Renewable Energy Sources Action Plan.....	156
8.4.5.	National Energy Efficiency Programme for 2008-2016 (NEEP)	156
8.4.6.	National Energy Efficiency Action Plan (1, 2 and 3).....	156

8.5. BASELINES.....	157
8.5.1. Regulatory framework	157
8.5.2. Price and market impact	157
8.5.3. Determined potential	157
8.6. STRATEGIC GUIDELINES	158
9. HIGH-EFFICIENCY COGENERATION SHARE, POTENTIAL IDENTIFIED AND PROGRESS MADE	159
9.1. INTRODUCTION	159
9.2. HIGH-EFFICIENCY COGENERATION SHARE IN THE CONSERVATIVE SCENARIO OF DETERMINED POTENTIAL	160
9.2.1. Equivalent heat consumption and thermal input	160
9.2.2. Electrical component of high-efficiency cogeneration	161
9.3. HIGH-EFFICIENCY COGENERATION SHARE IN THE OPTIMISTIC SCENARIO OF DETERMINED POTENTIAL	163
9.3.1. Equivalent heat consumption and thermal input	163
9.3.2. Electrical component of high-efficiency cogeneration	164
9.4. PROGRESS MONITORING.....	165
10. ESTIMATE OF EXPECTED SAVINGS.....	166
10.1. INTRODUCTION	166
10.2. ANALYSIS OF THE EXISTING SITUATION	166
10.3. ESTIMATE OF FUTURE USEFUL ENERGY CONSUMPTION.....	167
10.4. ACHIEVING SAVINGS IN ENERGY CONSUMPTION.....	167
10.5. POTENTIAL ENERGY SAVINGS.....	168
10.5.1. Primary energy savings in the conservative high-efficiency cogeneration scenario.....	169
10.5.2. Primary energy savings in the optimistic high-efficiency cogeneration scenario	171
11. ESTIMATE OF PUBLIC SUPPORT MEASURES FOR HEATING AND COOLING	174
11.1. ANALYSIS OF RELEVANT REGULATIONS (TREATIES, DIRECTIVES, REGULATIONS AND GUIDELINES) ALLOWING THE GRANT OF STATE AID.....	174
11.1.1. Treaty on the Functioning of the European Union	174
11.1.2. Guidelines on State Aid for environmental protection and energy 2014-2020.....	175
11.1.3. Commission Regulation (EU) No 651/2014 of 17 June 2014 declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty on the Functioning of the European Union	176
11.1.4. Commission Regulation (EU) No 1407/2013 of 18 December 2013 on the application of Articles 107 and 108 of the Treaty on the Functioning of the European Union to <i>de minimis</i> aid	177
11.2. OVERVIEW OF POSSIBLE WAYS OF GRANTING STATE AID FOR DISTRICT HEATING AND COOLING	177

11.2.1.	State aid in accordance with the <i>de minimis</i> rules	177
11.2.2.	State aid under Regulation 651/2014, according to which certain categories of aid are compatible with the EU's internal market	177
11.3.	SPECIFIC NOTIFICATION	178
12. PLANS FOR DISTRICT HEATING SECTOR DEVELOPMENT _		179
12.1.	INTRODUCTION	179
12.2.	ANALYSIS OF DEVELOPMENT PLANS FOR EXISTING ENERGY OPERATORS IN THE HEATING SECTOR	179
12.2.1.	Annual thermal energy generation in 2012, 2013 and 2014	179
12.2.2.	Investments in heating systems implemented in 2012, 2013 and 2014	180
12.2.3.	Three-year development plans	181
12.2.4.	Analysis of the financial potential	183
12.3.	ANALYSIS OF SPATIAL PLANNING DOCUMENTS OF RELEVANCE TO HEATING SYSTEMS	185
12.3.1.	Zagreb County	186
12.3.1.1.	City of Velika Gorica	186
12.3.1.2.	City of Samobor	187
12.3.1.3.	City of Zaprešić	187
12.3.1.4.	City of Ivanić Grad	187
12.3.2.	Krapina-Zagorje County	187
12.3.2.1.	City of Krapina	187
12.3.3.	Sisak-Moslavina County	187
12.3.3.1.	City of Sisak	188
12.3.4.	Karlovac County	188
12.3.4.1.	City of Karlovac	189
12.3.5.	Varaždin County	189
12.3.5.1.	City of Varaždin	190
12.3.6.	Koprivnica-Križevci County	190
12.3.6.1.	City of Koprivnica	190
12.3.7.	Bjelovar-Bilogora County	191
12.3.7.1.	City of Bjelovar	191
12.3.8.	Primorje-Gorski Kotar County	192
12.3.8.1.	City of Rijeka	192
12.3.9.	Lika-Senj County	194
12.3.9.1.	City of Gospić	194
12.3.10.	Virovitica-Podravina County	194
12.3.10.1.	City of Virovitica	195
12.3.11.	Požega-Slavonia County	195
12.3.11.1.	City of Požega	196
12.3.12.	Slavonski Brod-Posavina County	196
12.3.12.1.	City of Slavonski Brod	197
12.3.13.	Zadar County	197
12.3.13.1.	City of Zadar	198
12.3.14.	Osijek-Baranja County	198
12.3.14.1.	City of Osijek	199

12.3.15. Šibenik-Knin County	199
12.3.15.1. City of Šibenik	199
12.3.16. Vukovar-Syrmia County	199
12.3.16.1. City of Vukovar	200
12.3.16.2. City of Vinkovci	201
12.3.17. Split-Dalmatia County	202
12.3.17.1. City of Split	202
12.3.18. Istria County	203
12.3.18.1. City of Pula	203
12.3.19. Dubrovnik-Neretva County	203
12.3.19.1. City of Dubrovnik	204
12.3.20. Međimurje County	204
12.3.20.1. City of Čakovec	204
12.3.21. City of Zagreb	204
12.4. FINAL OBSERVATIONS.....	205
13. FINAL OBSERVATIONS	208
14. ANNEXES	210
14.1. HEAT CONSUMPTION DEVELOPMENT UNTIL 2030 – POTENTIAL FOR HIGH-EFFICIENCY COGENERATION	210
14.2. RESULTS OF CALCULATION OF PREFERENTIAL ELECTRICITY PRODUCER STATUS	216
14.3. INFORMATION ON THE CURRENT ENERGY INFRASTRUCTURE CONDITION.....	220
14.3.1. Samobor	220
14.3.2. Zaprešić	221
14.3.3. Velika Gorica	222
14.3.4. Sisak	225
14.3.5. Karlovac	226
14.3.6. Ogulin	228
14.3.7. Varaždin	229
14.3.8. Rijeka	232
14.3.9. Virovitica	234
14.3.10. Slavonski Brod	236
14.3.11. Osijek	240
14.3.12. Vukovar	241
14.3.13. Zagreb	242
15. LIST OF FIGURES	248
16. LIST OF TABLES	251
17. REFERENCES	253

LIST OF ABBREVIATIONS

ATMIP	Agency for Transactions and Mediation in Immovable Properties
BAU	Business As Usual
CBS	Croatian Bureau of Statistics
CCCGT	Cogeneration Combined Cycle Gas Turbine
CG	Croatian Government
CHS	Closed heating system
DHS	District heating system
DHW	Domestic hot water
EC	European Commission
ELEN	Electricity
ELFO	Extra light fuel oil
EPEEF	Environmental Protection and Energy Efficiency Fund
EIC	Energy Sector and Investment Monitoring Centre
EU	European Union
GAA	Governance and administration
GPP	Gas-turbine power plant
HEC	High-efficiency cogeneration
HERA	Croatian Energy Regulatory Agency
LEDS	Low-emission Development Strategy
LNB	Low NOx burners
LPG	Liquefied petroleum gas
LSGU	Local self-government unit
MAED	Model for Analysis of Energy Demand
MCPPI	Ministry of Construction and Physical Planning
MoE	Ministry of the Economy
MENP	Ministry of Environmental and Nature Protection
NEEAP	National Energy Efficiency Action Plan (1, 2 and 3)
NEEP	National Energy Efficiency Programme for 2008-2016
NREAP	National Renewable Energy Action Plan until 2020
Programme	Programme of Exploiting Heating and Cooling Efficiency Potential for 2016-2030
RoC	Republic of Croatia
RES	Renewable energy sources
SANI	State Aid Notification Software
SHS	Stand-alone heating system
TFEU	Treaty on the Functioning of the European Union

UNDP	United Nations Development Programme in Croatia
UNFCCC	United Nations Framework Convention on Climate Change

SUMMARY

The Thermal Energy Market Act, transposing into the Croatian energy legislation, *inter alia*, Directive 2012/27/EC on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, came into force in July 2013.

Articles 17 and 55 of the Act, in accordance with Article 14 of the Directive and Annex VII thereto, lay down the obligation for the Croatian Government to adopt a Programme of Exploiting Heating and Cooling Efficiency Potential for 2016-2030 (hereinafter referred to as: the Programme) by 1 July 2015.

Taking into account the requirements and complexity of this obligation, the Ministry of the Economy's Energy and Mining Directorate, Energy Sector found it necessary to define in a timely manner the Terms of Reference, detailing the Programme scope and content, and defining the grounds for the Programme development, the methodology and the time frame of its implementation, as well as to designate the persons responsible for various activities, that is, experts who will ensure quality implementation of specific tasks.

This study presents the Programme of Exploiting Heating and Cooling Efficiency Potential for 2016-2030 through the following topics:

Chapter 1 Potential for the development of district heating and cooling thermal systems based on increase in energy consumption

The chapter provides an overview of the current situation in the Croatian district heating sector, covering total energy consumption as well as the consumption of thermal energy in each of the existing heating systems. Furthermore, it gives a forecast of thermal energy consumption for three sectors by 2035. Challenges and opportunities for further development of district heating systems, along with potential application of new technologies for thermal energy generation are also presented. A short comment on district cooling systems is provided at the end of the chapter.

Chapter 2 Forecast changes in energy consumption for heating and cooling in the next 10 years

This chapter analyses energy consumption for heating and cooling by final consumption sectors (households, services and industry) for cities and municipalities with more than 10 000 inhabitants. Based on the current energy consumption figures and useful thermal energy needs, thermal energy needs for these sectors by 2030 are projected.

Chapter 3 Map of Croatia showing the locations of thermal energy consumption

This chapter provides a graphical representation of the distribution of thermal energy consumption on the map of Croatia. The data collected have been synthesised into a single common database, and factors relevant for the development of thermal energy consumption and market penetration of particular fuels have been identified. A graphical representation of thermal energy consumption indicators has been provided at the level of Croatian municipalities.

Chapter 4 Determining thermal energy demand which can be met through high-efficiency cogeneration

The chapter describes the characteristics of district heating and cooling energy supply systems, and provides an overview and the characteristics of heating and cooling energy generation technologies. Heat consumption development has been analysed and the projections of that development for relevant consumption sectors – households, industry and the service sector – by 2030 have also been provided. Prerequisites for potential introduction of high-efficiency cogeneration in district heating and cooling energy supply systems, by settlement, have been derived for consumption justifying capacities of at least 20 MW_t.

Chapter 5 Impact of electricity, gas, thermal energy and renewable energy sources markets

This chapter provides an analysis of natural gas, electricity and thermal energy markets, and of renewable energy sources and waste markets. It also identifies market barriers which might have a negative impact on the development and implementation of high-efficiency cogeneration projects.

Chapter 6 Determining the potential for additional high-efficiency cogeneration

The current condition of thermal energy installations is analysed in this chapter, as well as the potential to build new ones under the presumption that high-efficiency cogeneration will be used.

Chapter 7 Determining the potential to increase the energy efficiency of infrastructure

This chapter contains an analysis of the 'base' status of district heating systems and the entire infrastructure for thermal energy generation, distribution and supply. The relevant parameters of all thermal energy generation units are also analysed and documented, as are all district heating systems and corresponding heating stations.

Chapter 8 Strategy, policies and measures

The first part of this chapter provides an overview of the directives laying down specific measures regulating or affecting thermal energy generation/consumption for heating and cooling, as well as Croatia's relevant legal framework, including the applicable planning documents.

The second part provides strategic guidelines that should support the design of national energy and climate policies and measures, with regard to the DHSs' potential for heating and cooling and their contribution to the objectives of the relevant policies. The guidelines are based on the results obtained by analysing the potential for developing DHSs by increasing consumption.

Chapter 9 High-efficiency cogeneration share, potential identified and progress made

This chapter analyses the high-efficiency cogeneration share. The analysis covers two scenarios concerning the development of the share of future consumers in district heating systems by 2030. Measures for monitoring progress are also proposed.

Chapter 10 Estimate of expected savings

This chapter analyses the potential for primary energy savings by 2030, presuming the application of high-efficiency cogeneration. The potential is determined on the basis of two scenarios regarding the share of future consumers in the district heating system by 2030.

Chapter 11 Estimate of public support measures for heating and cooling

The chapter provides an overview of relevant legislation governing the allocation of state aid, followed by a presentation of three methods for allocating state aid and a particular state aid allocation method which might be suitable for this project.

Chapter 12 Plans for the district heating sector development

The chapter presents an analysis of the current situation in the district heating sector. It also provides an overview of physical plans and other available data, as well as a plan for the development of the district heating sector in all relevant cities.

Chapter 13 Final observations

The chapter presents final observations about the Programme.

1. POTENTIAL FOR THE DEVELOPMENT OF DISTRICT HEATING AND COOLING THERMAL SYSTEMS BASED ON INCREASE IN ENERGY CONSUMPTION

1.1. AIDE-MEMOIRE ON THE CROATIAN DISTRICT HEATING SECTOR

The district heating sector is regulated by the following legislation:

- Energy Act (*Narodne Novine* (NN; Official Gazette of the Republic of Croatia) Nos 120/12, 14/14, 95/15 and 102/15)
- Energy Efficiency Act (NN No 120/12)
- Thermal Energy Market Act (NN Nos 80/13, 14/14, 102/14 and 95/15),

and the following subordinate legislation:

- General Terms and Conditions of Thermal Energy Supply (NN No 129/06) – for the procedures initiated before 1 September 2014;
- General Terms and Conditions of Thermal Energy Supply (NN No 35/14) – for the procedures initiated after 1 September 2014;
- Tariff system for the services of thermal energy generation, distribution and supply, with no tariff amounts (NN Nos 65/07, 154/08, 22/10, 46/10, 50/10 and 86/11);
- Tariff system for the services of thermal energy generation and supply, with no tariff amounts (NN No 86/11);
- Decision on tariff item amounts in the Tariff system for heat generation, distribution and supply activities (NN No 154/08);
- Rules on the method of cost allocation and billing for thermal energy supplied (NN Nos 99/14 and 27/15);
- Rules on licences for energy activities and keeping the register of issued and cancelled licences for energy activities (NN No 88/15).

In Croatia in 2013, as the last year for which the data set out here were obtainable, 1 800 MW of thermal power was installed for the district heating sector needs and a total of 9 678 TJ of thermal energy was supplied to final customers. That energy was transported through distribution pipeline systems (hot water pipelines, pipelines, steam lines), 410 km in total length (unidirectional measurement). A total of 110 district heating systems¹ installed in the territory of Croatia supply thermal energy for space heating and domestic hot water generation to approximately 155 000 final customers. The following table provides an overview of the basic indicators relating to the district heating sector in recent years.

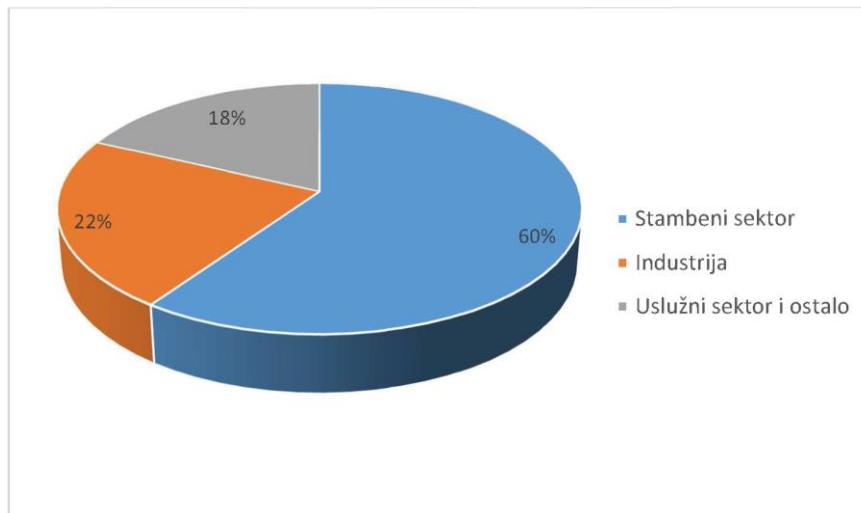
Table 1: Basic indicators relating to the Croatian district heating sector

Indicator	Unit	2009	2011	2013
Total installed thermal capacity	MW _t	1 800	1 800	1 800
Total distribution network length	Km	460	460	410
Number of district heating systems	Pcs	125	125	110
Total thermal energy delivered	TJ	9 550	9 980	9 678

¹ A district heating system denotes a distribution network with its own heat source which is technically independent of other networks.

The thermal energy generated by district heating systems is mostly delivered to households (about 60 %), while a smaller part is delivered to the industry (22 %) and service sector (18 %), as shown in the figure below. Of the total number of households in Croatia, 11 % are connected to a district heating system, accounting for 15 % of the total thermal energy consumption for heating and domestic hot water generation.

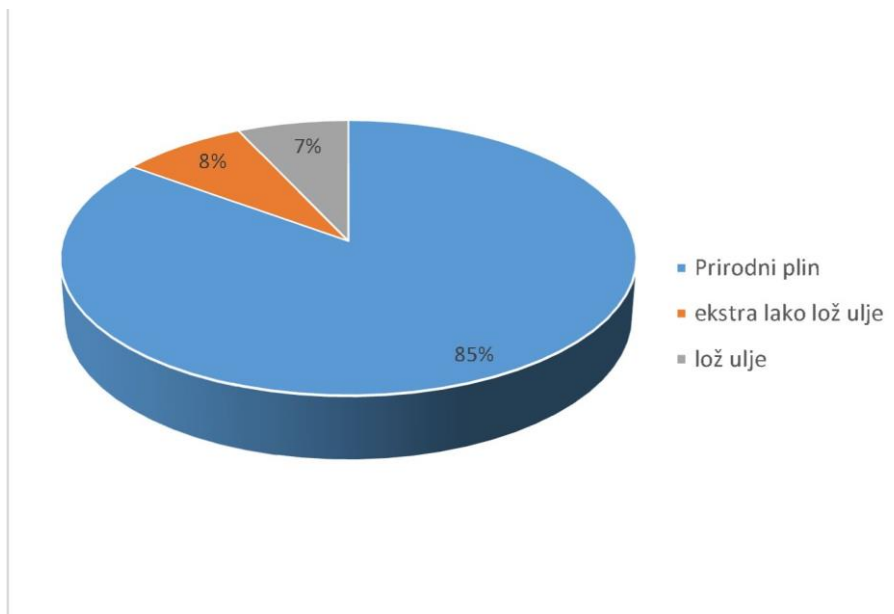
A graphical representation of the structure of thermal energy deliveries in Croatia in 2013 is provided in the following figure.



<i>Stambeni sektor</i>	<i>Housing sector</i>
<i>Industrija</i>	<i>Industry</i>
<i>Uslužni sektor i ostalo</i>	<i>Service sector and other</i>

Figure 1: Structure of thermal energy delivered in Croatia in 2013

As to the type of fuel used for thermal energy generation in the heating sector, natural gas is the predominant fuel, with extra light fuel oil and fuel oil contributing a smaller share to the total fuel mix. A graphical representation of fuel consumption by the type of fuel used in heating systems, excluding cogeneration units, is provided in the figure below.



<i>Prirodni plin</i>	<i>Natural gas</i>
<i>ekstra lako lož ulje</i>	<i>Extra light fuel oil</i>
<i>lož ulje</i>	<i>Fuel oil</i>

Figure 2: Share of fuels for thermal energy generation in the heating sector in Croatia in 2013 (excl. cogeneration units)

In 2013, district heating systems supplied thermal energy to 18 Croatian cities. Thermal energy was produced by cogeneration plants (in Zagreb, Osijek and Sisak), public heating plants, small heating plants and in block or home boiler rooms. Process steam was generated and distributed for industrial use in Zagreb, Osijek and Sisak. A detailed overview of energy operators in Croatia's district heating sector is provided in the table below.

Table 2: Data on energy operators in Croatia's heating sector in 2013

Company name	City	No of consumers	Heated area of households	Heated area of other consumers	Thermal energy delivered	Length of distribution network	Fuel **
		–	m ²	m ²	MWh	km	–
HEP Toplinarstvo d.o.o.*	Sisak	4 133	230 024	n/a	61 507	10	NG
	Osijek	11 692	602 063	n/a	180 702	56	NG, FO, ELFO
	Zagreb***	108 347	5 623 363	–	1 869 200	285	NG, FO, ELFO
Brod plin d.o.o.	Slavonski Brod	3 769	176 353	22 719	38 774	6	NG, FO
Plin VTC d.o.o.	Virovitica	483	23 517	6 613	3 430	1	NG
Hvidra d.o.o.	Split	908	62 864	1 711	2 204	1	FO, ELFO
Energo d.o.o.	Rijeka	10 010	537 776	42 908	73 639	16	NG, FO, ELFO
Grižanje Varaždin d.o.o.	Varaždin	1 860	99 791	4 102	16 180	2	NG
Tekija d.o.o.	Požega	417	19 839	–	2 378	1	NG
GTG Vinkovci d.o.o.	Vinkovci	1 698	86 352	2 845	8 919	2	NG, FO, ELFO
Tehnoštan d.o.o.	Vukovar	3 712	186 271	19 236	19 128	7	NG, ELFO
Toplana d.o.o.	Karlovac	8 094	407 447	102 078	66 281	21	NG, FO, ELFO
Termalna Voda d.o.o.	Topusko	191	8 980	14 837	–	2	GEO
Ivakop d.o.o.	Ivanić Grad	3	–	6 451	772	1	NG
SKG d.o.o.	Ogulin	192	7 503	4 187	8 545	1	FO, ELFO
TOTAL		155 509	8 072 143	227 687	2 351 659	412	

*Includes process steam deliveries

** NG – Natural gas, FU – fuel oil, ELFO – extra light fuel oil, GEO – geothermal

*** HEP Toplinarstvo Zagreb, including Velika Gorica, Zaprešić and Samobor

Economic operators wanting to participate in the thermal energy market must meet the requirements defined by the Rules on licences for energy activities and, accordingly, obtain appropriate licences for the energy generation, distribution and supply activities from the HERA. On 31 December 2013, there were 21, 13 and 19 valid licences for thermal energy generation, distribution and supply, respectively. *HEP Toplinarstvo d.o.o.* may be singled out as the key participant in the thermal energy market, supplying 80 % of final customers and delivering approximately 90 % of total thermal energy.

The biggest opportunity for the development of the Croatian heating sector is lies in increasing energy efficiency, and reliability and safety of supply through the use of new and modern technologies. This primarily refers to high-efficiency cogeneration, combustion of biomass and waste, replacement of old and inefficient pipeline networks with new, pre-insulated pipelines, as well as amendment to the legislative and regulatory framework.

Among other main challenges to the development of the heating sector, natural gas among others may be outlined as the primary competitor of district heating systems. Quite frequently, natural gas is preferred as a solution for meeting local thermal energy needs. Furthermore, further expansion of the heating sector might be thwarted by the need for substantial investments for the purpose of revitalising and modernising the existing systems, and by the lack of systematic planning in the sector.

1.2. ANALYSIS OF THE CURRENT SITUATION IN THERMAL ENERGY GENERATION, DISTRIBUTION AND SUPPLY

The activities of thermal energy generation, distribution and supply are pursued by 11 economic operators in Croatia. Thermal energy is supplied through district heating systems (DHS), closed heating systems (CHS) and stand-alone heating systems (SHS) in the following cities: Zagreb, Osijek, Sisak, Samobor, Zaprešić, Velika Gorica, Slavonski Brod, Rijeka, Karlovac, Vinkovci, Virovitica, Ogulin, Vukovar, and Varaždin, and the municipality of Topusko. As expected, *HEP Toplinarstvo d.o.o.* has the largest market share and share of installed thermal capacity. The distribution of installed thermal capacity by economic operators engaging in the

energy activity in the heating sector is shown in the figure below. *HEP Toplinarstvo d.o.o.* is evidently the dominant operator, accounting for more than 70 % of the total installed capacity in thermal energy generation.

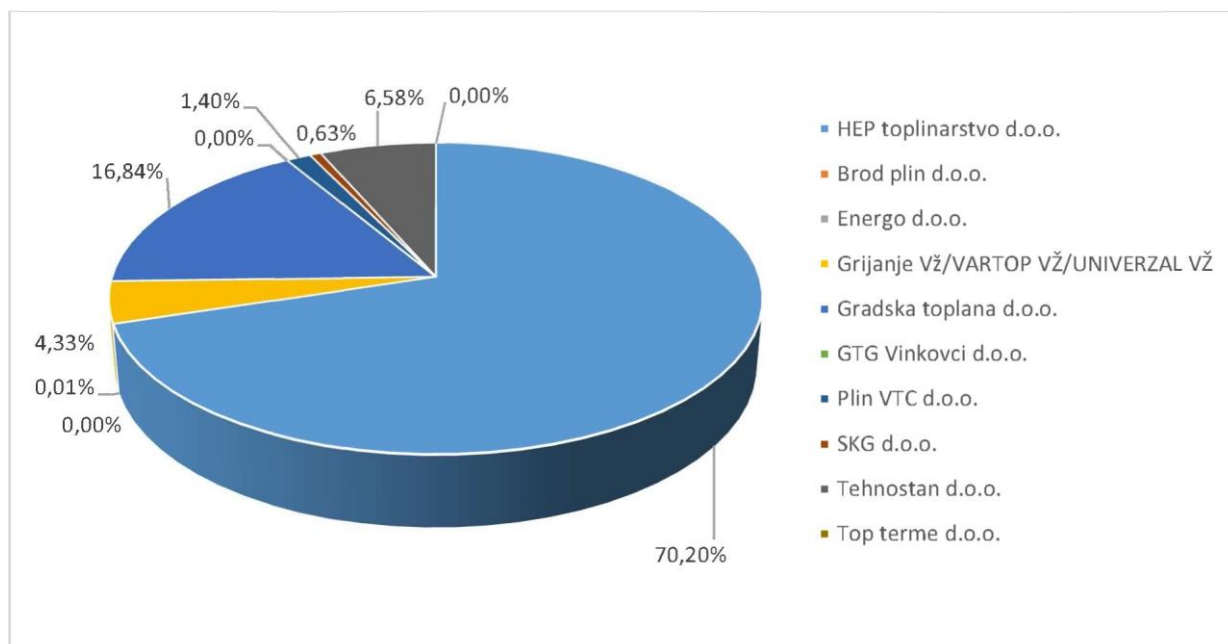


Figure 3: Distribution of installed thermal capacity in 2014

A detailed overview of the main indicators relating to all operators, including the installed thermal capacity, thermal energy generated, distribution network length, number of connected residential buildings and users, number of heating substations, total heated area, leased power and thermal energy delivered, is provided below. The authors of this Programme obtained the data analysed here from the Croatian Energy Regulatory Agency, to which they had been submitted by the analysed operators, in accordance with statutory obligations. The data presented concern the past three calendar years, in respect of which they were available. It must also be noted that some data are unknown, possibly because they are unknown to the operators themselves. Table fields with missing data are left blank.

1.2.1. HEP Toplinarstvo d.o.o., Zagreb

HEP Toplinarstvo d.o.o. is a supplier of thermal energy in the territory of the following cities: Zagreb, Osijek, Sisak, Samobor, Zaprešić and Velika Gorica. The following table provides a summary of the main indicators for the year 2014. Since the 2012 and 2013 data were not provided to the Programme authors, they have not been included. In 2014, *HEP-Toplinarstvo d.o.o.* engaged in the activities of thermal energy generation, distribution and supply. Its suppliers of the primary fuel used in thermal energy generation are *Gradska Plinara*, *Energometan*, *HEP Plin d.o.o.* and *INA d.d.*

Table 3: Main indicators – *HEP-Toplinarstvo d.o.o.*

HEP Toplinarstvo d.o.o.	Unit	2012	2013	2014
Number of DHSs	–			13
Number of CHSs	–			26
Number of SHSs	–			24
Total boiler room capacity installed	kW			490 389
Thermal energy delivered				
Thermal energy generated	kWh			2 213 755 735
Distribution network/external installation length	m			368 760
Number of buildings (energy units)	pcs			2 940
Number of heating substations	pcs			3 826
Number of heating substations with DHW	pcs			366

HEP Toplinarstvo d.o.o.	Unit	2012	2013	2014
Number of final customers				
Households	–			118 427
Industry, commercial consumers and for predominantly commercial use	–			6 137
Number of final customers with DHW	–			894
Total heated area				
Households	m ²			6 472 188
Industry, commercial consumers and for predominantly commercial use	m ²			1 114 156
Installed/leased power				
Households	kW			840 860
Industry, commercial consumers and for predominantly commercial use	kW			650 917
Thermal energy delivered				
Households – heating	kWh			1 097 462 845
Households – DHV	kWh			0
Industry and commercial consumers – heating	kWh			395 337 835
Industry and commercial consumers – DHW	kWh			0
Industry and commercial consumers (process steam)	kWh			249 640 739
Predominantly for commercial use	kWh			113 735 929

1.2.2. Gradska Toplana d.o.o., Karlovac

Gradska Toplana d.o.o., a public heating plant established in Karlovac, is registered for thermal energy generation, distribution and supply, with thermal energy purchase added as a registered business activity in 2014. In the period under observation, its supplier of the primary fuel used in thermal energy generation was Montcogim – Plinara d.o.o.

Table 4: Main indicators – Gradska Toplana d.o.o

Gradska Toplana d.o.o. Karlovac	Unit	2012	2013	2014
Number of DHSs	–	1	1	1
Number of CHSs	–	1	1	1
Number of SHSs	–	0	0	0
Total boiler room capacity installed	kW	117 628	117 628	117 628
Thermal energy delivered				
Thermal energy generated	kWh		75 319 080	55 871 098
Distribution network/external installation length	m	21 200	21 200	21 200
Number of buildings (energy units)	pcs			
Number of heating substations	pcs	189	187	185
Number of heating substations with DHW	pcs			
Number of final customers				
Households	–	7 747	7 700	7 685
Industry, commercial consumers and for predominantly commercial use	–	334	329	319
Number of final customers with DHW	–			
Total heated area				
Households	m ²	412 147	412 710	408 417
Industry, commercial consumers and for predominantly commercial use	m ²	114 424	104 300	97 439
Installed/leased power				
Households	kW	52 120	54 199	52 176
Industry, commercial consumers and for predominantly commercial use	kW	16 722	14 572	14 572

Gradska Toplana d.o.o. Karlovac	Unit	2012	2013	2014
Thermal energy delivered				
Households – heating	kWh	18 192 771	54 152 649	39 903 795
Households – DHV	kWh			
Industry and commercial consumers – heating	kWh	4 457 635	13 547 879	9 800 650
Industry and commercial consumers – DHW	kWh			
Industry and commercial consumers (process steam)	kWh			
Predominantly for commercial use	kWh			

1.2.3. Tehnoston d.o.o., Vukovar

Tehnoston d.o.o. of Vukovar is registered for thermal energy generation, distribution and supply, building management, chimney-sweeping and thermal energy purchase. Its suppliers of the primary fuel used in thermal energy generation are *INA d.d.* for ELFO and *Prvo Plinarsko Društvo Vukovar* for NG.

Table 5: Main indicators – *Tehnoston d.o.o.*

Tehnoston d.o.o. Vukovar	Unit	2012	2013	2014
Number of DHSs	–	2		2
Number of CHSs	–	3		3
Number of SHSs	–	3		2
Total boiler room capacity installed	kW	45 990		45 940
Thermal energy delivered				
Thermal energy generated	kWh			18 941 202
Distribution network/external installation length	m	7 215		7 215
Number of buildings (energy units)	pcs			100
Number of heating substations	pcs	93		93
Number of heating substations with DHW	pcs			60
Number of final customers				
Households	–	3 658		3 621
Industry, commercial consumers and for predominantly commercial use	–	55	0	50
Number of final customers with DHW	–			2 513
Total heated area				
Households	m ²	186 282		186 342
Industry, commercial consumers and for predominantly commercial use	m ²	19 796	0	17 977
Installed/leased power				
Households	kW	252 926		21 094
Industry, commercial consumers and for predominantly commercial use	kW	32 711	0	2 633
Thermal energy delivered				
Households – heating	kWh	17 776		9 096 506
Households – DHV	kWh			4 105 152
Industry and commercial consumers – heating	kWh	2 599		2 108 115
Industry and commercial consumers – DHW	kWh			
Industry and commercial consumers (process steam)	kWh			
Predominantly for commercial use	kWh			

1.2.4. Grijanje Varaždin d.o.o./Vartop d.o.o./Grijanje Univerzal d.o.o., Varaždin

The economic operator *Grijanje Varaždin d.o.o.* declared bankruptcy on 1 February 2013 and has ceased operations since 1 February 2014. *Grijanje Varaždin d.o.o.* was registered for the business activities of thermal energy generation, distribution and supply. In 2014, the economic operator *Vartop d.o.o.* took over the activities of thermal energy generation and supply, while thermal energy purchase was taken over by *Grijanje Univerzal d.o.o.* In the period under observation, the supplier of the primary fuel used for thermal energy generation was *Termoplin Varaždin*.

Table 6: Main indicators – Vartop d.o.o./Grijanje Univerzal d.o.o.

Grijanje Varaždin/Vartop d.o.o.	Unit	2012	2013	2014
Number of DHSs	–	0	0	0
Number of CHSs	–	2	2	2
Number of SHSs	–	11	11	7
Total boiler room capacity installed	kW		31 348	27 099
Thermal energy delivered				
Thermal energy generated	kWh		1 516 373	0
Distribution network/external installation length	m		1 680	1 570
Number of buildings (energy units)	pcs			28
Number of heating substations	pcs	37	39	39
Number of heating substations with DHW	pcs		19	15
Number of final customers				
Households	–	1 820		1 401
Industry, commercial consumers and for predominantly commercial use	–	40	0	28
Number of final customers with DHW	–			532
Total heated area				
Households	m ²	99 791	99 805	72 779
Industry, commercial consumers and for predominantly commercial use	m ²	4 102	3 670	2 235
Installed/leased power				
Households	kW	12 705	12 705	9 030
Industry, commercial consumers and for predominantly commercial use	kW	617	611	406
Thermal energy delivered				
Households – heating	kWh	15 312 606	11 457 456	2 678 588
Households – DHV	kWh	0		1 887 363
Industry and commercial consumers – heating	kWh	867 458	762 348	0
Industry and commercial consumers – DHW	kWh			0
Industry and commercial consumers (process steam)	kWh			0
Predominantly for commercial use	kWh			910 774

1.2.5. Plin VTC d.o.o., Virovitica

The economic operator *Plin Virovitica d.o.o.* is registered for the business activities of thermal energy generation, distribution and supply. In 2014, it was also registered for thermal energy purchase. During the period under observation, *Plin VTC d.o.o.* was also the supplier of the primary fuel used in thermal energy generation.

Table 7: Main indicators – Plin VTC d.o.o.

Plin VTC d.o.o. Virovitica		2012	2013	2014
Number of DHSs	–	0	0	0
Number of CHSs	–	5	5	5
Number of SHSs	–	0	0	0
Total boiler room capacity installed	kW	9 800	9 800	9 800
Thermal energy delivered				
Thermal energy generated	kWh		3 419 889	–
Distribution network/external installation length	m	900	900	900
Number of buildings (energy units)	pcs	18	18	19
Number of heating substations	pcs	17	18	19
Number of heating substations with DHW	pcs			
Number of final customers				
Households	–	435	435	436
Industry, commercial consumers and for predominantly commercial use	–	47	47	45
Number of final customers with DHW	–			
Total heated area				
Households	m ²	23 439	23 437	23 530
Industry, commercial consumers and for predominantly commercial use	m ²	6 613	6 613	6 490
Installed/leased power				
Households	kW	3 058	36 692	3 060
Industry, commercial consumers and for predominantly commercial use	kW	926	11 110	909
Thermal energy delivered				
Households – heating	kWh	2 515 969	2 438 489	1 754 084
Households – DHV	kWh			602 766
Industry and commercial consumers – heating	kWh			
Industry and commercial consumers – DHW	kWh			
Industry and commercial consumers (process steam)	kWh			
Predominantly for commercial use	kWh	113 108	981 400	

1.2.6. Stambeno Komunalno Gospodarstvo d.o.o., Ogulin

The economic operator *Stambeno Komunalno Gospodarstvo d.o.o.* (SKG d.o.o.) is registered for the following business activities: thermal energy generation, distribution and supply, municipal services, building management and real estate business (cleaning, waste disposal, marketplaces, cemetery maintenance, parking services, waste transport). Its supplier of the primary fuel used in thermal energy generation was *INA-Industrija nafte d.d.*

Table 8: Main indicators – SKG d.o.o.

SKG d.o.o. Ogulin	Unit	2012	2013	2014
Number of DHSs	–	0	0	0
Number of CHSs	–	2	2	2
Number of SHSs	–	0	0	0
Total boiler room capacity installed	kW	4 400	4 400	4 400
Thermal energy delivered				
Thermal energy generated	kWh			1 786 197
Distribution network/external installation length	m			448
Number of buildings (energy units)	pcs			18
Number of heating substations	pcs			12

SKG d.o.o. Ogulin	Unit	2012	2013	2014
Number of heating substations with DHW	pcs			
Number of final customers				
Households	–	150		101
Industry, commercial consumers and for predominantly commercial use	–	29	0	25
Number of final customers with DHW	–			
Total heated area				
Households	m ²	7 549	7 503	62 019
Industry, commercial consumers and for predominantly commercial use	m ²	3 960	4 187	3 008
Installed/leased power				
Households	kW	975	975	672
Industry, commercial consumers and for predominantly commercial use	kW	463	463	453
Thermal energy delivered				
Households – heating	kWh			858 859
Households – DHV	kWh			
Industry and commercial consumers – heating	kWh			403 212
Industry and commercial consumers – DHW	kWh			
Industry and commercial consumers (process steam)	kWh			
Predominantly for commercial use	kWh			

1.2.7. Energo d.o.o., Rijeka

Energo d.o.o., established in Rijeka, is registered for the business activities of thermal energy generation, distribution and supply. In 2012, its suppliers of the primary fuel used in thermal energy generation were INA d.d. and *Prirodni Plin d.o.o.* from Zagreb. In 2014, the suppliers were *HEP Plin d.o.o.* and INA d.d. Information on the 2013 primary fuel supplier is unknown, i.e. it has not been submitted.

Table 9: Main indicators – *Energo d.o.o.*

Energo d.o.o. Rijeka	Unit	2012	2013	2014
Number of DHSs	–	3	3	3
Number of CHSs	–	8	8	8
Number of SHSs	–	4	4	4
Total boiler room capacity installed	kW	104 107		102
Thermal energy delivered				
Thermal energy generated	kWh			65 737 157
Distribution network/external installation length	m	16 041		16 541
Number of buildings (energy units)	pcs			264
Number of heating substations	pcs			168
Number of heating substations with DHW	pcs		0	0
Number of final customers				
Households	–		9 870	9 963
Industry, commercial consumers and for predominantly commercial use	–	0	140	47
Number of final customers with DHW	–			0
Total heated area				
Households	m ²		537 780	544 021
Industry, commercial consumers and for predominantly commercial use	m ²	0	42 905	32 207
Installed/leased power				
Households	kW			70 723

Energo d.o.o. Rijeka	Unit	2012	2013	2014
Industry, commercial consumers and for predominantly commercial use	kW	0	0	4 187
Thermal energy delivered				
Households – heating	kWh			46 313 301
Households – DHV	kWh			0
Industry and commercial consumers – heating	kWh			4 520 917
Industry and commercial consumers – DHW	kWh			0
Industry and commercial consumers (process steam)	kWh			0
Predominantly for commercial use	kWh			0

1.2.8. Brod-Plin d.o.o., Slavonski Brod

The economic operator *Brod-Plin d.o.o.*, established in Slavonski Brod, is registered for the business activities of natural gas distribution and supply, as well as thermal energy generation, distribution and supply. In 2014, the company was also licensed for thermal energy purchase. *Brod-Plin d.o.o.* is also the supplier of the primary fuel used in thermal energy generation.

Table 10: Main indicators – Brod-Plin d.o.o.

Brod-Plin d.o.o. Slavonski Brod	Unit	2012	2013	2014
Number of DHSs	–	1	1	1
Number of CHSs	–	2	2	2
Number of SHSs	–	18	18	18
Total boiler room capacity installed	kW	43	41	35
Thermal energy delivered				
Thermal energy generated	kWh		42 475 583	35 477 401
Distribution network/external installation length	m	9 953	7 050	7 050
Number of buildings (energy units)	pcs			73
Number of heating substations	pcs	48	48	48
Number of heating substations with DHW	pcs		41	39
Number of final customers				
Households	–	3 611		3 614
Industry, commercial consumers and for predominantly commercial use	–	159	0	153
Number of final customers with DHW	–			2 869
Total heated area				
Households	m ²	175 165	176 353	174 410
Industry, commercial consumers and for predominantly commercial use	m ²	26 655	22 719	22 851
Installed/leased power				
Households	kW	21 847 360	21 810 854	21 810 854
Industry, commercial consumers and for predominantly commercial use	kW	3 626 429	3 553 798	3 553 798
Thermal energy delivered				
Households – heating	kWh	34 573 379	34 466 581	17 923 182
Households – DHV	kWh			10 721 333
Industry and commercial consumers – heating	kWh	4 908 938	4 307 314	3 389 047
Industry and commercial consumers – DHW	kWh			23 498
Industry and commercial consumers (process steam)	kWh			0
Predominantly for commercial use	kWh			0

1.2.9. GTG Vinkovci d.o.o., Vinkovci

In 2012 and 2013, GTG Vinkovci d.o.o. was registered for the following business activities: thermal energy generation, distribution and supply, cemetery maintenance, marketplace activities. In 2014, it was registered for the supply and generation of thermal energy in a closed heating system, as well as the generation of thermal energy in a **closed heating system**. Its supplier of the primary fuel used in thermal energy generation was *Plinara Istočne Slavonije*, INA d.d.

Table 11: Main indicators – GTG Vinkovci d.o.o.

GTG Vinkovci d.o.o.	Unit	2012	2013	2014
Number of DHSs	–	0	0	0
Number of CHSs	–	6	6	6
Number of SHSs	–	0	0	1
Total boiler room capacity installed	kW			
Thermal energy delivered				
Thermal energy generated	kWh		9 221 000	7 188 470
Distribution network/external installation length	m		1 600	1 600
Number of buildings (energy units)	pcs			62
Number of heating substations	pcs	39	39	54
Number of heating substations with DHW	pcs			
Number of final customers				
Households	–	1 646		1 647
Industry, commercial consumers and for predominantly commercial use	–	52	0	51
Number of final customers with DHW	–			
Total heated area				
Households	m ²	85 574	85 574	86 938
Industry, commercial consumers and for predominantly commercial use	m ²	4 042	4 042	2 757
Installed/leased power				
Households	kW	10 735	10 734	10 815
Industry, commercial consumers and for predominantly commercial use	kW	589	589	397
Thermal energy delivered				
Households – heating	kWh	10 426 352	8 635 046	6 754 213
Households – DHV	kWh			
Industry and commercial consumers – heating	kWh		297 044	
Industry and commercial consumers – DHW	kWh			
Industry and commercial consumers (process steam)	kWh			
Predominantly for commercial use	kWh			192 039

1.2.10. Termalna Voda d.o.o./Top-Terme d.o.o., Topusko

Until 2013, the activities of thermal energy generation, distribution and supply were performed by the economic operator *Termalna voda d.o.o.* Since then, along with the activities mentioned, *Top-Terme d.o.o.* has also engaged in thermal energy purchase. *Lječilište Topusko* was the supplier of the primary fuel used in thermal energy generation in the observed period. The authors of the Programme obtained only the data relating to 2014 from the HERA.

Table 12: Main indicators – Top-Terme d.o.o.

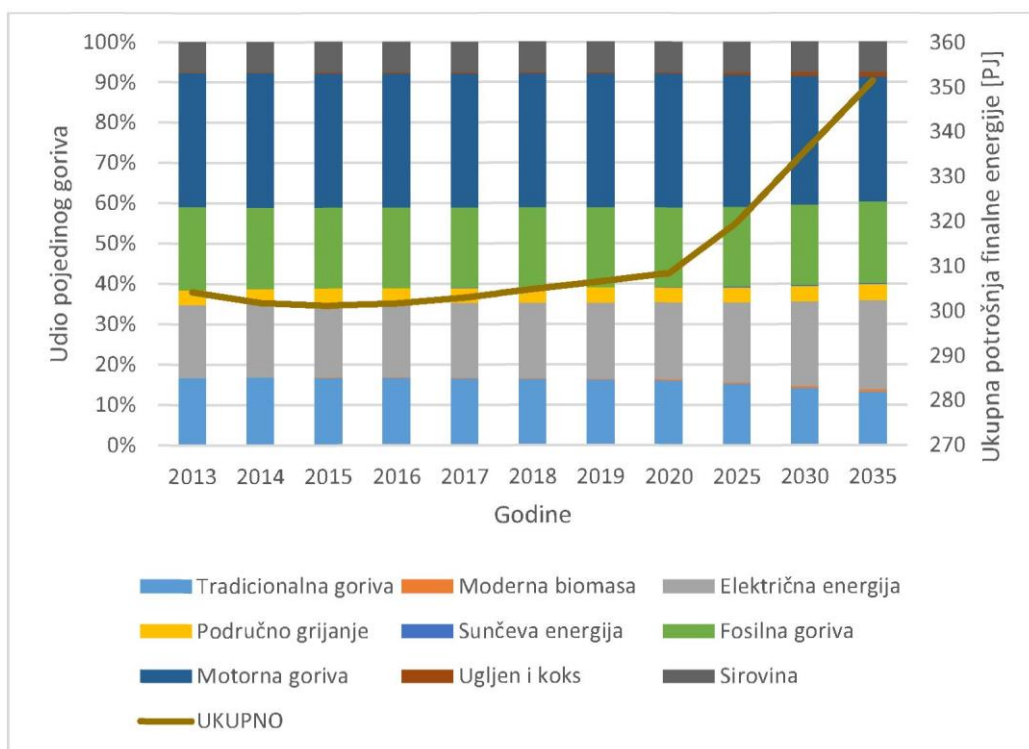
Top-Terme d.o.o.	Unit	2012	2013	2014
Number of DHSs	–			
Number of CHSs	–			1
Number of SHSs	–			1,700

Top-Terme d.o.o.	Unit	2012	2013	2014
Total boiler room capacity installed	kW			
Thermal energy delivered				
Thermal energy generated	kWh			–
Distribution network/external installation length	m			1 500
Number of buildings (energy units)	pcs			21
Number of heating substations	pcs			19
Number of heating substations with DHW	pcs			
Number of final customers				
Households	–			155
Industry, commercial consumers and for predominantly commercial use	–	0	0	13
Number of final customers with DHW	–			
Total heated area				
Households	m ²			8 356
Industry, commercial consumers and for predominantly commercial use	m ²	0	0	23 048
Installed/leased power				
Households	kW			6 516
Industry, commercial consumers and for predominantly commercial use	kW	0	0	11 013
Thermal energy delivered				
Households – heating	kWh			2 394 707
Households – DHV	kWh			1 923 093
Industry and commercial consumers – heating	kWh			
Industry and commercial consumers – DHW	kWh			
Industry and commercial consumers (process steam)	kWh			
Predominantly for commercial use	kWh			

1.3. ANALYSIS OF THERMAL ENERGY CONSUMPTION

The total final energy consumption in Croatia has recorded a mild decrease in the last few years (-0.8 % for 2013-2014). Based on the economic, political and demographic trends, 2015 is forecast to mark a turning point, followed by an increase in final energy consumption. The next significant milestone is forecast for 2020, which is expected to bring a more substantial increase in energy consumption at a rate of approximately 3.5 % a year.

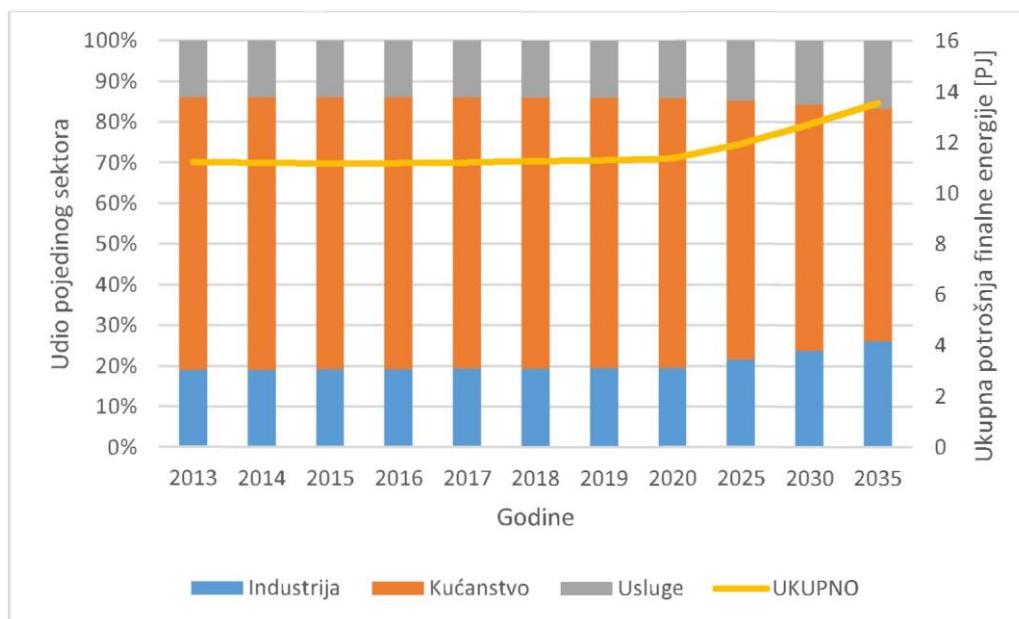
The following figure represents the structure of total final energy consumption in Croatia in 2013 and 2014 and a forecast of consumption by 2035. The total final energy consumption will increase from the current 301 PJ to 351 PJ expected in 2035. With regard to energy sources or fuel structure, no major changes are expected. The share of final energy delivered to heating systems will not change substantially and will amount to approximately 3.7-3.9 %. It should be noted that the forecasts presented are based on the Business As Usual (BAU) scenario, i.e. a scenario which includes no major changes in the energy structure or balance.



<i>Udio pojedinog goriva</i>	<i>Individual fuel share</i>
<i>Ukupna potrošnja finalne energije [PJ]</i>	<i>Total final energy consumption [PJ]</i>
<i>Godine</i>	<i>Years</i>
<i>Tradicionalna goriva</i>	<i>Traditional fuels</i>
<i>Područno grijanje</i>	<i>District heating</i>
<i>Motorna goriva</i>	<i>Motor fuels</i>
<i>UKUPNO</i>	<i>TOTAL</i>
<i>Moderna biomasa</i>	<i>Modern biomass</i>
<i>Sunčeva energija</i>	<i>Solar energy</i>
<i>Ugljen i koks</i>	<i>Coal and coke</i>
<i>Električna energija</i>	<i>Electricity</i>
<i>Fossilna goriva</i>	<i>Fossil fuels</i>
<i>Sirovina</i>	<i>Raw material</i>

Figure 4: Total final energy consumption in the Republic of Croatia, 2013-2035

The figure below provides a more detailed overview of the forecast consumption of thermal energy delivered to heating systems. According to the BAU scenario, total final energy consumption will record no substantial growth by 2020, and will stand at a level of 11.2 PJ. Final energy consumption is expected to increase to a level of 13.5 PJ by 2035. It should be noted that, in the current structure thermal energy consumption, the household sector accounts for the largest share of total thermal energy delivered to heating systems. In 2013, almost 67 % of thermal energy deliveries were to households, with the industry and entrepreneurship sector accounting for 19 %. The remaining 14 % was consumed by the service sector. Under the BAU scenario, the share of thermal energy consumption by households is expected to decline somewhat (to 57 %) by 2035, mostly in favour of consumption growth by the industry and entrepreneurship sector (26 %) and to a lesser extent by the service sector (17 %).



<i>Udio pojedinog sektora</i>	<i>Sector share</i>
<i>Ukupna potrošnja finalne energije [PJ]</i>	<i>Total final energy consumption [PJ]</i>
<i>Godine</i>	<i>Years</i>
<i>Industrija</i>	<i>Industry</i>
<i>Kućanstvo</i>	<i>Households</i>
<i>Usluge</i>	<i>Services</i>
<i>UKUPNO</i>	<i>TOTAL</i>

Figure 5: Structure of thermal energy consumption by sector

While the forecast increase in the consumption of thermal energy by district heating systems is modest, it is nevertheless sufficient to allow further development and improvement of district heating systems in Croatia.

With regard to district cooling system, it can be said that there are no such systems in Croatia at the moment or plans to build any in the near future.

1.4. OPPORTUNITIES AND CHALLENGES FOR FURTHER DISTRICT HEATING SYSTEM DEVELOPMENT

District heating systems are determined as one of the priorities of Croatia's energy policy, with the following guidelines for further improvement:

- improvement of the legislative framework to ensure better and more efficient district heating sector functioning;
- need for planned thermal energy supply in urban areas with regard to minimum cost criteria for the period observed;
- need for the modernisation of district heating systems, with proposals for the development and use of domestic equipment and services in the district heating sector (both for production units and the district heating system network);
- use of renewable energy sources for thermal energy generation and incentives for distributed generation;
- promotion of efficient thermal energy use;
- use of modern information technology in infrastructure management and maintenance.

The most significant potential for the improvement and development of district heating systems in Croatia can primarily be realised by increasing energy efficiency of production units, end-user infrastructure and equipment, as well as improving reliability and safety of supply. This may be achieved primarily by applying and using the latest technology and knowledge in the field. This refers, in particular, to the use of cogeneration units, biomass and waste, replacement of old pipeline networks

characterised by major heat losses and losses due to leakage of the heating medium transported with new pre-insulated pipelines, as well as to the introduction of advanced technologies for the operation and control of the entire thermal energy generation, distribution and consumption system. Meanwhile, as a progressive approach to managing a modern and dynamic system, Demand Side Management must not be neglected either.

A forecast of thermal energy consumption in district heating systems for the period until 2035 has been made on the basis of predicted economic and demographic trends. The results of that analysis are presented in the previous chapter. Based on the analysis and strategic guidelines, it is safe to assume that Croatia will create the basic prerequisites for growth and development of district heating systems, including improving the technical and technological condition of the existing system, creating a comprehensive, integral legislative framework for the heating sector and embarking on systematic energy planning and energy management in the heating sector as a result, among other things, of an increase in energy prices and environment-related costs.

Further development and expansion of the use of district heating systems in Croatia is determined by certain challenges, of which the following may be singled out as the most relevant:

- Natural gas, as the key competitor to district heating systems, is often perceived by the economic operators in this sector to be the preferred energy source for heating among local communities and politicians due to its very favourable price for the end users;
- The existing district heating systems require substantial investment in order to be revitalised and modernised with the aim of increasing the reliability and safety of supply;
- Lack of energy planning and detailed guidelines to enable cooperation between county-based state administration offices in charge of energy issues and the local governments' representative bodies when it comes to development and the adoption of physical development and planning documents;

The main challenge related to district heating systems is to raise the awareness among citizens of their advantages and create the prerequisites for making them profitable. That can be achieved by setting such thermal energy prices that will enable developing the systems themselves. The implementation of Croatia's Energy Development Strategy through its action plans is a demanding process since it will define the measures, actions and implementation dynamics of the energy policy over the next four years. Public perception of district heating systems should be improved, focusing on the groups which currently use alternative heating systems to satisfy their thermal energy needs. This may be accomplished through a variety of measures, including educational workshops and promotions.

There are numerous options for the expansion, further development and construction of district heating systems. One of these involves connecting new consumers (residential blocks, settlements, industrial and commercial consumers) to district heating systems. Such options will be analysed in more detail in the following chapters. Another solution would be to increase energy efficiency, which is certainly one of the most important milestones in further development of district heating systems. The energy efficiency issue concerns two segments: the first one is the building sector, while the other concerns energy efficiency of the thermal systems themselves (pipeline networks and supporting infrastructure). Furthermore, district heating systems can base their development on the use of various high-efficiency and/or renewable energy sources.

1.5. USE OF NEW TECHNOLOGIES IN HEAT GENERATION FOR DISTRICT HEATING SYSTEMS

Most of the existing district heating systems are based on hot water/boiler units or high-power cogeneration plants using fossil fuels as the main fuel in heat generation. The most common fuels are natural gas and heavy oil, which is gradually going out of use. Croatia's statutory regulations encourage the use of fossil fuels for heat generation in the cogeneration process, also producing electricity – cogeneration installations. However, such installations must be based on high-efficiency cogeneration. According to the Rules on the eligible electricity producer status, a cogeneration installation may acquire the status of eligible producer provided that it achieves primary energy savings of 10 %. These savings must be achieved in comparison with the equivalent amount of electricity and thermal energy separately produced by stand-alone, separate reference thermal and electrical power plants. Reference plants are also defined by these Rules.

In addition to fossil fuels, biomass, waste and renewable energy sources may be used for thermal energy generation. Given that biomass is also classified as a renewable energy source, the development of cogeneration installations using biomass as a primary fuel is also encouraged. The criteria for acquiring the eligible producer status for such cogeneration installations are much simpler than ones for those

using fossil fuels. More precisely, under the Rules on the eligible electricity producer status, it is sufficient to prove the annual installation performance of at least 50 %. Thermal energy generation systems which harness solar energy are only partially present in Croatia. However, as a rule, such systems are dispersed facilities intended to satisfy local thermal energy needs. The use of solar energy for heat generation in district heating systems has not taken root in Croatia yet.

Heat pumps are a new and still rare method of thermal energy generation for district heating system needs. The advantage of heat pumps lies in their high efficiency and low environmental impact. But they are not widely used in the existing energy system because of compatibility of such sources with low-temperature heating systems, which are still rare in Croatia. Given that heat pumps are incompatible with the existing infrastructure, increased energy prices and/or incentives will be necessary to make such systems competitive and provide appropriate infrastructure for low-temperature heating.

1.6. ANALYSIS OF DISTRICT COOLING SYSTEMS

At present, there are no district cooling systems in Croatia. Some estimates of annual cooling energy needs amount to as much as 10 TWh. Of that, the housing sector accounts for 6 TWh and the service sector for the rest.

District cooling systems are still subject to debate on a theoretical, academic level. So it is safe to conclude that any discussion of the development of such high-efficiency cooling systems is premature. However, their development will surely depend on new technologies, the availability of such technologies, degree of technical development and economic viability. The economic viability will certainly hinge on the competitiveness of current, conventional cooling systems. It may be concluded that a greater impetus to the development of district cooling systems is yet to come.

2. FORECAST CHANGES IN ENERGY CONSUMPTION FOR HEATING AND COOLING UNTIL 2030

2.1. FINAL ENERGY CONSUMPTION IN THE REPUBLIC OF CROATIA

The analysis of energy consumption for the purpose of heating and cooling is carried out separately by individual sectors of final consumption: households, services, industry and agriculture. The analysis of energy consumption includes cities/municipalities/settlements with a population of more than 10 000. In addition to the analysis of energy consumption for heating, the consumption of energy for DHW generation has also been analysed. In order to ensure calculation precision, the model has been implemented for the entire Croatian territory, that is, for all cities/municipalities/settlements, to enable separate examination of the cities/municipalities/settlements being the subject of this study.

The model will show the so-called useful energy consumptions which represent the actual energy needs obtained after the final energy consumption delivered to the end user is reduced by the losses incurred on the appliance/technology which consumes energy to produce heat for heating and DHW or for space cooling. The energy efficiency standards of the appliances/technologies used for heating and cooling have been adopted from the recommendations provided by international organisations.

2.2. STARTING POINTS

According to the 2011 census, Croatia had 4 290 612 inhabitants² and 1 535 635 households (of which 1 534 148 private households) that year.

The number of cities with a population of more than 10 000 was 67 and they had a total of 2 659 627 inhabitants, or 62 percent of the population. The list of cities and municipalities with the number of dwellings, households and inhabitants is provided in the table.

Furthermore, it should be noted that the 2011 Census included yet another variable to describe the censused persons, households and residential units. With regard to the latest, the following was censused:

- Residential units – total number;
- Residential units – permanent housing.

According to the census results, the number of residential units in the category 'Residential units – permanent housing' was 1 923 552, considerably exceeding the number of households. This arises from the methodology on which the census is based. Dwellings were censused regardless of whether they were being used only for housing, for both housing and work, for work only, for housing during seasonal work in agriculture, for holiday and recreation, or were temporarily uninhabited or abandoned but structurally valid dwellings at the moment when the Census was carried out.

Considering that energy is thus also consumed in dwellings which are not inhabited by households, that consumption must further be modelled using the parameters which are not identical to those for the household sector. An extra step includes an estimate of the characteristics of useful heat consumption in such residential units. This calculation is planned in the final modelling stage after data have been collected from distributors of networked energy sources.

The distribution of dwellings, households and population in the cities with more than 10 000 inhabitants is illustrated in the table below.

² Croatian Bureau of Statistics, 2011 Census (The total number of persons covered by the census was 4 456 096)

Table 13: Household, dwelling and population distribution in cities with more than 10 000 inhabitants

No	County	Name of city or municipality	Dwellings	Households	Population
1	City of Zagreb	Zagreb	300 272	303 610	789 966
2	Split-Dalmatia County	Split	61 743	63 050	178 097
3	Primorje-Gorski Kotar County	Rijeka	52 120	52 909	128 620
4	Osijek-Baranja County	Osijek	41 417	41 993	108 044
5	Zadar County	Zadar	27 189	27 483	75 060
6	Zagreb County	Velika Gorica	20 773	20 952	63 515
7	Brod-Posavina County	Slavonski Brod	19 669	20 159	59 141
8	Istria County	Pula – Pola	22 671	22 946	57 456
9	Karlovac County	Karlovac	20 895	21 278	55 701
9	Sisak-Moslavina County	Sisak	18 016	18 214	47 766
10	Varaždin County	Varaždin	16 753	17 036	46 945
11	Šibenik-Knin County	Šibenik	17 200	17 319	46 328
12	Dubrovnik-Neretva County	Dubrovnik	15 083	15 364	42 615
13	Bjelovar-Bilogora County	Bjelovar	13 608	13 717	40 275
14	Split-Dalmatia County	Kaštela	12 413	12 543	38 667
15	Zagreb County	Samobor	12 167	12 295	37 632
16	Vukovar-Syrmia County	Vinkovci	12 017	12 160	35 312
17	Koprivnica-Križevci County	Koprivnica	10 528	10 719	30 852
18	Osijek-Baranja County	Đakovo	8 590	8 765	27 744
19	Vukovar-Syrmia County	Vukovar	10 690	10 899	27 683
20	Međimurje County	Čakovec	8 811	8 953	27 104
21	Požega-Slavonia County	Požega	9 038	9 152	26 248
22	Zagreb County	Zaprešić	8 571	8 642	25 223
23	Split-Dalmatia County	Sinj	7 524	7 612	24 826
24	Sisak-Moslavina County	Petrinja	8 456	8 609	24 671
25	Split-Dalmatia County	Solin	7 685	7 749	23 926
26	Sisak-Moslavina County	Kutina	7 817	7 962	22 760
27	Virovitica-Podravina County	Virovitica	7 590	7 704	21 291
28	Koprivnica-Križevci County	Križevci	6 761	6 874	21 121
29	Zagreb County	Sveta Nedelja	5 492	5 579	18 058
30	Zagreb County	Dugo Selo	5 343	5 374	17 466
31	Dubrovnik-Neretva County	Metković	4 589	4 829	16 788
32	Istria County	Poreč	6 207	6 254	16 696
33	Osijek-Baranja County	Našice	5 475	5 593	16 223
34	Zagreb County	Sveti Ivan Zelina	4 816	4 912	15 959
35	Zagreb County	Jastrebarsko	4 979	5 006	15 866
36	Šibenik-Knin County	Knin	5 165	5 262	15 406
37	Split-Dalmatia County	Omiš	4 829	4 913	14 935
38	Zagreb County	Vrbovec	4 321	4 373	14 797
39	Zagreb County	Ivanić-Grad	4 902	4 962	14 548
40	Istria County	Rovinj – Rovigno	5 509	5 576	14 292
41	Brod-Posavina County	Nova Gradiška	5 056	5 169	14 229
42	Karlovac County	Ogulin	4 854	4 912	13 915
43	Split-Dalmatia County	Makarska	4 873	4 885	13 833
44	Varaždin County	Ivanec	4 007	4 060	13 758
45	Virovitica-Podravina County	Slatina	4 706	4 749	13 685
46	Sisak-Moslavina County	Novska	4 432	4 460	13 517
47	Istria County	Umag – Umago	5 342	5 357	13 465
48	Varaždin County	Novi Marof	3 950	3 994	13 246
49	Split-Dalmatia County	Trogir	4 499	4 570	13 192
50	Lika-Senj County	Gospić	4 649	4 675	12 745
51	Krapina-Zagorje County	Krapina	3 864	3 946	12 480
52	Vukovar-Syrmia County	Županja	3 871	4 009	12 089
53	Primorje-Gorski Kotar County	Opatija	4 701	4 736	11 658
54	Istria County	Labin	4 632	4 694	11 642
55	Bjelovar-Bilogora County	Daruvar	4 446	4 475	11 633
56	Osijek-Baranja County	Valpovo	3 997	4 089	11 563

No	County	Name of city or municipality	Dwellings	Households	Population
57	Požega-Slavonia County	Pleternica	3 488	3 536	11 323
58	Karlovac County	Duga Resa	4 028	4 052	11 180
59	Primorje-Gorski Kotar County	Crikvenica	4 541	4 587	11 122
60	Zadar County	Benkovac	3 596	3 626	11 026
61	Osijek-Baranja County	Belišće	3 750	3 850	10 825
62	Split-Dalmatia County	Imotski	2 669	2 690	10 764
63	Bjelovar-Bilogora County	Garešnica	3 553	3 612	10 472
64	Primorje-Gorski Kotar County	Kastav	3 732	3 773	10 439
65	Dubrovnik-Neretva County	Ploče	3 262	3 382	10 135
66	Osijek-Baranja County	Beli Manastir	3 630	3 796	10 068
Total:			955 822	968 985	2 659 627

2.3. ANALYSIS OF HOUSEHOLD SECTOR ENERGY CONSUMPTION

The model used for the analysis of energy consumption in households is based on the results of the 2011 Census. In addition to the data on the number of people and floor areas of permanent housing buildings/dwellings by settlement also contains two other types of crucial information:

- type of technology used for heating in households: DHS, own central/apartment heating, room stoves, no heating;
- fuel type and apartment floor area in households using central heating;
- fuel type and apartment floor area in households using room heating;
- number of households and floor area of apartments which are cooled.

Total energy consumption in the household sector was 103.7 PJ in 2013. In the structure of final consumption by fuel, firewood has the largest share of 48 %, followed by electricity with 21 %, natural gas with 19 %, heat with 5 %, and fuel oil and liquefied petroleum with 4 and 3 %, respectively.

The figures for final and useful energy consumption per square meter of heated space are taken from the *Survey on energy consumption in households*, which calculated the standards for three specific energy consumption areas: continental Croatia, central Croatia and southern Croatia. The share of energy consumption by particular purposes and areas with typical energy consumption in 2013 is shown in the figure below.

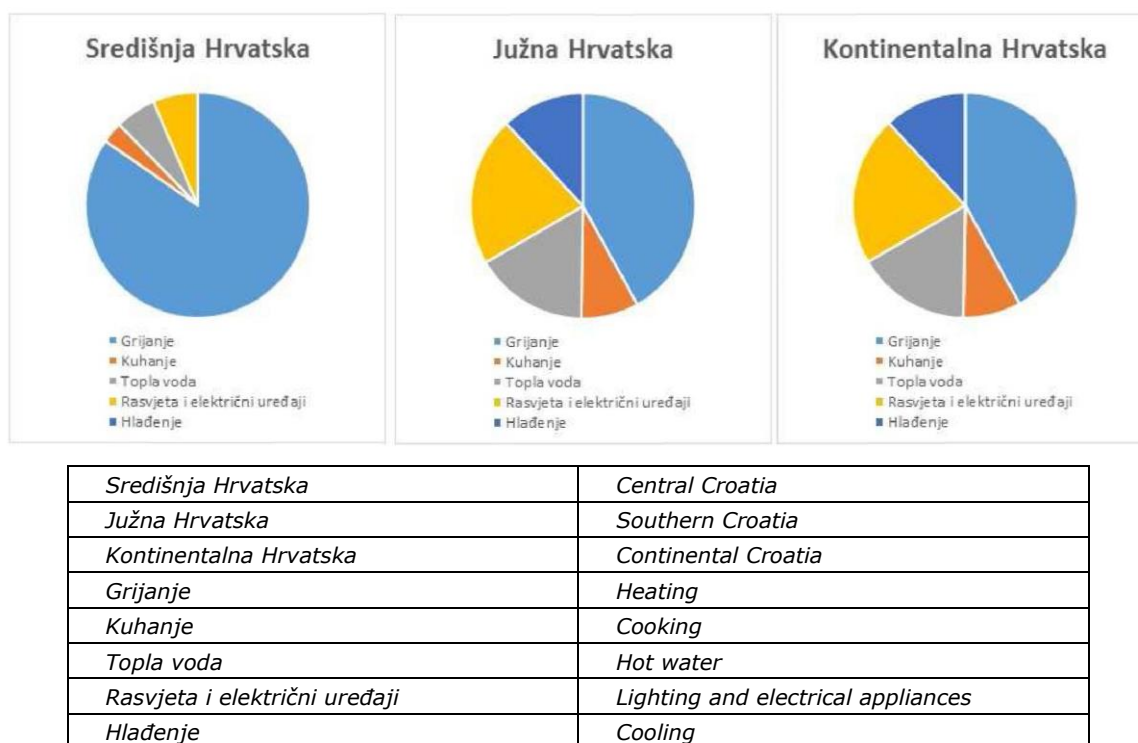
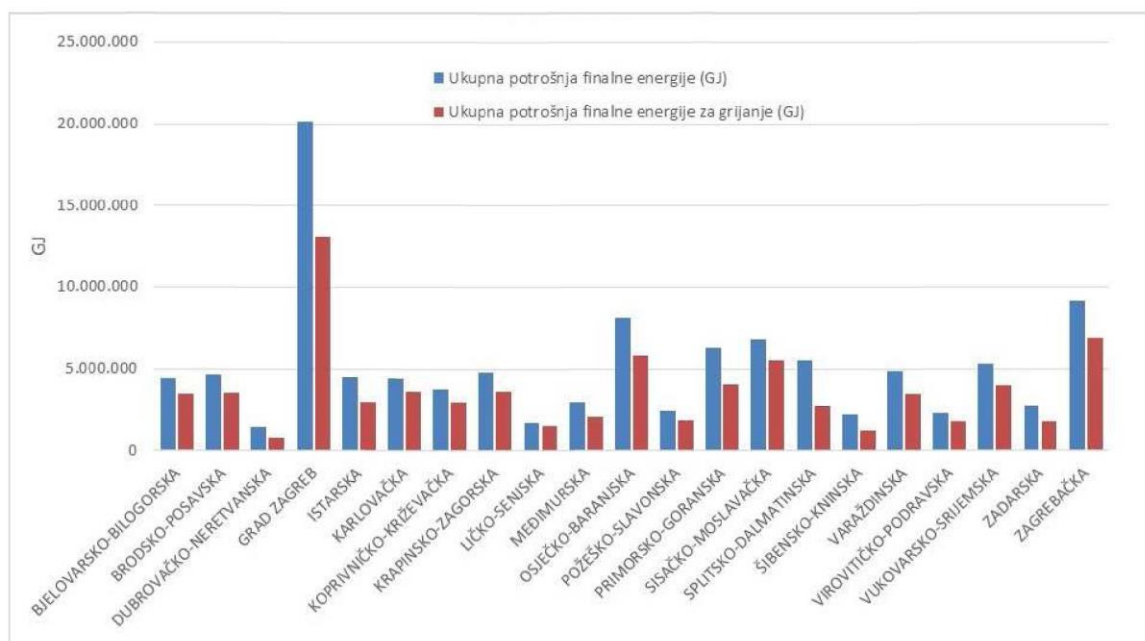


Figure 6: Structure of household sector end-use consumption by region

The survey results have shown the regional approach to the analysis of energy consumption to be exceptionally useful and relevant, since the differences in consumption are extremely high in certain specific areas of Croatia. For example, energy consumption in the households of central Croatia accounts for approximately 84 % of the total household energy needs, for 42 % in southern Croatia and 70 % in continental Croatia. Major differences have also been noted in the shares of energy consumption for cooling.

The total final energy consumption and total final energy consumption for heating by Croatian counties is shown in the following figure.



<i>Ukupna potrošnja finalne energije (GJ)</i>	<i>Total final energy consumption (GJ)</i>
<i>Ukupna potrošnja finalne energije za grijanje (GJ)</i>	<i>Total final energy consumption for heating (GJ)</i>
BJELOVARSKO-BILOGORSKA	BJELOVAR-BILOGORA COUNTY
BRODSKO-POSAVSKA	BROD-POSAVINA COUNTY
DUBROVAČKO-NERETVANSKA	DUBROVNIK-NERETVA COUNTY
GRAD ZAGREB	CITY OF ZAGREB
ISTARSKA	ISTRIA COUNTY
KARLOVAČKA	KARLOVAC COUNTY
KOPRIVNIČKO-KRIŽEVAČKA	KOPRIVNICA-KRIŽEVCI COUNTY
KRAPINSKO-ZAGORSKA	KRAPINA-ZAGORJE COUNTY
LIČKO-SENSKA	LIKA-SENJ COUNTY
MEĐIMURSKA	MEĐIMURJE COUNTY
OSJEČKO-BARANJSKA	OSIJEK-BARANJA COUNTY
POŽEŠKO-SLAVONSKA	POŽEGA-SLAVONIA COUNTY
PRIMORSKO-GORANSKA	PRIMORJE-GORSKI KOTAR COUNTY
SISAČKO-MOSLAVAČKA	SISAK-MOSLAVINA COUNTY
SPLITSKO-DALMATINSKA	SPLIT-DALMATIA COUNTY
ŠIBENSKO-KNINSKA	ŠIBENIK-KNIN COUNTY
VARAŽDINSKA	VARAŽDIN COUNTY
VIROVITIČKO-PODRAVSKA	VIROVITICA-PODRAVINA COUNTY
VUKOVARSKO-SRIJEMSKA	VUKOVAR-SYRMIA COUNTY
ZADARSKA	ZADAR COUNTY
<i>Ukupna potrošnja finalne energije (GJ)</i>	<i>ZAGREB COUNTY</i>

Figure 7: Final household energy consumption by Croatian counties

The total final energy consumption by Croatian households was 105 PJ in 2013, with the share of total consumption at approximately 75 % of final consumption.

The 2011 Census showed the total number of cities/municipalities with more than 10 000 inhabitants to be 66, so the total final and useful energy consumption was calculated for those cities/municipalities.

The analysis of thermal energy consumption is based on an estimate of the so-called useful energy consumption. As opposed to final consumption, useful consumption shows the actual consumption used for a specific purpose. To simplify, useful consumption may be said to be equal to final consumption minus losses generated by a consumer unit. For example, a room stove burning solid fuels will transfer a part of the heat generated by fuel combustion into the heated space. However, a considerable part of the heat will be released into the chimney. According to some analyses, the energy efficiency of old stoves is no more than 35 %.

Initial preliminary analyses of useful energy consumption for heating showed the total useful consumption in centrally-heated dwellings to be about 22.7 PJ and useful energy in room-heated dwellings to be 1.5 PJ, while the consumption of district heating system energy is 6.6 PJ.

The calculations of useful energy consumptions for DHW generation have been done in a similar manner.

Useful heat consumption has been modelled using the following parameters: total floor area of the housing space and its heated area, and the standards of useful energy consumption determined specifically for different heating methods of central/room heating, in combination with fuels used for that purpose: firewood, fuel oil, natural gas, coal, district heating system, etc. It should be noted that these standards have been calculated according to the areas with typical energy consumption, characterised by climate, available energy infrastructure, natural resources and other. The average energy consumption standard in centrally-heated residential units in Croatia is around 180 kWh/m² of the heated area, while standing at around 124 kWh/m² of the heated area in room-heated residential units.

The average useful energy standard values in room- and centrally-heated Croatian dwellings, grouped in three characteristic zones: continental Croatia, central Croatia and southern Croatia, are shown in the figure below.

The total floor area of housing space is available in the 2011 Census, and is a very reliable parameter for assessing useful needs, while heated area has been determined on the basis of a survey conducted in 2013.

2.4. PROJECTED FUTURE USEFUL THERMAL ENERGY CONSUMPTION IN THE HOUSEHOLD SECTOR

To prepare the consumption estimates of future needs for useful thermal energy, an internationally recognised end-use MAED model, developed by the International Atomic Energy Agency (IAEA), has been used and adapted to the specific characteristics and requirements of the project task.

The end-use model enables covering the impact of all relevant energy consumption determinants, such as: domestic product growth and structure, demographic changes, housing standard, population mobility, climate, changes in efficiency of the energy use, habits and customs, etc.

In the household sector, two types of permanent housing, namely, family houses and apartments, have been modelled for each of the three climate zones. For each type of building, different useful energy for heating and conditioning of the housing space has been modelled, depending on the climate of a particular geographical area. The same useful energy has been modelled for DHW preparation, useful energy for cooking and electricity consumption for lighting, laundry washing and drying, food conditioning, dish washing and other purposes for all types of households in each particular zone.

The basic concept of the end-use model is to use structural analysis of the energy consumption achieved to establish the specific energy consumption per unit amounts of energy consumption determinants and subsequently to synthesise the overall future consumption, based on the development scenarios for individual determinants and specific consumptions. Structural analysis determines the functional relations of the relevant energy consumption determinants to the energy consumption itself. It is a simulation, where the functional relations are formally recorded and represented by simple linear equations.

Future energy needs are always forecast on the basis of several scenarios. Each scenario represents assumed development of a set of consumption determinants. Frequently, the analyses of a possible future course of development of relevant determinants may be found in specialised studies or strategies, such as studies of economic development, demographic structure, traffic development or housing stock development, etc. Where no official assessment of development of a certain determinant is available, it is

usually estimated officially by experts, typically by analogy to the countries which have already gone through that stage of socio-economic development.

In principle, the scenarios can be divided into two sub-scenarios:

- the first one concerns the socio-economic system, and describes the fundamental characteristics of social and economic development of the country;
- the second one concerns the technological factors affecting the calculations of energy needs, e.g. efficiency and market penetration of competing energy forms.

The key to success for the establishment of a viable and useful scenario lies in internal consistency of the assumptions, particularly as regards social, economic and technological progress. What it takes, above all, is very good knowledge of the dynamic interaction among the various driving parameters (determining factors). Future energy needs, as the result of the model, actually reflect the scenario assumptions.

The key parameter in estimating energy consumption in the household sector is a population projection of a particular area. For that purpose, projections of the population in the territory of Croatia until 2030, according to the 'Population projections for the Republic of Croatia, 2010-2061' (Croatian Bureau of Statistics, 2011) and corrections published in the document entitled *Spatial aspects of demographic potentials in Croatia, 2011-2051* (Wertheimer-Baletić, A.; Akrap, A; 2014) have been used.

Population projections in characteristic climate zones are shown in the figure below.

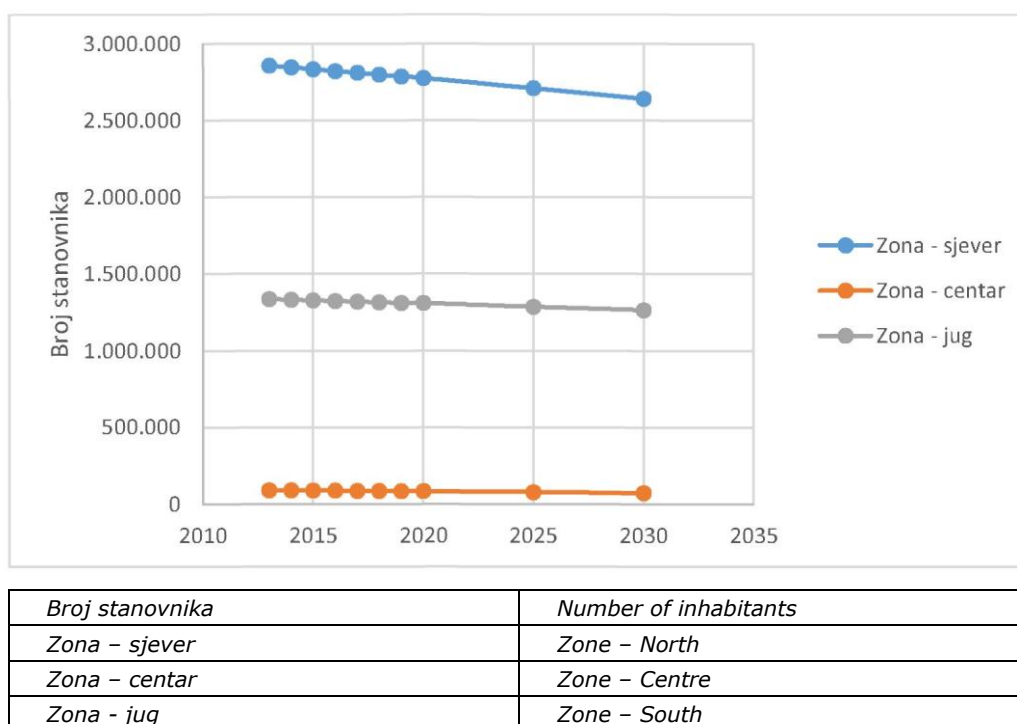


Figure 8: Population projections by climate zones until 2030

In conclusion, the model used in analysing useful consumption consists of the following sequential operations:

- mutually coordinated distribution of total energy needs of the country or region analysed into a great number of energy consumption sectors;
- identification of social, environmental and technological parameters affecting each category of useful energy consumption;
- determination of mathematical relations with regard to energy needs and factors affecting them;
- development of scenarios consistent with social, economic and technological development of the observed country;
- increase in energy needs as a result of each scenario; and, finally,
- selection of the most likely development pattern for the particular country among all potential scenarios proposed.

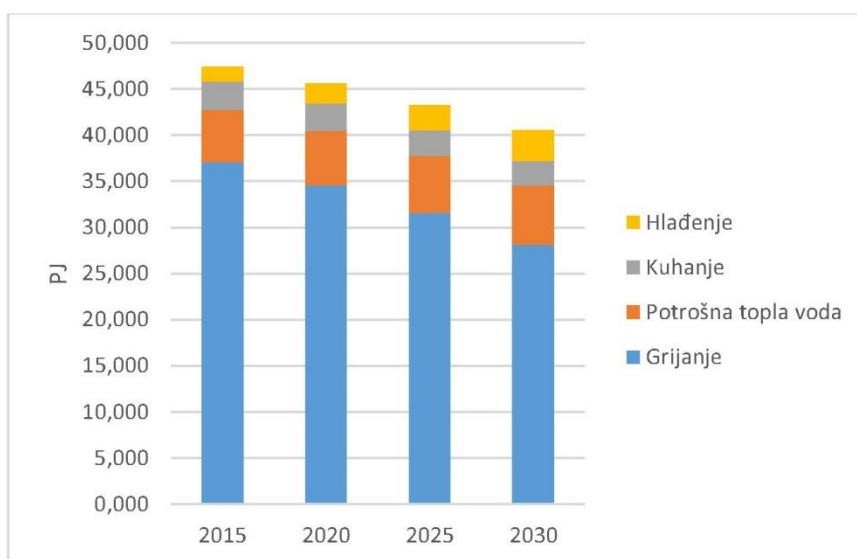
A detailed overview of useful thermal energy needs by cities and municipalities with more than 10 000 inhabitants is provided in the table below.

Table 14: Estimated useful thermal energy needs in cities and municipalities with more than 10 000 inhabitants until 2030

Name of city/municipality	Useful thermal energy needs [GJ]			
	2015	2020	2025	2030
Bjelovar	630 314	597 479	557 732	512 101
Daruvar	206 129	195 391	182 392	167 470
Garešnica	164 773	156 189	145 799	133 870
Nova Gradiška	234 544	222 327	207 537	190 558
Slavonski Brod	911 028	863 573	806 126	740 176
Dubrovnik	323 357	327 546	328 016	324 881
Metković	98 457	99 732	99 876	98 921
Ploče	69 934	70 840	70 941	70 263
City of Zagreb	13 976 862	13 247 935	12 365 608	11 352 686
Labin	123 754	124 813	124 220	122 001
Poreč – Parenzo	165 745	167 163	166 369	163 397
Pula – Pola	605 141	610 314	607 417	596,565
Rovinj – Rovigno	146 928	148 185	147 481	144 846
Umag – Umago	142 705	143 925	143 242	140 683
Duga Resa	189 422	179 516	167 527	153 764
Karlovac	980 735	929 447	867 374	796 117
Ogulin	220 639	211 582	202 802	193 166
Koprivnica	495 064	469 167	437 825	401 845
Križevci	317 694	301 075	280 962	257 873
Krapina	182 338	172 791	161 238	147 975
Gospić	247 491	237 146	227 078	216 013
Čakovec	418 796	396 818	370 223	339 694
Nedelišće	168 251	159 422	148 737	136 472
Belišće	174 750	165 635	154 601	141 934
Đakovo	399 996	379 131	353 875	324 881
Našice	255 179	241 868	225 756	207 259
Osijek	1 929 529	1 828 879	1 707 048	1 567 186
Valpovo	186 174	176 462	164 707	151 212
Čepin	174 004	164 928	153 941	141 329
Pleternica	161 774	153 345	143 142	131 428
Požega	419 275	397 429	370 985	340 626
Crikvenica	127 369	128 349	127 584	125 095
Kastav	104 691	105 496	104 867	102 822
Opatija	131 748	132 761	131 970	129 395
Rijeka	1 461 070	1 472 307	1 463 533	1 434 982
Matulji	115 581	116 470	115 776	113 517
Viškovo	142 217	143 311	142 457	139 678
Kutina	354 702	336 342	314 109	288 583
Novska	201 122	190 711	178 105	163 631
Petrinja	383 882	364 011	339 949	312 323
Sisak	817 987	775 646	724 374	665 509
Popovača	172 351	163 430	152 627	140 224
Imotski	79 019	79 555	78 979	77 301
Kaštela	285 988	289 250	289 039	285 438
Makarska	112 287	113 567	113 485	112 071
Omiš	111 179	112 447	112 365	110 965
Sinj	222 745	224 257	222 634	217 905
Solin	177 185	179 206	179 076	176 845
Split	1 422 605	1 438 832	1 437 782	1 419 869
Trogir	103 658	104 840	104 764	103 459
Knin	160 556	161 519	160 170	156 524

Name of city/municipality	Useful thermal energy needs [GJ]			
	2015	2020	2025	2030
Šibenik	423 814	428 076	426 953	420 548
Ivanec	190 579	180 578	168 475	154 583
Novi Marof	187 533	177 692	165 783	152 112
Varaždin	796 540	754 738	704 155	646 089
Slatina	221 711	210 107	196 064	179 943
Virovitica	357 274	338 575	315 946	289 968
Vinkovci	548 917	520 447	485 976	446 400
Vukovar	488 668	463 323	432 636	397 404
Županja	176 629	167 468	156 376	143 641
Benkovac	87 842	88 739	88 526	87 224
Zadar	664 394	671 180	669 567	659 720
Dugo Selo	245 461	232 704	217 260	199 529
Ivanić-Grad	225 520	213 799	199 610	183 320
Jastrebarsko	228 743	216 856	202 463	185 940
Samobor	559 447	530 373	495 173	454 762
Sveta Nedelja	252 645	239 515	223 619	205 369
Sveti Ivan Zelina	221 421	209 914	195 982	179 988
Velika Gorica	955 684	906 017	845 887	776 853
Vrbovec	198 579	188 259	175 764	161 420
Zaprešić	394 533	374 029	349 205	320 707
Brdovec	158 697	150 450	140 465	129 001

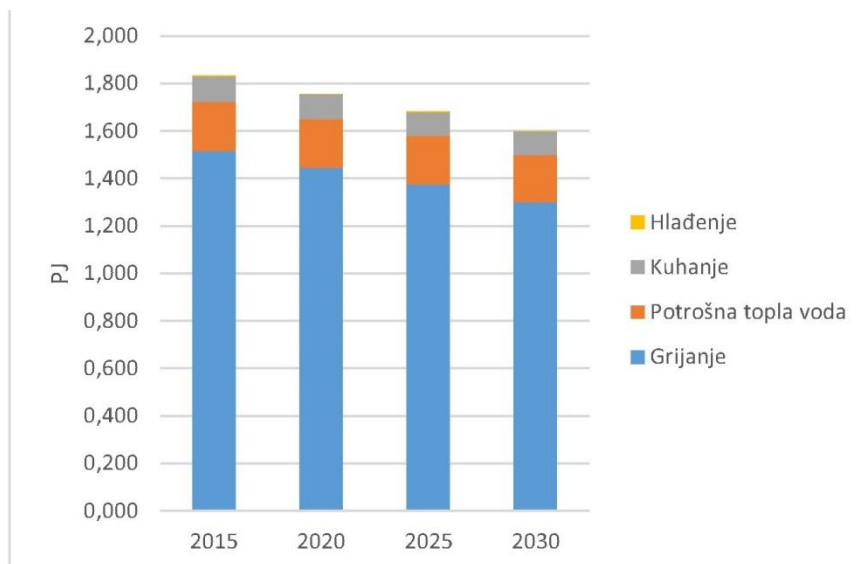
In the climate zone North, which includes the northern part of Croatia and almost a million of permanently occupied residential units, the projected useful thermal energy needs are to fall in the period until 2030.



<i>PJ</i>	<i>PJ</i>
<i>Hlađenje</i>	<i>Cooling</i>
<i>Kuhanje</i>	<i>Cooking</i>
<i>Potrošna topla voda</i>	<i>Domestic hot water</i>
<i>Grijanje</i>	<i>Heating</i>

Figure 9: Estimate of useful thermal energy for climate zone – North

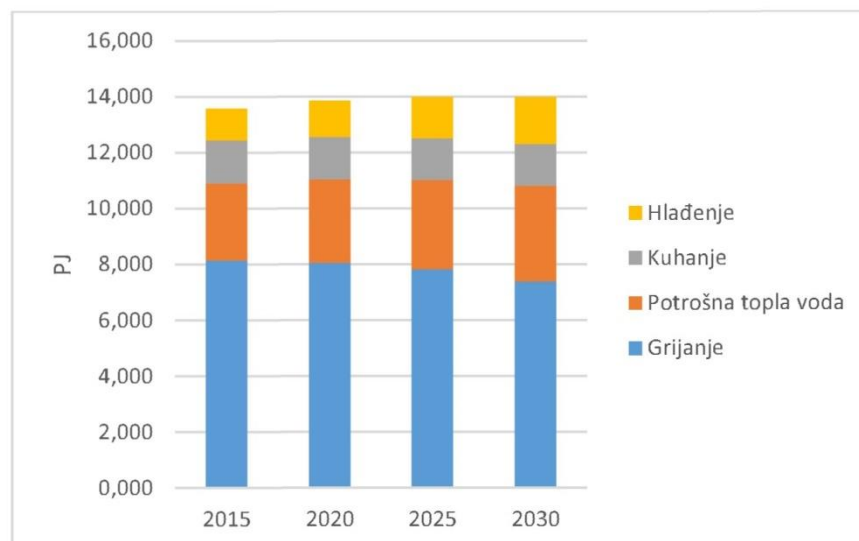
Such a trend is a result of improved building standards and increased energy efficiency levels in the household sector, but also a significant population decline in this part of Croatia by 2030.



<i>PJ</i>	<i>PJ</i>
<i>Hlađenje</i>	<i>Cooling</i>
<i>Kuhanje</i>	<i>Cooking</i>
<i>Potrošna topla voda</i>	<i>Domestic hot water</i>
<i>Grijanje</i>	<i>Heating</i>

Figure 10: Estimate of useful thermal energy for climate zone – Centre

We can find a similar trend in the northern part of Croatia in the coldest climate zone – Centre, as well. The reduced thermal energy requirements primarily result from increased levels of energy efficiency and thermal performance of residential buildings.



<i>PJ</i>	<i>PJ</i>
<i>Hlađenje</i>	<i>Cooling</i>
<i>Kuhanje</i>	<i>Cooking</i>
<i>Potrošna topla voda</i>	<i>Domestic hot water</i>
<i>Grijanje</i>	<i>Heating</i>

Figure 11: Estimate of useful thermal energy for climate zone – South

The slight increase in estimated thermal energy consumption in the climate zone South is a result of increased standards of living, and above all, the increased need for space cooling by means of air conditioners.

Total energy consumption in the household sector amounted to 103.7 PJ in 2013. In the structure of final energy fuels, firewood holds the largest share in consumption with 48 %, followed by electricity with 21 %, natural gas with 19 %, heat with 5 %, and fuel oil and liquefied petroleum with 4 and 3 %, respectively.

The results of modelling the projections of future thermal energy needs show that throughout Croatia, except in coastal areas, the reduction of thermal energy consumption may be expected, which is largely a result of an expected population decline in these parts of Croatia, but also expected improvement of the energy performance of buildings. In the zone South, that is, in the coastal area of Croatia, a slight increase in thermal energy needs prompted by an increase of living standards and increased energy needs for cooling is foreseen, along with expected population growth.

2.5. ANALYSIS OF SERVICE SECTOR ENERGY CONSUMPTION

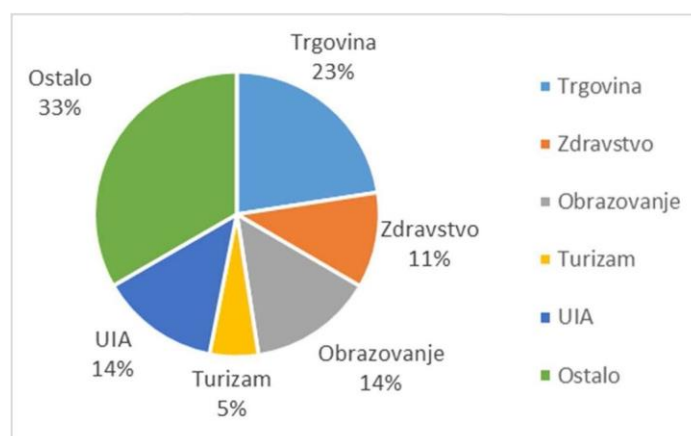
In the service sector, energy consumption has been analysed by all cities/municipalities, singling out those with more than 10 000 inhabitants. Services have been modelled separately for education, health, governance and administration, trade, tourism, and hotels and restaurants sub-sectors by calculating the standards of energy consumption for heating and cooling purposes and non-thermal consumption for each of these service sub-sectors.

The entire service sector has been modelled upon the school sector. The consumption of useful heat for space heating, DHW preparation and cooling is based on adherence to several criteria: the number of permanent employees, the number of students, the total heated area and the total useful floor area.

Energy consumption in three groups of counties has been modelled, and other parameters affecting energy consumption, such as duration of daily use of the facility/shift work etc., have been analysed in addition to the basic criteria.

According to the Croatian Bureau of Statistics data, the schools and education sector had 109 294 employees in 2013, and the average building floor area per employee was 63 m², or 12 m² per student. The total floor area of education sector buildings is estimated at 6.2 million m².

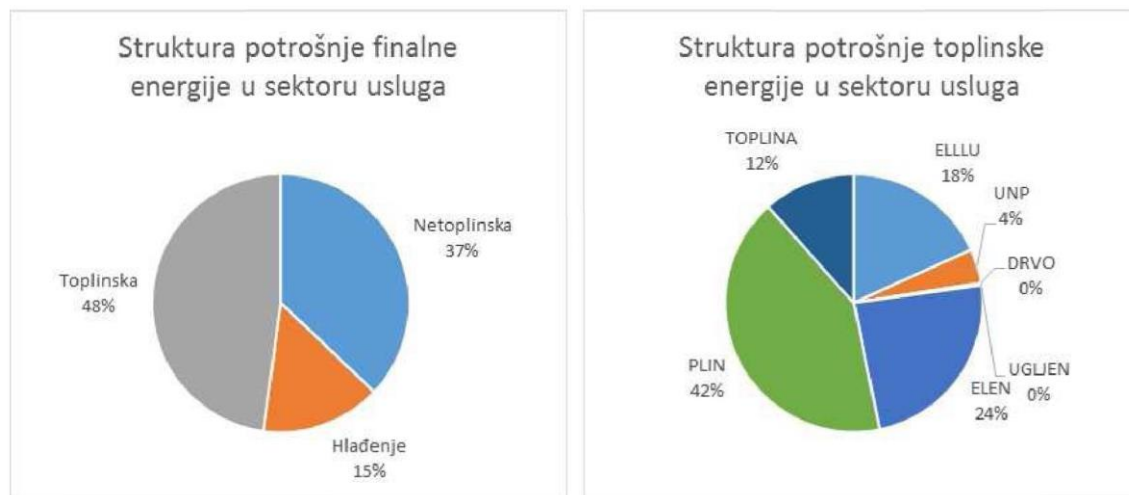
The total number of employees in the service sector in Croatia was 780 722 in 2013. The structure of the total employed by service sub-sectors is shown in the following figure. Other services sub-sector accounts for the largest share of employees in the service sector, followed by trade with a 23 % share, governance and administration sectors, each with a share of 14 %, health sector with 11 %, and tourism sector with a 5 % share of permanent employees.



<i>Trgovina</i>	<i>Trade</i>
<i>Zdravstvo</i>	<i>Health</i>
<i>Obrazovanje</i>	<i>Education</i>
<i>Turizam</i>	<i>Tourism</i>
<i>UIA</i>	<i>GAA</i>
<i>Ostalo</i>	<i>Other</i>

Figure 12: Employee structure by service sub-sectors

In 2013, the total energy consumption in the service sector amounted to 29 118 TJ. The share of thermal energy in total consumption was 48 %, while cooling energy accounted for 15 %. In the structure of thermal energy consumption, natural gas was the prevalent [fuel] with a 42 % share, followed by electricity with 24 %, extra light fuel oil with 18 %, heat with 12 %, and liquefied petroleum gas with 4 %.



<i>Struktura potrošnje finalne energije u sektoru usluga</i>	<i>Structure of service sector final energy consumption</i>
<i>Toplinska</i>	<i>Thermal</i>
<i>Netoplinska</i>	<i>Non-thermal</i>
<i>Hlađenje</i>	<i>Cooling</i>
<i>Struktura potrošnje toplinske energije u sektoru usluga</i>	<i>Structure of service sector thermal energy consumption</i>
<i>TOPLINA</i>	<i>HEAT</i>
<i>ELLU</i>	<i>ELFO</i>
<i>UNP</i>	<i>LPG</i>
<i>DRVO</i>	<i>WOOD</i>
<i>UGLJEN</i>	<i>COAL</i>
<i>ELEN</i>	<i>ELEN</i>
<i>PLIN</i>	<i>GAS</i>

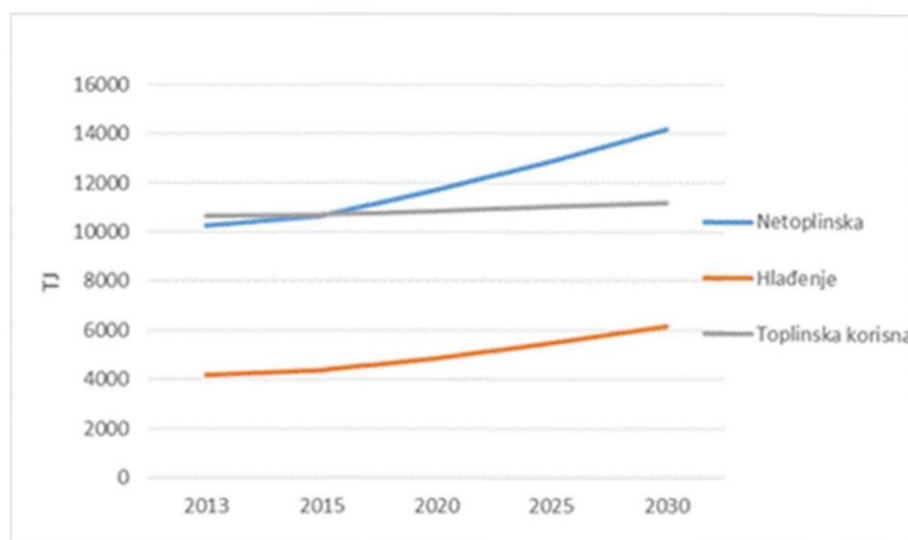
Figure 13: Structure of service sector final energy and thermal energy consumption in 2013

2.6. PROJECTED FUTURE USEFUL THERMAL ENERGY CONSUMPTION IN THE SERVICES SECTOR

Projected future service sector needs have been calculated on the basis of the presumed number of service sector employees, modelled on the projections of total and working-age population. In addition to modelling the projected number of employees, other determinants of energy consumption common to all sub-sectors, e.g. floor area of the enclosed space in which service activity is performed, structure of the energy used and other indicators, have also been analysed.

The model used for projecting heat needs is based on a presumed increase in the floor area of enclosed space in which service activity is performed. The increase in heat consumption in 2030 is much lower than in other consumption categories since the calculation took into account improved thermal insulation of buildings and technologies used to generate thermal energy (central, individual heating). The consumption for thermal needs is presumed to be around 11 180 TJ in 2030. The average rate of increase in energy consumption for heating purposes is around 0.3 %.

An increase in projected cooling needs is based on the estimates of a growing share of cooled areas. The share of cooled areas was around 45 % in 2013, but is estimated to reach 62 % in 2030. The average rate of increase in cooling energy consumption was approximately 2.4 % in the period under observation.



<i>TJ</i>	<i>TJ</i>
<i>Netoplinaska</i>	<i>Non-thermal</i>
<i>Hlađenje</i>	<i>Cooling</i>
<i>Toplinska korisna</i>	<i>Useful thermal</i>

Figure 14: Projected increase in service sector energy consumption for heating and cooling purposes, 2013-2030

An overview of projected thermal energy consumption in the 10 largest cities in Croatia is shown in the following table.

Table 15: Projected thermal energy increase in 10 largest Croatian cities by 2030

No	Name of city/municipality	2015	2020	2025	2030
1	Zagreb	13 976 862	13 247 935	12 365 608	11 352 686
2	Split	1 422 605	1 438 832	1 437 782	1 419 869
3	Rijeka	1 461 070	1 472 307	1 463 533	1 434 982
4	Osijek	1 929 529	1 828 879	1 707 048	1 567 186
5	Zadar	664 394	671 180	669 567	659 720
6	Velika Gorica	955 684	906 017	845 887	776 853
7	Slavonski Brod	911 028	863 573	806 126	740 176
8	Pula – Pola	605 141	610 314	607 417	596 565
9	Karlovac	980 735	929 447	867 374	796 117
10	Sisak	817 987	775 646	724 374	665 509

Total energy consumption in the service sector was 29 118 TJ in 2013. The share of thermal energy in total consumption was 48 %, while cooling energy accounted for 15 %. In the structure of thermal energy consumption, natural gas was the prevalent [fuel] with a 42 % share, followed by electricity with 24 %, extra light fuel oil with 18 %, heat with 12 %, and liquefied petroleum gas with 4 %.

In the service sector, a modest increase of useful thermal energy and a substantially greater increase in energy needed for cooling are expected as a result of economic development.

2.7. ANALYSIS OF INDUSTRY SECTOR ENERGY CONSUMPTION

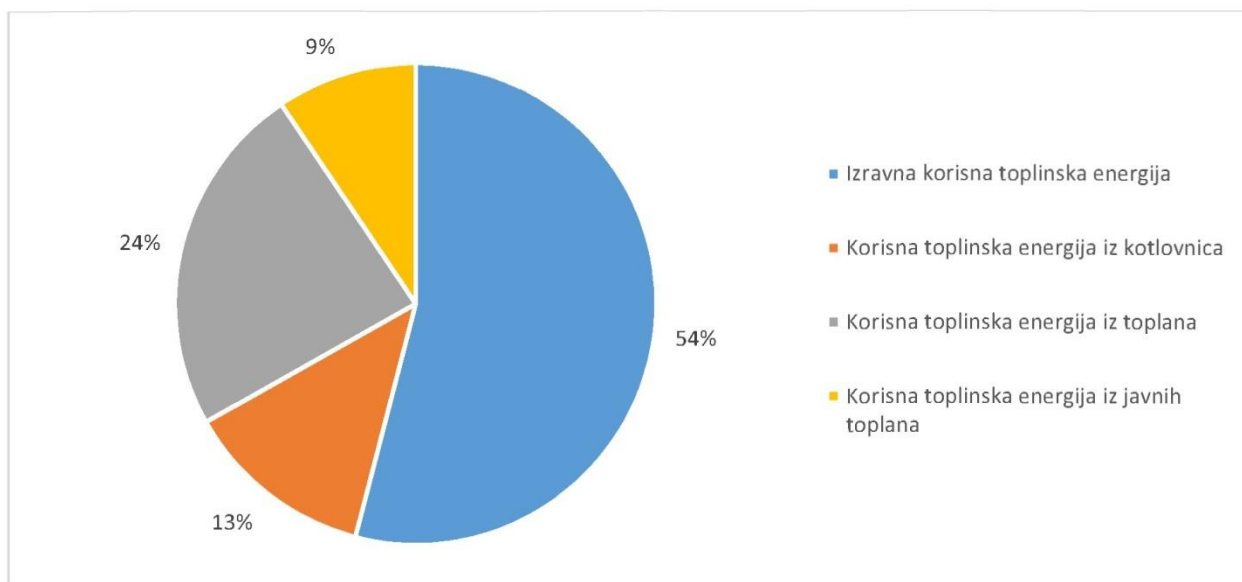
Given that industrial plants often have very specific requirements for the parameters of heat used in the process, the required heat has been divided into direct heat generated by direct combustion of different fuels in the plant itself, and indirect heat produced in the boiler room or heating plant and used subsequently in the technological process.

This differentiation is also relevant from the aspect of assessing the potential of using cogeneration to meet the industry's thermal needs, where it is important to note that the room for efficient heating and cooling lies mainly in the area of indirect heat.

Direct thermal energy consumption in the industry has been calculated and modelled by analysing the consumption of all fuels in industrial plants, on the assumption that 10 % of the total electricity consumed is used to meet thermal needs.

Indirect thermal energy includes heat produced in boiler rooms and heating plants within industrial plants, and heat obtained from public heating plants in Zagreb, Osijek, Varaždin and Udbina.

In 2013, the total useful thermal energy consumed at industrial plants amounted to 22.729 PJ, of which 12.281 PJ was direct thermal energy and 10.447 PJ indirect thermal energy.



<i>Izravna korisna toplinska energija</i>	<i>Direct useful thermal energy</i>
<i>Korisna toplinska energija iz kotlovnica</i>	<i>Useful thermal energy from boiler rooms</i>
<i>Korisna toplinska energija iz toplana</i>	<i>Useful thermal energy from heating plants</i>
<i>Korisna toplinska energija iz javnih toplana</i>	<i>Useful thermal energy from public heating plants</i>

Figure 15: Share of individual types of useful energy in industry

Direct useful thermal energy with a share of 54 % dominates in the overall structure of useful thermal energy in the industrial sector, followed by thermal energy obtained from cogeneration plants with a share of 24 % and thermal energy from public heating plants and own boiler rooms.

The table below shows the useful energy consumed at industrial plants in cities and municipalities with more than 10 000 inhabitants.

Table 16: Useful thermal energy needs in industry, 2013

Name of city/municipality	Direct thermal energy (GJ)	Indirect thermal energy (GJ)
Bjelovar	142 471	120 386
Daruvar	8 343	10 404
Garešnica	18 527	51 000
Nova Gradiška	118 885	6 000
Slavonski Brod	108 595	106 898
Dubrovnik	10 204	0
Metković	3 221	0
Ploče	1 164	0
City of Zagreb	847 575	2 038 088
Labin	5 967	0
Poreč – Parenzo	15 864	0
Pula – Pola	1 293 789	3 602
Rovinj – Rovigno	5 642	63 752
Umag – Umago	86 756	73 319
Duga Resa	18 622	0

Name of city/municipality	Direct thermal energy (GJ)	Indirect thermal energy (GJ)
Karlovac	100 947	111 079
Ogulin	12 304	0
Koprivnica	302 320	243 801
Križevci	32 470	0
Krapina	11 154	12 196
Gospić	17 718	0
Čakovec	112 747	66 759
Nedelišće	6 497	0
Belišće	42 408	795 000
Đakovo	108 019	0
Našice	1 208 692	0
Osijek	289 107	780 539
Valpovo	11 339	0
Čepin	2 479	16 534
Pleternica	25 676	0
Požega	179 515	120 346
Crikvenica	1 380	0
Kastav	1 994	0
Opatija	6 561	0
Rijeka	35 865	70 787
Matulji	2 571	0
Viškovo	1 511	0
Kutina	79 758	3 376 500
Novska	5 001	0
Petrinja	8 995	107 400
Sisak	118 424	14 739
Popovača	23 386	0
Imotski	718	0
Kaštela	2 504 510	0
Makarska	62	0
Omiš	27 647	11 975
Sinj	4 379	0
Solin	9 011	0
Split	44 659	11 075
Trogir	3 700	0
Knin	17 770	0
Šibenik	163 815	3 036
Ivanec	20 659	50 000
Novi Marof	187 505	0
Varaždin	239 269	261 144
Slatina	32 356	8 294
Virovitica	52 285	553 838
Vinkovci	118 246	0
Vukovar	19 821	0
Županja	142 626	390 879
Benkovac	27 125	0
Zadar	18 711	100
Dugo Selo	17 871	0
Ivanić-Grad	23 031	0
Jastrebarsko	9 613	0
Samobor	38 171	0

Name of city/municipality	Direct thermal energy (GJ)	Indirect thermal energy (GJ)
Sveta Nedelja	84 628	173
Sveti Ivan Zelina	21 909	173
Velika Gorica	9 636	0
Vrbovec	21 679	123 519
Zaprešić	57 343	101 959
Brdovec	27 031	86 873

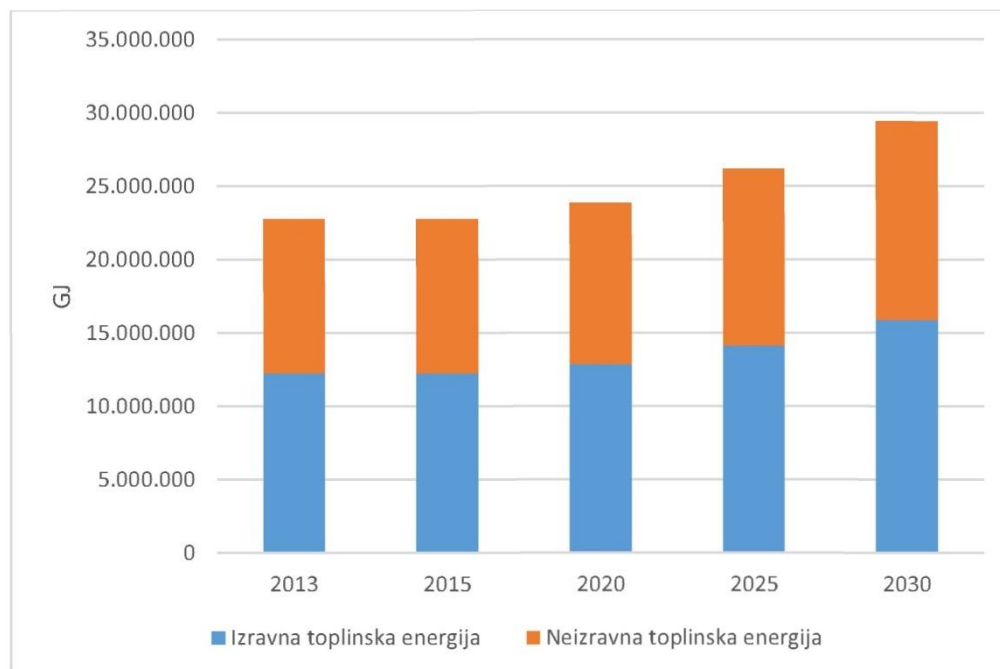
2.8. PROJECTED FUTURE USEFUL THERMAL ENERGY CONSUMPTION IN THE INDUSTRY SECTOR

The following categories of useful consumption have been defined in the industry: useful thermal needs and electricity for non-thermal needs, and energy used for powering motor vehicles.

Useful thermal energy needs have been divided into two categories: low- and medium-temperature, and high-temperature needs. Low- and medium-temperature thermal needs are met by heat from boilers, cogeneration, public heating plants, heat pumps or solar installations, and are hereinafter referred to as indirect thermal energy. High-temperature thermal needs are met by direct combustion of fossil fuels or direct electricity heating in technological processes, and are hereinafter referred to as direct thermal energy. Where more detailed statistical data are available, that which is defined as low-temperature heat can be further divided into two temperature levels.

Electricity for non-thermal use is electricity for lighting, motor drives, compressors and chemical processes. Since that electricity cannot be substituted, it is also known as the specific use of electricity.

The estimate of future useful energy consumption in the industry sector is based on projected GDP growth until 2030, strategic documents related to the development of the economy and industry, such as Croatia's Industrial Strategy 2014-2020, recommendations on and analyses of economic developments for the period until 2030 provided by international organisations, such as the World Bank and the International Monetary Fund, as well as expert evaluations.



<i>GJ</i>	<i>GJ</i>
<i>Izravna toplinska energija</i>	<i>Direct thermal energy</i>
<i>Neizravna toplinska energija</i>	<i>Indirect thermal energy</i>

Figure 16: Estimate of useful thermal energy in industry until 2030

In view of the expected GDP growth in the period until 2030, an increase of thermal energy needs by up to almost 30 PJ is expected; also, it is important to distinguish between direct thermal energy (heat caused by direct fuel combustion and used in the production process) and indirect thermal energy (heat produced in boiler rooms and heating plants), since only indirect thermal energy can be substituted by heat from high-efficiency cogeneration.

2.9. THERMAL ENERGY AND COOLING ENERGY CONSUMPTION MONITORING

2.9.1. Energy consumption monitoring at the level of Croatia

Timely, consistent and reliable energy statistics are essential for numerous energy analyses, planning of the energy sector development, safe energy supply, implementation of energy efficiency measures, increased use of renewable energy sources, reduction of greenhouse gas emissions, etc.

In the overall energy statistics, final energy consumption is of particular importance for the said analyses. Since final consumption is a very demanding segment of the energy statistics owing to extremely complex consumption characteristics in individual sectors of final consumption (households, services, industry, transport, agriculture, construction sector), major importance has been given to this form of statistics in Croatia in recent years.

The European Commission has adopted amendments to the prescribed standards of preparing energy statistics in the European Union, that is, to Regulation (EC) No 1099/2008 on energy statistics, requiring that final consumption statistics be improved by further dividing total final energy consumption by individual sectors to sub-sectors and, additionally, by energy consumption purpose (e.g. heating, cooking, hot water, cooling, lighting, etc.). This also ensures the monitoring of thermal energy and cooling energy consumption, that is, the monitoring of the energy efficiency indicator.

With a view to separating final energy by intended use (thermal, non-thermal and cooling energy), it is necessary to collect adequate data and have models available on which consumptions will be modelled. The next requirement laid down by regulations is to ensure the continuity of data collection and calculation of energy efficiency indicators.

In recent years, the consumption of thermal energy and cooling energy in Croatia has been determined by methodological procedures based on surveys of particular sectors of final consumption as the only source of such information, conducted mainly at the level of counties, municipalities and cities. Being quite expensive and complex, these surveys and need not be implemented every year but at intervals of three to five years.

In addition to data collection by statistical methods, namely, surveying, it was necessary not only to develop models for calculating final energy consumption by purpose, but also to collect additional information used in calibrating survey results and estimating values in non-surveyed periods. This concerns particularly the collection by distributors of networked fuels (electricity, natural gas, thermal energy) of additional consumption data by individual consumer categories in the manner laid down by the energy statistics.

The first comprehensive survey of energy consumption in the Republic of Croatia was launched by the Croatian Bureau of Statistics (CBS) in 2011; it has since implemented three IPA projects related to improving the energy statistics, entitled Technical assistance in business statistics, under which the methods of surveying and examining energy consumption in households, services and transport have been developed. The Energy Institute Hrvoje Požar (EIHP) was also involved in the projects by setting up the methodological surveying concepts and developing calculation models.

These surveys have greatly contributed to the improvement of statistics, particularly the biomass (firewood) statistics, which had a major impact on the overall energy balance. However, the main survey contribution was the development of consistent models to calculate energy efficiency indicators.

One of the goals of the projects was to ensure the sustainability and continuity of research on energy consumption and consumption characteristics. Given that the CBS is the official Croatian authority for data collection, conducting such surveys should remain within the CBS competence.

In Member States, state statistics bureaus, as well as ministries competent for the energy or environment, are responsible for the compilation of the energy balance achieved. In Croatia, under the Statistics Act, the CBS is formally responsible for the energy balance compilation. But in practice, the compilation of the energy balance achieved is the responsibility of the Ministry of the Economy, and is

done by the EIHP. The Ministry publishes an annual bulletin, and the CBS republishes the results in the Statistical Yearbook.

2.9.2. Energy efficiency monitoring at the level of counties, municipalities and cities

In Croatia, the Energy Efficiency Act provides for the preparation of the Energy Efficiency Programme and Energy Efficiency Plan in final consumption which are based on the energy balance achieved at the county level.

A long-standing practice of energy balance compilation in Croatia, as well as recent final consumption surveys conducted by the Croatian Bureau of Statistics since 2011, provided an additional contribution to the development of detailed energy statistics, thus creating conditions for the compilation of the energy balances of individual counties, cities and municipalities. The Rules governing the compilation of the energy balance achieved could define the relations between the Ministry of the Economy, the CBS and the EIHP in the annual performance of these activities.

The survey on energy consumption in the household, service and transport sectors, to be carried out every three to five years at the level of entire Croatia, would allow for the spatial dispersion of consumption of non-networked energy to be properly determined at the local level. The final calibration of consumption would be carried out using data on the networked energy consumption achieved by individual consumption sectors, to be collected by distributors of networked fuels (electricity, natural gas and public heating plant) at the level of cities and municipalities. An advanced stage of energy statistics would include the monitoring of total energy consumption by individual customer, i.e. by each metering point.

Final fuels are used both for stationary energy needs and mobility. Final energy consumption for mobility is shown in the structure of fuels consumed in transport. The procedure for determining fuel consumption in transport within the administrative boundaries of a county is a relatively complex process. The EIHP has developed a method of fuel consumption surveying, metering and modelling at the level of a single county through a project financed by the City of Zagreb during 2012 and 2013 (Study: Compiling the energy balance of the City of Zagreb). It found a significant difference between the annual amounts of motor fuel sold in Zagreb and the annual amounts of motor fuel consumed in the Zagreb area. In 2012, 20 % more motor fuels were sold than consumed in the Zagreb area.

3. MAP OF CROATIA SHOWING THE LOCATIONS OF THERMAL ENERGY CONSUMPTION

3.1. CARTOGRAPHIC DATA

Maps of Croatia have been prepared on the basis of input data and their processing described in Chapter 2 – Forecast changes in energy consumption for heating and cooling until 2030. Official data used in map preparation are those available according to the methodology referred to in the preceding chapter.

Collected data have been synthesised into a single common database, and relevant factors related to the development of thermal energy consumption and market penetration of particular fuels have been identified. Finally, thermal energy consumption indicators have been presented at the level of municipalities. Thermal energy consumption has been divided by consumer categories (households, industry and services) and determined for the years 2020, 2025 and 2030.

All cartographic representations were made by geocoding numeric (tabular) data first, that is, by attributing a spatial component to them. Data visualisation on an appropriate map was the next step, which included classification (grouping) for graphical representation purposes.

Open source software was mainly used in preparing the map, with routines developed by the EIHP as part of its planning methodology and written in Python applied in automatic geocoding. They operate on OpenStreetMap database of geographic information, and OpenStreetMap Nominatim was used for geocoding, i.e. adding a spatial component to these data. Map processing and making was done using QGIS 2.8.2, another open source software package. Final results and graphical representations are suitable for interactive display even without the use of GIS tools. Therefore, the maps shown here are based on those from the OpenStreetMap system, which are also suitable for interactive display.

The authors of the Programme also prepared an interactive online representation of all the data obtained. The open sources LeafletJS library was used for interactive display of the map, which was prepared as an HTML website to be viewed in a web browser, with no need for specialised GIS software. For the purpose of web display, final results were converted to GeoJSON format.

In the interactive web map, it is possible to select the desired view (layer) to see the selected data at the level of the municipality or city, or view all results at the methodological level described in Chapter 2. The interactive web map was delivered with the Programme.

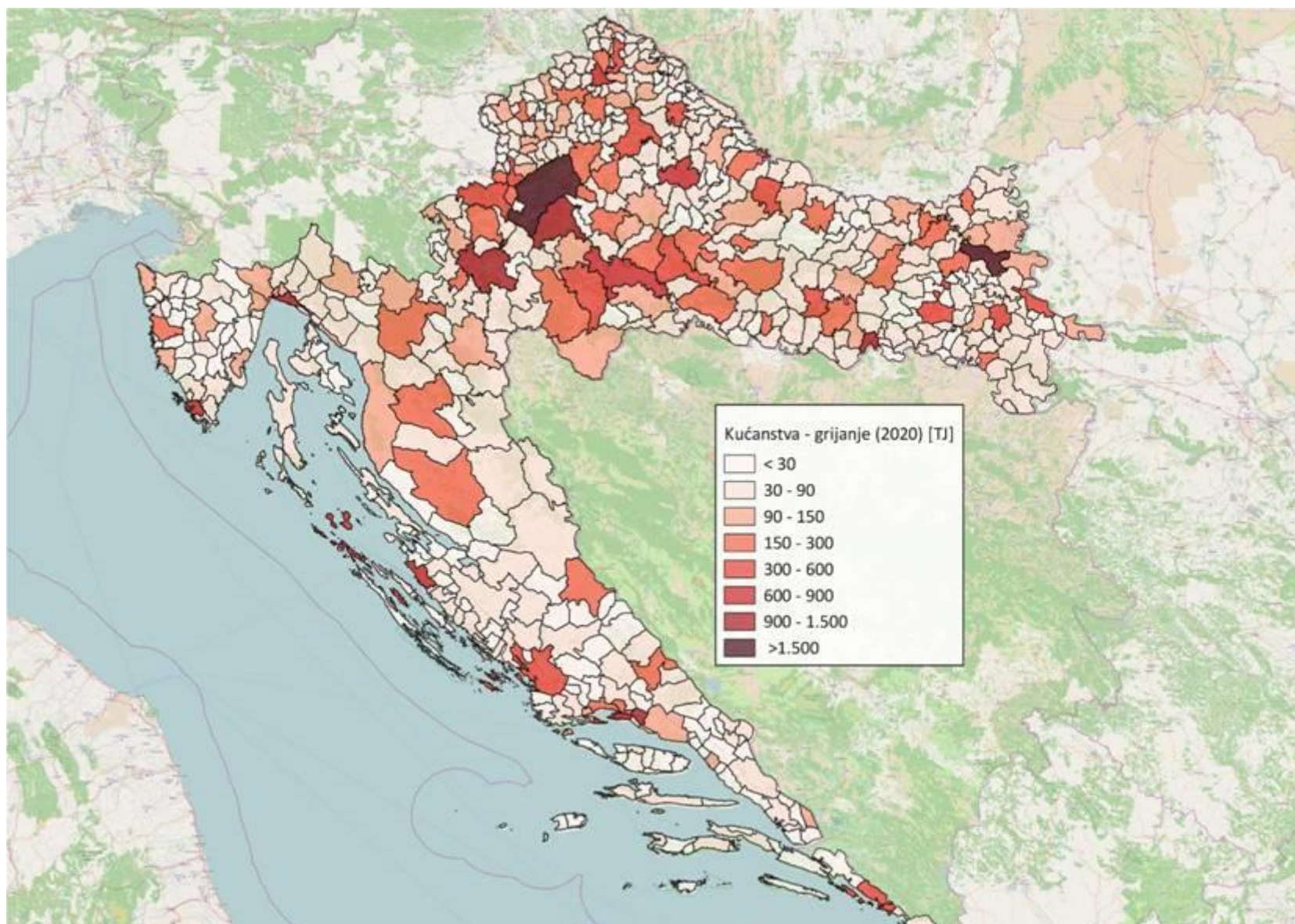
3.2. CARTOGRAPHIC REPRESENTATIONS

The following cartographic representations of the data obtained are available below:

- Thermal energy consumption for heating in households;
- Thermal energy consumption for cooling in households;
- Total thermal energy consumption in households;
- Direct thermal energy consumption in industry;
- Indirect thermal energy consumption in industry;
- Thermal energy consumption in service sector;
- Thermal energy consumption for cooling in service sector.

All cartographic representations are provided for the years 2020, 2025 and 2030.

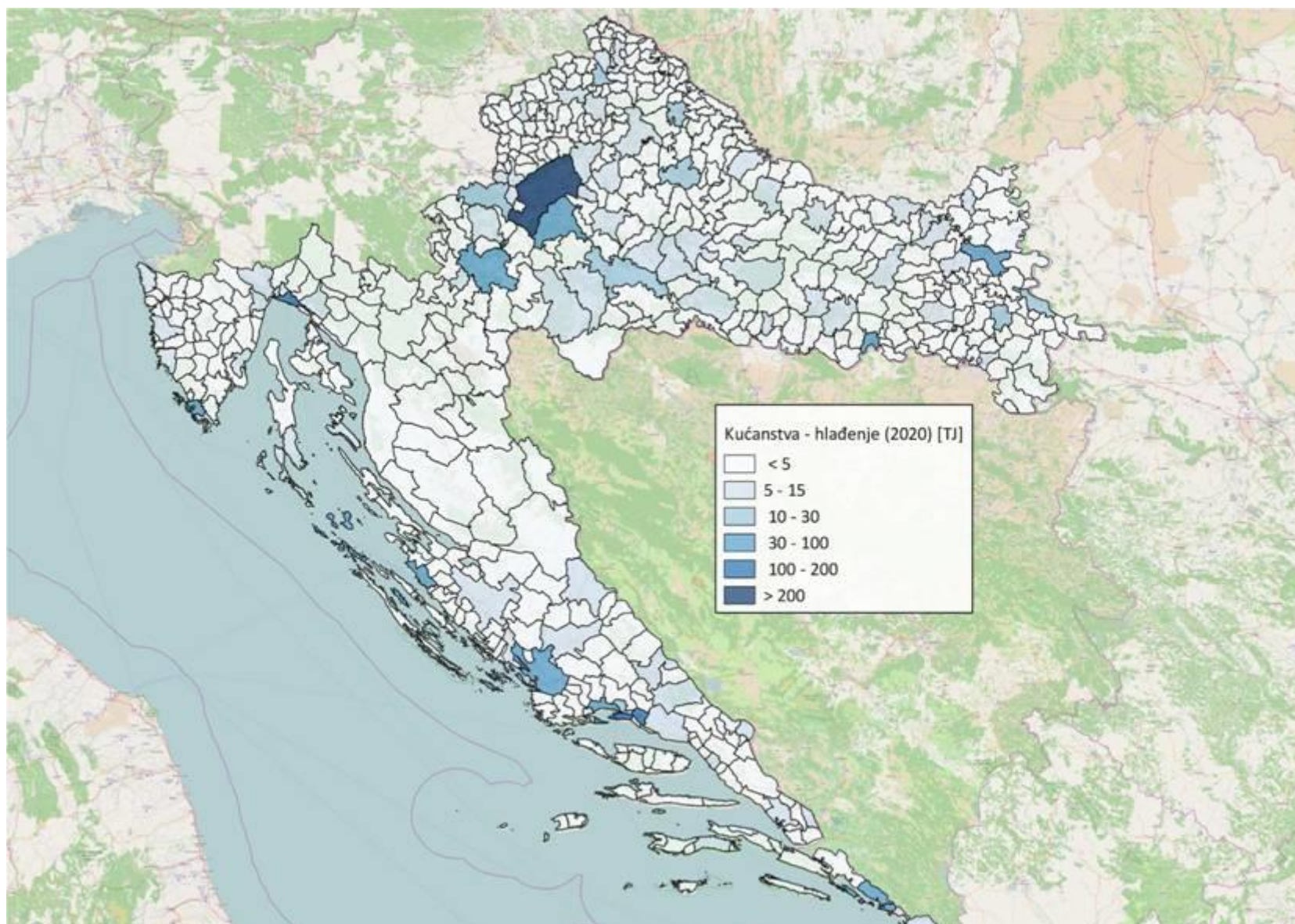
The graphic interface of the interactive web map is available at the end of the chapter.



Kućanstva - grijanje (2020) [TJ]

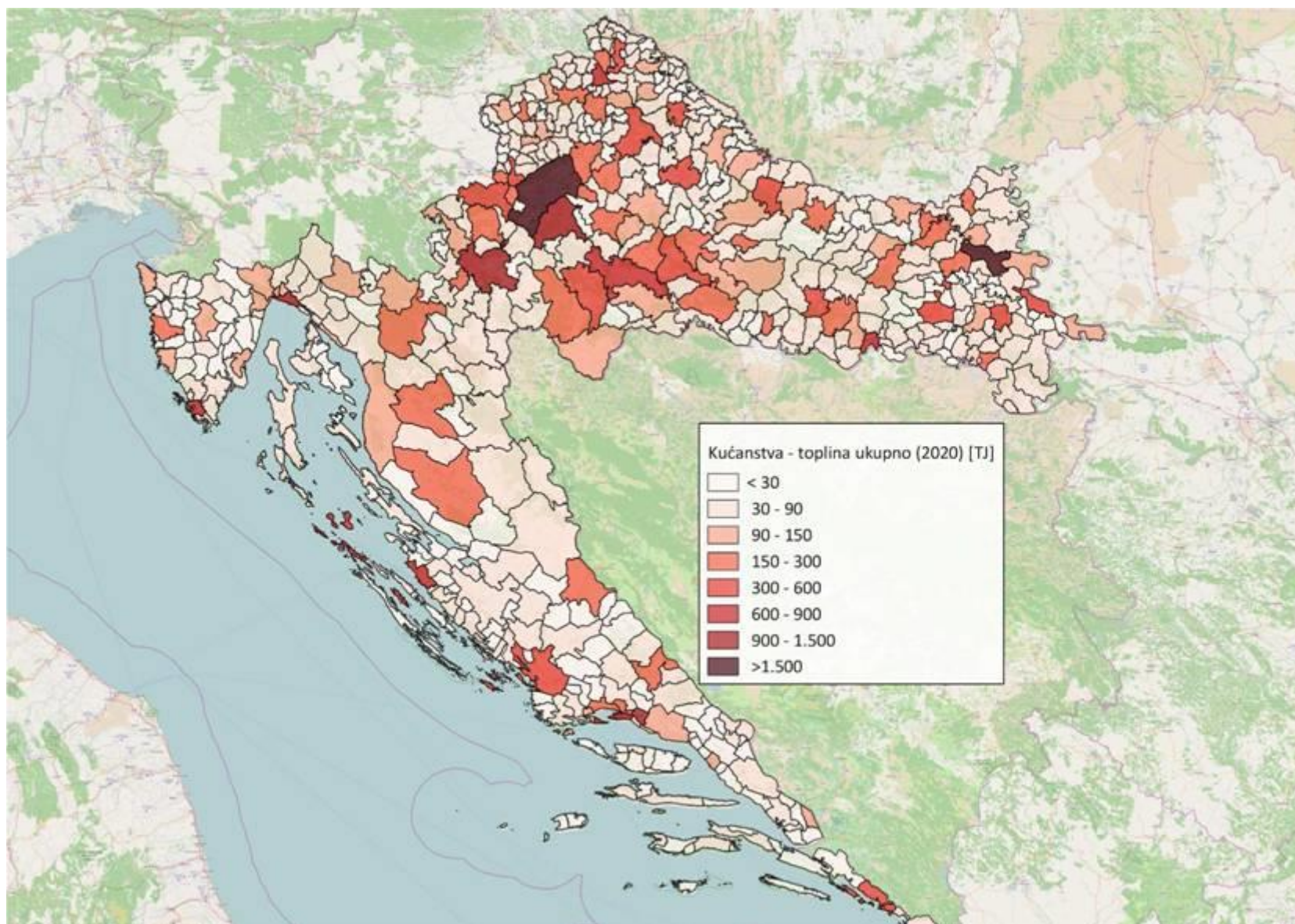
Households – heating (2020) [TJ]

Figure 17: Map of household thermal energy consumption for heating (2020)



Kućanstva - hlađenje (2020) [TJ]	Households – cooling (2020) [TJ]
----------------------------------	----------------------------------

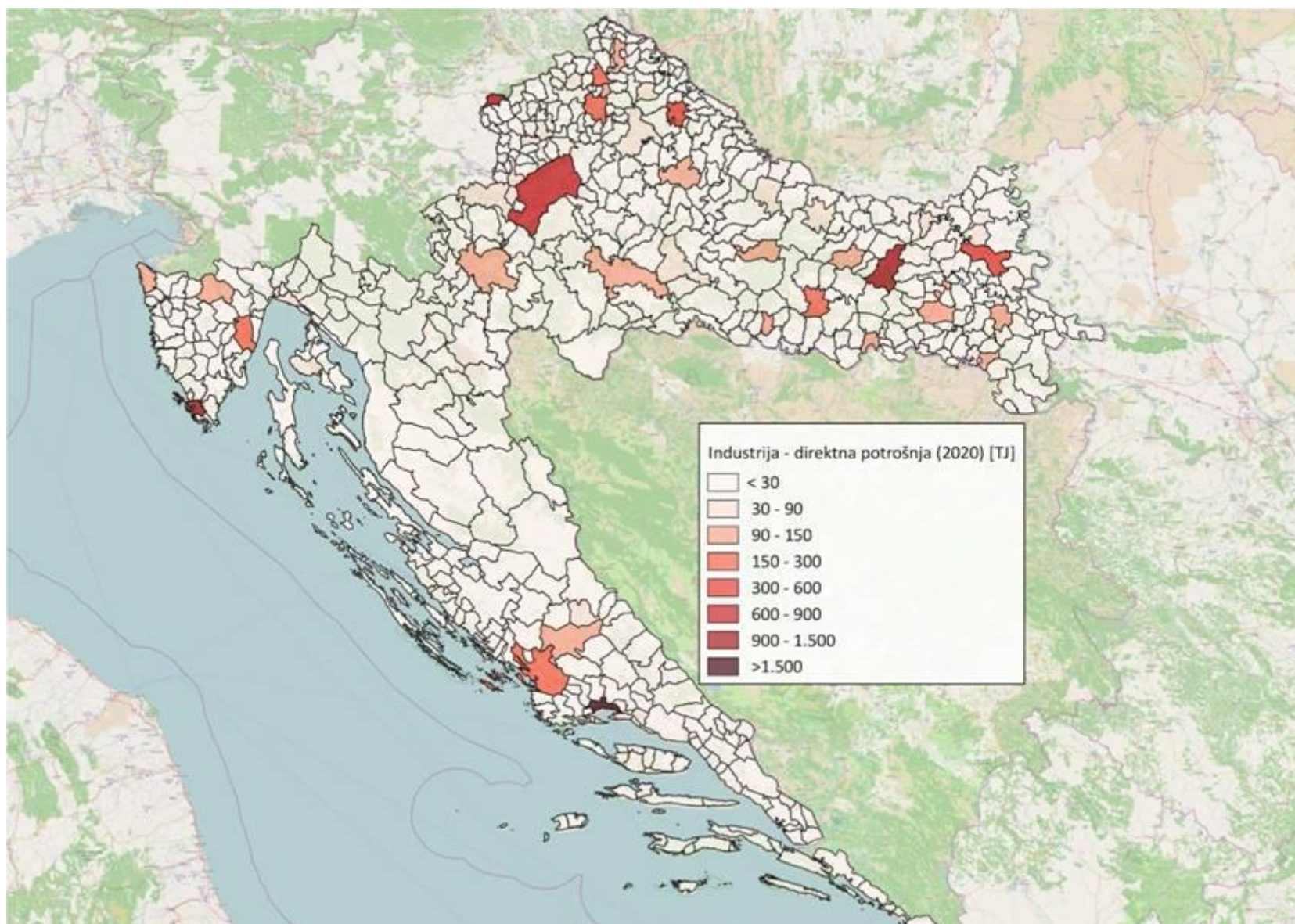
Figure 18: Map of household thermal energy consumption for cooling (2020)



Kućanstva - toplina ukupno (2020) [Tj]

Households – heat total (2020) [Tj]

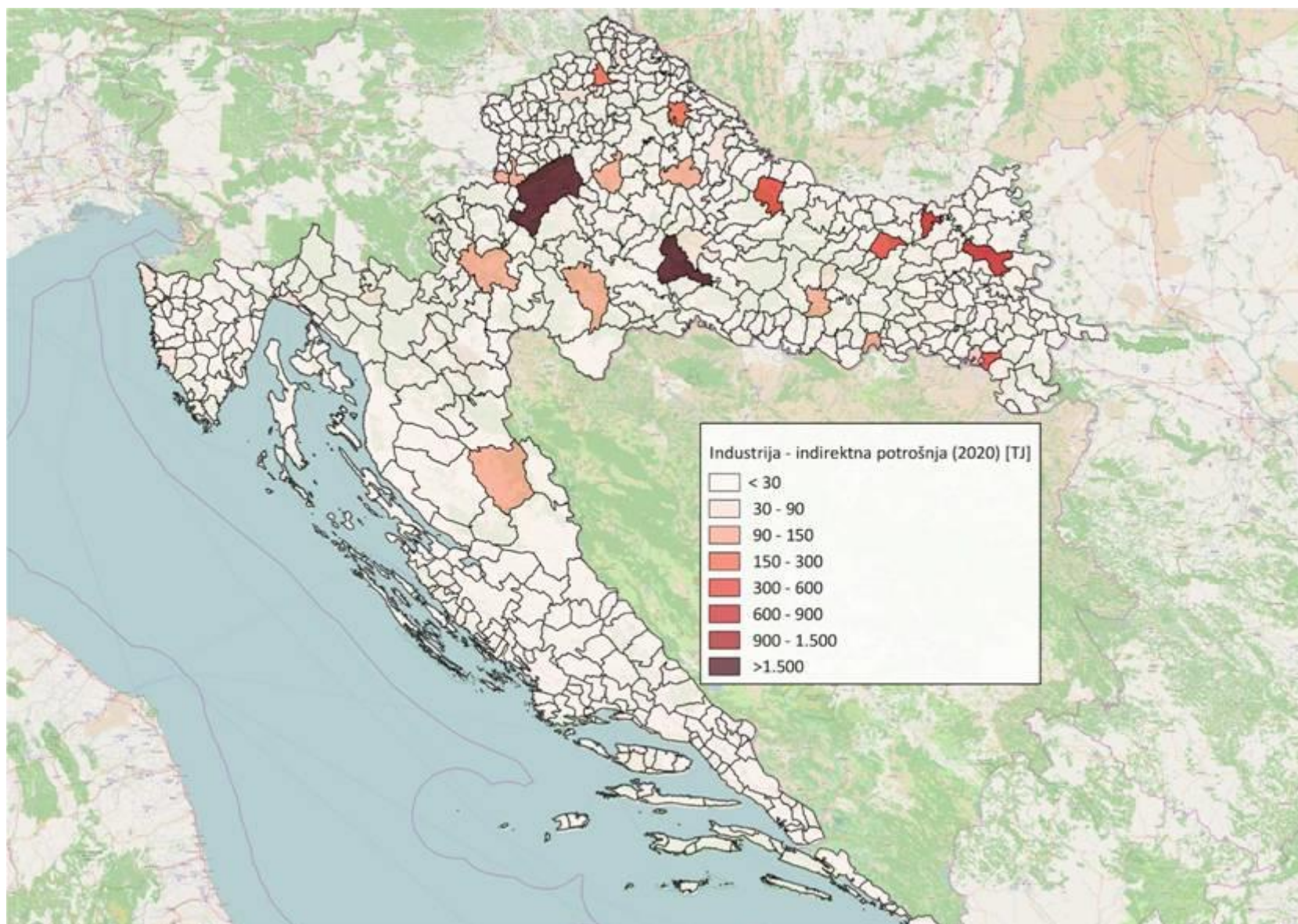
Figure 19: Map of total household thermal energy consumption (2020)



Industrija - direktna potrošnja (2020) [TJ]

Industry – direct consumption (2020) [TJ]

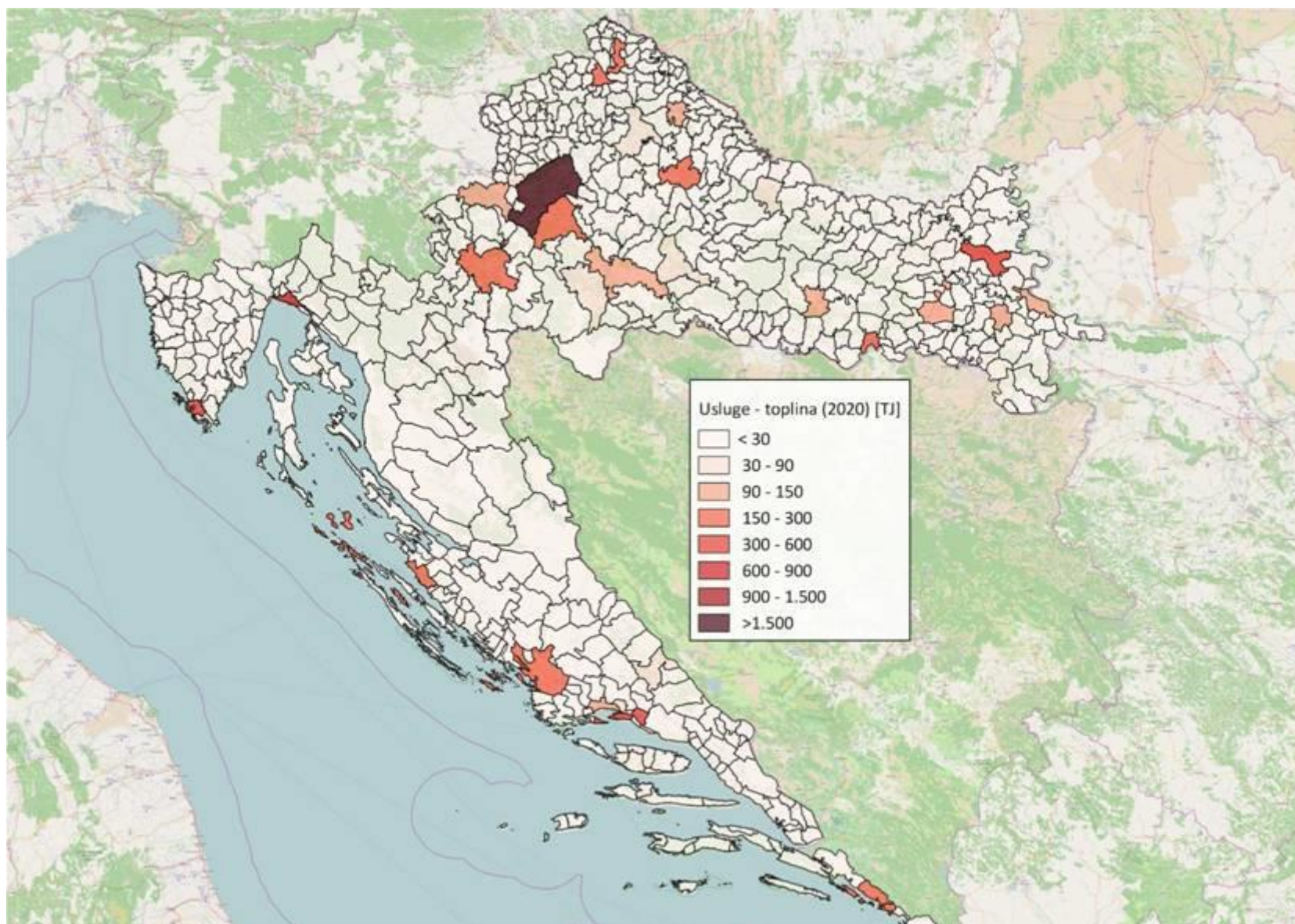
Figure 20: Map of direct thermal energy consumption in industry (2020)



Industrija - indirektna potrošnja (2020) [Tj]

Industry - indirect consumption (2020) [Tj]

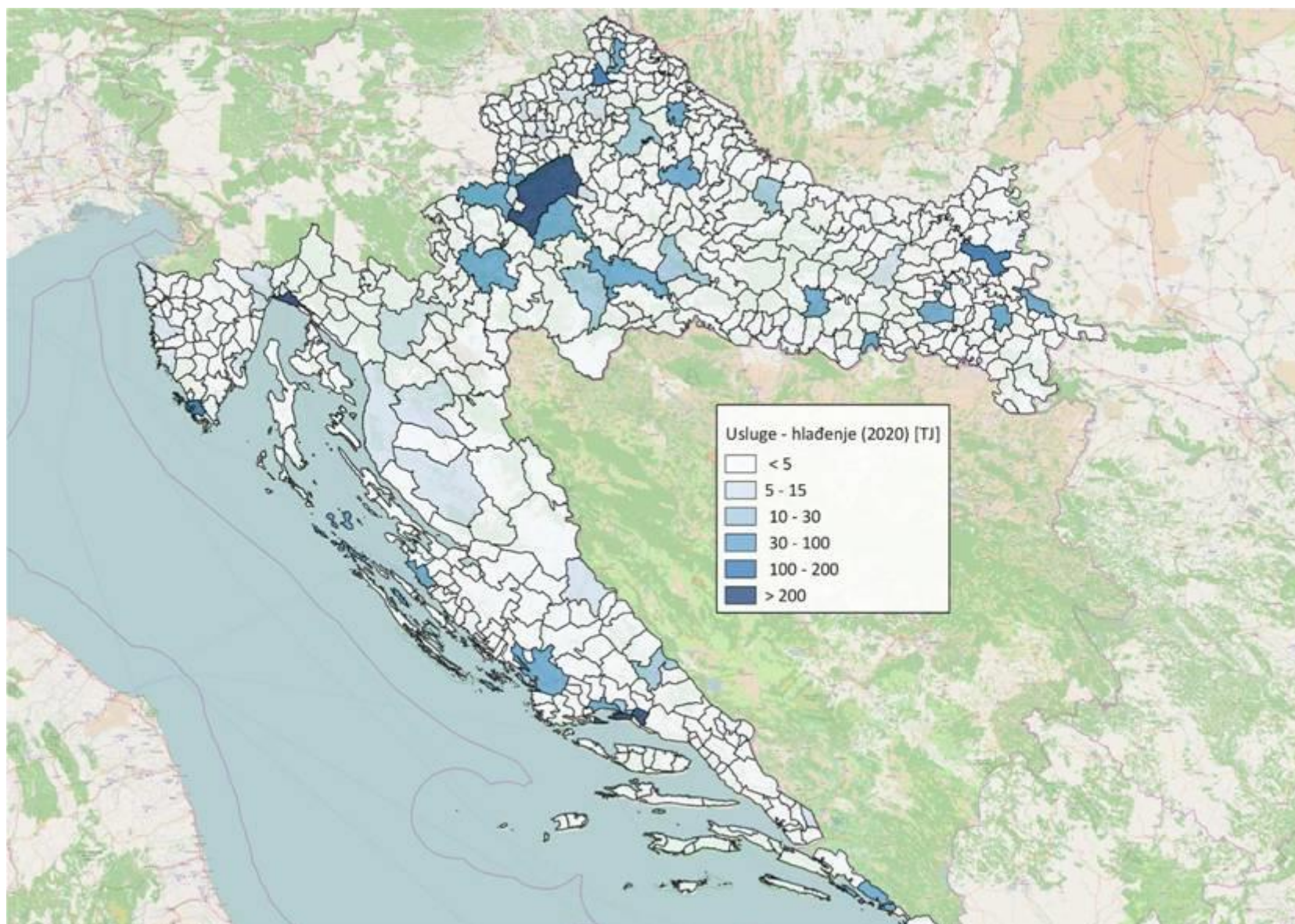
Figure 21: Map of indirect thermal energy consumption in industry (2020)



Usluge - toplina (2020) [Tj]

Services - heat (2020) [Tj]

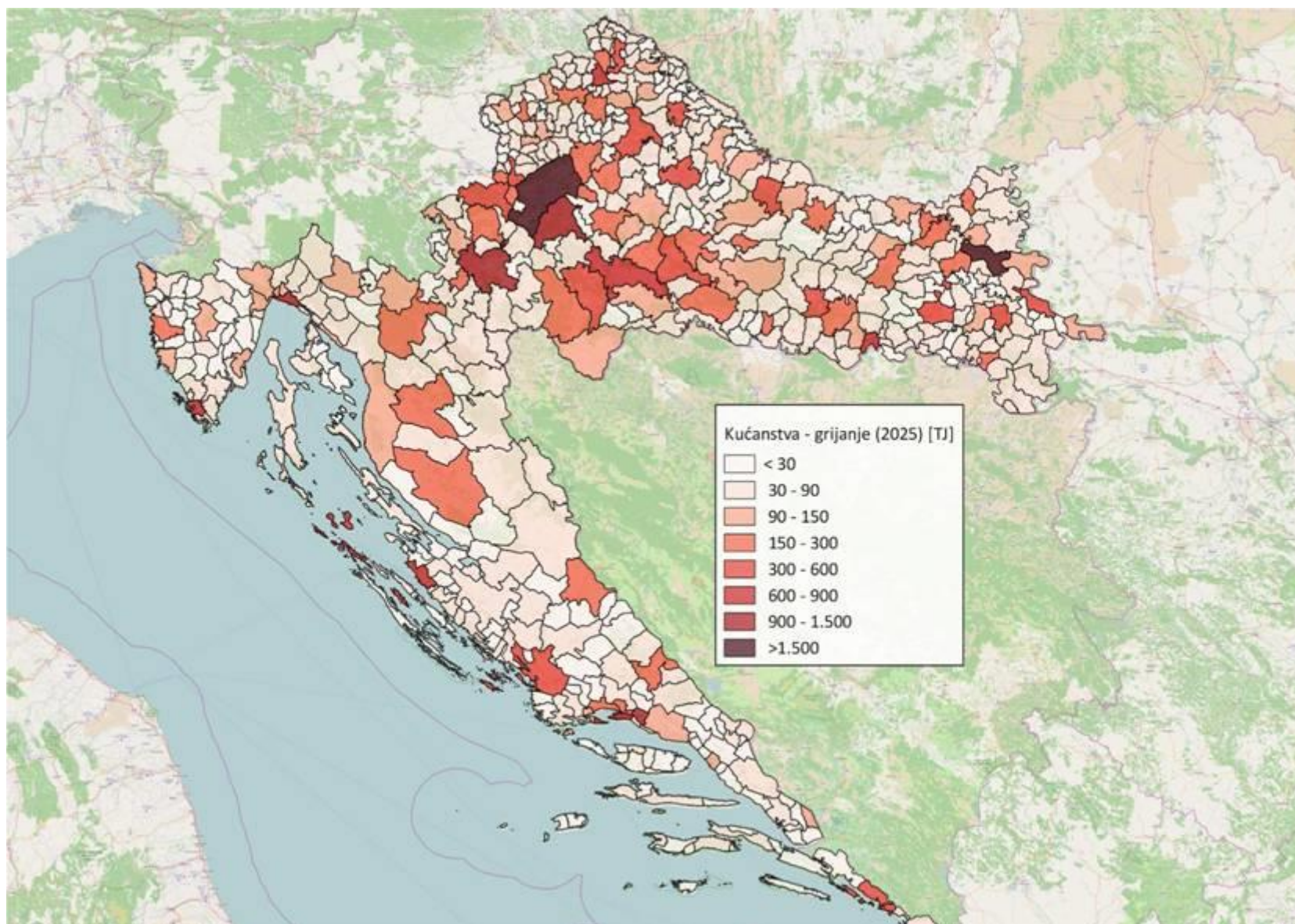
Figure 22: Map of service sector thermal energy consumption (2020)



Usluge - hlađenje (2020) [TJ]

Services – cooling (2020) [TJ]

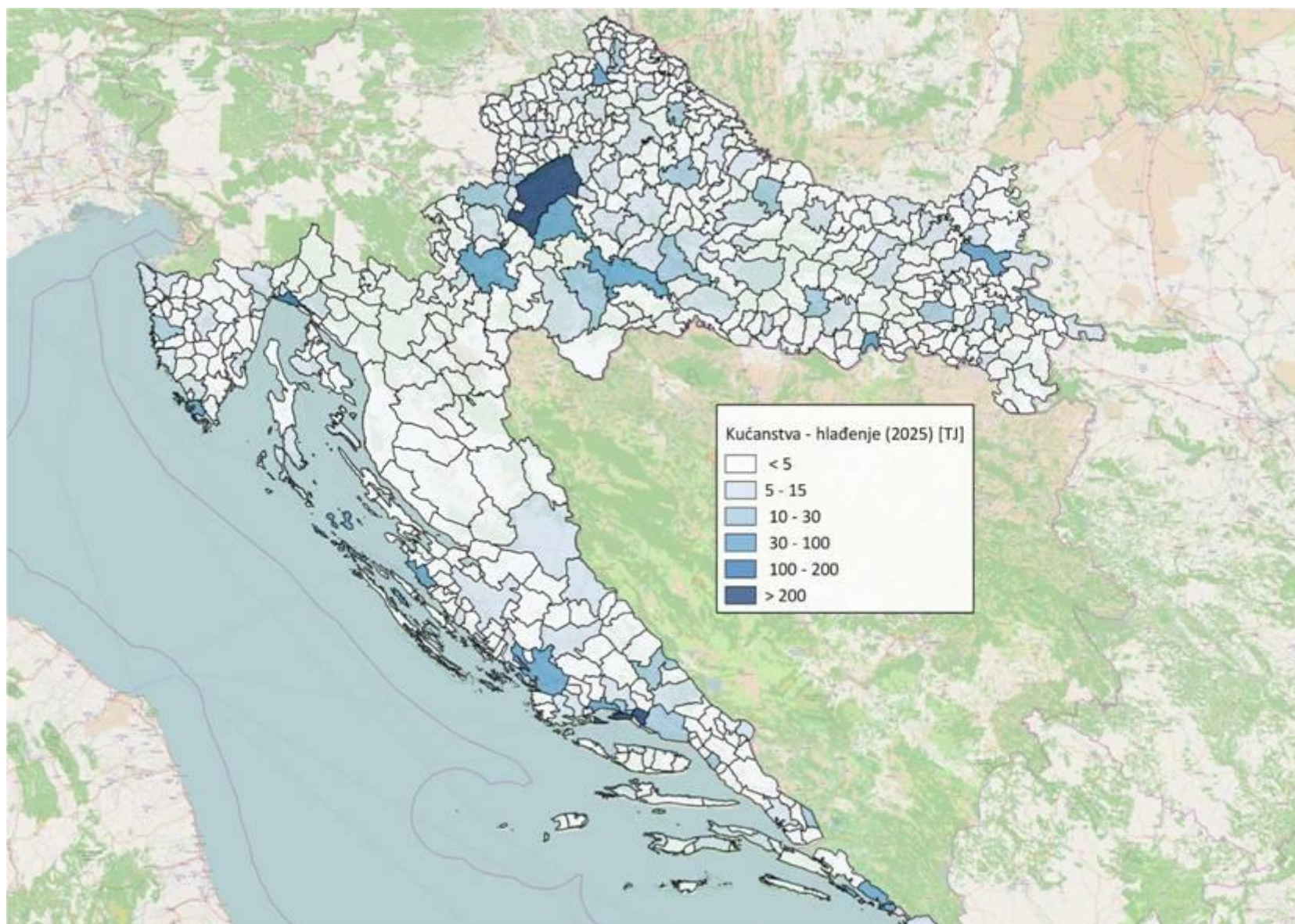
Figure 23: Map of service sector thermal energy consumption for cooling (2020)



Kućanstva - grijanje (2025) [TJ]

Households - heating (2025) [TJ]

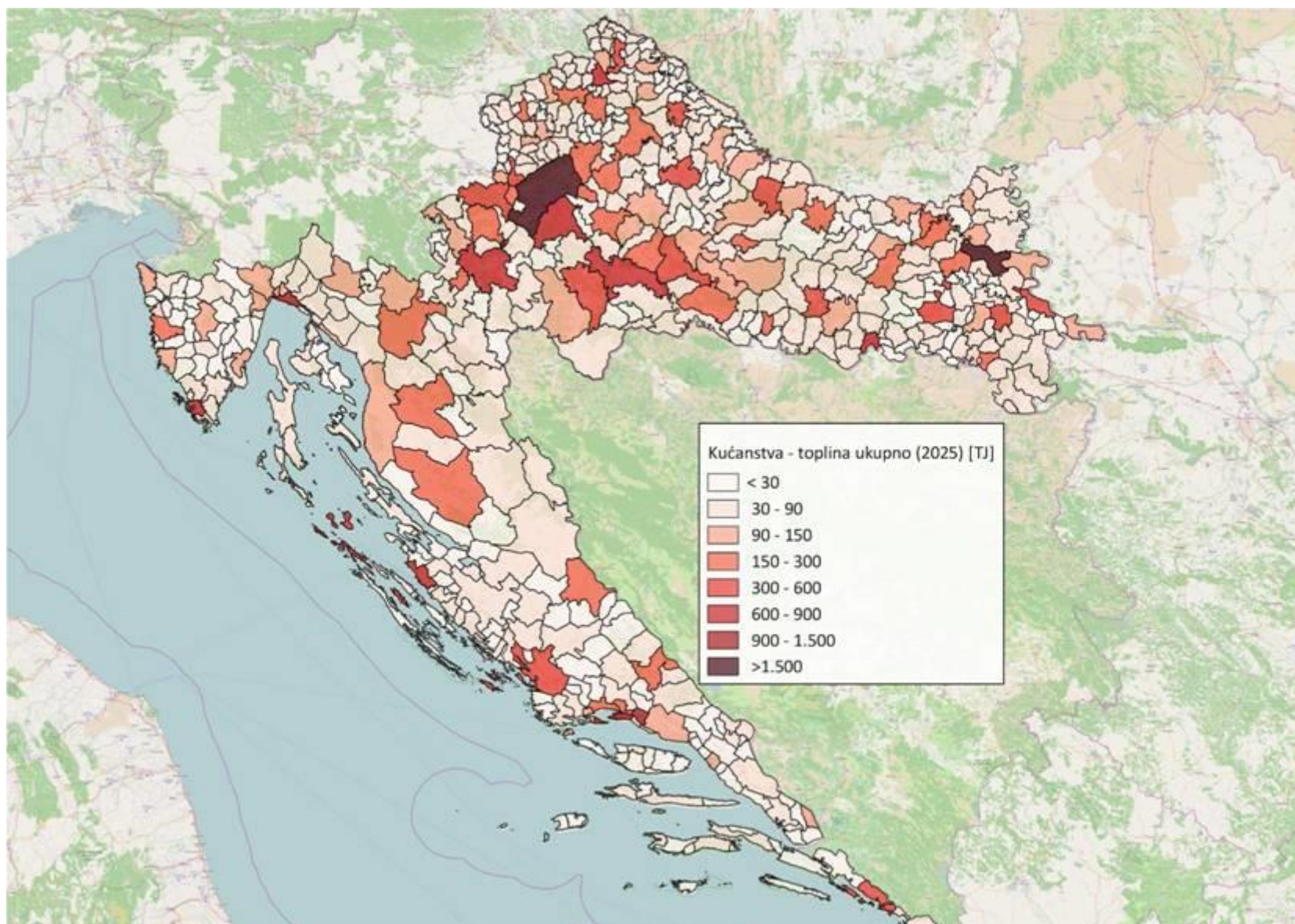
Figure 24: Map of household thermal energy consumption for heating (2025)



Kućanstva - hlađenje (2025) [TJ]

Households – cooling (2025) [TJ]

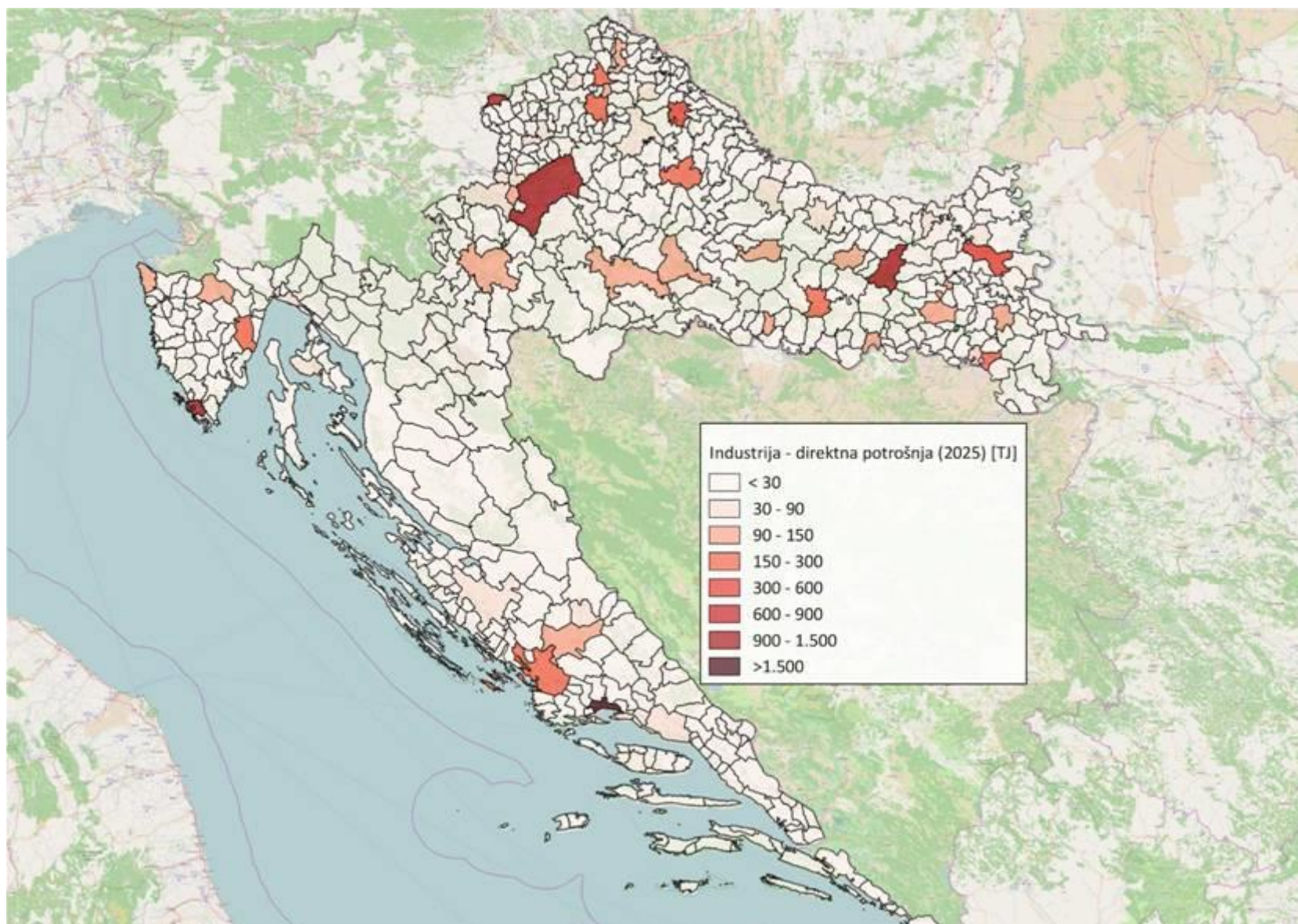
Figure 25: Map of household thermal energy consumption for cooling (2025)



Kućanstva - toplina ukupno (2025) [Tj]

Households - heat total (2025) [Tj]

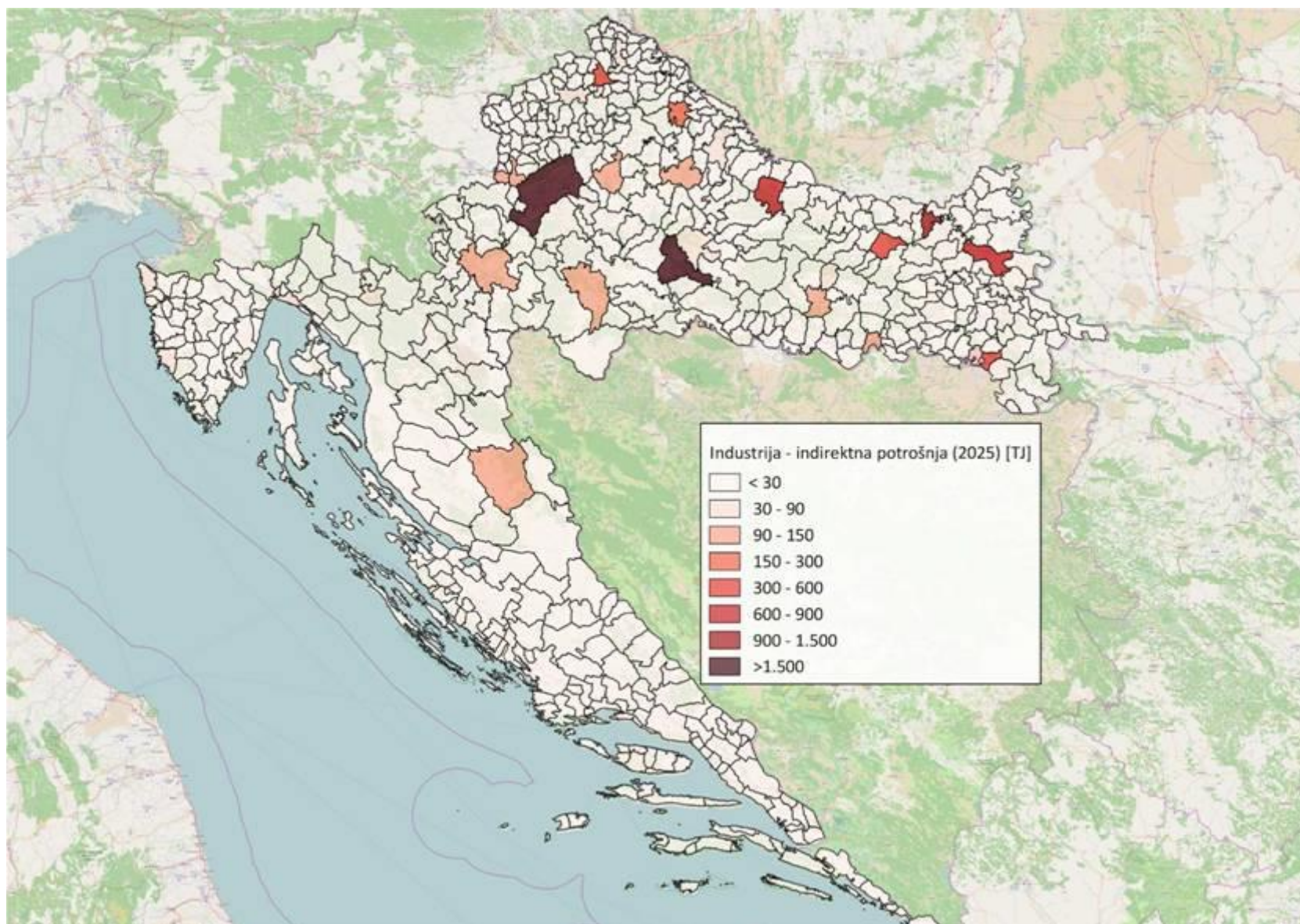
Figure 26: Map of total household thermal energy consumption (2025)



Industrija – direktna potrošnja (2025) [Tj]

Industry – direct consumption (2025) [Tj]

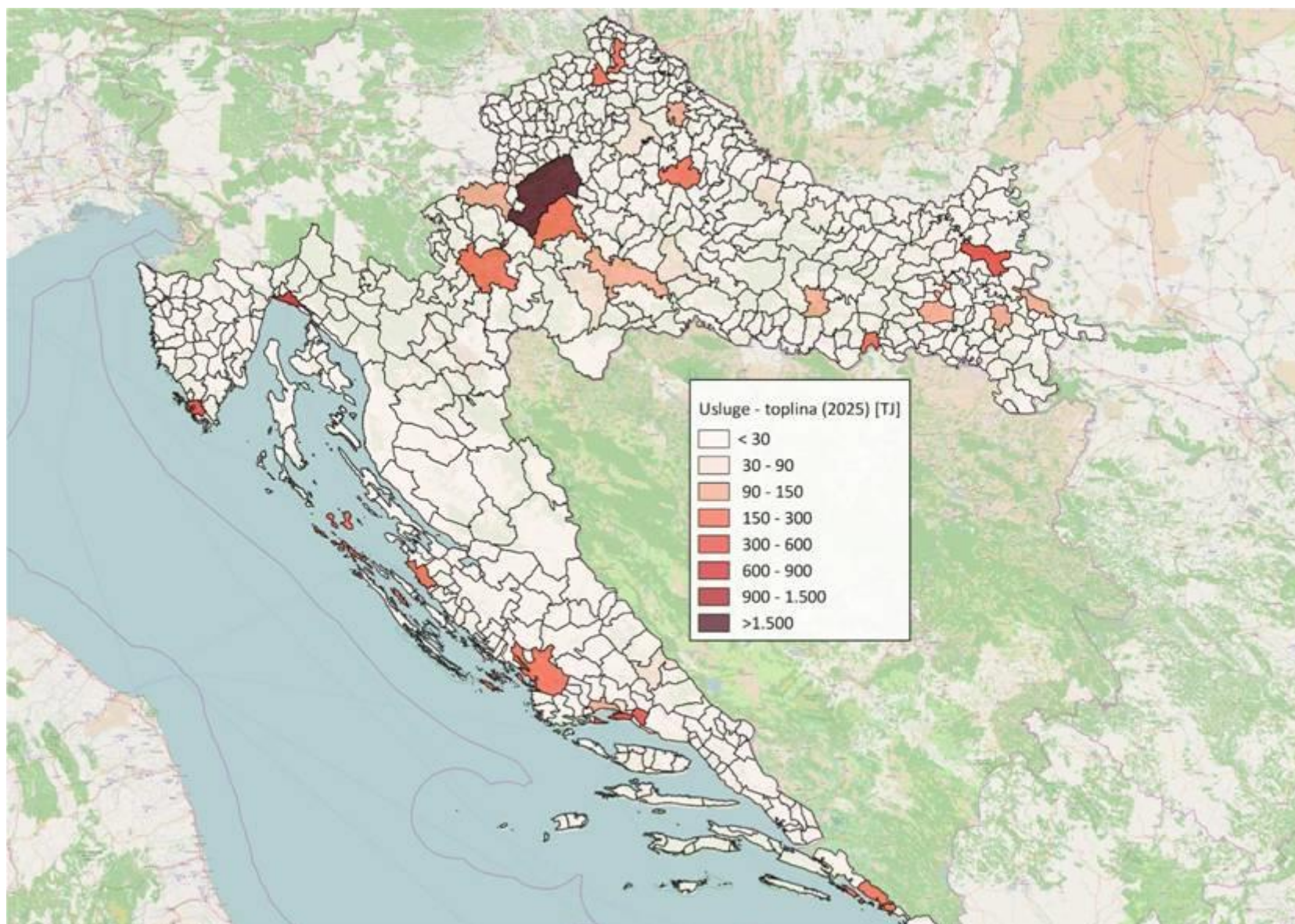
Figure 27: Map of direct thermal energy consumption in industry (2025)



Industrija – indirektna potrošnja (2025) [Tj]

Industry – indirect consumption (2025) [Tj]

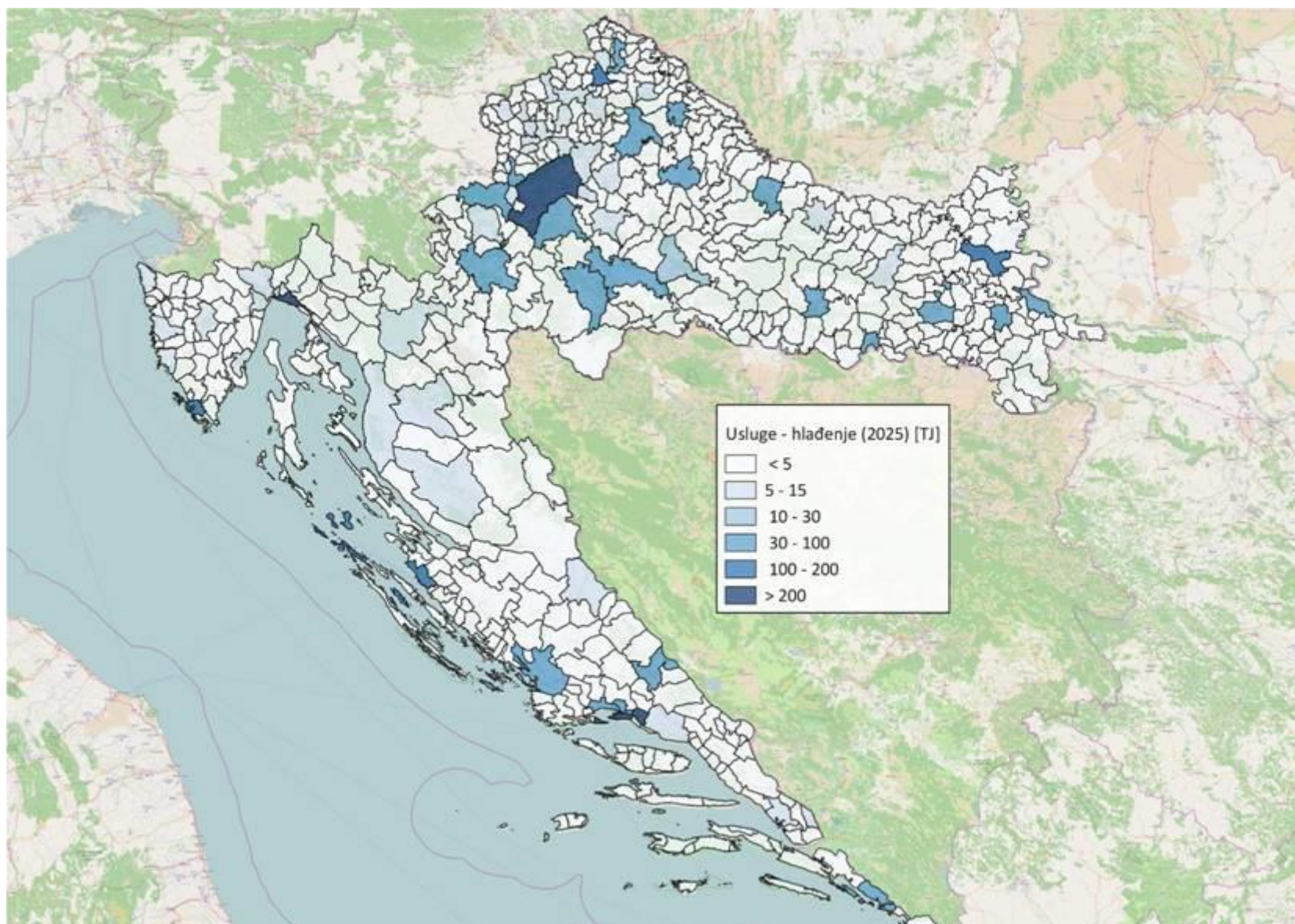
Figure 28: Map of indirect thermal energy consumption in industry (2025)



Usluga – toplina (2025) [Tj]

Services – heat (2025) [Tj]

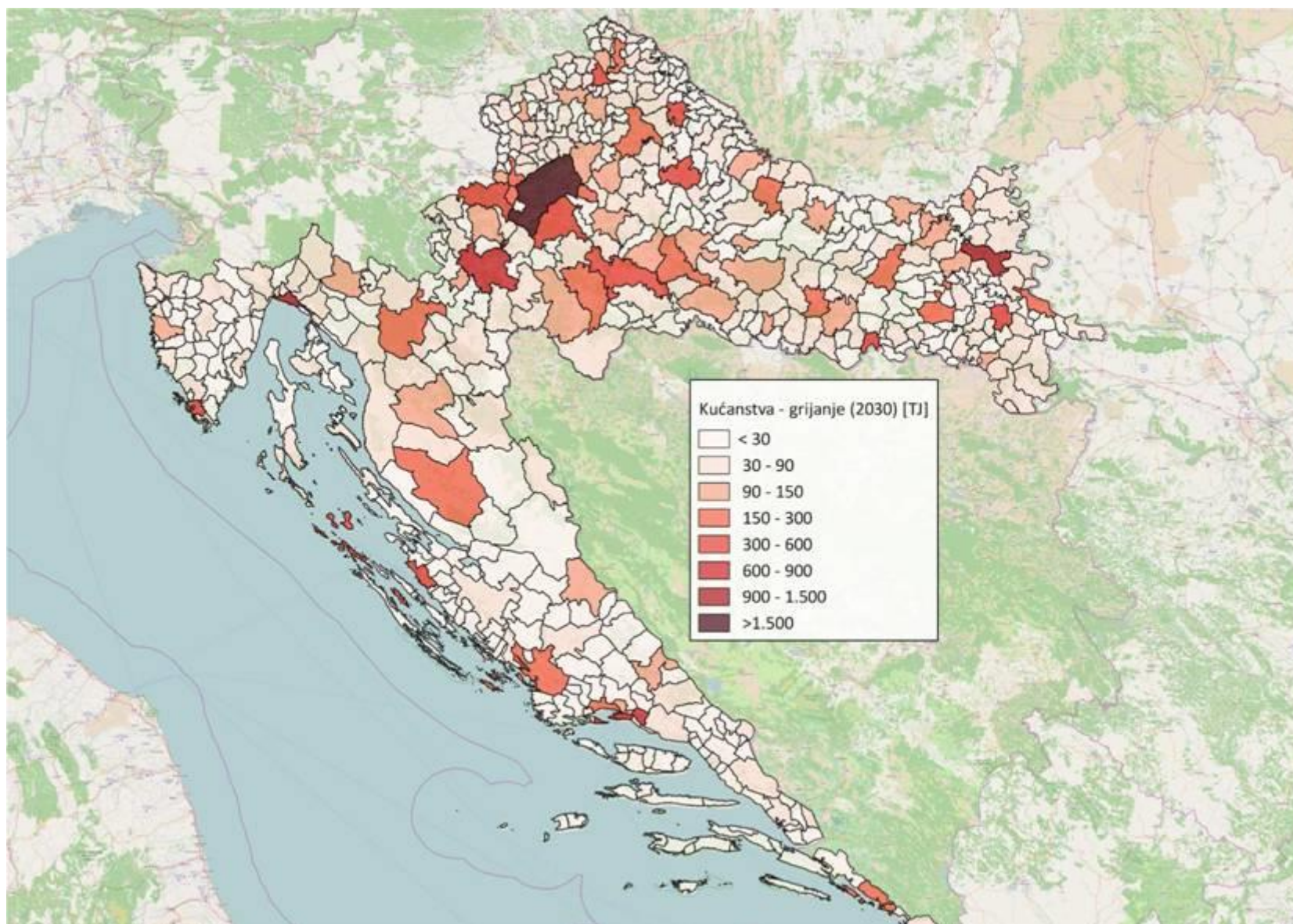
Figure 29: Map of service sector thermal energy consumption (2025)



Usluga – hlađenje (2025) [TJ]

Services – cooling (2025) [TJ]

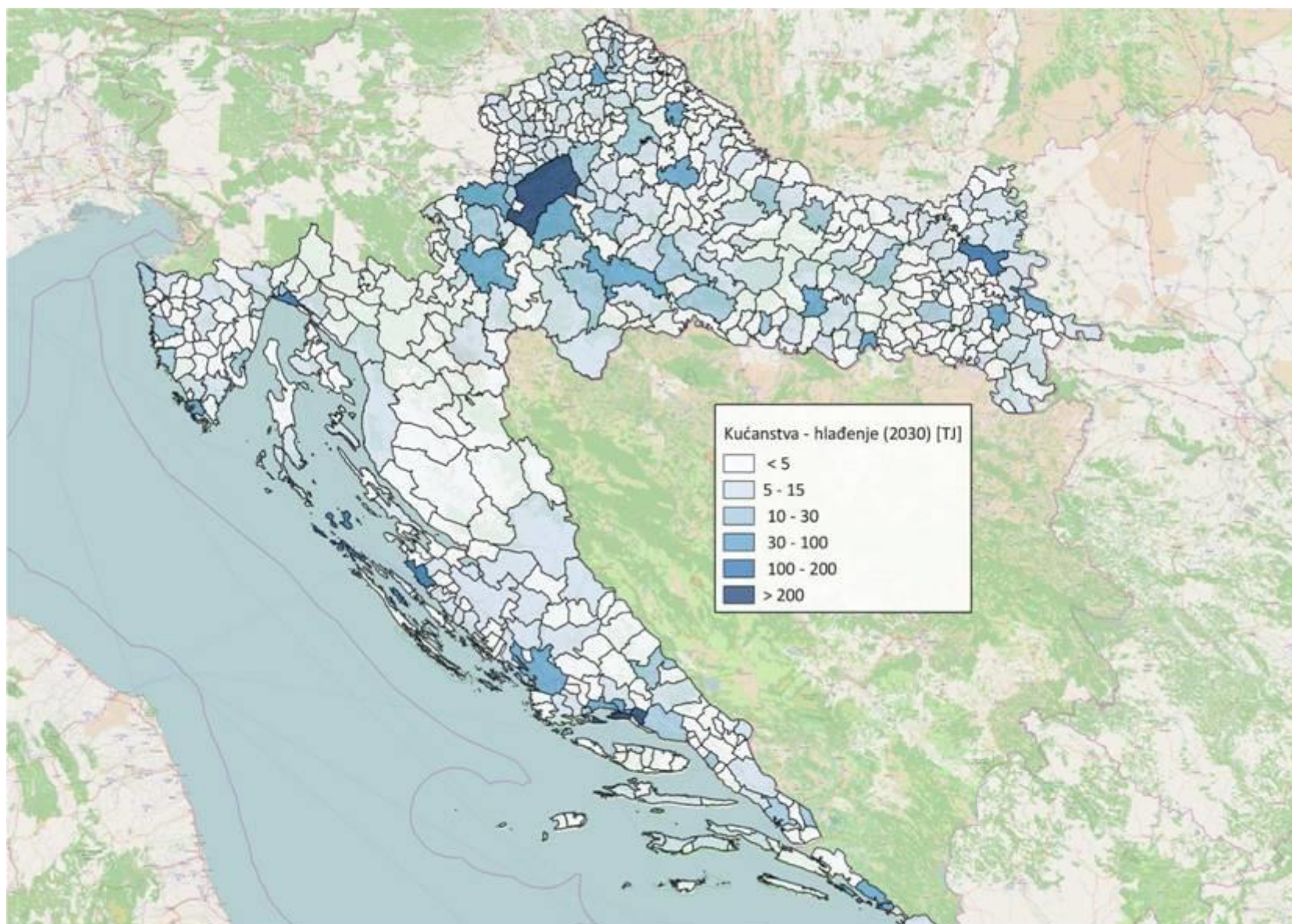
Figure 30: Map of service sector thermal energy consumption for cooling (2025)



Kućanstva - grijanje (2030) [TJ]

Households - heating (2030) [TJ]

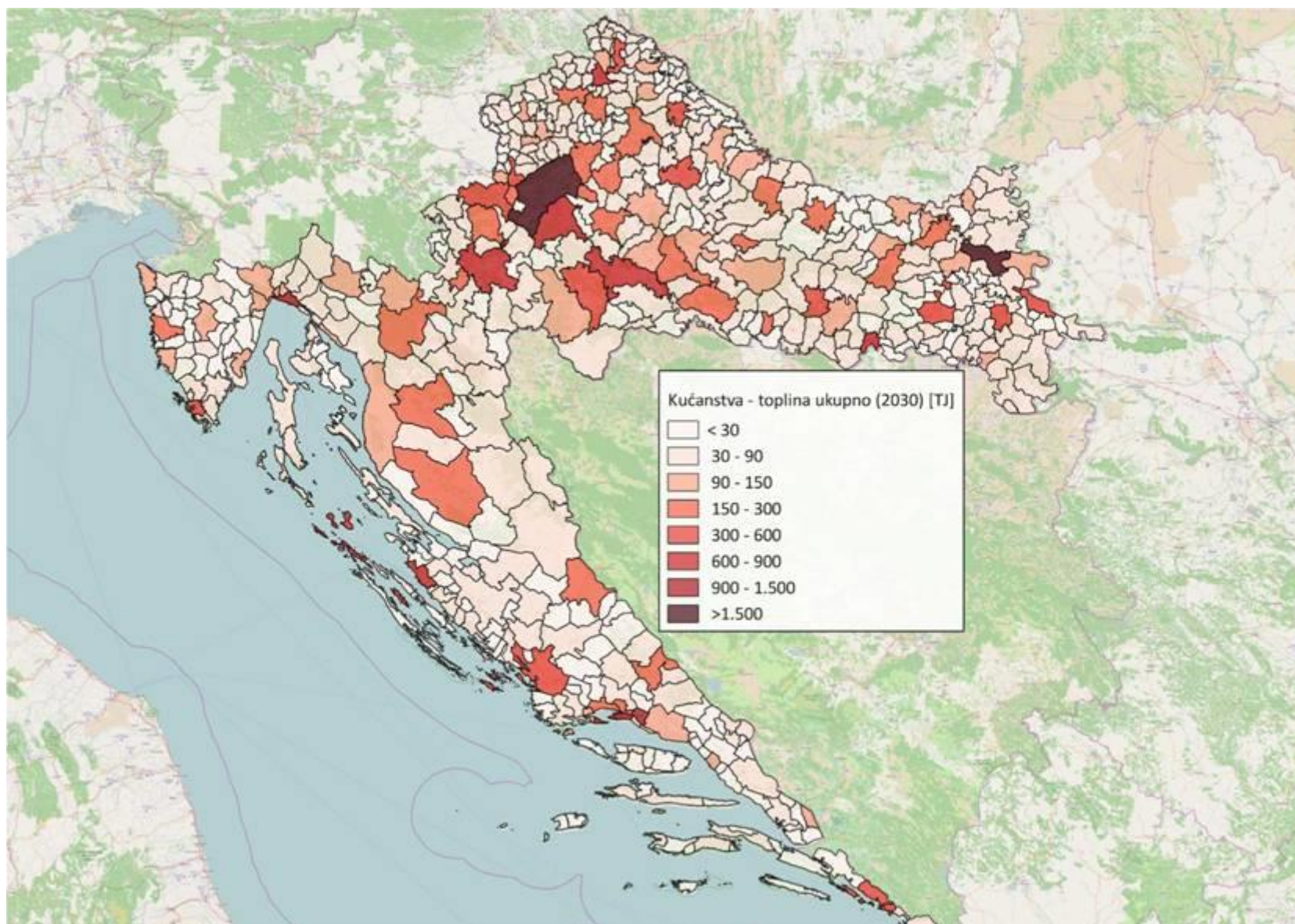
Figure 31: Map of household thermal energy consumption for heating (2030)



Kućanstva – hlađenje (2030) [TJ]

Households – cooling (2030) [TJ]

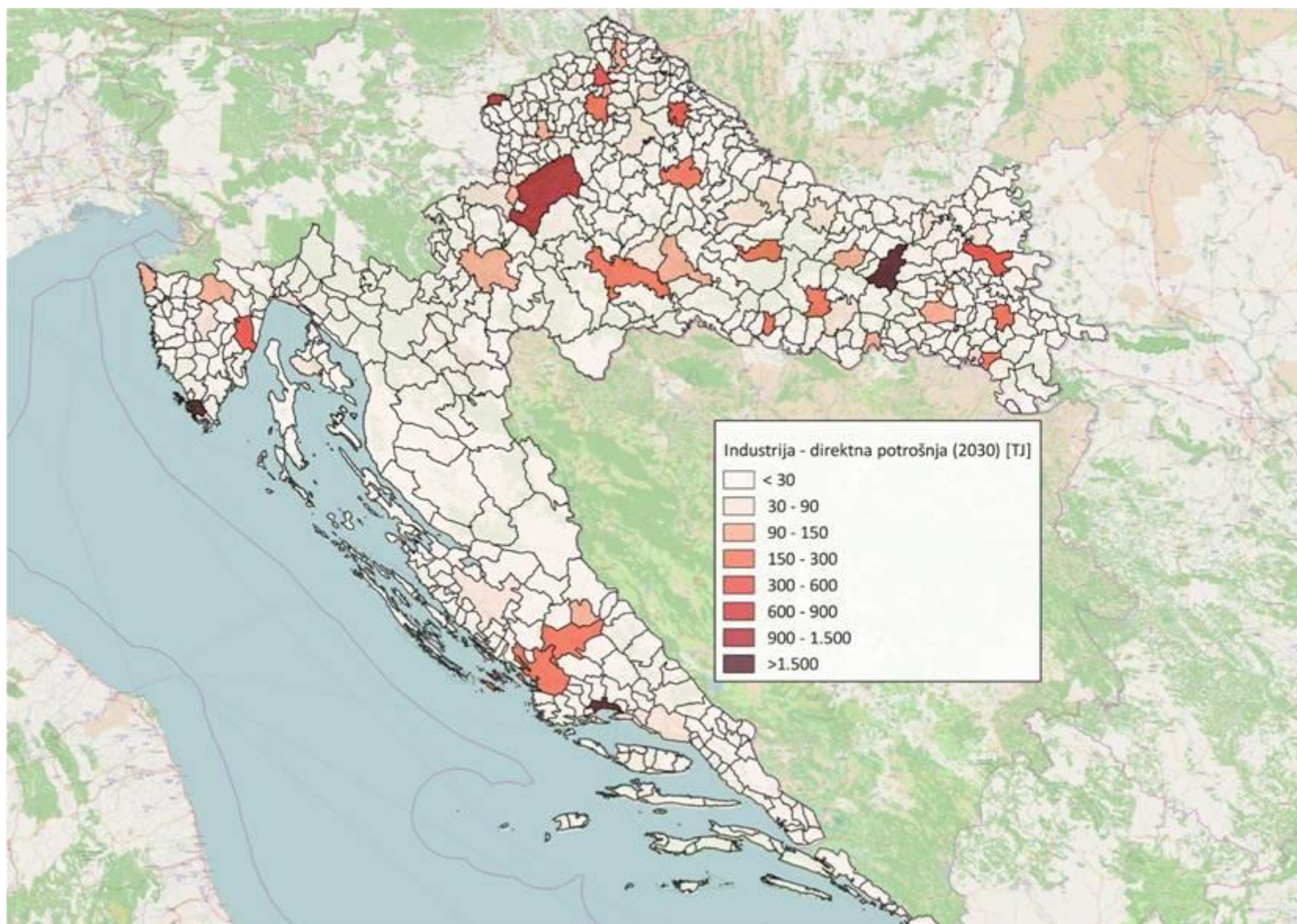
Figure 32: Map of household thermal energy consumption for cooling (2030)



Kućanstva – toplina ukupno (2030) [Tj]

Households – heat total (2030) [Tj]

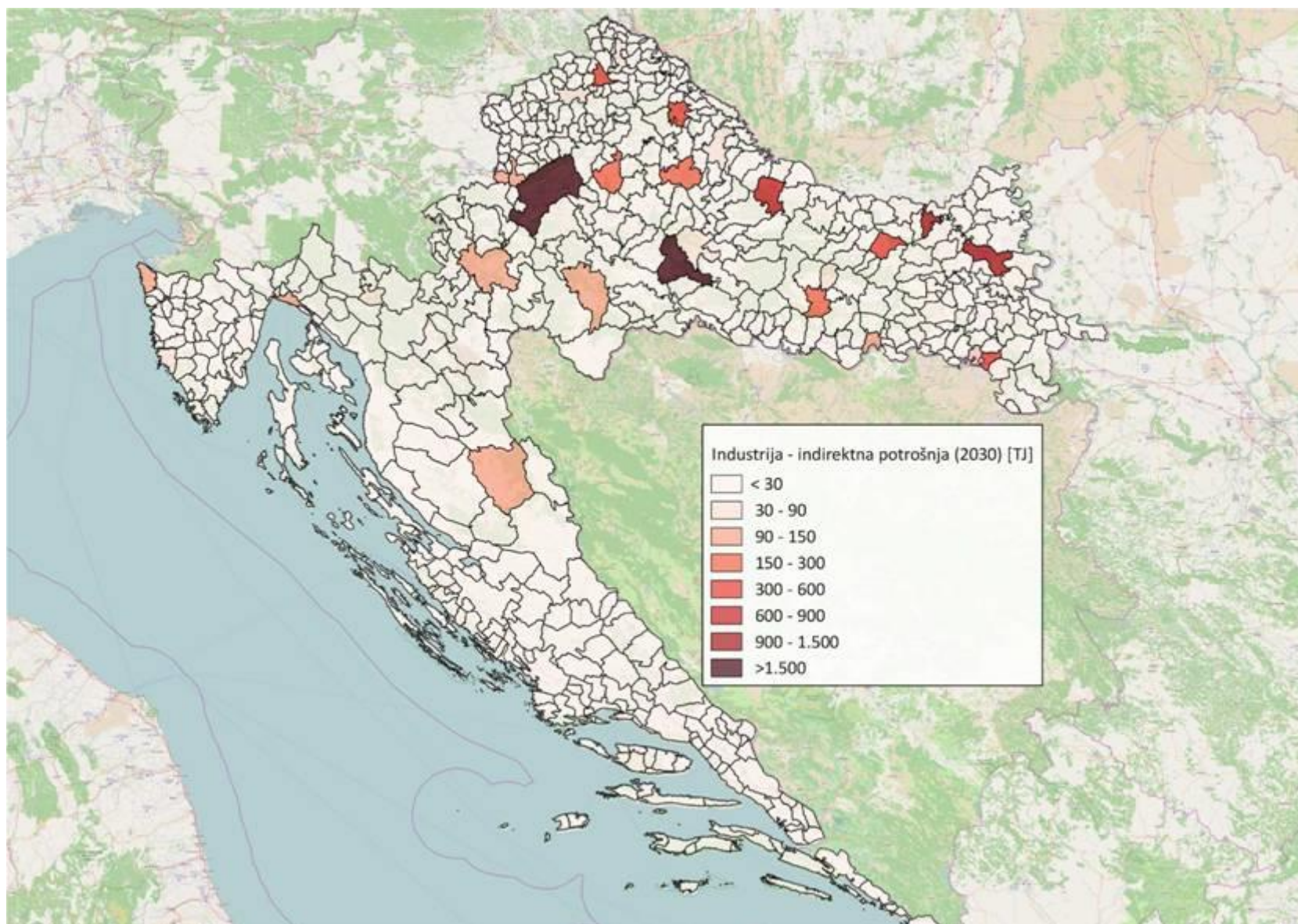
Figure 33: Map of total household thermal energy consumption (2030)



Industrija – direktna potrošnja (2030) [Tj]

Industry – direct consumption (2030) [Tj]

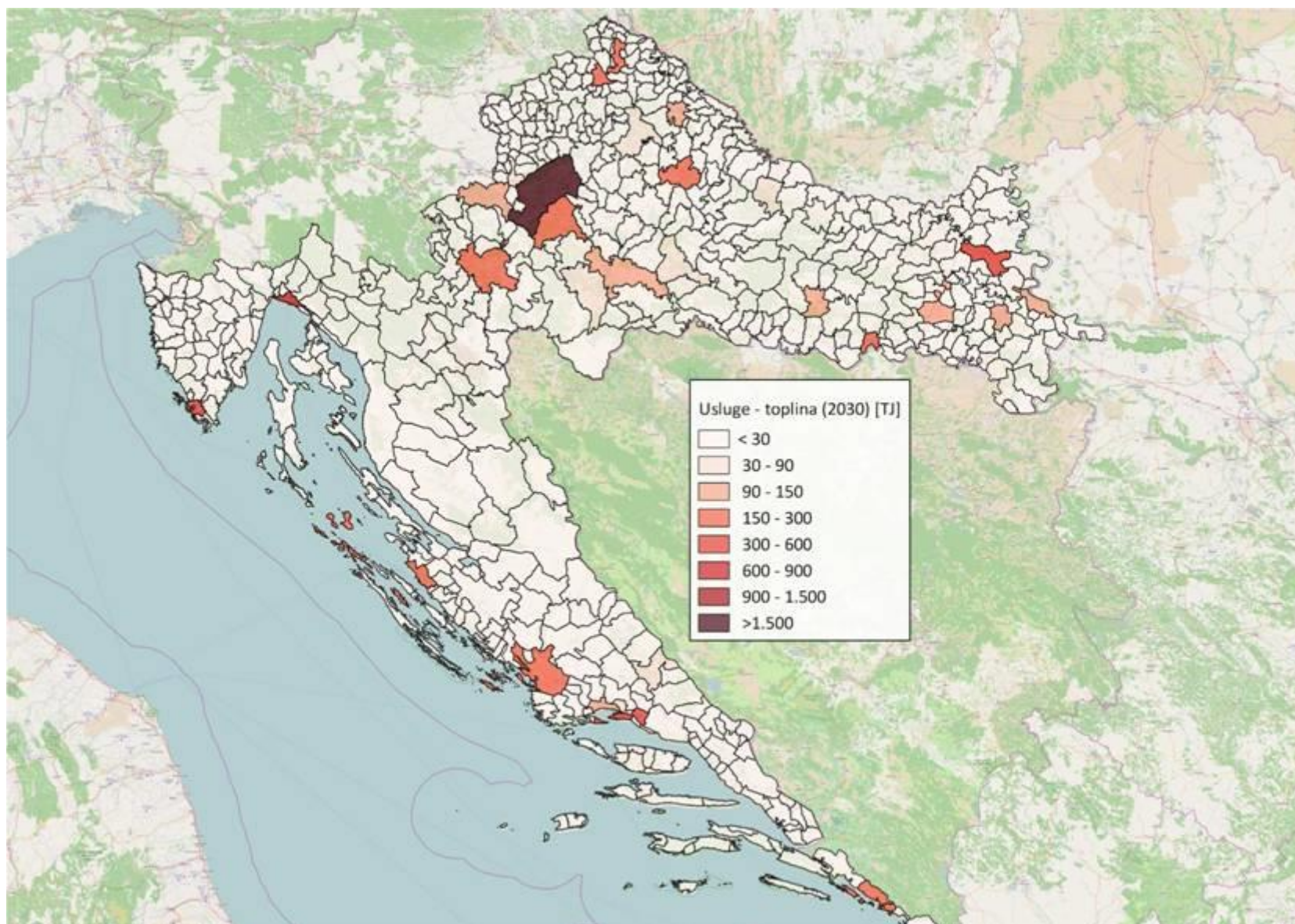
Figure 34: Map of direct thermal energy consumption in industry (2030)



Industrija – indirektna potrošnja (2030) [Tj]

Industry – indirect consumption (2030) [Tj]

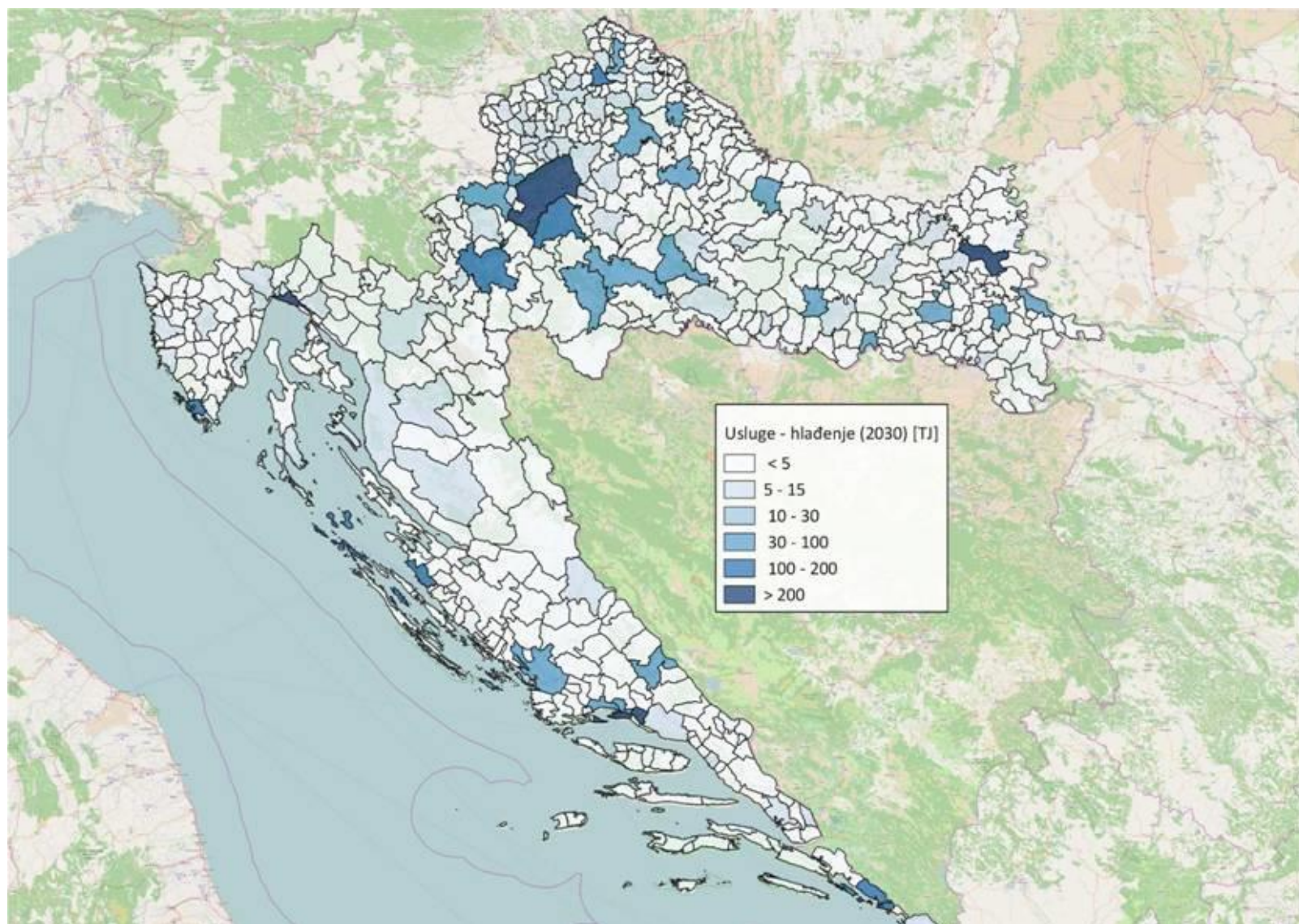
Figure 35: Map of indirect thermal energy consumption in industry (2030)



Usluge – toplina (2030) [Tj]

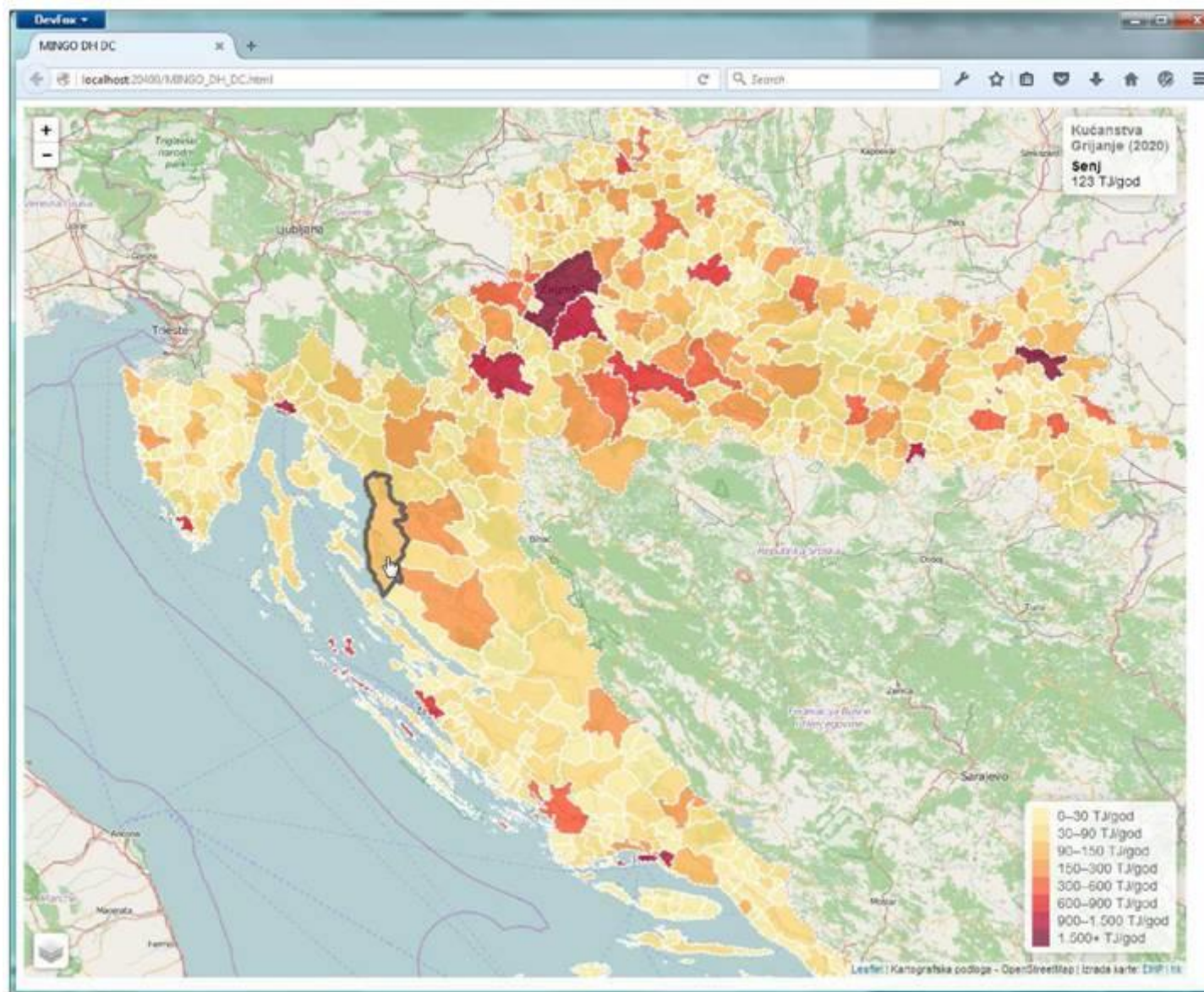
Services – heat (2030) [Tj]

Figure 36: Map of service sector thermal energy consumption (2030)



<i>Usluge – hlađenje (2030) [Tj]</i>	<i>Services – cooling (2030) [Tj]</i>
--------------------------------------	---------------------------------------

Figure 37: Map of service sector thermal energy consumption for cooling (2030)



Kućanstva Grijanje (2020)	Households Heating (2020) [TJ]	TJ/god	TJ/yr
---------------------------	--------------------------------	----------	---------

Figure 38: Representation of the interactive web map graphic interface

4. DETERMINING THERMAL ENERGY DEMAND WHICH CAN BE MET THROUGH HIGH-EFFICIENCY COGENERATION

4.1. OVERVIEW OF TECHNOLOGIES ACCEPTABLE FOR USE IN DISTRICT HEATING AND DISTRICT COOLING SYSTEMS

4.1.1. Levels of thermal supply centralisation

4.1.1.1. General

With regard to the level of consumer network development, heat sources and the number of connected consumers, heating networks may be observed at the following centralisation levels:

- residential building,
- group of buildings,
- settlement/city district,
- multi-settlement network,
- DHS at city level,
- DHS of city and surrounding settlements.

The observed heat generation installations at different levels of centralisation can be categorised by the following types:

- boiler room (house),
- block-boiler,
- small heating plant,
- heating plant, thermal electricity generation and heating plant (TE-TO).

Basically, all types of heat generation installation can be upgraded to cogeneration, i.e. a simultaneous generation of heat and electricity; while rare in small networks, this is a general rule in large heating plants, aimed at functioning as thermal electricity generation and heating plants.

With regard to the form of thermal energy use, i.e. heat transfer medium, consumers of thermal energy supplied by district heating systems may be divided into three categories:

- consumers of process steam, largely industrial ones using steam primarily for processing and – to a lesser extent – for heating; furthermore, larger consumers still using steam for heating (larger spaces etc.), and for certain special purposes also fall into this category;
- consumers of hot water, including a large number of consumers of varying sizes and characteristics – practically, any consumers who are supplied from the DHS, while not falling into the first category;
- consumers of domestic hot water, primarily referring to the consumers with major domestic hot water needs using thermal systems primarily for that purpose.

Such categorisation is useful for heating system planning and management, with regard to the determination of the number of consumers and their characteristics, forecasting peak and seasonal loads, etc.

4.1.1.2. Centralisation at the residential building level

Strictly speaking, at the level of large residential buildings, it is not the heating network that is considered but rather connecting a large number of residential units into one networked whole. However, thanks to the preparedness of heat consumers to connect to the external network, methods of distribution and consumption billing already in place and, most importantly, thanks to the presence of a single heat generation unit for the building which can be easily substituted by a heating substation, such buildings are an important element to consider in the heating network development. Buildings are generally equipped with hot water piping for distribution of the thermal medium, and radiator heating. Where of natural gas distribution network is available, boilers are most frequently fuelled by natural gas. Otherwise, liquid fuel (extra light fuel oil, ensuring the easiest exploitation) are used. Coal-fired boilers are mostly being abandoned, while liquefied petroleum gas is not used owing to its high price. A centralised heat supply may be implemented in larger residential buildings with or without domestic hot water generation.

Even though elementary, such a level of centralisation is nevertheless an improvement compared to individual heat supply in view of slightly higher efficiency of fuel use in a larger common unit and initial steps towards heat supply service outsourcing for individual consumers. As to the environmental impact, thanks to their higher presumed efficiency, such installations reduce specific emissions of hazardous substances. Also, the purchase of larger quantities of commercially available fuel and higher presumed maintenance quality have a lowering impact on the content of hazardous substances in flue gas since the fuel is more pure, improving combustion.

A special case to be observed is the centralisation of heat supply in larger public, service and commercial facilities – hospitals, administration and office buildings, hotels, educational institutions, etc. Fan coils are used there as terminal elements instead of radiators, especially in office buildings and hotels. This enables the centralisation of both heating and cooling, and domestic hot water generation is centralised in such cases as well.

4.1.1.3. Group of buildings level

The centralisation of the heat supply at the level of a group of buildings, i.e. one or several large residential buildings, has the same characteristics as that at the level of a single residential building. The difference is that, in this case, detached boiler rooms are separate facilities, with more advanced system management organisation, as well as better preparedness and higher motivation to join a more developed DHS.

4.1.1.4. Settlements and city districts

The existence of a district heating system at the level of settlement or city district is often a precursor to heating sector development in urban areas. Such a system implies the outsourcing of heat supply from a consumer group and introduction of an external service provider. In terms of organisation, it translates into better system management and maintenance, more regulated consumption billing and easier development. Furthermore, such a system is open to expansion and an increased number of consumers, allowing the construction of the local thermal network to be observed separately from the management of a heat generation unit – boiler room. In such a setting, it is the external service provider who undertakes the planning of system development, forecasting the supply capacity and development potential. Also, within the scope of such a system, providing for internal infrastructure for a centralised heat supply is stimulated in new building construction. This also helps achieve commercial maturity necessary for the introduction of cogeneration systems; this, however, is present only in the most developed environments and requires a well-developed and functioning regulation. Natural gas is the predominant fuel used in the thermal systems of settlements and city districts because a gas distribution network is usually available in urban settlements. As a rule, the thermal network is based on hot water. Block and detached boiler rooms are used instead of obsolete in-house boiler rooms. Each consumer's building requires a heating substation to be installed. In the thermal network development from individual buildings towards a settlement connected to a network, in-house boiler rooms are replaced by substations and their installation and maintenance places specific requirements on the service provider.

Thermal networks in industrial zones may be a separate case. Industrial facilities mostly build their own boiler room installations and distribution networks, but it is also possible to build a single boiler room and network connecting multiple facilities. However, thermal energy supply by an industrial facility with excess capacity to surrounding ones is more common. As the nature of industrial thermal processes is such that they most frequently require steam, steam pipeline networks are quite common; however, both hot water and steam pipelines may be used simultaneously. Fuels used in these cases vary, ranging from

solid fuels (coal, wood biomass, other waste) to liquid ones (heavy and light oil fuel oils etc.) and gas. Increased emissions of hazardous substances into the environment may occur at this level of centralisation, given the diversity of fuels used by industrial installations for economic reasons. There are also cases in which larger industrial installations use the thermal they have built to deliver heat the surrounding residential buildings and settlements. Such examples occur in some large wood-processing industry installations.

4.1.1.5. Multi-settlement network

Several settlements connected into a separate thermal network within a single city are the next stage of heating sector development in urban settings. Such networks are more frequently operated by a single service provider than by several of them. Such systems are more common in smaller cities, implying the presence of a sufficiently developed and heating sector company, as well as a higher level and greater reliability of service, maintenance and development. Along with strong heating sector presence as a well-developed option for meeting thermal energy needs in the residential and other sectors, the development policy of such cities is directed at planning for further development of the heating sector and new consumers have a clear option and incentive to connect. Thermal networks use hot water as a medium given an adopted principle to use lower temperatures for heating purposes wherever possible. Modern practice calls for channel-free installation of pre-insulated hot water pipelines. At this level of development, thermal network are still distribution rather than transportation networks. Heat supply may or may not involve domestic hot water generation. Heat generation units in use are mainly small heating plants and boiler rooms, fired by liquid fuels (extra light fuel oil) and natural gas. Heating substations present in consumers' buildings are of either direct or indirect type, but compact heat substations have been introduced in recent years.

4.1.1.6. DHS at city level

A single district heating system at the level of a city implies the integration of all recipients of thermal sector services within a single thermal network. This implies both more extensive networks, the introduction of (main) transport pipelines and more powerful thermal production units to meet the needs of a large number of consumers. Hot water and steam pipelines may be built simultaneously, depending on consumer needs. Steam pipeline systems used to be more common on account of existing steam heating systems, primarily among consumers with large premises, as well as for industrial and technology consumer purposes. Hot water pipelines have been favoured in recent years, while steam pipelines are still used by industrial consumers of steam within the scope the heating network and for other specific purposes, such as the possibility of installing centralised cooling systems using absorption devices. The use of steam pipelines is connected to specific problems, such as maintenance, service life of piping, heat and steam losses, steam pressure drops and condensate recovery. Also, the efficiency of existing steam pipelines has decreased substantially, largely on account of a drop in steam consumption, seasonal fluctuations and frequent operation under adverse conditions.

The natural course of heating sector development in larger cities lies in connecting separate heating networks in settlements in a single DHS. On the assumption that the existing thermal networks are operated by a single heat supplier, there is a clear interest in consolidation; energy generation moves to more cost-effective centralised heating plants, DHS is expanded to include new areas, its consumption increases, while uneconomical and fully amortised boiler rooms are being decommissioned. Having a DHS at the city level strongly influences the heating sector option in planning the city's energy supply, additionally underpinning cogeneration installations. The network development and improvement planning becomes very important and complex. In such systems, domestic hot water is typically generated using network heat. In addition to the industry, larger facilities in the public sector - hospitals, pre-school and school institutions, public buildings, etc., as well as other large consumers of thermal energy from the service sector provide an important incentive for extending DHS. When new residential areas are designed it is assumed that they would rely on heating supplied by the heating network so the buildings are designed accordingly.

Heat generation units used for DHS supply at the level of a city are central heating plants capable of supplying steam and hot water pipelines. An arbitrary number of heating plants may be connected to a single DHS, depending on the level of network development, location and characteristics of existing heat generation units. The advantages of introducing cogeneration installations are fully pronounced in urban area DHS thanks to the efficiency of the coupling process and local presence of both heat and electricity consumers. The implementation of cogeneration installations using a gas turbine in a combined cycle is particularly advantageous because the presence of such numerous heat consumers in close proximity can contribute to achieving particularly high performance levels. In addition to the availability of networked fuels and more favourable terms of their purchase, the choice of fuel to fire the heating plants also

depends on requirements for minimum emissions in populated urban settings. Given that a developed DHS can integrate a greater number of sources contributing heat to the network, so the use of incinerators, industrial waste heat etc. is also considered.

In certain cities with traditional industrial zones nearby, especially those involving heavy industry, thermal power plants situated within particular industrial facilities may be a heat source for the thermal network if they have sufficient capacity. Such systems are either planned during a period of industrialisation or they become more interesting amid reduced heat consumption in the industry and excess capacity of respective thermal power plants. Such relationships require special contractual arrangements between plant owners, service providers and the city.

4.1.1.7. DHS of city and surrounding settlements

Presuming that heat generation units have sufficient capacity, in larger cities with developed district heating systems and smaller (satellite) settlements in the vicinity, a main pipeline can be implemented to transport heat from the city's DHS to local heating network in those settlements. This would mean that there is economic and technological justification for such an intervention which, in turn, depend on actual distances, number of consumers, the level of and possibilities for further development of local networks, etc. Both steam and hot water systems may be implemented. The biggest issue is achieving a favourable [price] of the main pipeline at an acceptably low heat loss level. This is also the highest attainable level of heating system centralisation in wider urban areas, and represents an essential component in regional energy planning, clearly favouring the heating sector.

4.1.1.8. Further characteristics

In addition to heat supply, the development of thermal networks also enables the centralisation of cooling energy supply, that is, centralised cooling for multiple consumers. In practice, this mainly applies to larger public buildings and service sector facilities, but it is also feasible in the case of smaller local networks (centralisation at the level of groups of buildings and, possibly, of a smaller settlement). Possible options involve direct distribution of the cooling medium (cold/ice cold water) or the construction of absorption cooling units using the distributed heating medium. The use of a steam pipeline is preferred in the latter case since higher temperature levels increase efficiency of the absorption process, but a hot water pipeline network is also feasible. Such development implies that the preliminary technical and economic analysis has been completed, as well as certain organisational prerequisites.

The emissions of hazardous substances to the environment are easier to manage at a higher level of DHS centralisation. The control of single heat generation units enables easier management of the fuel being used, possible fuel replacement, flue gas purification, and direct operating procedures to ensure minimisation of emissions (maintenance, adequate combustion, increased plant efficiency, etc.).

Centralisation at various levels also enables the use of alternative fuels, i.e. heat sources. As already stated, the use of incineration facilities as heat generation units connected to a DHS at city level is acceptable in urban settings. Of renewable sources, geothermal energy may be used where abundant sources are available and actual distances ensure minimum losses. The temperature level is lower, meaning that such heat can be distributed to consumers nearby, mainly at local network levels. Biomass – wood, forest and agricultural residue, as well as food and paper industry residue, constitutes another potential renewable energy source for heating. It is applicable especially in the settlements close to developed wood-processing industry, having abundant wood residue – sawdust, chips, scrap lumber, etc. The construction of a local heating network (at the settlement level) based exclusively on the combustion of biomass is possible in this situation, or else the installation of biomass-fired boiler rooms in the existing district heating network (level of centralisation from the settlement itself and higher). Cogeneration installations are another favourable solution in such cases. The planning of such systems should take into account long-term availability of biomass, the possibilities of its delivery and storage, as well as biomass price developments.

4.1.2. DHS and cogeneration

4.1.2.1. Basic characteristics of cogeneration

Cogeneration installations have been developed for a long time in energy-intensive industries experiencing balanced needs for heat and electricity. The most common cogeneration processes for such applications involve a traditional steam turbine cycle, enabling the use of waste steam for process heat.

Intense development over the past two decades has enabled the availability of much new equipment, so various cogeneration installations applicable today are suitable for different systems.

Basic elements of every cogeneration system are:

- cogeneration process carried out in the power (energy) generation unit;
- fuel supply and preparation appliance;
- electricity generation plant;
- waste heat recovery system;
- exhaust (flue) gas system;
- management and control system.

The factors determining the use of a specific system are primarily:

- power capacity of a plant,
- plant efficiency,
- quality, i.e. energy level of the generated thermal energy,
- electricity to thermal energy ratio.

As to the connection and operation with regard to the distribution network, a cogeneration installation is most often configured for parallel operation with the electricity distribution network, meeting its own electricity needs while relaying any excess electricity to the external network. Clearly, a cogeneration installation can operate in a stand-alone (island) mode, only and exclusively meeting own electricity consumption needs of the building (complex). There is also a possibility of combining parallel and island mode operation.

Cogeneration systems may be organised according to different power generators used. With regard to the type of the power generation unit, following are the basic types of cogeneration processes:

- steam turbine cogeneration,
- gas turbine cogeneration,
- internal combustion engine cogeneration,
- combined cycle cogeneration,
- fuel cell cogeneration.

Other technologies, such as those using reciprocating steam or other types of engines, are either rarely used or they are still in a demonstration rather than commercial operation mode.

Internal combustion engines or low-power gas turbines are most frequently used for meeting electricity needs of up to several megawatts, but the use of gas turbines is more frequent where demand exceeds 3 MW_e. In high-power industrial cogeneration projects, on the other hand, combined cycle plants are commonly used and steam turbines occasionally.

Internal combustion engines are most commonly used where thermal energy is required in the form of warm or hot water. Thermal energy in the form of steam is typically required in industrial applications; therefore, gas turbines or the combined cycle are used. In the case of gas turbines and internal combustion engines, exhaust gases obtained in the process can be used directly, so such systems are commonly used in drying or similar processes. Basic characteristics of particular types of cogeneration processes and their use, depending on the quality of the thermal energy produced and installation capacity, are shown in the table below.

Table 17: Basic characteristics of the cogeneration process

Type of the generation unit	Fuel	Capacity [MWC]	Efficiency		Temperature level	Most common application
			Electrical	Total		
Steam turbine	any	500 kW _e – 500 MW _e	7-20 %	60-80 %	120-400 °C	biomass use (district heating and industry)
Gas turbine	gaseous and liquid	250 kW _e – 50 MW _e	25-42 %	60-87 %	120-500 °C	Industry, district heating
Combined cycle	gaseous and liquid	3 MW _e – 300 MW _e	35-60 %	70-90 %	120-400 °C	Industry (processing), district heating

Type of the generation unit	Fuel	Capacity [MWC]	Efficiency		Temperature level	Most common application
			Electrical	Total		
Gas and diesel engine	gaseous and liquid	3 kW _e – 20 MW _e	25-45 %	65-92 %	80-120 °C	HVAC systems, food processing and textile industry, greenhouses
Fuel cell	gaseous and liquid	3 kW _e – 3MW _e	~37-50 %	~85-90 %	80-100 °C	HVAC systems
Stirling engine	any	3 kW _e – 1.5 MW _e	~40 %	65-85 %	80-120 °C	HVAC systems

Considering the application of cogeneration processes in HVAC installations, internal combustion engines can be said to be used as a rule, but a frequent application of fuel cells may be expected in the future.

For better understanding of the very cogeneration technology, as well as the benefits and possibilities of using particular technologies in HVAC installations, a brief presentation of basic properties of all these cogeneration process is provided below. Finally, internal combustion engine cogeneration is given more in-depth consideration.

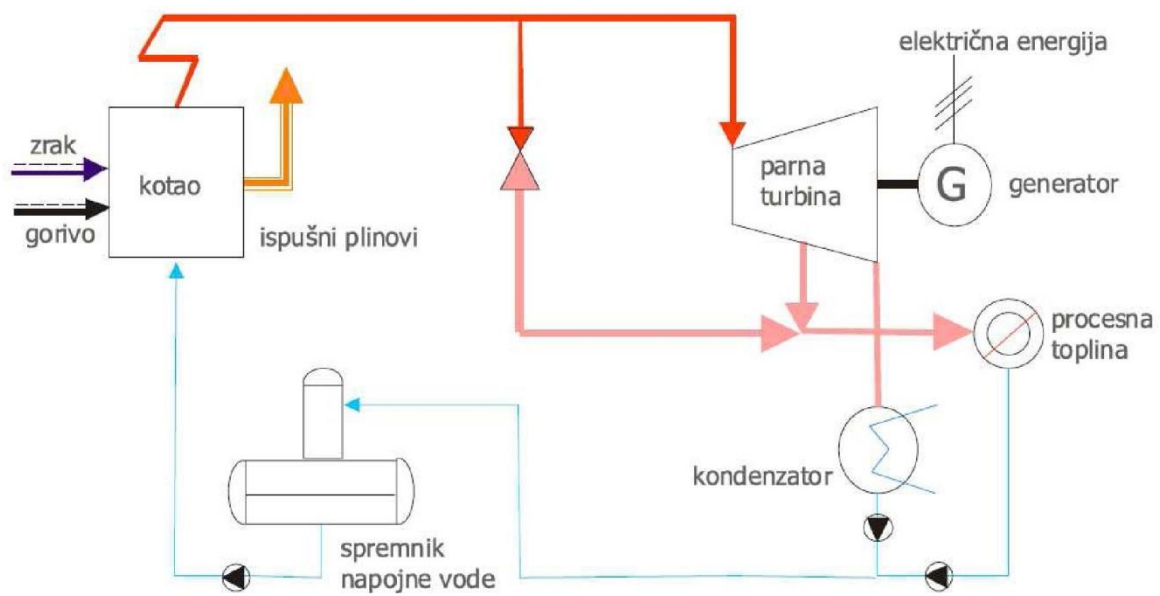
4.1.2.2. Types of cogeneration installations

Steam turbine cogeneration

Cogeneration using steam turbines, or the steam turbine cogeneration cycle, consists of two main elements – a steam turbine and a steam generator – and their auxiliary systems. There are two types of steam turbine cogeneration, depending on the process, i.e. steam pressure at the exit from the turbine:

- cogeneration with extraction condensing turbine (steam pressure at turbine exit is lower than atmospheric pressure);
- cogeneration with back-pressure turbine (steam pressure at turbine exit is higher than atmospheric pressure).

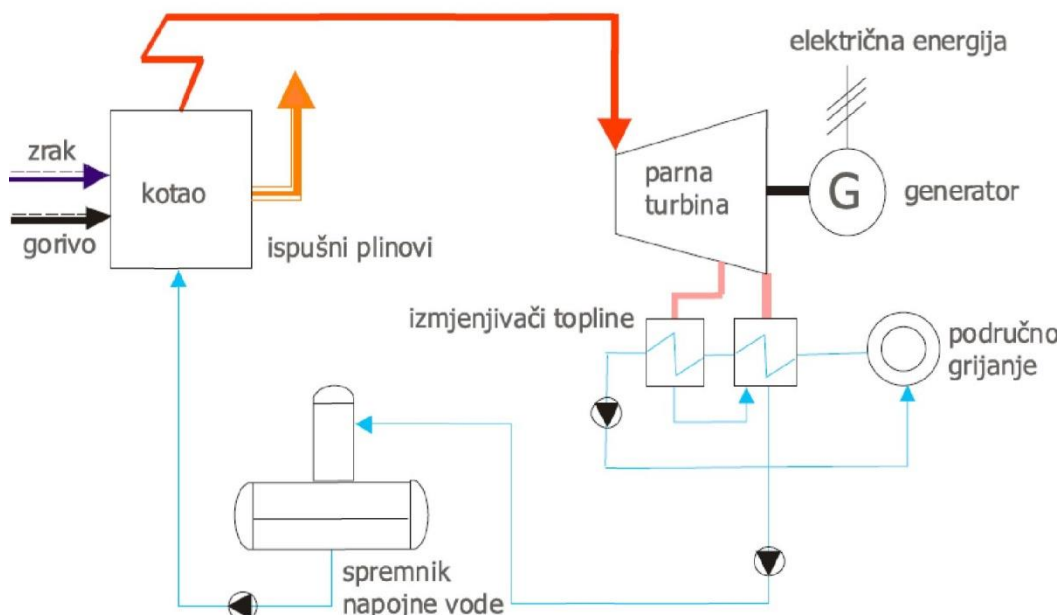
Diagrams of condensing steam turbine and back-pressure steam turbine cogeneration are shown in the figures below.



<i>zrak</i>	<i>air</i>
<i>gorivo</i>	<i>fuel</i>
<i>kotao</i>	<i>boiler</i>
<i>ispušni plinovi</i>	<i>flue gas</i>
<i>spremnik napojne vode</i>	<i>feed water tank</i>
<i>parna turbina</i>	<i>steam turbine</i>

<i>kondenzator</i>	<i>condenser</i>
<i>električna energija</i>	<i>electricity</i>
<i>generator</i>	<i>generator</i>
<i>procesna toplina</i>	<i>process heat</i>

Figure 39: Diagram of condensing steam turbine cogeneration



<i>zrak</i>	<i>air</i>
<i>gorivo</i>	<i>fuel</i>
<i>kotao</i>	<i>boiler</i>
<i>ispušni plinovi</i>	<i>flue gases</i>
<i>spremnik napojne vode</i>	<i>feed water tank</i>
<i>izmjenjivači topline</i>	<i>heat exchangers</i>
<i>parna turbina</i>	<i>steam turbine</i>
<i>električna energija</i>	<i>electricity</i>
<i>generator</i>	<i>generator</i>
<i>područno grijanje</i>	<i>district heating</i>

Figure 40: Diagram of back-pressure steam turbine cogeneration

In the case of back-pressure turbines, thermal energy is generated directly by exhaust steam from the turbine, while condensing turbines use steam bleed-out from the turbine middle stage (possibly also the heat produced by steam condensation that would otherwise need to be relieved by cooling water). The concept, design parameters and actual installation construction depend on the needs of energy consumers and available fuel. Condensing turbines are not typically part of industrial or agricultural cogeneration installations, but are more frequently applied in the cogeneration processes of public heating plants.

Total energy efficiency of steam turbine cogeneration is relatively high, normally ranging between 60 and 80 per cent. A steam turbine installation produces substantially less electricity than heat, so its electrical efficiency is typically up to 20 per cent.

Unlike other cogeneration installations, steam turbine applications are not limited to one fuel only (e.g. gas), since steam generators can use various solid, liquid or gaseous fuels, provided that the environmental protection regulation permits it (coal, light or heavy oils, gas and other fuels). This type of installation is often found in industrial plants, requiring steam of varying pressure or in plants with high energy consumption (thermal or electricity).

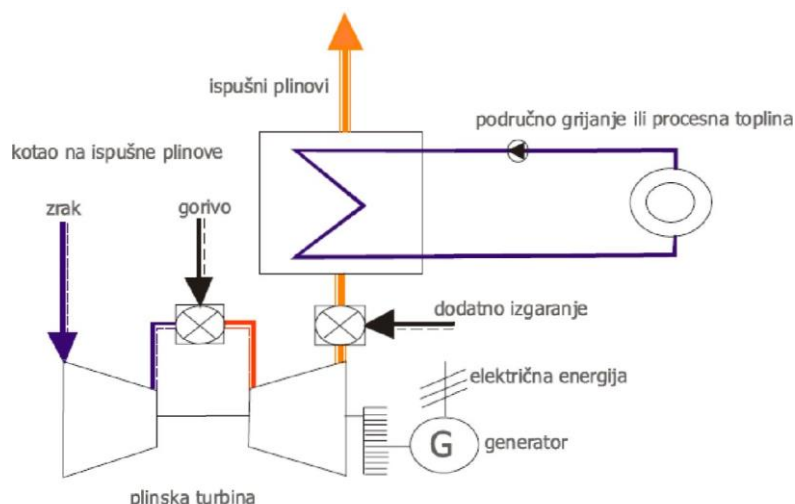
For economic reasons, smaller cogeneration installations with steam turbines are justified only if using solid fuels, biomass in particular, so they are most commonly used precisely in the locations where

biomass available as a fuel. The best solution is to use waste of the industrial plant's technological process (combustible by-products or industrial waste) as fuel, combining the energy production and waste disposal solutions. It is also often used in district heating systems to supply smaller cities and cities, especially in rural areas where large quantities of biomass are also available.

Gas turbine cogeneration

A cogeneration installation with gas turbines or the gas turbine cogeneration cycle consists of a gas-turbine generator, power generator and other auxiliary systems. Gas-turbine generator is a compact unit consisting of a compressor, combustion chamber, gas turbine and starting engine.

Heat is generated using exhaust gases of high temperatures (450-600 °C) and high oxygen content at the turbine outlet. The most common gas turbine application solutions in cogeneration processes involve heat recovery boiler processes and, in addition, direct use of exhaust gases.



<i>kotao na ispušne plinove</i>	<i>exhaust boiler</i>
<i>zrak</i>	<i>air</i>
<i>gorivo</i>	<i>fuel</i>
<i>plinska turbina</i>	<i>gas turbine</i>
<i>ispušni plinovi</i>	<i>flue gas</i>
<i>područno grijanje ili procesna toplina</i>	<i>district heating or process heat</i>
<i>dodatno izgaranje</i>	<i>additional combustion</i>
<i>električna energija</i>	<i>electricity</i>
<i>generator</i>	<i>generator</i>

Figure 41: Diagram of gas turbine cogeneration with heat recovery boiler

In plants using a heat recovery boiler, hot exhaust gases are directed from the turbine through the exhaust channel to an exhaust gas (heat recovery) boiler. If necessary, the level of thermal energy produced can be increased by combustion of additional fuel in the heat recovery boiler, enabled by a relatively high oxygen content of exhaust gases. Cogeneration systems equipped with a heat recovery boiler produce thermal energy in the form of steam of superior characteristics, suitable for use in various technological processes or in large heating systems (district heating systems).

The characteristics of hot exhaust gases obtained at the exit of the gas turbine are suitable for direct use, primarily in drying processes or else in furnaces requiring combustion up to a certain point. Direct use of exhaust gases from gas turbine eliminates the use of intermediate media and ensures more effective energy delivery.

Fuel used for a gas-turbine cogeneration installation is natural gas or extra light oil (usually as a backup fuel). To power a gas turbine, high-pressure gas supply from 13 to 20 bar, depending on the type of generator and the manufacturer, is required. Where only low-pressure gas (e.g. from the city distribution network) is available at a potential location, a compressor needs to be installed in front of the gas turbine.

The overall energy efficiency of such cogeneration processes can reach up to a maximum 87 per cent. Nominal electrical (mechanical) efficiency of small and medium-sized gas turbines is 25 to 35 per cent,

but it is higher in large turbines, reaching 42 per cent or more. The mechanical efficiency of a gas turbine is largely affected by its working load; therefore, it is recommended to employ such generation units at the levels approximately equal to their nominal working capacity at all times.

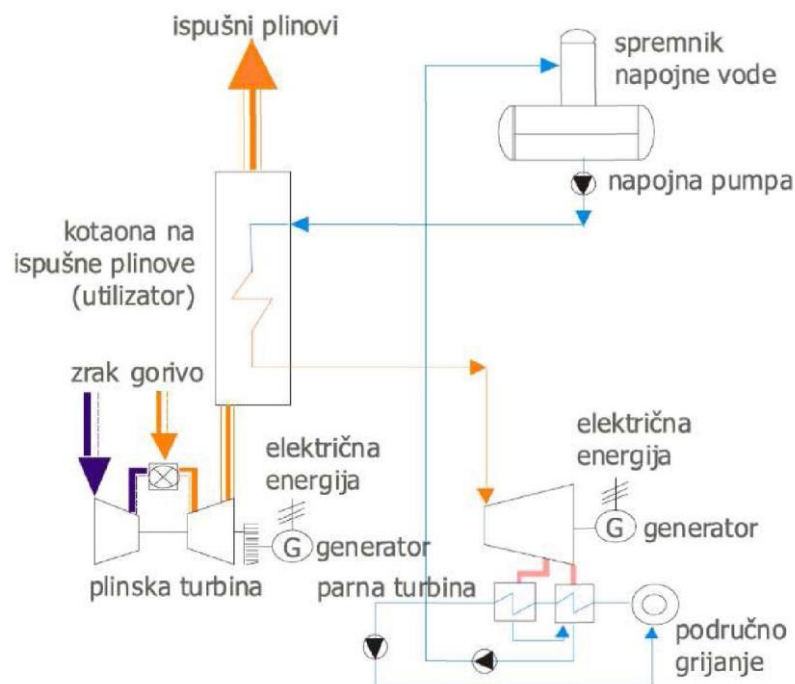
Some of the basic characteristics of gas turbines include high reliability, relatively little environmental pollution thanks to the use of gas, low cost per unit of installed power, short period of time until they reach full capacity, and a relatively small space required for installation.

Gas turbine cogeneration installations are applied only in complexes with high electricity demand which require the use of generators with the electrical power of at least 500 kW, since lower power equipment currently does not provide sufficient economic and technical advantages. Nevertheless, cases in which such cogeneration is employed in larger HVAC systems in hospitals etc. have also been known.

Very low-power gas turbines of 25 to 500 kWe (i.e. micro turbines) are being developed nowadays, characterised by high energy efficiency (80 per cent), good operational flexibility, durability, and low environmental impact. Such systems are not in commercial application as yet, but we can expect their wider use in HVAC systems, or even in the heating and cooling systems of family houses etc. in the future. It is believed that the first such commercial systems may be expected in less than five years, although they may take longer to come into actual commercial use.

Combined cycle cogeneration

The term 'combined cycle' is used for the processes which consist of two thermodynamic cycles, sharing a single working medium and operating at different temperature levels. Combined cycle cogeneration processes usually refer to the processes combining the simultaneous use of gas and steam turbines. In this type of cogeneration process, high-temperature exhaust gases from a gas turbine may be subjected to post-combustion to produce high-pressure (40-100 bar) steam in the heat recovery boiler. The steam expands in the back-pressure or condensing steam turbine generating electricity and steam, which is used in the technological process or for heating.



<i>ispušni plinovi</i>	<i>flue gases</i>
<i>kotao na ispušne plinove (utilizator)</i>	<i>exhaust (heat recovery) boiler</i>
<i>zrak</i>	<i>air</i>
<i>gorivo</i>	<i>fuel</i>
<i>plinska turbina</i>	<i>gas turbine</i>
<i>električna energija</i>	<i>electricity</i>
<i>generator</i>	<i>generator</i>
<i>parna turbina</i>	<i>steam turbine</i>
<i>spremnik napojne vode</i>	<i>feed water tank</i>
<i>napojna pumpa</i>	<i>feed pump</i>

područno grijanje	district heating
-------------------	------------------

Figure 42: Principal diagram of combined cycle cogeneration

The efficiency level is usually 35-45 per cent (in contemporary systems it can be up to 60 per cent), while the overall energy efficiency of such cogeneration processes ranges from 70 to 88 per cent. Such cogeneration processes are not typically used in the plants with less than 3.5 MW in installed capacity.

The installations of this type are highly suitable for use in district heating plants and have the highest energy efficiency. Integrated utilisation of heat at all available temperature levels may produce very high levels of fuel energy efficiency (under certain conditions, even more than 90 %).

4.1.2.3. Special cases of cogeneration processes

Biomass cogeneration

Contemporary systems of biomass energy utilisation enable exceptionally high fuel efficiency, which may exceed 90 per cent. Modern bio-power plants, boasting superior technology in the conversion of energy in the wood production chain, are used in the wood-processing industry, district heating systems, cogeneration and for family house heating.

In the process of biomass combustion, special attention is paid to flue gases and solid waste because of their impact on the environment. Gaseous emissions of CO, NO_x, and other harmful substances are reduced to a minimum in modern installations. Measurements at existing bio-power plants have confirmed the emissions to be well below the statutory limit values.

Where biomass is used, a heating system of up to 1 000 kW (1 MW) is considered as a small one. Such installations are smaller and partly differ from the district heating system. There are numerous such installations in EU Member States. While any kind of biomass can be used as fuel, the installations using wood waste and straw prevail. Such plants are typically automated.

Biomass-fired district heating systems are most commonly heating systems between 1 and 10 MW_t, often built to operate in combination with existing fuel oil- or coal-fired systems. Straw or wood mass of different origins are used as fuel.

From the standpoint of thermal energy use in the wood-processing industry and agriculture, low-pressure and high-pressure boilers and electricity installations are present. The very biomass-fired boilers are designed as shell or flued (tube) boilers. Shell boilers are built mainly for plants of up to 25 MW in power. Because of their use in industrial plants, particularly in the wood-processing industry, shell boilers are very widespread. Industrial biomass-fired flued boilers are designed for larger industrial consumers and plants with power ranging between 2 and 50 MW. Heat production from biomass in low-pressure boilers is most widespread in smaller installations, primarily to meet own needs of industries for heat, and technological needs for water or lower-quality steam. These boilers and installations are designed as warm and hot water boilers, and low-pressure steam boilers.

Heat production from biomass in high-pressure boilers is most widespread in larger installations, primarily for heating and to meet technological needs for water or higher-quality steam. These boilers and plants are designed as hot water boilers and steam boilers for the production of saturated steam.

Additionally, steam boilers with steam superheaters (40 bar and 400-450 °C) are also used, typically operating in a combined cycle with a steam turbine. Commonly, the capacity is between 10 and 50 t/h.

Grid furnaces are a proven and reliable technology enabling the use of fuels of different properties (moisture content and particle size), while varied design provides for a high degree of control and efficiency. However, modern development is aimed at minimising emissions. This tendency has led to the development of the fluidised bed combustion technology, as the main alternative to grid systems.

ORC cycle processes

The Organic Rankine Cycle (ORC process) is a thermodynamically closed process using a specific working fluid. Unlike the traditional Rankine steam cycle, where water/steam is used as a working fluid, the organic Rankine cycle uses an organic fluid of high molecular density and boiling point below that of water. Thus, heat sources of lower temperature levels may be exploited. The maximum power of the cycle may be achieved at temperatures as low as around 100 °C and pressures lower than 20 bar.

An important ORC characteristic is, therefore, the use of organic working fluids of favourable thermodynamic properties at lower temperatures and pressures. These include hydrocarbons, such as isopentane, isooctane or toluene, and silicone oil. Nowadays, typical applications concern geothermal and waste heat recovery and particularly the thermal utilisation of biomass, primarily in the wood-processing

industry. An integration of ORC processes with gas-turbine installations, at the cooler end of the cycle, is also considered.

The selection of a suitable organic working fluid is extremely important for the optimum operation of an ORC process installation. In order to select the optimum medium according to the operating conditions, certain general criteria have been set. Of these, the following are the most important:

- thermodynamic properties,
- stability in each phase and compatibility with contacting substances,
- environmental and health safety,
- availability and price.

The most frequently used working medium used in biomass-fired cogeneration installations based on this process is silicone oil, octamethyltrisiloxane (OMTS). Its operating properties are adequate, but the overall efficiency of the heat recovery for the cycles with higher temperatures is relatively low. Therefore, other media are also being tested. Typically, a cogeneration installation with the ORC process employs a thermal oil boiler, with a circuit of hot oil transferring heat through the evaporator to the silicone oil (OMTS) circuit in the ORC cycle. The temperature level of the hot oil in the boiler is around 300 °C. In using the condensation heat of the silicone oil and waste heat of flue gases, heating the hot water circuit can yield flow temperature of 80 °C to 100 °C, and return water temperature of 50 °C to 85 °C. Typical electrical power of such plants ranges between 300 kW_e and more than 1 MW_e, with thermal input levels of up to 5-6 MW_t.

On account of their relatively small size, heat from ORC cycle installations is well-suited for use in the local heat network of the facility. Major district heating systems employing an ORC cycle generation unit are found where geothermal installations, such as those in Iceland and San Salvador, are integrated. Iceland's Svartsengi geothermal/ORC cogeneration installation has the installed capacity of 46 MW_e and 150 MW_t.

Fuel cell cogeneration

Fuel cell cogeneration installations enable electricity generation and thermal energy production directly from chemical energy of the gas through electrochemical reaction without standard combustion. The fuel cell process is an electrochemical process continuously transforming the chemical energy of gas and oxidising agent into electricity and thermal energy. Thus, fuel cells are devices for direct conversion of fuel, without thermal fluid or mobile elements within the device itself. A fuel cell is essentially similar to a standard battery cell. It consists of two electrodes with an electrolyte (galvanic cell) between them. However, fuel cell reagents are not part of the cell itself but are supplied from the outside. Hydrogen and oxygen are supplied to platinum electrodes, immersed in the electrolyte. Thus, fuel cell capacity is not limited by reagent accumulation.

Total energy efficiency of the fuel cell cogeneration process is between 85 and 90 per cent. The electrical efficiency of commercially available fuel cells ranges between 37 and 45 per cent, but is expected to reach 50 per cent through future development.

The advantages of fuel cells compared to conventional cogeneration generators are the following:

- simpler operation and maintenance compared to engines or turbines,
- modular structure,
- high fuel efficiency level,
- negligible influence of unit size and change in load on the efficiency,
- quiet operation thanks to absence of moving or rotating parts,
- minimal pollution (no emissions of CO or NO_x).

There are several types of fuel cells, differing by operating temperatures, electrolyte type, as well as electric and thermal characteristics. The most common are:

- low-temperature, Polymer Electrolyte Membrane (PEM) alkaline fuel cells (approx. 80-100 °C) or Phosphoric Acid Fuel Cell (PAFC, approx. 200 °C);
- medium-temperature (650 °C) using molten carbonate as electrolyte – Molten Carbonate Fuel Cell (MCFC);
- high-temperature (approx. 1 000 °C) Solid Oxide Fuel Cell (SOFC).

Fuel cells cogeneration is already in use, mostly by distributors, in office buildings, district heating systems, etc., but it is still undergoing a demonstration or trial run. Fuel cell is the most promising technology for cogeneration applications, and is among the mostly likely technologies in HVAC systems.

However, considering that commercial installations require high investments per installed kW (50 to 400 per cent more than in traditional cogeneration systems) and have a relatively short service life (25 000 h), their market presence is symbolic for the time being. The latest recent market research shows that this technology may not become fully competitive for the next five to ten years.

4.1.3. Characteristics of district cooling

4.1.3.1. DHS district cooling

The advantages of centralised, both heating and cooling energy supply were discovered a long time ago. Specifically, the incorporation of a number of cooling consumers with different quantities and forms of cooling into a single system opens the possibility of better utilisation of installed cooling units.

The grouping a number of consumers into a single system enables the use of a small number of high-capacity production units (cooling devices). Large cooling units are more efficient than the smaller ones, so their energy costs are lower. When a small number of units is located in a single place, the number of staff required to operate them and related costs are also reduced. Higher-capacity cooling units require lower specific investment. Due to the different consumption dynamics among consumers (simultaneity factor), the installed cooling capacity of a cooling installation in a centralised cooling system may be lower.

The mode of cooling unit operation consists in supplying driving energy, which conducts heat away from the air to be cooled in the cooling process and transferring it to the environment. This may be achieved either directly or indirectly, using a cooling medium. The main characteristic of the cooling processes is that they have to conduct heat away from a colder substance and transfer it to a warmer environment. In order to reach the desired cooling effect, an additional process must be used to increase the temperature level of conducted heat. This requires a certain amount of energy, called driving energy. A working fluid capable of moving heat from the cooled substance and transferring it to the environment is also required.

This additional process may be proven to be essentially secondary. There is a series of additional processes, the most common of which are the following:

- compressor-driven cooling process, using mechanical energy supplied, so the process is also known as compressor cooling;
- absorption cooling process, using heat supplied, where the cooling processes using it is frequently also called absorption cooling.

Absorption cooling systems are of primary interest for employment in district heating systems.

In the steam-driven compressor cooling process, vapour of the working fluid is compressed to a higher pressure to increase its temperature level. The compressor unit compressing that vapour uses a certain amount of mechanical work.

Instead of using direct mechanical compression, the working fluid may be compressed by another method, i.e. indirectly. Certain substances have so-called absorption capacity – when in liquid form, they absorb the vapour of another substance. The absorption capacity decreases as temperature increases. The absorbing substance in this case is called adsorbent or absorbent, while the absorbed substance is called absorbate. The absorption process results in a solution of absorbate in the absorbent, i.e. an absorbent-absorbate mixture.

In the absorption cooling process, having effected a certain amount of cooling, the working fluid is absorbed by the absorbent. The resulting solution is elevated to a higher pressure and heated, using a heating medium. Heating reduces the absorption capacity of the absorbent, causing the working fluid to evaporate from the solution, that is, to its boiling down. As a consequence, the mixture is separated to its components – working fluid and absorbent. In fact, the separation of the two is never complete in actual cooling units. Rather, vapours of the cooling medium regularly contain a certain amount of absorbent, while the absorbent liquid always contains a certain amount of working fluid. The solutions in absorption cooling processes are therefore usually referred to as strong or weak, depending on the high or low content of working fluid in the absorbent, respectively. The following two pairs of substances are used as absorbent/working fluid in current commercial absorption cooling systems:

- water as working medium, lithium bromide as absorbent, and
- ammonia as working fluid, water as absorbent.

A solution with a high water content is always called weak; therefore, in cooling units with lithium bromide it is the solution obtained by absorption, while in the ones using ammonia, the weak solution is obtained by boiling down.

A strong solution obtained by boiling down is returned to the process, where it absorbs the working fluid again, thereby closing its own circuit – the solution circuit. The evaporated working fluid also continues the absorption cooling process in its own circuit – the working fluid circuit.

In the absorption process, the absorbent is regularly cooled by coolant water. The removed heat is called absorption heat. A higher temperature of the heating medium cannot be exploited sufficiently in a single-phase absorption cooling process. Specifically, increasing the temperature of the heating medium above a certain limit does not increase the amount of working fluid circulating in the single-phase absorption cooling process. Therefore, a two-phase absorption cooling process, in which the absorption takes place in two compression stages, was developed.

The two-phase absorption cooling process consists of two related processes taking place at two temperature (and pressure) levels – low temperature and high temperature. The basic, low-temperature process contains all the elements of a single-phase absorption cooling process. The high-temperature process consists of one additional evaporation process, in which outside fuel heat is introduced via the heating medium. The working fluid, which evaporates in the high-temperature process, uses its own condensation heat for heating the low-temperature process, in which an additional amount of working fluid is produced by evaporation.

Thanks to double evaporation, the two-phase process can achieve almost double the working fuel flow rate for the same amount of heat consumed, compared to the single-phase process. Therefore, energy efficiency or the cooling ratio of this process is almost double that of the single-phase process.

Accordingly, we can differentiate between:

- a single-phase absorption cooling process and
- a two-phase absorption cooling process.

Single-phase systems typically use hot (warm) water or low-pressure steam as the heating medium, while mid-pressure (8 bar) steam is used as the heating medium in two-phase systems.

Thanks to almost double the energy efficiency of the two-phase cooling process compared to the single-phase process, single-phase systems are generally not as cost-effective in district heating systems of larger settlements. Systems using two-phase hot-water absorption cooling units, however, require a high-temperature working fluid, so steam pipelines are far more suitable for that method of cooling energy production. The fact that two-phase absorption cooling units are better than compression devices only with higher installed power (more than 1 MW) is also relevant.

Basically, district cooling systems may either make use of the thermal network with a high-temperature medium, such as steam, to supply thermal energy to decentralised absorption cooling units or produce cooling energy in a central installation and distribute it to consumers through a cold water network. The latter concept assumes a shorter distribution network.

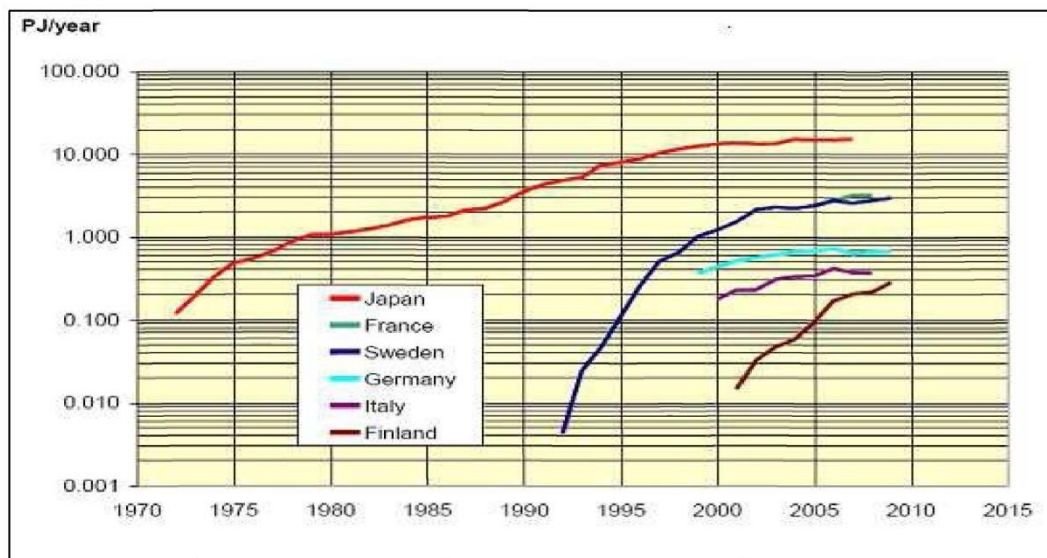


Figure 43: Growth of district cooling energy supplied in selected countries by various statistics

4.1.3.2. Characteristics of district cooling using cooling water distribution

In district cooling using cooling water distribution, cooling water is typically distributed by underground pipelines.

The fact the relatively low amounts of energy may be delivered using the same working fluid flow rate is relevant. In district cooling, the Δt is considerably lower, with the feed water temperature of approx. +5 °C and the return water temperature of +15 °C. The temperature difference in district heating is much higher and can reach up to 40 °C. Consequently, district cooling system pipelines are larger in diameter and usually more expensive.

4.1.3.3. Application of DHS – DH and DC – suitable building types

Urban commercial centres are regularly much smaller than the areas intended for housing. District heating implemented in commercial buildings is less cost-effective than in residential areas, but it is used occasionally. At the presumed maximum thermal load of 12 hours a day and no residential buildings to be connected, thermal networks are rarely justified in commercial areas. On the other hand, the density of heated space in commercial buildings, the value of the space, as well as no need for the allocation of boiler or chimney space and the absence of emissions to the air, are the factors in favour of district heating.

The presence of district cooling in the commercial areas of cities, however, is more justified. Cooling load is high, as is the necessity of meeting cooling needs, and sometimes the cooling load extends to most of the year. The introduction of a centralised district cooling system frees up valuable space in this case as well, especially on rooftops and in underground levels.

Consequently, district heating and district cooling evidently do not have completely symmetrical applicability. Therefore, district heating is introduced in larger urban areas with households, while district cooling is intended for urban centres with commercial and service buildings. However, urban settings having a parallel distribution of district heating and cooling have developed in recent times. DC – or cooling – is based on much lower temperature differences than heating is, so cooling energy distribution is not as cost-effective at distances such as those covered by district heating. This is true of direct centralised cooling water distribution, unless local decentralised absorption devices using heat from the heating network are employed.

4.2. PROJECTIONS OF HEATING CONSUMPTION DEVELOPMENT, AND DETERMINING HIGH-EFFICIENCY COGENERATION POTENTIAL

4.2.1. Definitions

The subject of these analyses is the possibility of applying high-efficiency cogeneration. Under the provisions of the regulations set out in Chapter 8, a high-efficiency cogeneration installation is defined as that ensuring primary energy savings of at least 10 % compared to separate reference electricity generation and heat production or, in the case of a cogeneration installation with up to 1 MWe in installed capacity, that ensuring any primary energy savings and meeting specific efficiency and/or heat use requirements. These requirements, which are laid down specifically, include high-efficiency requirements for cogeneration installations using fossil fuels, efficiency and/or thermal energy requirements for cogeneration installations using renewable energy sources, fossil fuel co-incineration requirements, waste co-incineration requirements, and exemptions from compliance with the requirements for thermal energy use or efficiency due to *force majeure* or other situations caused by third parties. Deviations from the laid down efficiency requirements (corrective coefficients to be applied to reference values), the method of determining the net electricity delivered, and thermal energy and fuel consumption by metering, as well as other important aspects are also covered.

The primary energy savings (PES) indicator of cogeneration energy efficiency is therefore the key indicator. It is expressed as the relative saving in fuel exploitation achieved in comparison to the equivalent production in separate reference plants. It is defined as:

$$UPE = 1 - \frac{1}{\frac{\eta_e}{\eta_{ref,e}} + \frac{\eta_t}{\eta_{ref,t}}}$$

where η_e^* denotes the average annual electricity generation efficiency of the cogeneration installation, defined by the expression:

$$\eta_e = \frac{3600 * E_k}{Q_f}$$

with E_k as the annual electricity produced in cogeneration, and Q_f as the annual primary energy consumption for the operation of the cogeneration installation. Q_f refers to the sum of fossil fuels used according to the lower heating value; the annual energy consumption Q is calculated in case of biomass, liquid biofuels or biogas and waste combustion, or a combination of fuels.

Factor η_t denotes the average annual efficiency of heat cogeneration, defined as follows:

$$\eta_t = \frac{H_k}{Q_f}$$

where H_k denotes the useful thermal energy produced in the cogeneration process and used in the technological processes, heating processes or secondary cooling processes (trigeneration) not exceeding the economically justified demand, i.e. demand which is not greater than that to be covered by a substitute thermal energy source.

In the formula for PES, $\eta_{ref,e}$ denotes the electrical efficiency of a reference power plant, while $\eta_{ref,t}$ is the thermal efficiency of a reference boiler room. Value $\eta_{ref,e}$ is determined according to the base value of a reference power plant, set out in a respective table by fuel type (solid, liquid, gaseous fuels), with corrections to the electrical efficiency according to climate conditions and any network losses avoided. The thermal efficiency of a reference boiler room, $\eta_{ref,t}$, depends on the type of fuel used and on the method of waste heat use (for production of steam/hot water or directly in the process). With regard to the fuel type, it is determined according to the lower heating value and standard environmental conditions.

According to the efficiency defined by applicable regulations, for all practical purposes, it is clear that the use of thermal energy in practice has a crucial impact on the actual efficiency of the cogeneration installation. As a high-value form of final energy and thanks to developed network infrastructure, any electricity generated is relatively easy to sell (a more complex situation evolves with its transfer to the network from larger installations). The thermal energy situation is different; to enable useful thermal energy consumption simultaneously with the electricity generation, heat needs to be consumed on site or there should be a heat network available. Thus, to achieve a relevant primary energy saving at an annual level, it is necessary to ensure continuous and even consumption of thermal energy produced. The possibility of implementing district cooling is of great importance as it could substantially improve the annual load and utilisation, provided that heat is used in absorption cooling units and adequate infrastructure is developed. The aim is to achieve more balanced consumption throughout the year, in the heating and cooling season, and in transitional situations.

Therefore, possible development of heat consumption in the observed upcoming period is of crucial importance for the potential to implement and develop high-efficiency cogeneration in the Republic of Croatia.

4.2.2. Heat consumption development until 2030

The development of heat consumption in Croatian cities has been analysed, with particular consideration of the household, industry and service sector. All cities and municipalities, as well as settlements with substantial heat consumption have been covered. The analysis took into account the characteristics of climate zones, heating degree-days, population and housing units. The methodology of analysis covered the following:

- heat consumption for space heating, domestic hot water generation, and cooling energy consumption for households;
- direct heat consumption, i.e. consumption of fuel for process heat, hot water and steam, as well as indirect heat consumption for industries;
- heat consumption for heating, and cooling consumption for the service sector.

Based on the results, only the areas with heat consumption relevant for the introduction of cogeneration installations were taken into account to provide an overview of possible DHS heat consumption and equivalent installed capacity of heat generation units for 18 cities, as a projection for the year 2030.

4.2.2.1. Characteristics of settlements

The first study took into account all cities and municipalities in Croatia, or a total of 556 settlements observed. The observed characteristics are the following:

- population of a particular cities/municipality,
- number of households in a particular cities/municipality,
- average number of persons per household,
- total estimated area of housing units,
- local climate conditions (climate zone, degree-days),
- number of permanently occupied housing units,
- estimate of that figure in intervals by 2030.

These data make the base assumptions for further considerations and projections of the heat consumption development by consumption sectors and period observed.

Data for the first-ranking 31 cities/municipalities, sorted according to their current heat consumption, are provided in Annex 14.1.

4.2.2.2. Household projections

For households, thermal energy for space heating is presented separated from that for domestic hot water generation and cooking, as stated. Data and projections of cooling energy consumption are provided next.

Heat required for cooking is excluded from the useful heat which could be met from cogeneration. Thermal energy for DHW generation may be considered here, but the use of centralised heat for that purpose requires a developed infrastructure of heating networks with substations and installed internal infrastructure in most households; according to current indicators, it should be taken with caution. Therefore, only useful heat for space heating is taken into account for easier and more conservative approach.

Cooling energy needs and projections of their development are taken into account as the potential for introducing and developing district cooling for household needs.

The projections of household heat and cooling consumption by 2030 are provided in Annex 14.1.

4.2.2.3. Industry projections

Direct and indirect industry heat is considered separately. Direct heat refers to fuel consumption for the production of process heat, i.e. mainly direct combustion for the purpose of specific thermal processes. Indirect heat refers to fuel consumption to produce steam, hot water and other media – heat transport media, i.e. the fuel consumed in boiler rooms for the preparation of such media, including the consumption of heat from thermal networks – steam and hot water pipelines – where available. Only indirect heat is taken for determining the consumption of useful heat that to be met from cogeneration, as the basis for determining its potential. Direct industry heat is too specific and temperature levels are mostly too high for it to be seriously considered as potential for the use of cogeneration. Certain ‘bottoming’ industrial processes may be taken into account, but are not considered for their marginally and for the sake of simplicity .

Cooling energy needs, mostly in food-processing industry, is presumed to be met by local compressor generation units. There is some potential for the use of larger absorption generation units, e.g. for refrigerated warehouses.

The projections of industry heat consumption by 2030 are provided in Annex 14.1.

4.2.2.4. Service sector projections

Unlike households, service sector consumption is treated as a whole since it mostly involves processes which can be centralised. This primarily concerns space heating, DHW generation and washing processes. The projections of cooling needs are again taken into as the potential for introducing and developing district cooling. The sum of needs is shown for illustration purposes in the table.

The projections of service sector consumption by 2030 are provided in Annex 14.1.

4.2.2.5. Position of district cooling capacities

Since the consumption of heating and cooling energy is mostly observed on the assumption that it largely does not take place simultaneously, cooling energy is not added to heating energy, not even applying

corrections. In all cases, the installed capacity should suffice to meet the needs for cooling energy, to be supplied by absorption units, in the cooling periods when the needs for heat decrease considerably. Therefore, the presumed maximum thermal capacity is analysed according to its dimensioning for the heating season.

4.2.2.6. Potential by the year 2030

The potential for the application and development of high-efficiency cogeneration by 2030 has been derived from the analysed data, considering the locations which might require installed capacity of at least 20 MW_t. This reduces the number of cities and municipalities observed to 18 locations.

Under the principles applied, thermal energy needs for the industry, households and service sectors have been added up. The equivalent installed capacity of generation units has been projected on the basis of the overall energy consumption obtained. The share of consumers who might be connected to the local district heating systems based on high-efficiency cogeneration is based on the characteristics of particular locations, heating sector development plans, and other relevant presumptions. In conclusion, the projection of the overall heating energy to be delivered to consumers from such systems is provided at the 2030 level.

The consumption potential for determining the high-efficiency cogeneration share by the year 2030 is shown in Annex 14.1.

5. IMPACT OF ELECTRICITY, GAS, THERMAL ENERGY AND RENEWABLE ENERGY SOURCE MARKETS

5.1. INTRODUCTION TO THE ENERGY MARKET IMPACT

This chapter identifies market barriers which might have a negative impact on the development and implementation of high-efficiency cogeneration projects. Primary emphasis is placed on market barriers resulting from the introduction of administrative and legal arrangements as a means of achieving particular economic, i.e. social objectives.

Market intervention for the purpose of achieving other objectives leads to imbalance, which can result in a market outcome with no technical or economic justification. Additionally, interference in the relations in one market may affect other markets, which are not directly connected. Therefore, markets in natural gas, thermal energy, electricity, as well as renewable energy and waste will be analysed below. The focus will be on the structure of each of these markets, and the impact of the existing legal arrangements on the use of energy from high-efficiency cogeneration will be analysed.

5.2. ELECTRICITY IMPACT

5.2.1. Impact of electricity price on thermal energy production

The regulatory and legal framework applying to the electricity market does not include any provisions governing the production of heat from electricity. However, in view of the current market situation, electricity may be used to produce heat in the following two manners:

- Individually. Thermal energy production is possible by using heat pumps.
- On a centralised basis. Thanks to the very low electricity price on the wholesale market, there is a realistic possibility of using large electric boilers to produce thermal energy. Such boilers would replace thermal energy production using fuel oil and natural gas-fired boilers, as well as from cogeneration installations.

5.2.2. Impact of electricity price on the choice of centralised system

The current low price of electricity on the wholesale market poses a major problem and a barrier to thermal energy production from cogeneration installations. Such very low price of electricity brings into question the cost-effectiveness of cogeneration installations, since the revenue from thermal energy sales cannot compensate for the low price of electricity.

5.3. IMPACT OF NATURAL GAS PRICE

5.3.1. Impact of natural gas price on thermal energy production

The total price of natural gas consists of the (i) natural gas purchase price, (ii) natural gas transport price, (iii) natural gas distribution price and (iv) natural gas supply price. While natural gas transport and distribution belong to regulated activities, whose prices are set by the Croatian Energy Regulatory Agency based on the methodologies for determining tariff item amounts in each segment, the supply price of natural gas should be freely determined.

Thermal energy production from cogeneration installations using natural gas as an energy source should be competitive for a number of reasons:

- The price of natural gas supply to thermal energy producers from cogeneration installations should be lower than that paid by retail customers on account of the more favourable prices obtained by large customers compared to smaller customers.
- Cogeneration installations are connected to the natural gas transport system, which means that they pay no distribution fee.

However, the natural gas price at which thermal energy producers are supplied is substantially higher than the price paid for natural gas by households. The Croatian Government has adopted a number of regulations setting the price of natural gas for the category of households which is not in line with market trends. Specifically, the following acts have been adopted:

- Decision requiring the producer of natural gas to sell natural gas to the supplier on the gas wholesale market (NN No 29/14). The Decision defines the amount of natural gas to be offered by INA d.d., as the natural gas producer in the territory of Croatia, to the wholesale market supplier. The supplier has the obligation to sell the stated amounts of gas exclusively to other suppliers, who in turn supply households as a public service.
- Decision setting the price at which the natural gas producer is obliged to sell natural gas produced in Croatia to the supplier on the gas wholesale market (NN No 28/15). The Decision sets the price at which the natural gas producer is obliged to sell natural gas produced in Croatia to the gas wholesale market supplier. The said price includes all related costs of the natural gas producer, including any fees charged for the use of the transport system up to a virtual trading point. For the period between 1 April 2015 and 31 March 2016, that price is HRK 0.1715/kWh.
- Decision setting the price at which the supplier on the gas wholesale market is obliged to sell gas to public service suppliers who supply gas to households (NN No 28/15). The decision sets the price of natural gas at which the gas wholesale market supplier is obliged to sell gas to public service suppliers, who in turn supply gas to households. For the period between 1 April 2015 and 31 March 2016, that price is HRK 0.2289/kWh.

5.3.2. Impact of gas price on the choice and use of district heating systems

The above legal arrangement lays down that natural gas produced in Croatia is to be offered to household customers, who are supplied at regulated, i.e. non-market prices as a public service. Such a situation results in the creation of apparently low costs of natural gas use for heating. However, such a solution discriminates against customers who do not use natural gas for heating directly, but are connected to a heating system using natural gas to produce thermal energy. More specifically, thermal energy producers using natural gas for the purpose of thermal energy production pay a higher, industrial gas price.

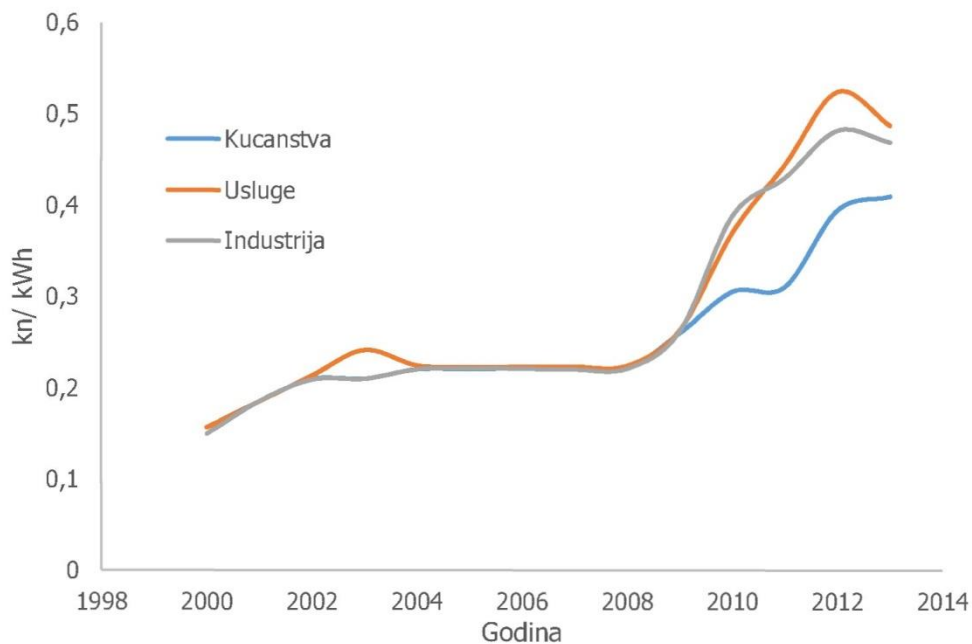
Similar normative arrangements which regulate the price of natural gas for households also existed in the past and include the following decisions:

- Decision setting the price at which the natural gas producer is obliged to sell natural gas produced in Croatia to the supplier on the gas wholesale market (NN No 29/14). The Decision sets the price at which the natural gas producer is obliged to sell natural gas produced in Croatia to the supplier on the gas wholesale market. That price is set at HRK 0.1842/kWh.
- Decision setting the price at which the supplier on the gas wholesale market is obliged to sell gas to public service suppliers who supply gas to households (NN No 29/14). The Decision sets the price at which the supplier on the gas wholesale market is obliged to sell gas to public service suppliers, who in turn supply gas to households. That price is set at HRK 0.2595/kWh.
- Decision setting the purchase price of gas for tariff customer suppliers (NN No 49/2012). The Decision sets the purchase price of gas for tariff customer suppliers at HRK 0.237563/kWh.
- Decision implementing a special measure for mitigating the increase in household natural gas prices in 2011 (NN No 148/10). The decision enabled the co-financing of gas prices for households with State Budget funds.
- Decision implementing a special measure for mitigating the increase in household natural gas prices in 2010 (NN No 158/09). The decision enabled the co-financing of gas prices for households with State Budget funds.
- Decision setting the purchase price of gas for tariff customer suppliers (NN No 77/07). The Decision sets the purchase price of gas for tariff customer suppliers at HRK 1.07/m³; this refers

to the price for 1 Sm³ of natural gas at a pressure of 101.325 Pa and a temperature of 288.15 K for the basic calorific value of 33 338.35 kJ/Sm³.

- Decision setting the purchase price of gas for tariff customer suppliers (NN No 153/09), which sets the purchase price of gas for tariff customer suppliers at HRK 1.70/m³; this refers to the price for 1 Sm³ of natural gas at a pressure of 101.325 Pa and a temperature of 288.15 K for the basic calorific value of 33 338.35 kJ/Sm³.

As a result of natural gas price regulation for households, economic operators and district heating companies using natural gas for thermal energy production in particular pay a significantly higher natural gas price than that paid by households. The figure below shows developments in natural gas prices (including VAT) for households, services and the industry. As evident from the figure, natural gas prices for households have been separated from those for the industry since 2010.



<i>Kućanstva</i>	<i>Households</i>
<i>Usluge</i>	<i>Services</i>
<i>Industrija</i>	<i>Industry</i>
<i>Godina</i>	<i>Year</i>

Figure 44: Natural gas price for households, services and industry (HRK/kWh, VAT included).
Source: Energy in Croatia, EIHP, 2013

Pursuant to the above regulations and decisions, the use of natural gas for thermal energy production at the customer's location (especially in households) used to be stimulated, creating a perception of natural gas as a cheap fuel for thermal energy production. In addition to the problems which plagued the heating sector, that situation led to an increase in the use of natural gas as a fuel for thermal energy production and a decrease in the share of district heating networks in cities.

5.4. IMPACT OF RENEWABLE ENERGY SOURCES, BIODEGRADABLE AND MUNICIPAL WASTE

5.4.1. Impact of renewable sources, biodegradable and municipal waste on thermal energy production

Under the Tariff system for electricity generation from renewable energy sources and cogeneration (NN Nos 133/13, 151/13, 20/14, 107/14, and 100/15), the facilities using RES and high-efficiency cogeneration, which acquired the eligible producer status, are entitled to an incentive price for electricity generation. Of all the technologies having the technical capability to produce thermal energy, incentives are directed towards biomass (including biodegradable parts of industrial and municipal waste) power plants and biogas (from agricultural crops and organic residues, vegetable and animal waste, biodegradable waste, landfill gas, and sewage treatment plant gas) power plants.

The tariff system sets an incentive price of electricity enabling a return on investment to the installation primarily through electricity generation. Commercial thermal energy production increases an installation's economic potential. More specifically, the total annual efficiency limit of 50 % set by the existing tariff system is technically not difficult to achieve and generally does not involve major thermal energy utilisation.

5.4.2. Impact of renewable sources on the choice of district heating system

A potential barrier to larger-scale use of RES and waste in the DHS lies in the absence of DHS networks at locations where such installations are built, i.e. in their relative distance from final customers. Also, thermal energy production from those installations is generally not cost-effective, giving rise to incentives for production at such installations. The use of RES and waste as part of a DHS is little likely, except in the situations in which other, primarily environmental issues need to be dealt with.

5.5. THERMAL ENERGY MARKET

Thermal energy market regulation covers the areas of thermal energy production, distribution and supply. Methodology for determining tariff item amounts for thermal energy production (NN No 56/14) is currently applicable to thermal energy production. It defines the method of determining the price of thermal energy in a district heating system as part of a public service. The methodology does not apply to thermal energy producers in a closed or stand-alone heating system or to thermal energy production for primarily business purposes.

The current methodology is an improvement compared to previous ones. More specifically, under the previous Tariff system for the services of thermal energy production, distribution and supply, without tariff item amounts (NN Nos 65/07, 154/08, 22/10, 46/10, 50/10, and 86/11), the price of thermal energy purchased from other producers was set as a three-year average of thermal energy purchase prices. Considering that the price of thermal energy production for the DHS system was not regulated, thermal energy producers could freely determine the selling price of thermal energy. In such a system, a thermal energy distributor faced a regulated price for final customers which was generally lower than the purchase price of thermal energy. However, the new methodology for determining tariff item amounts for thermal energy production corrected that anomaly.

In the context of thermal energy production from cogeneration installations, the issue of allocation of operating costs (fuel, staff and other costs) and the allocation of assets to the market share related to electricity generation and to the regulated share related to thermal energy production, play a major role. Article 8(2) of the current methodology lays down an obligation for a thermal energy producer generating electricity and thermal energy in a cogeneration process to keep the accounts and prepare financial statements for each of these activities specifically and separately, in accordance with the Decision on the manner and procedure for separate accounting of energy undertakings (NN No 86/14). However, according to public information available on the website of the Croatian Energy Regulatory Agency, there are no published rules defining unambiguously the method of cost and asset allocation in a cogeneration facility used for thermal energy and electricity generation.

5.6. CONCLUSION

The analysis of market conditions in the Croatian energy sector reveals the presence of two anomalies hindering the development of high-efficiency cogeneration installations:

- The price of natural gas for households as part of a public service is administratively regulated. The applicable decision governing the issue of administrative regulation of natural gas price as part of a public service applies to the period until 31 March 2016, and the Programme authors have no information on whether the stated period might be extended.
- The electricity price on wholesale markets of the European Union is exceptionally low, which does not benefit the use of high-efficiency cogeneration.

6. DETERMINING THE POTENTIAL FOR ADDITIONAL HIGH-EFFICIENCY COGENERATION

6.1. INTRODUCTION

This chapter analyses the potential for the reconstruction of the existing and construction of new energy facilities with thermal power exceeding 20 MW_t, having regard to the application of high-efficiency cogeneration.

In accordance with the applicable legislative provisions and other relevant directives, high-efficiency cogeneration is the production of electricity and thermal energy from cogeneration installations that ensures primary energy savings of at least 10 % compared with the reference values for separate production of thermal energy and electricity.

The primary energy savings calculation methodology is provided for by the Rules on Eligible Producer Status (NN Nos 132/2013, 81/14, 93/14, 24/15, 99/15, and 110/15), which also lay down the technical and operational requirements for such generation facilities.

In order to obtain eligible electricity producer status, each generation facility must meet the following criteria:

- be connected to the electricity transmission or distribution network and deliver electricity to the electricity network in accordance with the conditions of network use;
- meet the technical and operational requirements laid down by Article 4 of the Rules; and
- simultaneously generate electricity and thermal energy in a highly-efficient manner and/or use waste or renewable energy sources to generate electricity in an economically appropriate manner, in accordance with the regulations from the administrative field of environmental protection, regardless of the generation facility's power.

The analysis presented in this chapter includes the following:

- current condition of thermal energy facilities;
- potential new locations for thermal energy consumption with possible application of high-efficiency cogeneration.

The analysis of the current condition of thermal energy facilities covers the existing cogeneration installations and industrial power plants with a fuel power input exceeding 20 MW. The analysis determines annual electrical and heat efficiency on the basis of total fuel consumption, as well as [the amount of] electricity and useful thermal energy generated. Those values are compared with the reference values for separate production of electricity and thermal energy in order to calculate primary energy savings.

In analysing potential locations for thermal energy consumption with possible application of high-efficiency cogeneration, the results of the analyses presented in the chapters 'Determination of the thermal energy demand which can be met through high-efficiency cogeneration' and 'Determination of the potential for the improvement of infrastructure energy efficiency' have been taken into consideration. Potential new locations for [the construction of] high-efficiency cogeneration installations have been determined on the basis of consolidated results of these two analyses.

6.2. CURRENT CONDITION OF THERMAL ENERGY FACILITIES AND INDUSTRIAL POWER PLANTS

6.2.1. Zagreb electricity/heating plant (EL-TO Zagreb)

Under its original name *Munjara*, the Zagreb electricity/heating plant (abbr. EL-TO Zagreb) was put into operation in 1907, when it had the power of 0.8 MW_e and was fuelled by coal. The plant was constructed for the purpose of electrifying the City of Zagreb (first the water supply and public lighting system, and subsequently the industry and city electric trams). As the rising number of inhabitants led to an increase in electricity and thermal energy needs, the plant gradually developed. The construction of a 14.7 MW_t heating station in 1954 marked the beginning of district heating in the west part of Zagreb, whereas the supply of process steam for industrial applications was initiated in 1961. The plant started using heavy fuel oil as fuel in 1965, and natural gas in 1970. With the construction of a new 30 MW_e back-pressure Block B in 1980, the process water supply system was reconstructed and expanded. The latest expansion of the plant took place in 1998, when two gas turbines (2 x 26 MW_e) were relocated from Dujmovača to EL-TO Zagreb. For that reason, the plant was connected to the loop of the main gas pipeline in GRMS Jug in Botinec. In order to utilise the heat from turbine exhaust gases and, thereby, partially satisfy the need for industrial steam and mains water heating, waste water boilers were also constructed. In 2000, EL-TO Zagreb was physically connected to TE-TO Zagreb by a DHS. In 2006, the heating station was completely reconstructed and expanded. The features of the EL-TO Zagreb cogeneration installations are presented in the table below.

Table 18: Basic technical data on blocks A, B, H and J

Feature	Block A	Block B	Block H	Block J
Gas turbine				
Manufacturer			GE Energy Products	GE Energy Products
Type			PG 5371	PG 5371
Compression ratio				
Specific heat consumption			13.010 kJ/kWh	13.010 kJ/kWh
Gas-turbine generator				
Manufacturer			AEG	AEG
Type				
Rated power			28.1 MVA	28.1 MVA
Rated power factor			0.85	0.85
Steam turbine				
Manufacturer	Jugoturbina	Jugoturbina		
Type	1-OP 15.0, impulse, single-casing, back-pressure with regulated extraction	1-OP 35.0, impulse, single-casing, back-pressure with regulated extraction		
HP turbine inlet pressure	115 bar	115 bar		
Maximum steam flow	100 t/h	200 t/h		
Extraction	17 bar and 6.7 bar	17 bar and 6-9 bar		
Back-pressure/OK	3 bar	0.29-0.93 bar		
Steam-turbine generator				
Manufacturer	Končar	Končar		
Type				
Rated power	15.7 MVA	15.7 MVA		
Rated power factor	0.8	0.8		
Waste heat boiler				
Manufacturer			Đuro Đaković	Đuro Đaković
Type				
Amount of HP steam			122 t/h	122 t/h
HP steam			235 °C, 18 bar	235 °C, 18 bar

Steam boiler				
Manufacturer	Đuro Đaković	Wagner Büro		
Type				
Steam output	100 t/h	80 t/h	100 t/h	
Steam pressure	115 bar	115 bar	115 bar	
Steam temperature	515 °C	515 °C	515 °C	

6.2.1.1. Block A

Block A is the oldest generation block of EL-TO Zagreb. It was constructed in 1970, and it consists of a steam boiler (K6) and a back-pressure steam turbine with electrical power of 12 MW_e. Steam boiler K6 generates overheated steam (115 bar, 515 °C) through the combustion of heavy fuel oil and natural gas. The back-pressure steam turbine has dual-pressure extraction. The first extraction is regulated at 17 bar and used for the supply of the process steam system. The second extraction is regulated at pressures between 6 and 9 bar and used for the supply of water heaters WH3, WH4 and WH5. Steam exits the turbine at a pressure of 2.5 bar and then passes through water heaters WH1 and WH2. The maximum thermal capacity of the extraction is 55 MW_t, that is, 40 t/h of process steam.

A schematic representation of Block A is provided in the figure below.

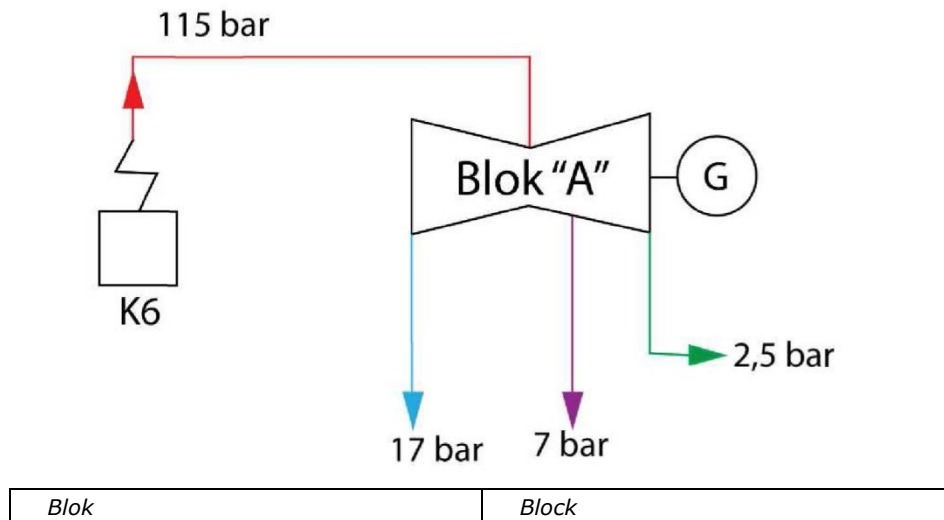


Figure 45: Principal schematic representation of Block A

6.2.1.2. Block B

Block B was constructed in 1979. It consists of two steam boilers (K8 and K9) and a 30 MW_e back-pressure steam turbine with a heating condenser. The steam boilers generate overheated steam (115 bar, 515 °C) through the combustion of heavy fuel oil and natural gas. The back-pressure steam turbine has two extractions. The first extraction is regulated at 17 bar and used for the supply of the process steam system. The second extraction is non-regulated at pressures between 6 and 9 bar. After the second extraction, the steam is reduced to a pressure of 2.5 bar and used in water heaters WH1 and WH2. When it exits the turbine, the steam passes through two heating condensers at a pressure between 0.3 and 9.9 bar. The maximum thermal power of the heating condensers is 55 MW_t (2 x 27.5 MW_t), and the total maximum thermal power of Block B is 90 MW_t, that is, 42 t/h of process steam.

A schematic representation of Block B is provided in the figure below.

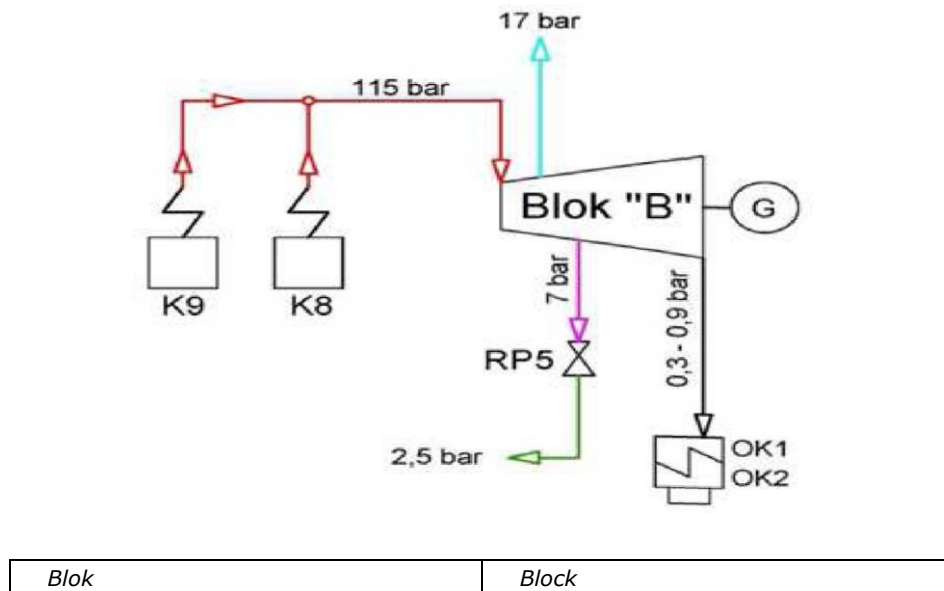
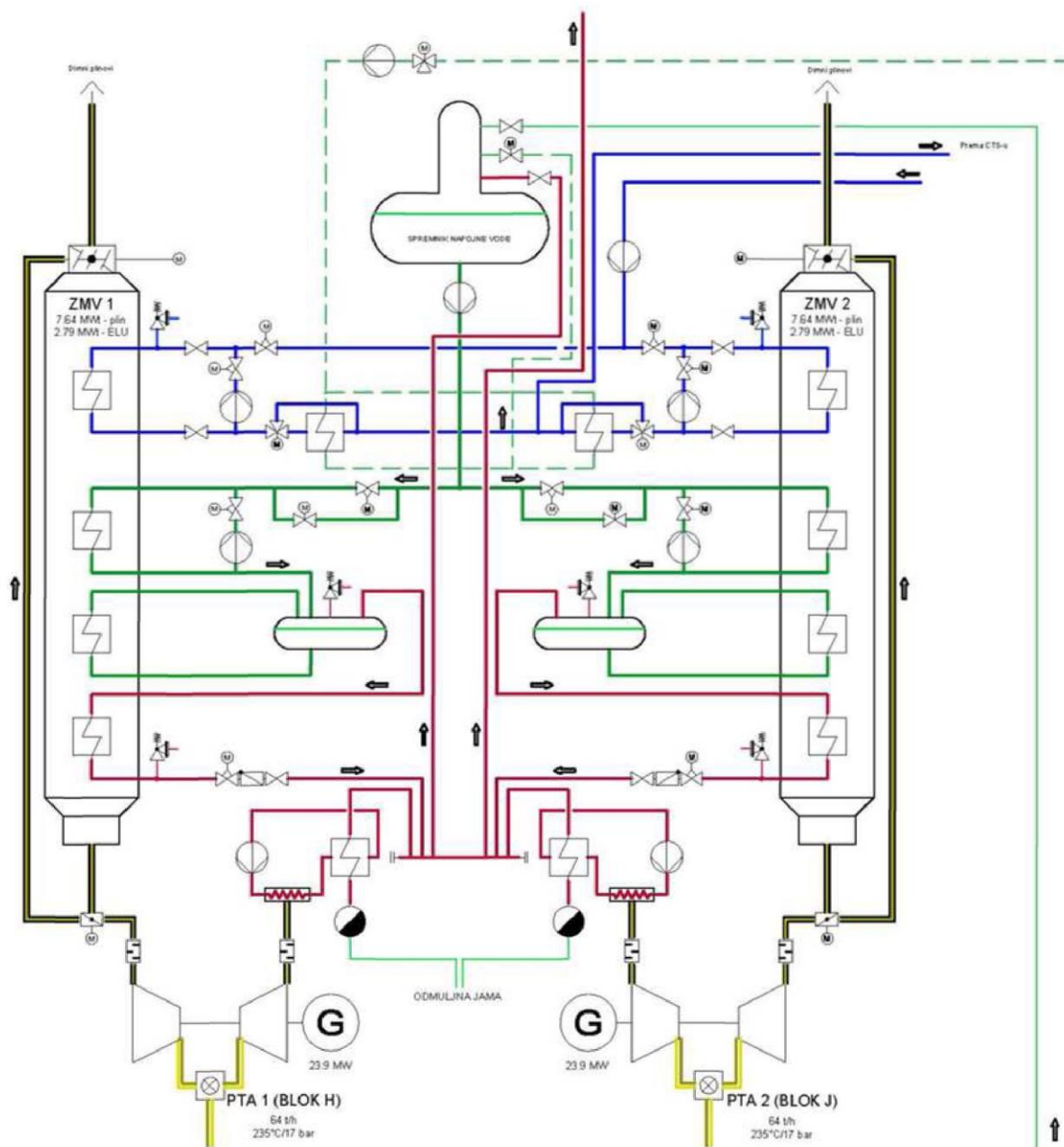


Figure 46: Principal schematic representation of Blok B

6.2.1.3. Blocks H and J

The Zagreb Gas-turbine Power Plant (GPP Zagreb) consists of two identical blocks, H and J. It was constructed in 1998, and its gas turbines were relocated from Dujmovača. A 25.6 MW_e gas turbine is connected to a waste heat boiler, which generates steam at a pressure of 17 bar. Generated steam is used by process steam consumers or the heating station. The waste heat boilers also include 8 MW_t water heaters, which preheat mains water to 77 °C. The maximum steam output of the boiler is 64 t/h. A schematic representation of the GPP Zagreb blocks is provided in the figure below.



<i>spremnik napojne vode</i>	<i>feedwater tank</i>
<i>plin</i>	<i>gas</i>
<i>ELU</i>	<i>ELU</i>
<i>odmuljna jama</i>	<i>blowdown pit</i>
<i>BLOK</i>	<i>BLOCK</i>

Figure 47: Principal schematic representation of blocks H and J

6.2.1.4. Auxiliary units

The auxiliary units of EL-TO Zagreb include two water boilers (WB3 and WB4) with individual power of 116 MWt and an auxiliary steam boiler (K7), which generates steam at a pressure of 17 bar and has a maximum steam output of 80 t/h.

The features of the auxiliary units are presented in the table below.

Table 19: Basic technical data on auxiliary sources at EL-TO Zagreb location

Code	Thermal power	Process steam (10 bar)	Type	Manufacturer	Year of construction
	MW	t/h			
WB3	116.0	–	n/a	TPK, Zagreb	1993
WB4	116.0	–	n/a	TPK, Zagreb	2011
K7	–	80.0	n/a	TPK, Zagreb	1971
TOTAL	232.0	80.0	–	–	–

6.2.1.5. Planned replacement of existing units in EL-TO Zagreb

The cogeneration installations of EL-TO Zagreb are nearing the expiry of their projected service life. The design lifetime of the Block A boiler (K6) has almost expired (only 3 years of operation remaining), whereas the Block A turbine still has 26 000 hours of operation remaining. Given that the turbine has experienced several technical problems during operation (turbine malfunction) and it has been in and out of commission more times than planned, it has approximately 10 000 hours of operation remaining. Furthermore, in accordance with the requirements laid down by Directive 2010/75/EU on industrial emissions, Block A does not comply with new emission limit values for polluting substances. Considering that the lifetime of the block has almost expired, significant investment in its modernisation is not justified. Therefore, it should remain in service as a cold reserve only by 2018, when a new block will be commissioned.

The Block B boilers (K8 and K9) still have approximately 50 000 hours of operation remaining, whereas the steam turbine has about 30 000 hours of operation remaining. At an average rate of 4 000 to 5 000 hours of operation before the new block is commissioned and 2 000 to 3 000 hours of operation after that, Block B could remain in service by 2025, and boilers K8 and K9 even somewhat longer. However, same as Block A, Block B does not comply with the permitted values of emissions into air set out by the IED³. Therefore, in the event that higher emission values are not permitted, Block B will have to be taken out of operation and converted into a cold reserve in 2018, when a new block will be commissioned.

Blocks H and J have somewhat more than 30 000 hours of operation remaining. At an average rate of 5 000 hours of operation before the new block is commissioned and 2 000 hours of operation after that, blocks H and J could remain in service by 2023. However, given that they do not comply with the permitted values of emissions into air set out by the IED either, without an exception for heating plants, those blocks could remain in service only by the end of 2015. In order to keep the blocks in service after 2015 (with an exception for heating plants), their NO_x emission must be reduced to less than 100 mg/m_n³sdp15 %.

Since its lifetime has expired, boiler K7 must be replaced with a new one as soon as possible. K7 should not be put into operation or be kept as a cold reserve after 2018.

Water boiler WB3 has had only 23 000 hours of operation and, at its current average annual utilisation, it could remain in service for about 20 more years. However, given that the boiler is old, it should not be kept in service after 2025. Since its reconstruction, WB3 complies with the values of emissions into air set out by the IED.

Water boiler WB4 is the newest generation unit of the EL-TO plant and it will remain in service after 2030. It complies with the values of emissions into air set out by the IED.

For the above reasons, new high-efficiency combined cycle cogeneration installations⁴ will be constructed in order to replace the existing worn out generation facilities of EL-TO Zagreb.

6.2.2. Zagreb thermal power/heating plant (TE-TO Zagreb)

The Zagreb thermal power/heating plant (abbr. TE-TO Zagreb) was put into operation in 1962, following the construction of two cogeneration blocks (1 and 2) fuelled by coal (lignite from the region of Hrvatsko Zagorje) and, subsequently, liquid fuel (the supply of coal proved to be too complicated). Over time, a continuous increase in thermal energy and process steam consumption resulted in a need for larger capacities. Therefore, a new cogeneration block, (3 – today's Block C) and four water boilers

³ IED – Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast); Official Journal of the European Communities, 27.12. 2010

⁴ Feasibility study for the construction of a new combined cycle cogeneration facility of EL-TO Zagreb

(WB3, WB4, WB5 and WB6 – blocks E, F, G and H) were put into operation in 1979, which ensured a high level of security of thermal energy supply. In 1985, an additional steam boiler, SB3 (Block D), was also put into operation, which brought the supply of process steam to a satisfactory level. Over time, blocks 1 and 2 (renamed blocks A and B) were partially dismantled/reconstructed and converted into a cold reserve. Blocks A and B are no longer in service. They were replaced with modern combined cycle cogeneration blocks K and L in 2001 and 2010 respectively.

The features of the TE-TO Zagreb cogeneration installations are presented in the table below.

Table 20: Basic technical data on blocks C, K and L

Feature	Block C	Block K	Block L
Gas turbine			
Manufacturer		General Electric	General Electric
Type		MS 3001 FA	PG 6111 FA
Compression ratio			15.6:1
Specific heat consumption		10 530 kJ/kWh	10 430 kJ/kWh
Gas-turbine generator			
Manufacturer		General Electric	VaTech
Type		7A6TEWAC	ELIN
Rated output		76.5 MW	97.8 MVA
Rated power factor		0.85	0.8
Steam turbine			
Manufacturer	UTMZ, Russia	ABB	Škoda Power
Type	T-100/120-130-3	2-ok 50.0	–
HP turbine inlet pressure	130 bar	90.8 bar	91.0 bar
LP turbine inlet pressure	–	10.0 bar	11.0 bar
Maximum steam flow	520.0 t/h	217.8 t/h	120.0 t/h
Extraction	35.0, 8.0 and 2.5 bar	10.0 and 2.5 bar	10.0 and 2.5 bar
Steam-turbine generator			
Manufacturer	Končar	Končar	Končar
Type	S 2405-2	S 2146-2	S 1805-2
Rated output	150 MVA	68.5 MW	47.6 MVA
Rated power factor	0.8	0.85	0.85
Waste heat boiler			
Manufacturer		Samsung	Đuro Đaković
Type		–	–
Amount of HP steam		30.2 kg/s	29.5 kg/s
HP steam		94.7 bar	95 bar
Amount of LP steam		3.3 kg/s	6.6 kg/s
LP steam		10.3 bar	11 bar
Steam boiler			
Manufacturer	Krasny-Kotelshchik-Taganrog		
Type	TGME-464-C		
Steam output	520 t/h		
Steam pressure	140 bar		
Steam temperature	560 °C		

6.2.2.1. Block C

Block C is a classic cogeneration unit consisting of a steam boiler (K3), a steam condensing extraction turbine and an electricity generator with a maximum power of 110 MW_e, which is connected to the steam turbine. Steam boiler K3 generates overheated steam through the combustion of heavy fuel oil and natural gas. The steam condensing extraction turbine of Block C includes as many as 7 extractions, three of which (the first, sixth and seventh) are used for the supply of thermal energy and process

steam to final customers, whereas the remaining two extractions (not shown in Figure 5) are used for the supply of steam for the regenerative preheating of the condensate. The first extraction, introduced in the 1990 reconstruction of the turbine, enables the extraction of high-pressure steam (35 bar) for process steam users. The pressure of this steam is extremely high, far exceeding the needs of process steam customers (10 bar). Therefore, the steam is reduced to the required 10 bar immediately after the extraction and conducted to a 10 bar steam tank as such. Such extraction of high-pressure steam is unjustified in terms of energy efficiency because it creates unnecessary additional losses in electricity generation. For that reason, Block C is used for the supply of steam to end users only in special circumstances. The sixth and seventh extractions are used for the supply of (mains) water heaters WH1 and WH2. Total thermal capacity of those exchangers [sic – heaters is probably meant] is 200 MW_t. A schematic representation of Block C is provided in the figure below.

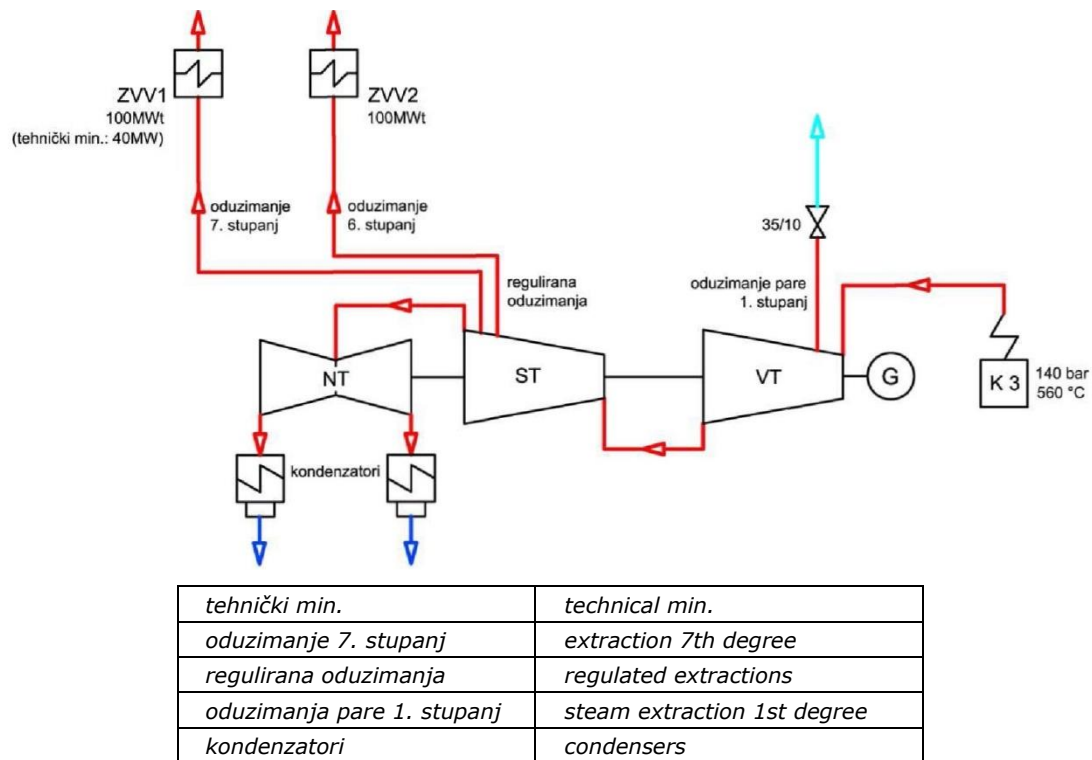
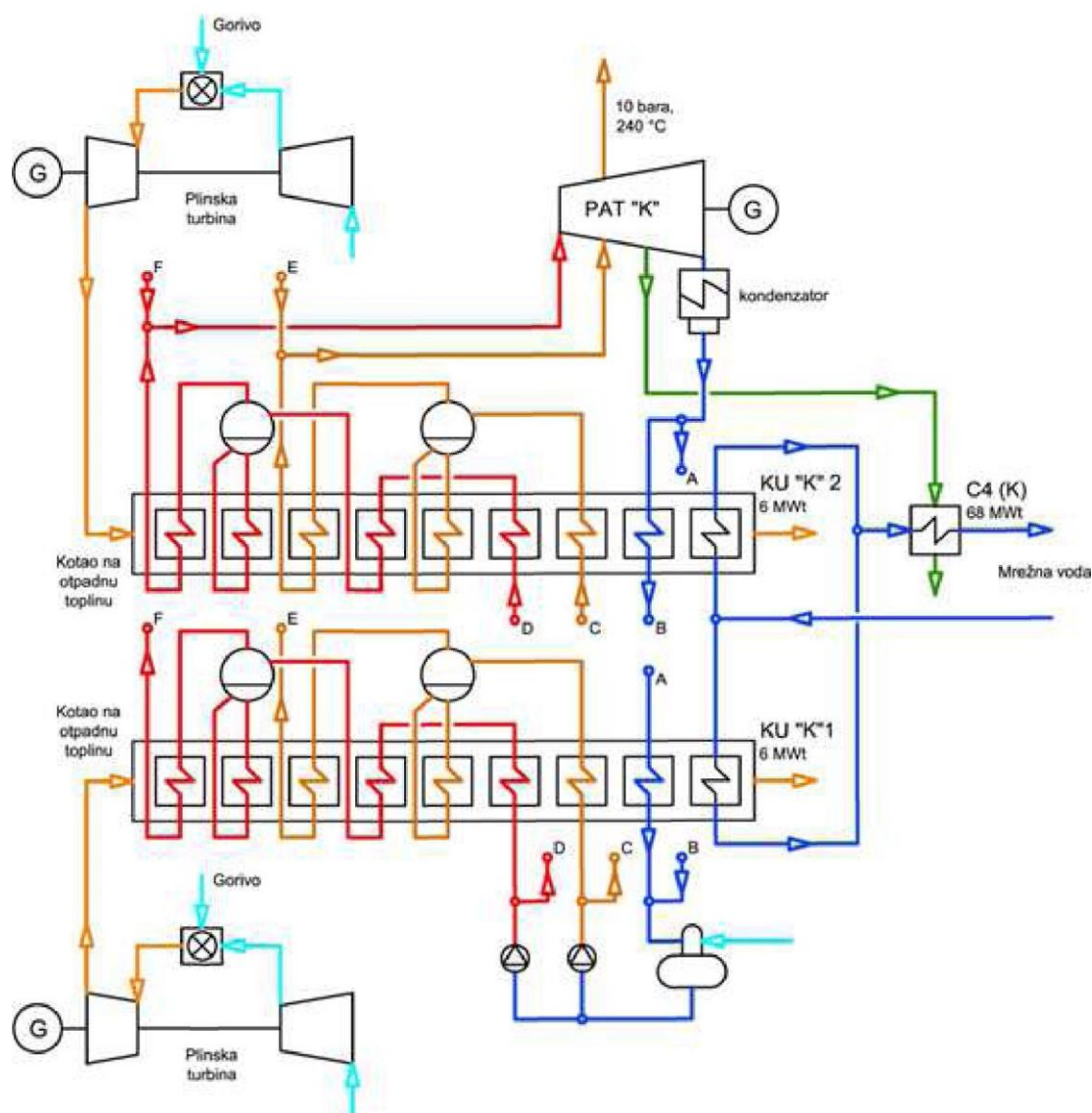


Figure 48: Principal simplified representation of Block C

6.2.2.2. Block K

Block K is a modern combined cycle cogeneration unit consisting of two gas turbines with 2 x 71 MW_e electricity generators, two dual-pressure waste heat boilers and one steam condensing extraction turbine with a generator with a maximum electrical power of 66 MW_e. The steam turbine has two regulated extractions. The regulated extractions are performed at pressures of 10 and 2.5 bar. In that process, higher-pressure steam (130 t/h maximum) is conducted to a 10 bar steam tank, that is, to process (industrial) steam users. Lower-pressure steam is conducted to a 74 MW_t condensing heat exchanger C4(K) and used for the heating of the DHS mains water. Before entering mains water heater C4(K), mains water is preheated in the final exchangers (KU'L'1 and KU'L'2) of the waste heat boilers.

A schematic representation of Block K is provided in the figure below.



<i>Gorivo</i>	<i>Fuel</i>
<i>Plinska turbina</i>	<i>Gas turbine</i>
<i>kondenzator</i>	<i>Condenser</i>
<i>Kotao na otpadnu toplinu</i>	<i>Waste heat boiler</i>
<i>Mrežna voda</i>	<i>Mains water</i>

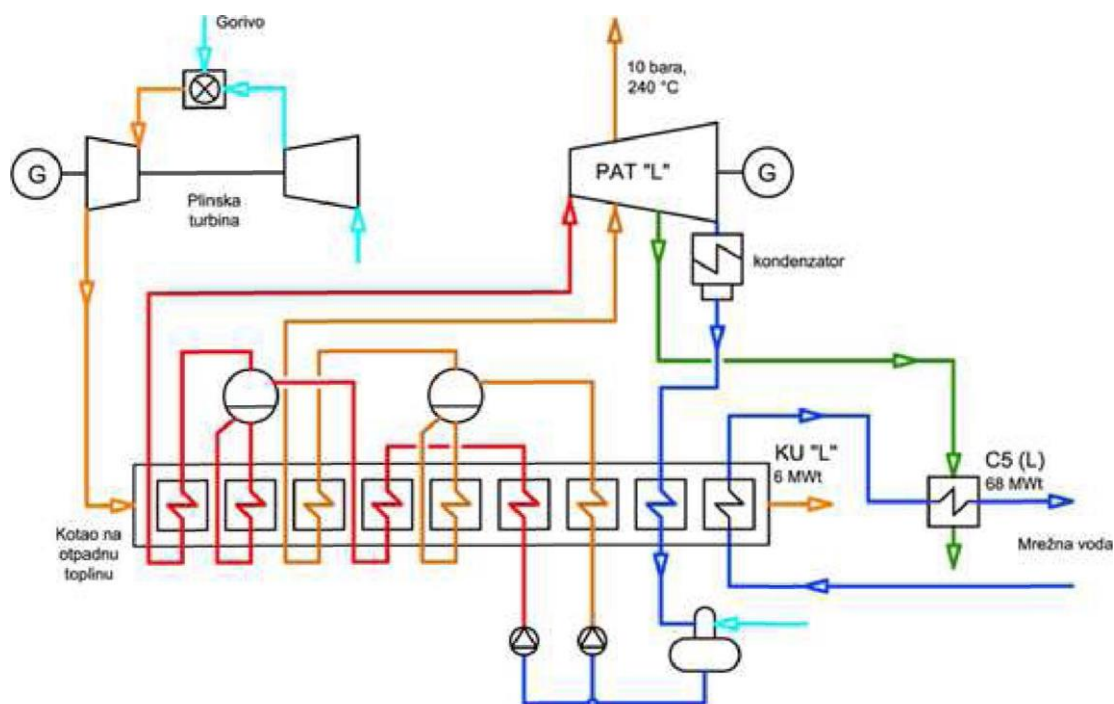
Figure 49: Principal simplified representation of Block K

6.2.2.3. Block L

Block L is a modern combined cycle cogeneration unit consisting of a gas turbine with a 75 MW_e electricity generator, a dual-pressure waste heat boiler and a steam condensing extraction turbine with a generator with a maximum electrical power of 40 MW_e.

The steam turbine has two regulated extractions. The regulated extractions are performed at pressures of 10 and 2.5 bar. In that process, higher-pressure steam (70 t/h maximum) is conducted to a 10 bar steam tank, that is, to the consumers of process (industrial) steam. Lower-pressure steam is conducted to condensing heat exchanger C5(L) with a maximum thermal power of 69 MWt and used for the heating of the DHS mains water. Before entering mains water heater C5(L), mains water is preheated in the final exchanger (KU'L') of the waste heat boiler.

A schematic representation of Block L is provided in the figure below.



<i>Gorivo</i>	<i>Fuel</i>
<i>Plinska turbina</i>	<i>Gas turbine</i>
<i>kondenzator</i>	<i>Condenser</i>
<i>Kotao na otpadnu toplinu</i>	<i>Waste heat boiler</i>
<i>Mrežna voda</i>	<i>Mains water</i>

Figure 50: Principal schematic representation of Block L

6.2.2.4. Auxiliary units

The auxiliary units of TE-TO Zagreb include four water boilers (WB3, WB4, WB5 and WB6 – blocks E, F, G and H) and a steam boiler (SB3 – Block D). Their features are presented in the table below.

Table 21: Basic technical data on blocks D, E, F, G and H

Code	Thermal power	Process steam (10 bar)	Type	Manufacturer	Year of construction
	MW	t/h	–	–	–
WB3 (Block E)	58.0	–	VKLM 50	TPK, Zagreb	1977
WB4 (Block F)	58.0	–	VKLM 50	TPK, Zagreb	1978
WB5 (Block G)	116.0	–	VKLM 100	TPK, Zagreb	1982
WB6 (Block H)	116.0	–	VKLM100	TPK, Zagreb	1990
SB3 (Block D)	–	70.0	–	TPK, Zagreb	1985
TOTAL	348.0	70.0	–	–	–

6.2.2.5. Planned replacement of existing units in TE-TO Zagreb

The future utilisation of the existing units of TE-TO Zagreb largely depends on the regulations governing environmental protection. More specifically, due to the ELV compliance requirement for all thermal energy facilities applicable from 1 January 2018, the existing units require significant investment in order to meet the ELV (emission limit values).

Combined cycle cogeneration installations (blocks K and L) meet the stricter ELV requirements. Under regular maintenance, blocks K and L may remain in service by 2030 and 2040 respectively.

Block C has had only 120 000 hours of operation and could remain in service for about 20 more years until the expiry of its lifetime. However, given that it cannot be reconstructed so as to comply with the

IED provisions, its decommissioning is planned for 2018, when the IED enters into force. Nevertheless, Block C will remain as a cold reserve until its planned decommissioning in 2028.

Low NO_x burners (LNB) can be installed in the existing water boilers to extend their lifetime. Old, worn out boilers WB3 and WB4 will be completely reconstructed in order to extend their lifetime to 2035. Burners in boilers WB5 and WB6 will also be replaced so as to extend their lifetime to 2035. Following their planned reconstruction, all water boilers will meet the ELV requirements.

Although boiler SB3 has had only 60 000 hours of operation and could remain in service, it will be replaced with two new 25 t/h boilers in accordance with the IED provisions on emissions into air.

6.2.3. Osijek thermal power/heating plant (TE-TO Osijek)

The Osijek thermal power/heating plant generates electricity for the Croatian electricity system, as well as thermal energy for the heating of the city of Osijek and supply of process steam for industrial applications. The facilities of the power plant were constructed in two stages: a gas-turbine power plant and a SBK boiler room in 1976, and a 45 MW_e district heating block in 1985.

6.2.3.1. GPP block

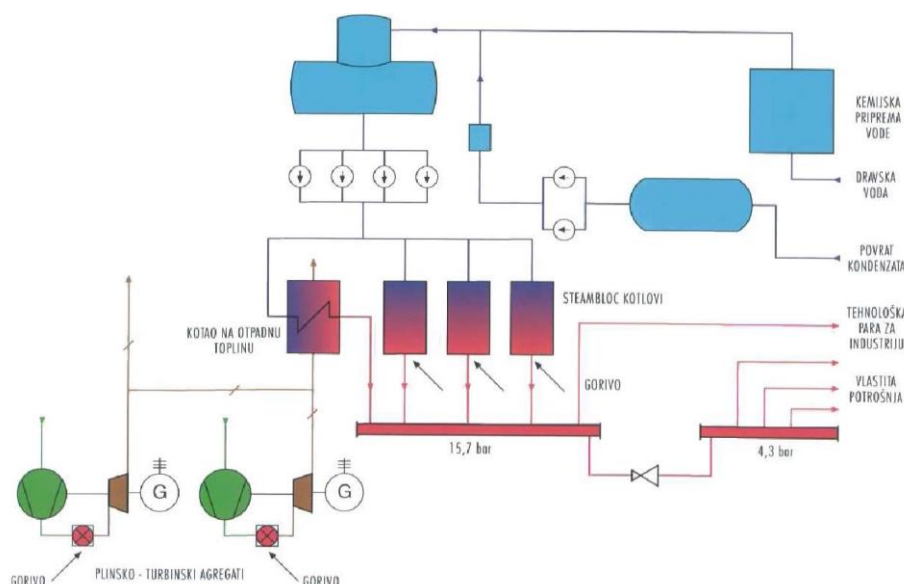
The GPP block consists of two gas-turbine generation units (GTA) that can be fuelled by natural gas and extra light fuel oil. Each generation unit has a rated power of 25 MW_e and consumes 9 500 m³/h of gas or 7 500 kg/h of EL fuel oil. The power generators are normally fuelled by gas, and only in special circumstances by EL fuel oil. It is also possible to combine fuels, as well as to switch from one fuel type to the other while the turbine is in operation. The generation units have the option of black start, island operating mode and compensation operating mode.

A heat recovery boiler, i.e. waste heat boiler (WHB), installed above GTA-1, utilises the output temperature of gas-turbine exhaust gases (approximately 500 °C) and enables steam generation in a combined process. A connection flue canal was subsequently constructed so that the boiler could also operate with GTA-2 (however, GTA-1 cannot be in operation at that time). At a rated turbine load, the boiler generates 56 t/h of steam at a temperature of 250 °C and pressure of 18 bar. That steam is used as process steam for industrial applications (direct delivery with boiler parameters) or as the primary medium for heat generation in a water heater.

At the time of its construction, the GPP block was designed as an auxiliary source [of electricity] that could rapidly reach the network (7 minutes from start to synchronisation, load increase speed of 3 MW/min). Later on, after the Homeland War, due to the condition of the system, the generation units became the basic source of electricity, which they generated in combination with the 45 MW block. The 45 MW block was in operation in the heating season, and the GPP outside of it. Since the establishment of the electricity system in eastern Slavonia in the summer of 2004, the GPP has been used very seldom, for the purpose of satisfying thermal energy needs in transitional periods (autumn, spring), when the operation of the 45 MW block is not economical. Given that Osijek does not have a developed sanitary hot water system and that summer needs for process steam are low, the waste heat boiler would not be utilised in the summer, so the generation of electricity from the GPP would be uneconomical in that period. The GPP block operates 500-1 000 h a year in the manner described.

Own electricity consumption of the GPP block is approximately 1 MW_e.

A schematic representation of the GPP block is provided in the figure below.



KOTAO NA OTPADNU TOPLINU	WASTE HEAT BOILER
GORIVO	FUEL
PLINSKO-TURBINSKI AGREGATI	GAS-TURBINE GENERATION UNITS
STEAMBLOC KOTLOVI	STEAMBLOC BOILERS
KEMIJSKA PRIPREMA VODE	CHEMICAL WATER TREATMENT
DRAVSKA VODA	WATER FROM THE RIVER DRAVA
POVRAT KONDEZATA	CONDENSATE RECOVERY
TEHNOLOŠKA PARA ZA INDUSTRIJU	PROCESS STEAM FOR INDUSTRIAL APPLICATIONS
VLASTITA POTROŠNJA	OWN CONSUMPTION

Figure 51: Principal schematic representation of the GPP block

6.2.3.2. 45 MW block

The 45 MW block is a district heating block with an electrical power of 45 MW_e, primarily used for thermal energy generation (as hot water for city heating and process steam for industrial applications). It also generates electricity in a combined process. It consists of a gas turbine and a generator with a rated power of 45 MW_e. The 45 MW block has the option of island operating mode and own consumption mode. Its load increase speed is 1 MW/min.

The steam condensing extraction turbine has one regulated and three non-regulated extractions. The maximum steam input in the turbine is 250 t/h. The steam from the first turbine extraction is conducted to a 16 bar manifold and used for process steam and own consumption purposes (ejector, burst steam and heavy fuel oil reheaters). The steam from the second extraction is conducted to a 4 bar manifold and used for own consumption (air heaters, heating station vessel, additional heating of heavy fuel oil, chemical water treatment, feed tank of the auxiliary boiler room) and, as needed, for the heating of the water in the 2nd degree water heater. The third extraction is used for the heating of the feedwater and hot water tanks. The only (pressure) regulated extraction is the fourth one, used for the supply of 1st degree water heaters and the preheating of turbine condensate. The amount of steam conducted to the condenser during continuous operation is limited to a minimum of 10 t/h (to protect the exhaust casing from overheating) and a maximum of 110 t/h (condenser cooling option). The turbine may also be in operation when one of these extractions are shut down. In that case, the required steam is substituted through the operation of boiler reductions.

The 45 MW block includes two high-pressure water-tube boilers with natural circulation and overpressure combustion, manufactured by *Wagner Büro* from Austria. Each boiler has a maximum steam output of 125 t/h, and a minimum steam output of 45 t/h. Their design steam parameters are 87.3 bar and 515 °C. Steam from both boilers is conducted to a high-pressure manifold, which supplies the steam turbine and boiler reductions (90/16, 90/4, 90/1.5 bar). Each boiler has 4 burners that can be fuelled by natural gas or heavy fuel oil. Each burner has a maximum fuel consumption of 2 900

m_n^3/h of gas or 2 400 kg/h of heavy fuel. The boilers may be powered by both fuels simultaneously, provided that heavy fuel oil is used at the bottom burner level and natural gas at the top level. The burden ratio between the boilers may range from 50:50 to 60:40. The same applies to boiler levels, and their ratio must always be 60:40 in favour of the bottom level. Fuel type depends on the situation in the gas system – if gas is available, it is consumed in the maximum amounts permitted. If those amounts are not sufficient, the remaining needs are compensated by heavy fuel oil.

A schematic representation of the 45 MW block is provided in the figure below.

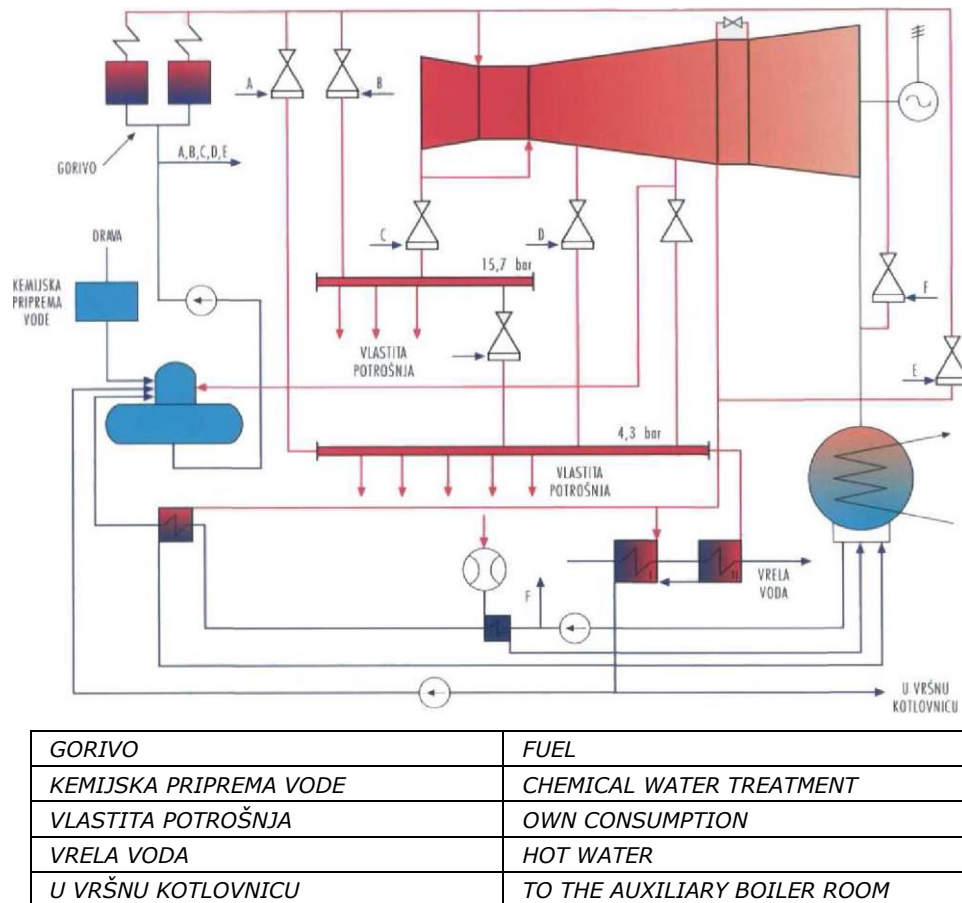


Figure 52: Principal schematic representation of the 45 MW block

The maximum process steam output of the 45 MW block is limited by the turbine extraction capacity to the amount of 70 t/h. The maximum thermal power of generated hot water is equivalent to the sum of the power of all three water heaters ($2 \times 42 + 55 = 139$ MW), but it depends on the availability of steam that powers the heaters. At an average process steam output (30-40 t/h), hot water power ranges from 90 to 100 MW_t. As needed, the power is increased by using the steam from the steamblock boilers (or the waste heat boiler).

The hot water station is composed of three heaters. Two heaters are powered by the steam from the regulated turbine extraction (or, alternatively, by the 90/1.5 bar reduction) and have a maximum capacity of 42 MW_t each. The third heater is powered by the steam from the 4 bar manifold and has a capacity of 55 MW_t. This heater can function during the operation of any steam source in the power plant. The starting water pressure in the hot water pipeline is achieved through the operation of circulation pumps and it amounts to 11 bar, with a water flow of approximately 2 050 m³/h. The hot water pipeline always sustains smaller or larger losses, in an average monthly amount of 3 000 m³.

The operating season of the 45 MW block begins and ends depending on the increased hot water pipeline heating needs. It usually begins in October and ends at the end of April. The duration of the heating season is between 5 000 and 5 500 hours. In that period, the block is in operation for approximately 4 500 hours. The 45 MW block normally does not operate in the summer. However, it can operate in a full condensing mode in order to cover potential needs in the system.

Its own electricity consumption amounts to approximately 3 MW_e.

6.2.3.3. SBK block

Three steamblock boilers (SBK) were also built in the first phase of the construction of TE-TO Osijek construction, primarily for the purpose of process steam generation when the GPP block is out of operation. Each boiler can generate a maximum of 18 t/h of steam at a temperature of 250 °C and pressure of 18 bar, and is fuelled by natural gas (1 500 m³/h maximum) or heavy fuel oil (1 200 kg/h maximum). Same as the steam from the waste heat boiler, the steam from the SBK boilers can be used for process steam applications, as well as for heating purposes. The SBK boilers are used as auxiliary boilers of the 45 MW block and the waste heat boiler in the main heating season and in transitional periods respectively. Outside the heating season, the SBK boilers are in continuous operation for the purpose of process steam generation.

6.2.4. Sisak Thermal Power Plant (TE Sisak)

TE Sisak generates electricity that is delivered to the electricity system, thermal energy for own needs and district heating purposes, as well as process steam for industrial applications.

TE Sisak is located in Sisak's southern industrial zone, on the right bank of the River Sava, in the Čret area. The plant is situated about 4 km south by south-east of the Sisak city centre. TE Sisak covers a surface area of approximately 151 000 m². The thermal power plant is adjacent to the INA Sisak Oil Refinery, whose facilities (including a number of petroleum product tanks) border its area on the west and south side. The area where the plant is located extends east to the River Sava. TE Sisak is a closed technological unit that consists of generation and auxiliary facilities.

6.2.4.1. Blocks A and B

The generation facility is composed of blocks A and B with a total installed capacity of 420 MW_e. Block A has been in operation since 1970, and Block B since 1976. The basic equipment and technological processes of both thermal power plant blocks are almost identical. Each block has two steam boilers (2 x 330 t/h of steam, 540 °C, 135 bar), one steam condensing turbine and one electricity generator. Other technological unit parts of blocks A and B include condensate desalting facilities, block transformers, own consumption transformers, 220 kV direct-current voltage facilities and switchyards.

All four boilers are fuelled by heavy fuel oil and/or natural gas. Heavy fuel oil is supplied by a pipeline directly from the neighbouring refinery or by railway tanks. It is stored in three tanks in the thermal power plant. Natural gas is supplied by a main pipeline.

The overheated steam generated in the boilers is conducted to the steam condensing turbine where thermal energy is converted into the mechanical energy that powers the turbine and the directly connected electricity generator. Generated electricity is conducted from the site through switchyards and power lines.

TE Sisak generates thermal energy for its own needs, as well as for the heating of residential, commercial and other facilities in the Sisak area, from an auxiliary boiler room or directly from the boilers of an operating block. The auxiliary boiler room consists of two steam boilers (2 x 28 t/h of steam), manufactured in 1988. The auxiliary boilers are fuelled by natural gas.

Water from the River Sava is used for cooling and technological purposes in the operation of the facility (as feedwater and supplement to the water/steam cycle), after it undergoes chemical treatment.

Waste water generated in the facility is purified in a waste water and sludge processing facility and then discharged into the River Sava.

6.2.4.2. Block C – under construction

A replacement combined cycle cogeneration block with a rated power of 230 MW_e/50 MW_t (CCPP Sisak – Block C) and a separate exhaust into air are under construction in the Sisak Thermal Power Plant.

CCPP Sisak (Block C) comprises a gas turbine with a generator, an exhaust gas boiler and a steam turbine with a generator. Gross input power of the block is 230.62 MW_e (calculation optimum) and its output power is 228.83 MW_e (calculation optimum). Own consumption of the block ranges between 1.64 and 1.79 MW_e. The degree of fuel utilisation (at the power plant threshold) depends on the load and operating conditions, and its average rate is 51.2 %. (Net) heat consumption depends on the load and operating conditions, and its average amount is 7 030.8-8 032.3 kJ/kWh. Total fuel utilisation depends on the load and operating conditions, and its average rate is 56.5-60.1 %.

Table 22: Basic technical data on Block C under construction

Unit	Capacity	Technical description
Gas-turbine generation unit	Design power: – 154.6 MW (at 100% load) – 112.3 MW (70 % load)	It provides approximately two thirds of the total Block C power. The 50 Hz gas turbine is composed of an air inlet casing, a compressor, two external combustion units, a turbine, an exhaust casing, a diffuser, a bearing assembly and a foundation frame with turbine holders. A combustion system with dry NO _x control and two separate combustion units located on both sides of a vertical casing are to be constructed. – Fuel consumption: 7.89-10.13 kg/s (optimum: 9.88 at 100 % load) – Degree of utilisation: 34.3 % for given electricity The gas-turbine electricity generator is a two-pole, synchronous, three-phase, horizontal, air-cooled generator.
Exhaust gas boiler		The exhaust gas boiler is a dual-pressure boiler with steam overheating, without additional firing. With a gas-turbine power of approximately 146 MW _e , the boiler generates sufficient steam for a 80 MW steam turbine operating in condensing mode (operating mode B). The condenser is cooled by water from the River Sava. The resulting high-temperature flue gases are conducted to a boiler where thermal energy is used for the generation of steam which powers the steam-turbine generation unit. In that process, flue gases are cooled and discharged through a 65 m high chimney. The temperature of flue gases is reduced in a gas condensate preheater, from which the condensate is delivered to a deaerator at a pressure of 6.5 bar. – Inlet flue gas flow: 414.7-519.8 kg/s – Inlet flue gas temperature depends on the load and operating conditions: 537.3-546.9 °C. – Outlet flue gas temperature depends on the load and operating conditions: 88.6-108.3 °C.
Steam-turbine generation unit	ST design power: – 52.75 MW (at 100 % load) – 80.4 MW (70 % load) Boiler power: – 50 MWt – Steam output: up to 65 t/h (pressure between 15.5 and 16.5 bar)	It provides approximately one third of the total Block C power. The steam turbine (K 80/65-7,0), with a power of approximately 80 MW and a rated pressure of 65 bar, is an axial condensing turbine that has two casings and two steam outlets in the high-pressure section, as well as two regulated extractions for district heating purposes. Its electrical power depends on the amount of steam extracted for process applications. Fresh steam from the waste gas boiler is conducted by high-pressure (HP) and low-pressure (LP) pipelines to the corresponding turbine section where it is expanded. Steam distribution valves that control the input of steam in the HP turbine section are located on the inlet casing. A non-regulated extraction outlet (rated pressure of 16 bar) is located behind the HP section. The remaining amount of steam goes through the LP turbine section to the condenser. All steam delivered from the steam generator to the condenser is liquefied through cooling and converted into condensate, which is delivered to the steam generator supply system, where the process is completed. The amount of steam extracted for industrial applications is compensated by adding demineralised water to the condensate tank. The electricity generator of the steam turbine is a two-pole, synchronous, three-phase, horizontal, air-cooled generator.

6.2.5. *Belišće d.o.o. Belišće*

The industrial power plant in Belišće was constructed to satisfy the needs of the former agricultural conglomerate *Belišće d.d.*, with an industrial tradition of more than 130 years. It was established in 1884 as a wood cutting and wood-processing industry and developed into a paper and packaging factory in the 1960s. Given that its ownership structure and production processes have changed over time, nowadays the power plant is used to cover the needs of two facilities – factories of the parent company. One of them produces packaging paper (Paper Factory), and the other produces paper packaging (Packaging Factory). Until recently, said facilities were members of Austrian group *Duropack* based in Vienna. In the spring of 2015, the company was taken over by British corporation *DS Smith* based in London. Due to the change of ownership, the company expects that new directions of its development will be defined, and that could also directly affect its energy needs.

A layout of the Belišće North industrial zone with a marked section owned by *DS Smith* is presented in the following figure.

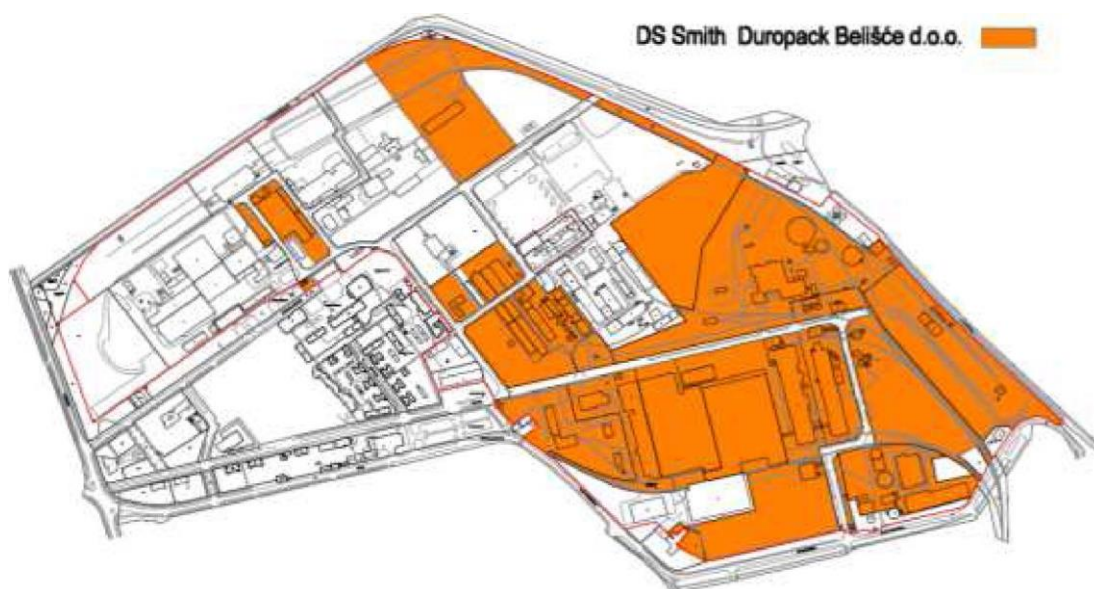


Figure 53: Layout of the Belišće North industrial zone and the location of DS Smith

The Paper Factory includes an organisational unit called Energy, which is engaged primarily in the activities of thermal energy generation, electricity generation, as well as extraction and preparation of cooling, process and feed water. The Energy unit supplies generated energy to other commercial facilities located in the Belišće North industrial zone.

The power facilities of the Energy organisational unit are located in the section owned by *DS Smith*. In addition to the activities of thermal energy and electricity generation, said unit performs the extraction of water from the River Drava for the preparation of process, feed and cooling water. The extraction of water from the River Drava not only secures the supply of process water to the entire Belišće industrial complex, but also the supply of water to a utility company which performs further water treatment and provides potable water to the city of Belišće.

Approximately 98 % of thermal energy generated is used in paper and packaging production processes in the parent company, while the remaining energy is used by other commercial facilities in the industrial zone. Electricity is generated from the Energy unit, but it is also delivered from the electricity network connected to the complex by a power line with a connection voltage level of 110 kV. Paper and packaging production processes account for approximately 90 % of total electricity consumption. It should be noted that the entire complex is supplied with electricity exclusively through the Energy organisational unit, that is, only through electricity generation and/or a power line connected to the transmission network of the electricity system, in the following operating modes of the power plant:

- Operation of the steam cogeneration facility with an additional delivery of the required amount of electricity from the electricity network (parallel operation);
- Operation of low-pressure steam boilers for process steam generation, with 100 % of required electricity delivered from the electricity network (since 2013, it is the preferred operating mode in summer and transitional periods because of lower costs);
- So-called 'island operating mode', without having electricity delivered from the electricity network (in the event of overhaul or power line malfunction).

The facility does not have the status of an eligible producer of electricity from cogeneration. As stated by the person responsible, the company is interested in obtaining that status, provided that it contributes to the improvement of economic feasibility of the entire facility.

The Energy unit uses a mixture of natural gas and petroleum or associated gas⁵ as the energy source for the generation of thermal energy and electricity. Petroleum gas is delivered by a special gas pipeline (22 km) from the INA Beničanci production field, which is more favourable in commercial terms. Its secured annual capacities amount to approximately 15 000 000 Sm³. The other energy source, natural gas, is delivered by a new high-pressure gas pipeline, which was constructed in 2007 with the Bistrinci gas station that supplies gas to the Baranja region. The natural gas pipeline has a nominal diameter DN 400, and a rated pressure of 50 bar. At that site, pressure is reduced to 2.2 bar, as required for the operation of gas boilers. The Energy unit also contains two heavy fuel oil tanks with

⁵ Petroleum gas (associated-dissolved gas) is natural gas dissolved in petroleum in reservoir conditions or contained in a gas cap above petrol in a reservoir.

a capacity of 6 000 m³, which are not in service (empty). Currently, there are no plans for their further utilisation or the use of heavy fuel oil as fuel.

The generation of thermal energy and process steam is ensured by two technical systems – the cogeneration system and low-pressure gas boilers (K5 and K6).

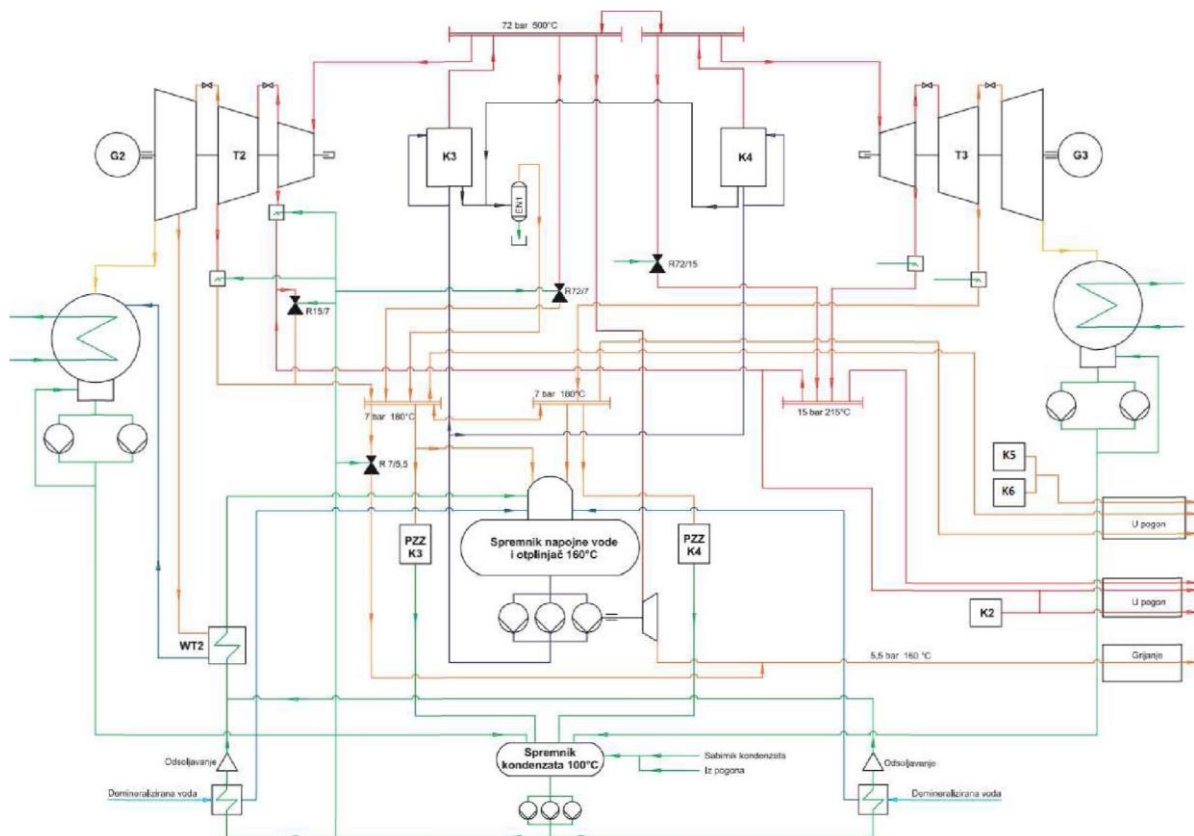
6.2.5.1. Cogeneration facility

The cogeneration facility includes two steam generators, K3 and K4, manufactured by *Babcock*. Boiler K3 was made in 1975, and boiler K4 in 1984. Both have been revitalised a number of times, and their control and management systems have been modernised. Both boilers have the same features. Their rated thermal capacity is 94 MWt each. They generate steam at a temperature of 500 °C, pressure of 72 bar and mass flow of 110 t/h. In 2010, the pressure system and thermal insulation of boiler K3 were renewed, and a new control and management system was installed in the boiler unit. Boiler K4 was revitalised in the same way in 2009.

Generated steam is conducted to a common tank, from which it is distributed to steam turbines. The main advantage of the common tank, which is located between steam generators K3 and K4 and turbines T2 and T3, is that it enables either steam generator to operate with either turbine. From the aspect of secure operation and availability of the facility, that is an efficient technical solution.

The facility has three steam turbines – T1, T2 and T3. T1 is a back-pressure turbine manufactured by *Jugoturbina*. It has been decommissioned, that is, taken out of service and is not expected to be put back into operation. The other turbine, T2, with a rated power of 15 MW_e, was manufactured by Siemens and put into operation in 1980. It is a condensing turbine with two regulated extractions, the first one at 15 bar and the second at 7 bar, as well as one non-regulated extraction. Turbine T2 was last overhauled in 2012. Mechanical energy generated by the T2 turbine is delivered to the G2 electricity generator, which was manufactured by Siemens in 1975, has a rated power of 16 MW_e, and was also last overhauled in 2012. The voltage level of the electricity generated by G2 is 6.3 kV. The third turbine, T3, was manufactured by *Jugoturbina* and put into operation in 1984. This is also a condensing turbine with two regulated steam extractions at pressure levels of 15 and 7 bar. Turbine T3 was last overhauled in 2007. As stated by the person responsible, turbine T3 is currently out of service and needs to be overhauled in order to be put back into operation. Turbine T3 is connected to generator G3, which was manufactured by *Rade Končar* in 1984. Generator G3 has a rated power of 15 MW_e and a voltage level of 6.3 kV.

A schematic representation of the generation facility is provided in the figure below.



<i>Spremnik napojne vode i otplinjač 160°C</i>	<i>Feedwater tank and deaerator 160 °C</i>
<i>Spremnik kondenzata 100°C</i>	<i>Condensate tank 100 ° C</i>
<i>Odsoljavanje</i>	<i>Desalting</i>
<i>Demineralizirana voda</i>	<i>Demineralised water</i>
<i>Sabirnik kondenzata</i>	<i>Condensate collector</i>
<i>Iz pogona</i>	<i>From the facility</i>
<i>U pogon</i>	<i>To the facility</i>

Figure 54: Schematic representation of the industrial cogeneration facility in Belišće

When all technological processes are in regular operation, the cogeneration facility meets all thermal needs for process steam and approximately 30 % of electricity needs. The remaining share of electricity is delivered from the electricity transmission network.

6.2.5.2. Process steam generation facility

In addition to the aforementioned and analysed cogeneration facility, two low-pressure steam generators, K5 and K6, which were installed and put into operation in June 2013, are also used by the Energy organisational unit for the purpose of process steam generation. The steam generators are the Universal UL-S type manufactured by *Bosch*. Each of them has a rated thermal capacity of 15.25 MWt and a saturated steam output of 22.5 t/h at a temperature of 158 °C and a pressure of 6 bar. The boilers have two economiser levels and a rated declared efficiency of 98 %. They are also fuelled by a mixture of natural and petroleum gas. Based on the owner's business strategy and utilised paper production capacities, as well as lower costs of energy generation, the steam generators analysed are in operation for most of the year (8-9 months). Due to the current ratio of gas and electricity prices and the efficiency of the cogeneration facility, it is more cost-effective to generate process steam using low-pressure steam generators and have electricity delivered from the electricity network, than to generate process steam and electricity using the cogeneration facility.

6.2.5.3. Power plant

The entire complex of the former agricultural conglomerate *Belišće d.d.*, which has been converted into an economic zone with a number of companies, is supplied with electricity from a cogeneration facility and a connection to the electricity transmission network. When the cogeneration facility is not in operation, all electricity is delivered from the electricity transmission network at a voltage level of 110 kV. Electricity is transmitted by a 6.1 km long high-voltage power line from the Valpovo transformer station built in 1984 to the high-voltage transformer station of 110/6.3 kV built in 1984 by the *Končar-Siemens Concern* in the Energy unit power plant. Its voltage level of 6.3 kV is maintained by two 110/6.3 kV transformers with a rated power of 20 MVA per unit. The low-voltage level of electricity is ensured by medium-voltage substations of 6.3/0.4 kV. Almost 50 such units are installed across the entire complex.

6.2.5.4. Water management

As previously mentioned, the Energy organisational unit extracts water from the River Drava for a number of purposes. The well at the water extraction point on the River Drava contains five vertical pumps for the extraction of raw water from the river. After undergoing a sedimentation-flocculation treatment, process water is distributed to consumers through horizontal pumps (3 installed) – for process applications in the production of paper and packaging, as well as for the preparation of feedwater. Process water is also used as input water (raw material) for the preparation of potable water. As such, it is delivered to a utility company which performs further water treatment and supplies potable water to Belišće. Raw river water, treated only in a process of mechanical filtration, is used for the cooling of the turbo generation unit, that is, for the condensation process taking place in the condenser.

Process steam used in the production of paper and packaging has a high degree of recovery in the form of condensate. About 80 % of condensate returns to the feed tank (recovered condensate). The responsible person of the facility estimates the temperature of recovered condensate at approximately 90 °C.

6.2.5.5. Potential for further development

Two production lines (PM2 and PM3) with a total capacity of 190 000 tonnes of paper per year were installed for paper and packaging production purposes. The production capacity of production lines PM2 and PM3 amounts to 120 000 and 70 000 tonnes of paper per year respectively. Production line PM3 has been out of service since April 2014. Considering the current situation, the cogeneration facility is overly large, while low-pressure steam generators can cover energy needs only in the warmer and transitional period of the year.

From the standpoint of the owner of the facility, current trends in electricity and gas market prices do not justify the use of the cogeneration facility over a longer period of the year. The cogeneration facility is in operation in the winter period (3 to 4 months a year), when thermal energy needs are increased. For the rest of the year, process steam is generated by low-pressure steam generators, and electricity is delivered from the electricity network.

During consultations, the persons responsible have presented a number of options concerning future business development plans. All of them include the plan to maintain the existing level of production. The first option concerns an increase in the capacity of production line PM2, while the second one involves the return of production line PM3 into operation, as well as its reconstruction and an increase in its production capacity. The last option combines the two previous solutions and involves the largest increase in production activities and, consequently, an increase in energy needs. In conclusion, based on the current information and potential strategic plans of the owner, the annual production of paper is expected to increase from 190 000 tonnes in 2016 to 230 000 tonnes in 2017.

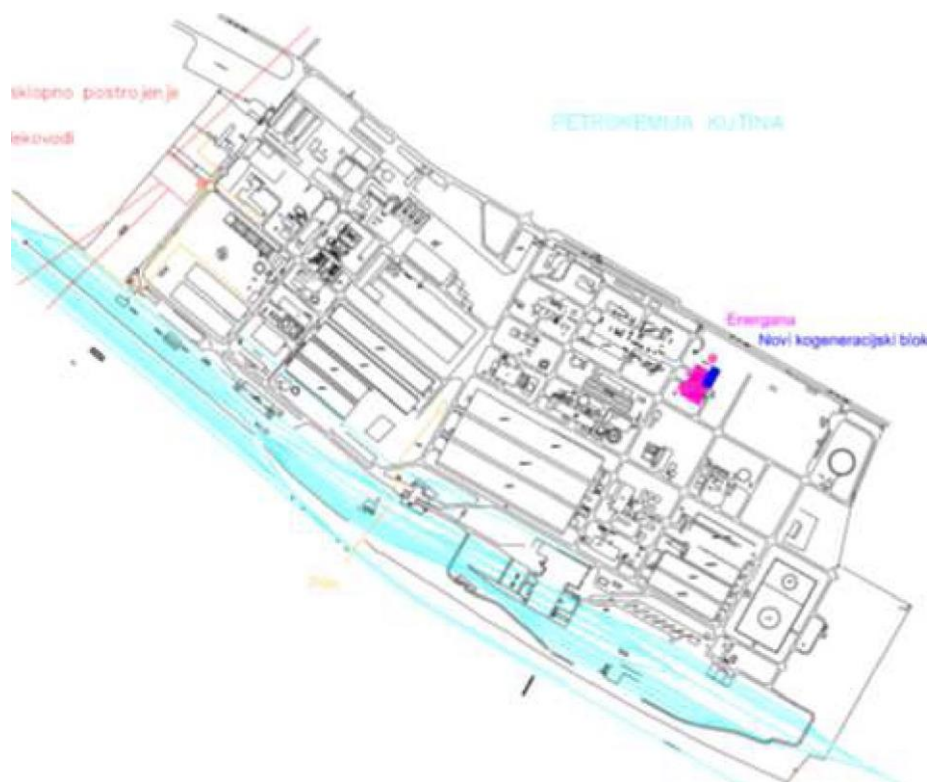
In view of the potential increase in production capacities, the cogeneration facility will probably have to be in operation in order to meet the energy needs (primarily thermal energy) in production processes.

It should be pointed out that additional infrastructure is available in case that there is a significant increase in production and, consequently, in energy needs. That includes the existing gas pipeline for the supply of natural gas and the existing 110 kV power line for the supply of electricity, as well as the installed capacities for the extraction of water from the River Drava and treatment of water. In this regard, it is possible to plan the construction of additional capacities not only for the production of paper, but also for high-efficiency cogeneration.

6.2.6. *Petrokemija d.d. Kutina*

The industrial power plant of the *Petrokemija d.d.* company in Kutina is used for the generation of process steam, thermal energy and electricity. The energy generated is primarily used for own needs. *Petrokemija d.d.* Kutina has a nearly 50-year-long tradition in the production of mineral fertilisers and chemical products. The main products include the following: ammonia, urea, nitric acid, KAN, sulphuric acid, phosphoric acid, NPK fertiliser, ammonium sulphate, ammonium nitrate. The company is predominantly state-owned.

The layout of *Petrokemija d.d.* is shown in the following figure.



<i>Rasklopno postrojenje</i>	<i>Switchyard facility</i>
<i>Dalekovodi</i>	<i>Power lines</i>
<i>Energana</i>	<i>Power plant</i>
<i>Novi kogeneracijski blok</i>	<i>New cogeneration block</i>

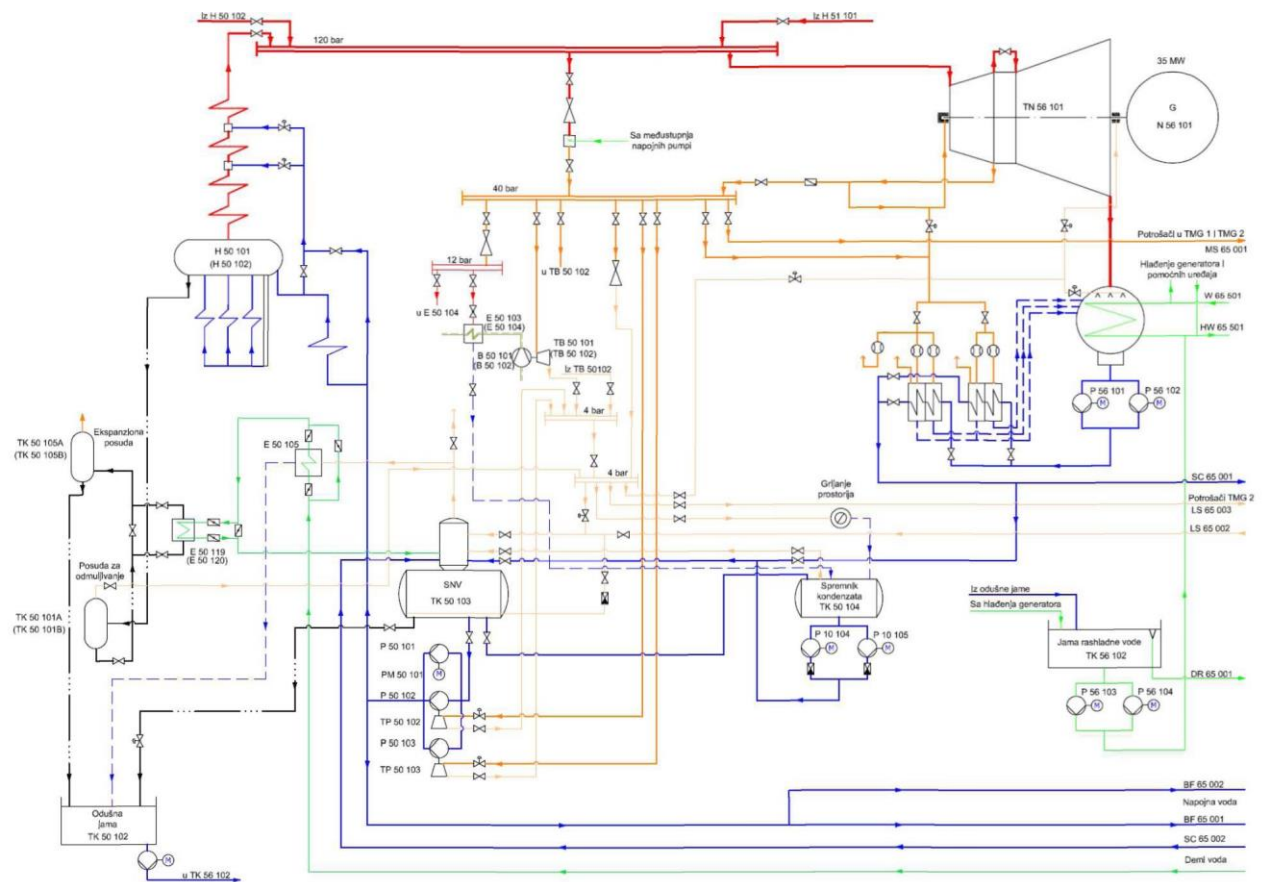
Figure 55: Layout of Petrokemija d.d.

The power plant was established in order to ensure the reliable and continuous operation of the entire company through the supply of the energy required. The power plant primarily generates thermal energy, as well as process steam, which is mostly used as raw material for other final products of *Petrokemija d.d.* It also generates electricity, which is used exclusively at the production site, that is, in the facility. The basic function of the power plant is the generation of 122 bar water vapour, as well as 40 bar and 4 bar process steam. During overhaul, 12 bar process steam is generated in the auxiliary boiler room. In respect of electricity, the entire facility can operate in island mode. However, in view of the price ratio of electricity and energy sources for plant operation (natural gas), as well as total capacity of the cogeneration facility, priority is given to the generation of larger amounts of thermal energy over electricity, as well as to the delivery of the remaining electricity required from the electricity system. Such technological process is ensured by minimising the level of condensation in the steam turbine. In respect of the delivery of electricity from the electricity network, *Petrokemija d.d.* is required to conclude monthly power lease agreements. The amount of leased power is between 5 and 8 MW_e. In order to prevent the consumption of electricity that exceeds the agreed amount, the level of condensation in the steam turbine is increased so as to generate additional amounts of electricity in a given time period. A similar practice is observed in the procurement of natural gas, which is used as a cogeneration fuel, as well as raw material in production processes of *Petrokemija d.d.*

6.2.6.1. Cogeneration facility

The power plant facility, which generates thermal power and electricity used in production processes of *Petrokemija d.d.*, comprises three steam generators (K1, K2 and K3) and one steam turbine. Steam generators K1 and K2 are located in a common boiler room, right next to the main turbine engine room and the main power plant building. Steam generator K3 is located outdoors, approximately 1 000 m from the power plant as the crow flies. It is structurally designed to be fuelled by waste gas from a new carbon black factory the construction of which was cancelled. Therefore, steam generator K3 can use combined natural gas and medium fuel oil (MFO). Gas burner capacity is not designed for the rated steam output, so the rated steam output can be achieved only through MFO or combined fuel

consumption. The steam from generator K3 is conducted by a 1 500 m long outdoor steam line to a 122 bar manifold in the power plant.



<i>Ekspanziona posuda</i>	<i>Expansion vessel</i>
<i>Posuda za odmuljivanje</i>	<i>Blowdown vessel</i>
<i>Odušna jama</i>	<i>Vent pit</i>
<i>Sa međustupnja napojnih pumpi</i>	<i>From feed pumps intermediate stage</i>
<i>Grijanje prostorija</i>	<i>Room heating</i>
<i>Spremnik kondenzata</i>	<i>Condensate tank</i>
<i>Potrošači u TMG 1 / TMG 2</i>	<i>Consumers in MFF 1 / MFF 2</i>
<i>Hlađenje generatora i pomoćnih uređaja</i>	<i>Generator and auxiliary device cooling</i>
<i>Sa hlađenja generatora</i>	<i>From generator cooling</i>
<i>Jama rashladne vode</i>	<i>Cooling water pit</i>
<i>Napojna voda</i>	<i>Feedwater pit</i>
<i>Demi voda</i>	<i>Demi water</i>

Figure 56: Schematic representation of the Petrokemija d.d. power plant

Steam generators K1 and K2 have the same technical features. Both are vertical tube steam generators with a drum and natural circulation, manufactured by *Wagner Büro* in 1981. Each generator has a rated thermal capacity of 115 MW_t and a minimum load of 33.5 MW_t. The overheated steam is generated at a temperature of 540 °C and a pressure of 122 bar. The declared degree of utilisation of both steam generators is 92 %. The differences between the technical features of steam generators K1 and K2 compared to steam generator K3 are almost negligible. Generator K3 was manufactured by *De Schelde*. The overpressure in the combustion chamber is between 17 and 30 mbar (overpressure combustion). The main air ventilators of steam generators K1 (B 50 101) and K2 (B 50 102) are driven by steam turbines TB 50 101 and TB 50 102, whereas the reserve ventilators are powered by an electric motor. The air ventilator of the K3 steam generator is driven by an electric motor. Steam generators K1 and K2 have steam air heaters (SEH) E 50 103 and E 50 104 that are regularly used

during the combustion of heavy fuel oil or natural gas when the input air temperature is too low. Air is preheated to a temperature of 120 °C.

The steam turbine (TN56 101) was manufactured by *Jugoturbina* in 1981, and it has a rated power of 35 MW_e and a maximum steam flow of 250 t/h. It is a condensing (impulse) turbine with a regulated extraction at 42 bar. According to the person responsible, the turbine was converted into a back-pressure turbine in a simple procedure of turbine type change. The sub-pressure in the steam turbine condenser of the power plant is maintained by steam-driven ejectors. The cooling water for the steam turbine condenser comes from 10 cooling towers with forced air circulation in the Water Preparation, Treatment and Distribution Facility. The mechanical energy generated by the steam turbine is delivered to an electricity generator (N65101) manufactured by *Rade Končar* in 1981. The maximum electrical power of the electricity generator is 40 000 kVA at a voltage level of 10.5 kV.

The feedwater tank with a deaerator (FWT, TK 50 103) and three feedwater pumps are used for all three steam generators. The main feedwater pumps P 50 102 and P 50 103 are driven by back-pressure steam turbines TP 50 102 and TP 50 103. After it passes through the feed pumps, feedwater is divided and an amount of it is used in generation facilities to regulate the temperature of 12 bar steam in the instrument and service air facility (auxiliary energy facilities and installations – AEFI) and 4 bar steam in the phosphoric acid production facility. The remaining amount of feedwater is delivered to steam generators K1, K2 and K3. A share of that feedwater is used to regulate the temperature of fresh steam (122 bar/540 °C) by injection, and the rest of it is heated in a feedwater heater of the steam generators before entering the drum.

The steam (122 bar/540 °C) produced by the steam generators is distributed to generation facilities at three energy levels: 40 bar/410 °C, 12 bar/190 °C, 4 bar/150 °C. A share of the steam at the pressure of 122 bar and temperature of 540 °C is conducted through a steam manifold to the steam turbine TN 56 101. In addition to that, the steam from the 122 bar manifold can be directly delivered to consumers through three reduction-cooling stations (RCS 122/40, RS 40/12 i RS 40/4).

The steam from the regulated steam turbine extraction and reduction-cooling station RRS 122/40 is delivered to a 40 bar steam manifold and, from there, to the consumers. A share of 40 bar steam is used in the power plant to power the back-pressure steam turbines which drive the feedwater pumps and air ventilators, as well as steam soot exhausts (when heavy fuel oil is used as boiler fuel).

A share of 40 bar steam is reduced in the RS 40/12 reduction station and conducted to a 12 bar manifold. 12 bar steam generated in the power plant is used by the air heaters of steam generators K1 and K2, as well as for fuel oil dispersion. Other consumers receive 12 bar steam mainly from a 40/12 bar back-pressure turbine that powers the compressor and the RCS 40/12 reduction-cooling station located in the AEFI sector. The same sector includes a reduction station, RS 12/4 bar. If there is a lack of 4 bar steam in the system, except from the power plant, the steam can be compensated from the so-called Sector 52. A share of 40 bar steam is reduced in the RS 40/4 bar reduction station and conducted to a 4 bar steam manifold. The exhaust steam from the back-pressure steam turbines that power the feedwater pumps and air ventilators is also conducted to the 4 bar steam manifold. 4 bar steam is used for the heating of the feedwater tank and power plant premises. The remaining share of steam is distributed to the facilities to supplement the 4 bar steam system as needed.

The thermal power from steam generation depends on the period of the year (summer – winter) and the production capacity of generation facilities. The maximum steam output in the winter is about 270 t/h (several days a year), while the average steam output in the summer amounts to approximately 220 t/h. The strategy governing the thermal energy generation process is that all steam generators generate the same amount of steam and equally cover the needs for it. As a rule, the load is always shared between all three steam generators for security reasons. The average steam generator load is between 70 and 80 t/h. During the overhaul of the facility, the energy facility, as well as steam generators K1, K2 and K3, are also overhauled. At that time, thermal energy needs are covered by an auxiliary boiler room. During the overhaul, the maximum steam output of the auxiliary boiler room is approximately 24 t/h of 12 bar steam.

6.2.6.2. Water management

Two water reservoirs were constructed for the supply of process steam, which can also be considered as raw material. The first reservoir was constructed to cover the needs of the facility built in the first phase (1968). The reservoir is supplied with water from the River Ilova. Six cooling towers with forced air circulation were constructed for cooling purposes. The cooling water temperature is maintained between 20 and 23 °C. A reservoir supplied with water from the River Pakra was constructed to meet the needs of the facility built in the second phase (1984). The reservoir is located 8 km from the facility where 10 cooling towers, also with forced air ventilation, were built in the same phase of construction (Figure 14). The rated capacity of the tower is 459.6 MW_t. The cooling towers cool the water from

44 °C to 24-28 °C. As previously mentioned, a large share of generated steam is not returned to the steam generators, but is used as raw material. The steam that returns to the generators is just the condensate recovered from the steam turbine and steam used in the production of ammonia and ammonium sulphate. The *Petrokemija d.d.* facility has secure capacities for process water preparation, as well as the option to deliver water for the communal needs of the city of Kutina. The organisational unit of *Petrokemija d.d.* responsible for water management is the Water Preparation, Treatment and Distribution Facility.



Figure 57: Phase 2 cooling towers

6.2.6.3. Potential for further development

Petrokemija d.d. is faced with strong market competition, and the person responsible has stated that no significant increase of production is expected. The ammonia production line will be revitalised in the near future, which should lead to a significant decrease in process steam consumption and, consequently, to a decrease in thermal energy needs. The option of increasing the cogeneration capacity was considered on several occasions, but that idea has been rejected. It should be pointed out that the facility is nearing the expiry of its lifetime and that, in order to ensure a secure supply of thermal energy and electricity to the entire *Petrokemija d.d.* facility, it will be necessary to revitalise the existing or construct a new, modern, energy transformation facility. The person responsible has added that, in its current condition, the facility does not meet the criteria for obtaining eligible energy producer status because of its inability to demonstrate high-efficiency cogeneration.

The capacity of a new thermal energy generation facility will definitely be lower than the capacity of the current one because certain facilities have been shut down since its construction. In addition to that, as previously mentioned, the planned reconstruction of the ammonia production facility will provide a certain amount of 40 bar steam that will be delivered to the technological system. It is estimated that a new facility would generate 40 bar steam in a capacity between 100 and 150 t/h. That would probably increase electricity consumption from the current average of 15 MWh. It is also safe to assume that a new cogeneration facility would generate more electricity, which would then be delivered to the electricity network.

Nevertheless, it should be pointed out that *Petrokemija d.d.* has all the prerequisites for an increase in thermal energy and electricity generation. That primarily concerns the existing power lines for the exchange of electricity with the electricity system and the gas pipeline constructed for the supply of larger amounts of gas that power the cogeneration facility. The *Petrokemija d.d.* facility includes a gas station which is connected by a gas pipeline with a nominal diameter NO 18" to a 50/15 bar gas reduction and metering station (GRMS) located adjacent to the main gas pipeline. The length of the gas pipeline is approximately 2 880 m. The design pressure in the gas pipeline is not declared, however, based on the gas pipeline features, it is estimated to be between 40 and 50 bar. The capacity of the gas pipeline is also unknown, however, based on its diameter and predicted pressure drop, it is estimated to exceed 100 000 m³/h (estimate data provided by *Petrokemija d.d.*). The gas station inlet pressure is 14.9 bar. The stated gas pipeline features and the previously analysed connection to the electricity system through power lines are the key prerequisites for considering the option of increasing cogeneration capacities. However, as previously mentioned, no such option will be pursued in *Petrokemija d.d.* in the near future.

6.2.7. INA Rijeka Oil Refinery

The Rijeka Oil Refinery is located in Urinj, 12 km south of the city of Rijeka, covering a 3.5 km² coastal area of Kostrena and Bakar. In order to enable the regular functioning of the Rijeka Oil Refinery, road, railway, maritime and pipeline infrastructure has been constructed for the purpose of supply and distribution of goods, crude oil and petroleum products. The Rijeka Oil Refinery is also connected to the port and petroleum terminal in Omišalj on the island of Krk through a 7.2 km long underwater oil pipeline. The primary products of the Oil Refinery's everyday operation include liquefied petroleum gas, primary petrol, coal oil, jet fuel, diesel fuels, fuel oil, marine fuels and liquid sulphur.

The safety and reliability in the operation, as well as product quality of the Oil Refinery are guaranteed by various INA, Croatian and European standards such as the international standard ISO 9001:2008 – Quality management systems, ISO 14001:2004 – Environmental management systems and OHSAS 18001:2007 – Occupational health and safety management systems.

An investment cycle in the Rijeka Oil Refinery was completed in 2011, and three process facilities in the hydrocracking complex were put into operation (mild hydrocracking, hydrogen production and sulphur extraction), along with numerous auxiliary facilities and installations. A natural gas pressure reduction station was installed and put into operation in the same year, enabling the use of natural gas as an energy source.

A power plant was installed to facilitate the operation of the described production facilities, that is, the regular functioning of all parts of the Oil Refinery. The power plant is a vital unit of the Oil Refinery. All other facilities of the Oil Refinery depend on the operation of the power plant, given that it produces special energy sources which power the machinery in the facilities.

The power plant is located on the coast, as shown in Figure 15, on the bottom platform of the Oil Refinery. One of the reasons for its location in the Oil Refinery is the ease of access to sea water, which is required as a coolant in the turbo generator condenser. The potential cooling capacity of the turbo generator condenser affects the operation of turbo generators and, consequently, the operation of all other facilities of the Oil Refinery.

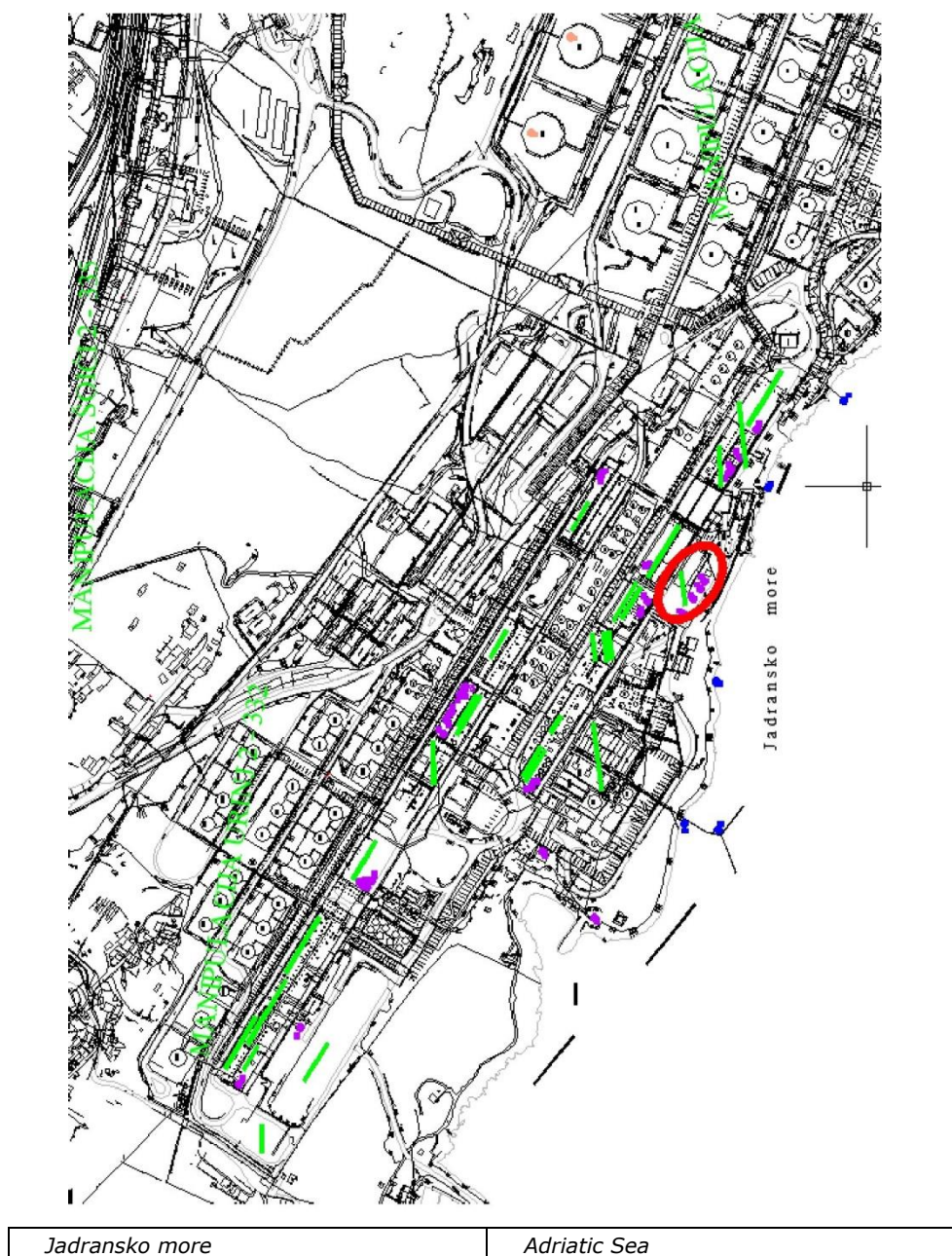


Figure 58: Location of the power plant in the Rijeka Oil Refinery

The main products of the power plant supplied to the Oil Refinery include water vapour, electricity, as well as process and instrument air. On the basis of those functions, the power plant is divided into the following facilities:

- Boiler facility;
- Turbo generator facility;
- Compressor station;
- Sea water pump system.

6.2.7.1. Cogeneration facility

The cogeneration facility of the power plant is used for the generation of electricity and thermal energy. One share of thermal energy generated powers the steam turbines, and the other is used as raw material or driving energy in other parts of the Oil Refinery. The steam turbines utilise the enthalpy potential of steam at a temperature of 420 °C and a turbine inlet pressure of 35 bar. A schematic representation of the Rijeka Oil Refinery cogeneration facility is provided in the figure below.

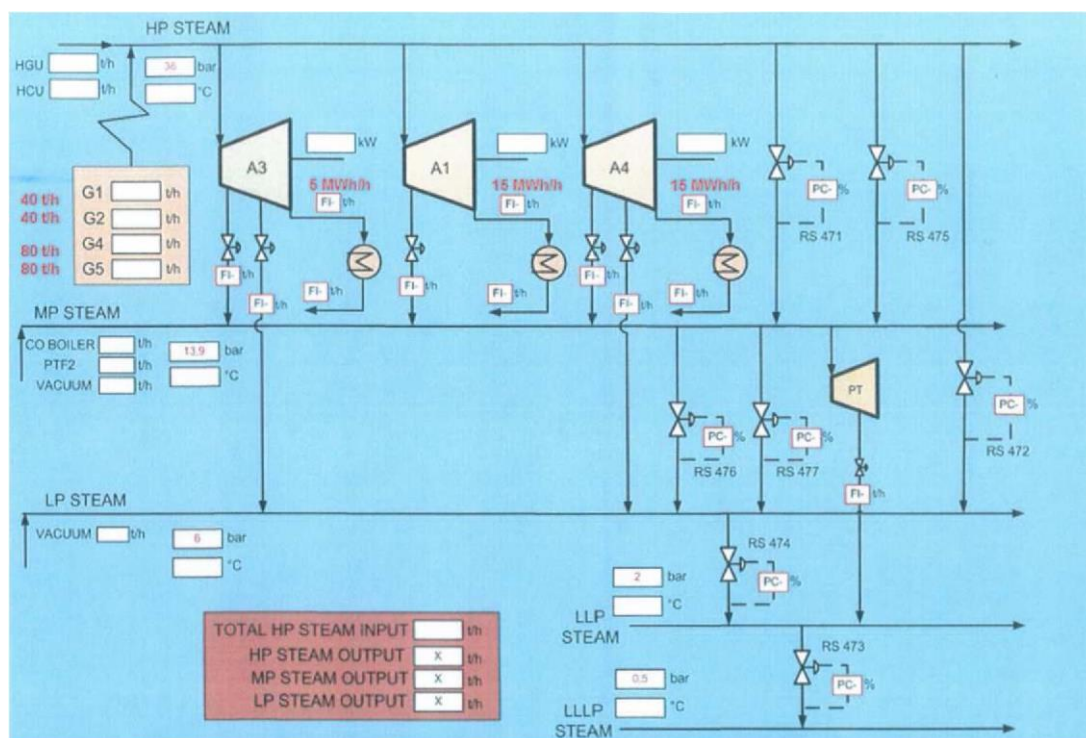


Figure 59: Schematic representation of the Rijeka Oil Refinery cogeneration installation

Depending on consumer needs, the Oil Refinery uses steam at different pressures and temperatures. Steam generation is ensured through the operation of the boiler facility and the corresponding ancillary systems and devices. The parameters of the steam used in the Oil Refinery are the following:

- High-pressure steam, pressure: 34-38 bar (steam generator 341-G-001, 341-G-002, 341-G-004 and 341-G-005) temperature: 380-450 °C;
- Medium-pressure steam, generated in a medium-pressure steam tank using steam pressure reduction valves VT-ST PV 471 and VT-ST PV 475, as well as by steam extraction from turbines 341-T10 and 341-T21. Steam parameters: 10-14 bar, 280-340 °C;
- Low-pressure steam, generated through reduction from a high-pressure tank using pressure reduction valve VT-NT PV 472, in medium-pressure tanks ST-NT PV 476 and ST-NT PV 477, as well as by stream extraction from turbine 341-T10. Steam parameters: 4-6 bar, 200-250 °C;
- Low-pressure steam (3 bar), generated through reduction from a low-pressure tank using pressure reduction valve PV 474. Steam parameters: 1.8-3 bar, 180-230 °C;
- Low-pressure steam (0.7 bar), generated through reduction from a low-pressure tank (3 bar) using pressure reduction valve PV 473. Steam parameters: 0.5-1 bar, 130-180 °C;

The power plant includes four steam generators that produce high-pressure overheated water vapour for process applications and own electricity generation purposes. An overview of the installed steam generators with their rated and maximum steam output capacity is presented in the following table.

Table 23: Features of the steam generators installed in the Rijeka Oil Refinery

Steam generator name	Steam output (t/h)	
	Rated	Maximum
341-G-001	40	50
341-G-002	40	50
341-G-004	80	100
341-G-005	80	100

The energy source used for steam generation is a liquid or gaseous fuel. The heat generated through fuel combustion in steam generators transforms into raw material, that is, feedwater. In that process, the enthalpy of feedwater is increased to the condition of overheated steam. Feedwater is thermally treated demineralised water which is conducted to the boiler by feed pumps after undergoing a chemical water treatment.

The cogeneration facility of the power plant is fuelled by fuel oil, refinery gas and natural gas. All steam generators can use combined liquid (fuel oil) and gaseous fuel (refinery and natural gas). Steam generators 341-G-001 and 341-G-002 each include two combustion devices (one above the other), whereas steam generators 341-G-004 and 341-G-005 each contain four combustion devices (two are horizontally positioned in the bottom section of the steam generator and two in the top section).

The latest fuel introduced in the Oil Refinery is natural gas. As a fuel, natural gas has significant advantages over fuel oil and refinery gas. The key advantage is its superiority in clean operation in the ecological sense, as well as in respect of the degree of soiling of the steam generator itself. The degree of soiling is significantly lower, so the generator does not have to be cleaned as frequently as when using other fuels. Furthermore, it has been shown that steam generators fuelled by natural gas achieve the highest degree of safety in operation. In other words, there are no oscillations in system operation or system power failures, as is the case when using refinery gas.



Figure 60: Rijeka Oil Refinery steam generators

The steam used by the power plant and other parts of the Oil Refinery is produced by the mentioned generators, as well as by a CO boiler and a hydrogen generation unit (HGU). The CO boiler produces medium-pressure steam, whereas the HGU generates hydrogen and high-pressure steam. When that steam expands in steam turbines, it drives the electricity generators, thereby producing electricity. The four steam generators, the CO boiler and the HGU constitute the steam supply system of the Oil Refinery. Steam is not only used to generate electricity, but also to drive different steam machinery. Therefore, it is necessary to ensure a continuous supply of steam to all facilities because a shortage of steam could cause disruptions in the operation of a facility and result in a power failure. A power failure of a particular facility usually significantly affects the oil refining process, given that it takes some time to restart the process after a failure.

A share of high-pressure steam produced by the steam generators and the HGU is used to power the steam turbines and, indirectly, the electricity generators. The remaining share of steam is not conducted to the steam turbines for expansion, but is used by other systems of the Oil Refinery, as presented in Figure 16.

The basic function of the turbo generator facility of the Oil Refinery's power plant is to generate electricity for the refinery's own needs and provide medium-pressure (14 bar) and low-pressure (6 bar) steam through turbine extractions or reduction stations. The electricity produced by the electric generators is used for the operation of the Oil Refinery, and its surplus can be delivered to the Croatian electricity system.

Three turbo generators with ancillary equipment and machinery have been installed for that purpose. Their combined functioning ensures the economical and secure operation of the facility. 341-T-010 is a condensing turbine with two regulated extractions at 14 and 6 bar, connected by a coupling to the electricity generator with a rated power of 8 MW_e. 341-T-021 is a condensing turbine with one regulated extraction at 14 bar. The turbines deliver the mechanical rotational energy generated to the electricity generator with a rated power of 20 MW_e. Turbine 341-T-040 has two regulated extractions and is connected to the electricity generator with a rated power of 20 MW_e.

The steam turbine input medium is high-pressure steam at a temperature of 420-450 °C and a pressure of 36-37 bar, which is used to power the turbines. A share of medium-pressure and low-pressure steam is delivered through regulated extractions to other consumers in the power plant or other process facilities, whereas a potential difference in the required amount of medium-pressure and low-pressure steam is compensated by reduction stations (37/14 bar, 37/6 bar, 14/6 bar). The steam that passes through the condensing section of the turbine is condensed in sea-water-cooled condensers. The electricity from the generators is delivered to the electricity network through a switchyard and distribution system. Generator G1 (8 MW_e) is connected to a 6 kV switchyard system in the power plant, whereas generator G2 (20 MW_e) is directly connected to central transformer station TS 300 by a 35 kV system.

6.2.7.2. Water management

The condensers installed in the power plant include a sea water pump station that cools the turbine condensate.

Cooling sea water is used by the condensers of the main turbines in the power plant. The temperature of sea water ranges between 14 and 26 °C, depending on the season. In the past, sea water was also used for the cooling of process devices, but that practice was abandoned due to water's damaging properties and replaced with a circulating cooling system and air coolers.



Figure 61: Sea water pump station of the Rijeka Oil Refinery

One pump in the sea water pump station is powered by a turbine, whereas the remaining five pumps are powered by an electric motor. Those pumps are automatically connected and their operation is monitored through a graphical display in the DCS system in the Control Room.

A failure of an operating pump during which a replacement pump is not automatically activated represents the main hazard in the operation of the sea water pump station. A lack of sea water leads to a failure of turbo generators and, indirectly, to a standstill in the operation of the entire power plant and the other Oil Refinery facilities supplied by the power plant at that time.

The power plant also includes a chemical feedwater treatment system. More specifically, the water used in the steam generators and the turbine facility must be adequately treated in respect of the content of oxygen, minerals and other chemical substances.

6.2.7.3. Potential for further development

Further development of the Rijeka Oil Refinery is difficult to predict because it depends on its short term business plans. However, the persons responsible say that a revitalisation of steam generators is planned for the near future. That primarily concerns steam generators 341-G-004 and 341-G-005, which were built in the period between 1976 and 1986 and manufactured by Đuro Đaković. Said steam generators lack certain economiser parts and still use outdated pneumatic control. Their revitalisation is expected in the next two years.

The Oil Refinery has no significant potential for the distribution of thermal energy. More specifically, the Oil Refinery is located in an area that is relatively remote from settlements. For that reason, the construction of infrastructure for the distribution of thermal energy to the closest settlements through a district heating system is not deemed economically and technically justified. In addition to that, the Oil Refinery is located in a coastal area where the need for thermal energy in the cold period of the year is significantly lower than in continental areas.

6.3. ANALYSIS OF THE APPLICATION OF HIGH-EFFICIENCY COGENERATION IN THE EXISTING THERMAL ENERGY FACILITIES AND INDUSTRIAL POWER PLANTS

As stated in the introduction, primary energy savings (PES) are calculated on the basis of the fuel consumed and thermal energy and electricity generated in one calendar year of operation of a generation facility, in accordance with the definitions and methodology laid down by the Rules governing the grant of eligible electricity producer status.

Furthermore, in accordance with the Rules, a generation facility that generates electricity and thermal energy must also ensure the measurement of the values required for determining PES or minimum total annual efficiency, that is, the measurement of the total amount of electricity generated by the generation facility (E_u), the total amount of thermal energy generated (H_u), the amount of thermal energy generated outside cogeneration (H_b), thermal energy recovery (H_p), as well as fuel consumption, based on the performance of a generation facility.

The input data required for the analysis have been submitted by the owners of thermal energy facilities and industrial power plants. The analysis covers the past three calendar years.

It is necessary to point out the following:

- Certain thermal energy facilities were unable to submit completely accurate data on determined parameters (e.g. own consumption of electricity and/or thermal energy of recovered condensate), so those data were estimated and assumed.
- The Rules on the Use of Renewable Energy Sources and Cogeneration lay down that cogeneration installations can also include parts of facilities in which cogeneration is not performed (e.g. auxiliary boilers or additional combustion systems), provided that they make a single unit with the cogeneration facility. In that respect, given that the boundaries between blocks were not strictly defined in some thermal energy and industrial cogeneration installations, they were determined so as to reflect the purpose and mode of operation of those facilities. Consequently, in respect of thermal energy facilities, the analysis of the operation of each block did not cover auxiliary boilers, whereas industrial cogeneration plants were observed as single blocks that also included auxiliary systems for additional firing.
- Given that there are no established practices or defined procedures for determining the boundaries of a cogeneration facility, the results of this analysis are purely illustrative, and their purpose is not to precisely determine the parameters relating to the operation of a facility, which also include the accurate value of primary energy savings. Nevertheless, the level of accuracy of this analysis and the insight into the current condition of the equipment are sufficient to draw conclusions about the condition of the facilities analysed, as well as their potential for achieving the primary energy savings of at least 10 % required to meet the criteria for high-efficiency cogeneration and the eligible producer status.
- The Tariff System for the Production of Electricity from Renewable Energy Sources and Cogeneration lays down that, for a generation facility which was in permanent operation before the date of submission of a power purchase agreement application, the power purchase incentive period (14 years) shall be reduced by the duration of the prior operation of the generation facility. There are no established practices or defined procedures in regard to the renewal, reconstruction and/or revitalisation of facilities and/or certain parts of facilities. More specifically, the extent of the renewal, reconstruction and/or revitalisation of an entire facility and/or some of its main components (e.g. boiler, gas-turbine facility, steam-turbine facility, electricity generator etc.) required to make that facility eligible for generation under the incentive system has not been defined.
- A new Renewable Energy Sources and High-efficiency Cogeneration Act (entering into force on 1 January 2016) was adopted during the final phase of this analysis. The Act will be followed by new subordinate legislation and rules that might change the methodology and the relevant criteria to a greater or lesser degree in comparison with the currently applicable solutions, based on which this analysis was conducted and conclusions were drawn.

6.3.1. Existing thermal energy facilities

6.3.1.1. EL-TO Zagreb

As stated in the section about the current condition of thermal energy facilities, the EL-TO Zagreb cogeneration plant consists of four cogeneration blocks, two auxiliary water boilers and one auxiliary steam boiler.

Based on the current configuration of the EL-TO Zagreb plant and the availability of certain generation units, heat consumption (thermal energy for heating and process steam) is covered in the following order:

- Blocks GTA H and GTA J (the so-called Dujmovača blocks);
- Block B;
- Block A;
- Auxiliary water boilers (WB3 and WB4);
- Auxiliary steam boiler (K7).

By covering heat consumption in such manner, the EL-TO Zagreb plant generates the largest amount of electricity and achieves the highest exergy efficiency. However, this is not the best solution for meeting energy needs in respect of energy efficiency. Blocks A and B have higher energy efficiency than blocks H and J. Therefore, in order to achieve maximum energy efficiency, EL-TO Zagreb should first engage blocks K and L and only then Block C in covering the load.

The results of the calculation of parameters relating to the operation of the EL-TO Zagreb cogeneration blocks are presented in the table below.

Table 24: Primary energy savings of EL-TO Zagreb

Block	Year	Type of cogeneration unit	Year of construction	Fuel type 1	Fuel type 2	η_u	PES
						%	%
Block A	2012	Back-pressure steam turbine	1996 and earlier	Natural gas	Gas oil, heavy fuel oil, LPG	85.22	6.28
	2013	Back-pressure steam turbine	1996 and earlier	Natural gas	Gas oil, heavy fuel oil, LPG	73.65	0.00
	2014	Back-pressure steam turbine	1996 and earlier	Natural gas	Gas oil, heavy fuel oil, LPG	83.10	-0.54
Block B	2012	Back-pressure steam turbine	1996 and earlier	Natural gas	Gas oil, heavy fuel oil, LPG	94.90	18.20
	2013	Back-pressure steam turbine	1996 and earlier	Natural gas	Gas oil, heavy fuel oil, LPG	86.51	9.29
	2014	Back-pressure steam turbine	1996 and earlier	Natural gas	Gas oil, heavy fuel oil, LPG	84.37	9.07
Block H	2012	Gas turbine with waste heat utilisation	1996 and earlier	Natural gas	–	68.40	-6.22
	2013	Gas turbine with waste heat utilisation	1996 and earlier	Natural gas	–	71.83	0.50
	2014	Gas turbine with waste heat utilisation	1996 and earlier	Natural gas	–	77.40	11.41
Block J	2012	Gas turbine with waste heat utilisation	1996 and earlier	Natural gas	–	68.15	-7.16
	2013	Gas turbine with waste heat utilisation	1996 and earlier	Natural gas	–	71.90	0.15
	2014	Gas turbine with waste heat utilisation	1996 and earlier	Natural gas	–	77.09	11.26

The results of the calculation of high-efficiency generation parameters show that Block A, which is the oldest block of EL-TO Zagreb, operating in the same mode as in the period from 2012 to 2014, does not have the potential for high-efficiency generation. Moreover, this block does not comply with the permitted values of emissions into air set out by the IED.

In recent years, Block B achieved respectable primary energy savings. When observed separately and independently from the other blocks of EL-TO Zagreb, this block has the potential to meet the criteria for high-efficiency cogeneration. However, this block does not comply with the permitted values of emissions into air set out by the IED. Therefore, in the event that higher emission values are not permitted, Block B will have to be taken out of operation and converted into a cold reserve already in 2018, when a new block will be commissioned.

Blocks H and J have the same technological features. They were installed in EL-TO Zagreb more recently and, in the appropriate operating mode, they could meet the criteria for high-efficiency cogeneration. In the past three calendar years (period 2012-2014), the indicators of high-efficiency operation for these blocks varied. In the operating mode that prevailed in 2014, the blocks could meet the criteria for high-efficiency cogeneration. However, these two blocks do not comply with the permitted values of emissions into air set out by the IED, so they are to be converted into a cold reserve. Therefore, there is no purpose in assessing their potential for high-efficiency cogeneration.

6.3.1.2. TE-TO Zagreb

As stated in the section about the current condition of thermal energy facilities, the TE-TO Zagreb cogeneration plant consists of three cogeneration blocks, four auxiliary water boilers and one auxiliary steam boiler.

Generation units of TE-TO Zagreb can be employed in different ways. TE-TO Zagreb supplies thermal energy to the North and South hot water network of the city of Zagreb. Given that the consumption concerned mostly depends on external climate conditions, different guidelines have been established for different climate conditions. Therefore, in principle, TE-TO Zagreb has three operating modes:

- Winter operating mode (all cogeneration blocks are in operation)
- Transitional period operating mode (Block C is out of operation)
- Summer operating mode (only one of the blocks is in operation – Block K or Block L)

Such operating modes enable TE-TO Zagreb to achieve maximum total efficiency in the conversion of fuel energy into thermal energy and electricity. In order to reach maximum exergy efficiency (electricity output value higher than the input value), TE-TO Zagreb should first engage blocks K and L and only then Block C in covering the load.

The results of the calculation of parameters relating to the operation of the TE-TO Zagreb cogeneration blocks are presented in the table below.

Table 25: Primary energy savings of TE-TO Zagreb

Block	Year	Type of cogeneration unit	Year of construction	Fuel type 1	Fuel type 2	η_u	PES
						%	%
Block C	2012	Steam condensing extraction turbine	1996 and earlier	Natural gas	Gas oil, heavy fuel oil, LPG	74.04	-7.76
	2013	Steam condensing extraction turbine	1996 and earlier	Natural gas	Gas oil, heavy fuel oil, LPG	74.72	-5.48
	2014	Steam condensing extraction turbine	1996 and earlier	Natural gas	Gas oil, heavy fuel oil, LPG	72.43	-5.44
Block K	2012	Combined cycle gas and steam turbine	2001	Natural gas	–	61.57	-94.79
	2013	Combined cycle gas and steam turbine	2001	Natural gas	–	63.71	-63.31
	2014	Combined cycle gas and steam turbine	2001	Natural gas	–	73.78	10.57
Block L	2012	Combined cycle gas and steam turbine	2006 and later	Natural gas	–	63.54	-78.40
	2013	Combined cycle gas and steam turbine	2006 and later	Natural gas	–	66.50	-41.42
	2014	Combined cycle gas and steam turbine	2006 and later	Natural gas	–	72.94	-0.55

Block C achieves very low efficiency in the generation of electricity when its steam turbine operates in a condensing mode. The unit cost of electricity generation is uneconomical and it does not justify the operation of this block at night-time, when the demand for electricity is usually low and the market price of electricity is also much more affordable. Given that Block C cannot be used to cover the heating load without generating large amounts of electricity when the steam turbine is operating the condensing mode, the management strategy of TE-TO Zagreb is to minimise the use of that block (its heating load is to be covered by auxiliary boilers). Consequently, Block C does not have the potential for high-efficiency cogeneration.

Unlike Block C, combined cycle cogeneration blocks K and L can be put into and taken out of operation more frequently, depending on the need for electricity and, primarily, thermal energy. Nevertheless, the technical characteristics of blocks K and L do not allow them to be taken out of operation at night and put back into operation in the morning. Their mode of operation is primarily determined by the regulated thermal energy demand and, where that is complementary to the mentioned characteristics, the demand for economical electricity generation. In their nominal operating mode, both blocks can meet the criteria for high-efficiency cogeneration. Whether the annual calculation of operation parameters will show that the blocks achieved the required results depends on their summer operating mode, when the reduced demand for thermal energy diminishes the economy of cogeneration for the rest of the year. The analysis of Block L did not include the calculation of the energy used for the heating of the water that was added to the hot water pipeline to compensate for the loss caused by leakage. In that process, the temperature of the water is increased from the temperature in the well to the temperature in the return hot water pipeline. According to the estimates from TE-TO Zagreb, that reduced the efficiency of Block L by 5 percentage points.

In addition to that, combined cycle cogeneration blocks K and L meet the stricter emission limit values for polluting substances. Under regular maintenance, blocks K and L may remain in service by 2030 and 2040 respectively. In conclusion, both combined cycle cogeneration blocks have the potential to meet the cogeneration criteria, provided that they operate in the appropriate mode, which depends on the energy needs determined by climate conditions.

6.3.1.3. TE-TO Osijek

As stated in the section about the current condition of thermal energy facilities, the TE-TO Osijek cogeneration plant consists of three cogeneration blocks and three auxiliary boilers used for process steam generation.

The existing generation units of TE-TO Osijek (from 1976 and 1985) cover the heat consumption of the city of Osijek and industrial consumers to the largest extent, but there is no appropriate safety reserve in the winter months. In respect of electricity consumption, TE-TO Osijek, as the only larger source of electricity in eastern Croatia, satisfies only about 5 % of total electricity consumption in the region. For that reason, there is an ongoing tender for the construction of a new high-performance combined cycle cogeneration plant in Osijek, with an electrical power of approximately 500 MW and a thermal power of approximately 160 MW, which would use natural gas as fuel.

That will strengthen HEP's electricity generation capacities in the region and overcome the technical and legal constraints of the existing production units that supply the city of Osijek and eastern Croatia with high-quality, safe, accessible and adequate energy. HEP has announced that the construction of the new plant in Osijek should be completed in 2018.

The results of the calculation of parameters relating to the operation of the TE-TO Osijek cogeneration blocks are presented in the table below.

Table 26: Primary energy savings of TE-TO Osijek

Block	Year	Type of cogeneration unit	Year of construction	Fuel type 1	Fuel type 2	η_u	PES
						%	%
45 MW block	2012	Steam condensing extraction turbine	1996 and earlier	Natural gas	Gas oil, heavy fuel oil, LPG	74.60	3.55
	2013	Steam condensing extraction turbine	1996 and earlier	Natural gas	Gas oil, heavy fuel oil, LPG	76.97	5.53
	2014	Steam condensing extraction turbine	1996 and earlier	Natural gas	Gas oil, heavy fuel oil, LPG	72.27	2.23
Block GTA 1	2012	Gas turbine with waste heat utilisation	1996 and earlier	Natural gas	–	57.17	-48.20
	2013	Gas turbine with waste heat utilisation	1996 and earlier	Natural gas	–	55.36	-58.85

	2014	Gas turbine with waste heat utilisation	1996 and earlier	Natural gas	–	55.31	-56.59
Block GTA 2	2012	Gas turbine with waste heat utilisation	1996 and earlier	Natural gas	–	0.00	0.00
	2013	Gas turbine with waste heat utilisation	1996 and earlier	Natural gas	–	56.82	-58.77
	2014	Gas turbine with waste heat utilisation	1996 and earlier	Natural gas	–	55.42	-56.58

Two gas-turbine blocks, GTA1 and GTA2, are used very seldom, primarily for the purpose of thermal energy generation in transitional periods. For that reason, as well as because of their use to satisfy peak needs, these blocks do not have the potential to meet the criteria for high-efficiency cogeneration.

The 45 MW block is a district heating block with an electrical power of 45 MW_e, primarily used for thermal energy generation (as hot water for city heating and process steam for industrial applications). It also generates electricity in a combined process. The results of the calculation of high-efficiency generation parameters show that the 45 MW block, operating in the same mode as in the period from 2012 to 2014, does not have the potential for high-efficiency generation. As previously mentioned, in the event that a new CCCGT generation facility is constructed, this block will be taken out of operation and kept only as a reserve generation unit.

As stated in the section about the current condition of thermal energy facilities, the Sisak Thermal Power Plant consists of two cogeneration blocks and three auxiliary boilers used for process steam generation.

The generation facility is composed of two generation units (blocks A and B) with a total installed electrical power of 420 MW_e. These blocks generate thermal energy for the facility's own needs, as well as for the heating of residential, commercial and other facilities in the city of Sisak, from an auxiliary boiler room or directly from the boilers of an operating block. Given that these blocks are no longer used for the generation of electricity, one cannot speak of a cogeneration process. Therefore, these generation units are not viable for high-efficiency cogeneration.

It should be pointed out that Block C should be put into operation in TE Sisak in the near future. That is a facility composed of one 160 MW_e gas turbine with its own generator and one 80 MW_e steam turbine with its own generator and a boiler that utilises gas turbine waste gases. The steam turbine has a regulated steam extraction used for the supply of steam to Sisak's heating system with a power of 50 MW_t.

The construction of the mentioned new gas cogeneration facility has been completed, and its trial operation is under way. It should be commissioned by the end of 2015. It is expected that, in its nominal operating mode, this block will be able to meet the criteria for high-efficiency cogeneration.

The results of the calculation of parameters relating to the operation of the TE Sisak generation blocks are presented in the table below.

Table 27: Primary energy savings of TE Sisak

Block	Year	Type of cogeneration unit	Year of construction	Fuel type 1	Fuel type 2	η_u	PES
						%	%
Block A	2012	Steam condensing extraction turbine	1996 and earlier	Natural gas	Gas oil, heavy fuel oil, LPG	35.74	0.00
	2013	Steam condensing extraction turbine	1996 and earlier	Natural gas	Gas oil, heavy fuel oil, LPG	37.25	0.00
	2014	Steam condensing extraction turbine	1996 and earlier	–	–	0.00	0.00
Block B	2012	Steam condensing extraction turbine	1996 and earlier	–	–	0.00	0.00
	2013	Steam condensing extraction turbine	1996 and earlier	–	–	0.00	0.00
	2014	Steam condensing extraction turbine	1996 and earlier	–	–	0.00	0.00
Block C	2012	Combined cycle gas and steam turbine	2006 and later	–	–	0.00	0.00
	2013	Combined cycle gas and steam turbine	2006 and later	–	–	0.00	0.00

	2014	Combined cycle gas and steam turbine	2006 and later	–	–	0.00	0.00
--	------	--------------------------------------	----------------	---	---	------	------

6.3.2. Existing industrial power plants

6.3.2.1. *Belišće d.o.o. Belišće*

The industrial cogeneration plant in Belišće is primarily used for generating sufficient amounts of process steam for the needs of the paper industry. It includes two steam generators, each with a rated capacity of 94 MW_t, and three steam turbines, one of which has been decommissioned. The total installed electrical power of the plant is 31 MW_e. In addition to the steam-turbine cogeneration facility, the plant also includes two low-pressure steam generators, each with a rated thermal power of 15.25 MW_t. The facility has three operating modes:

- Parallel operation – operation of the cogeneration facility with the delivery of electricity from the electricity network;
- Sole operation of low-pressure steam generators exclusively for the purpose of thermal energy (process steam) generation;
- Island operating mode – generation of the required amounts of thermal energy and electricity without the exchange of electricity with the electricity system.

In view of the price ratio of fuel (petroleum gas) and electricity, which was discussed in greater detail in previous chapters, the preferred operating mode involves the generation of thermal energy from low-pressure steam generators in the summer and transitional periods, and the additional generation of thermal energy from the cogeneration facility in the periods with higher thermal energy needs (the winter period). The mentioned operating mode also had an impact on primary energy savings, as presented in the table below.

Table 28: Primary energy savings of *Belišće d.o.o.*

Block	Year	Type of cogeneration unit	Year of construction	Fuel type 1	Fuel type 2	η_u	PES
						%	%
Entire power plant	2012	Steam condensing extraction turbine	1996 and earlier	Natural gas	Natural gas	75.33	-9.11
	2013	Steam condensing extraction turbine	1996 and earlier	Natural gas	Natural gas	79.30	-10.91
	2014	Steam condensing extraction turbine	1996 and earlier	Natural gas	Natural gas	88.21	-4.25

The analysis of the operation of the cogeneration facility in the period from 2012 to 2014 shows that the facility did not even achieve minimum primary energy savings. Taking that and the year of its construction (1975, 1984) into consideration, it cannot be expected that the cogeneration facility could meet the criteria for obtaining the eligible electricity producer status in its current configuration.

6.3.2.2. *Petrokemija d.d. Kutina*

The *Petrokemija d.d.* facility comprises three steam generators and one steam turbine, which are presented in more detail in the description of the existing industrial power plants.

The total installed electrical power of the cogeneration facility is 35 MW_e. The cogeneration facility is in operation all year round. In view of the ratio of fuel and electricity prices, the preferred operating mode involves the generation of thermal energy and electricity, largely in favour of the former. The cogeneration facility is connected to the electricity network and has the option to exchange electricity with the network.

Table 29: Primary energy savings of *Petrokemija d.d.*

Block	Year	Type of cogeneration unit	Year of construction	Fuel type 1	Fuel type 2	η_u	PES
						%	%
Entire power plant	2012	Steam condensing extraction turbine	1996 and earlier	Natural gas		80.69	-8.87
	2013	Steam condensing extraction turbine	1996 and earlier	Natural gas		84.97	-2.19

	2014	Steam condensing extraction turbine	1996 and earlier	Natural gas		88.96	1.46
--	------	-------------------------------------	------------------	-------------	--	-------	------

The key indicators presented in the table above show that, in the three-year period, the facility failed to provide the primary energy savings of 10 % required for obtaining the eligible electricity producer status. The primary energy savings achieved in 2014 were 1.46 %. In view of its present technological condition, this facility in its current configuration does not have the potential to obtain the eligible electricity producer status, that is, meet the high-efficiency cogeneration criteria. The mentioned status could be obtained provided that the existing facility is revitalised and/or a new cogeneration facility is constructed. Given that no procedure for the revitalisation of the existing cogeneration facilities is currently in place, it is difficult to define the required scope of revitalisation that would ensure the grant of the eligible producer status.

6.3.2.3. Rijeka Oil Refinery

The Rijeka Oil Refinery includes four steam generators and three steam turbines. High-pressure steam is generated by steam generators, as well as by a hydrogen generation unit. The share of high-pressure steam from those two sources is expanded in the steam turbines, and the rest of it is directly used for process applications in the Oil Refinery. For the purpose of determining primary energy savings, certain hypotheses and simplifications have been made in accordance with the Rules governing the grant of eligible electricity producer status. More specifically, given that there is a different number of steam generators and steam turbines, and that high-pressure steam is also generated by the HGU, the power plant could not be divided into cogeneration blocks which would include one steam generator and one turbine. For that reason, the entire facility was observed as one block with a total power of 48 MW_e. Furthermore, there are three types of fuel used for cogeneration, as described in the chapter on the Rijeka Oil Refinery. Fuel oil and refinery gas were added up and designated as the same fuel type – Fuel 1. That simplification is justified because both types of fuel have equal coefficients of reference electrical efficiency and virtually identical coefficients of reference heat efficiency. Natural gas was designated as Fuel 2.

The next approximation was made for the year 2012, when the amount of high-pressure steam generated from the steam generator was lower than the amount of high-pressure steam used by the steam turbines. In 2012, the difference in high-pressure steam was compensated by the hydrogen generation unit. Given that the methodology for the calculation of primary energy savings, laid down by the Rules on Eligible Electricity Producer Status, does not cover such instances, the mentioned amount of high-pressure steam (steam enthalpy) was added to Fuel 2 with an assumed efficiency of 90 %.

Table 30: Primary energy savings of the Rijeka Oil Refinery

Block	Year	Type of cogeneration unit	Year of construction	Fuel type 1	Fuel type 2	η_u	PES
						%	%
Entire power plant	2012	Steam condensing extraction turbine	1996 and earlier	Gas oil, heavy fuel oil, LPG	Natural gas	71.32	-45.56
	2013	Steam condensing extraction turbine	1996 and earlier	Gas oil, heavy fuel oil, LPG	Natural gas	74.46	-34.30
	2014	Steam condensing extraction turbine	1996 and earlier	Gas oil, heavy fuel oil, LPG	Natural gas	87.60	-18.26

The table above shows that the Oil Refinery's cogeneration facility does not meet the required primary energy savings of 10 %. Moreover, it does not even achieve the minimum primary energy savings through separate generation of electricity and thermal energy in reference boiler rooms. Its primary energy savings have a negative value, ranging between -18 % and -46 %. Therefore, it can be concluded that, in this instance, cogeneration is less favourable in terms of energy efficiency than separate generation processes. One of the reasons for that are the already mentioned and explained trends in electricity and gas markets.

It should also be pointed out that, due to data reliability, the obtained results might not be completely accurate. More specifically, the person responsible say that the measurement points/instruments have not been calibrated for years, so the accuracy of the measurements obtained could not be guaranteed. However, it is safe to assume that completely accurate measurements would not significantly change

the potential of the Rijeka Oil Refinery's cogeneration facility. In other words, it is estimated that the facility cannot achieve the required primary energy savings of 10 % in its current configuration.

6.4. ANALYSIS OF POTENTIAL NEW LOCATIONS FOR HIGH-EFFICIENCY COGENERATION

The analysis of potential new locations for the likely application of high-efficiency cogeneration is based on the results of the analyses presented in Chapter 4 'Determination of the thermal energy demand which can be met through high-efficiency cogeneration' and Chapter 7 'Determination of the potential for the improvement of infrastructure energy efficiency'. Potential new locations for new high-efficiency cogeneration facilities have been determined on the basis of consolidated results presented in these two chapters. The reasons for the development of the necessary thermal energy distribution infrastructure were also explored for the purpose of this analysis.

The results of the analysis of the thermal energy demand which can be met through high-efficiency cogeneration for the period 2016-2030 (Chapter 4) were obtained as follows:

- For the purpose of this analysis, research was carried out and projections were made in respect of heat consumption for all cities and municipalities in Croatia, namely for the sectors of households, industry and services. Projections were made for the years 2020, 2025 and 2030. The projections for 2030 were used in the analysis presented in this chapter.
- Data on climate zones of determined locations and heating degree days were taken into consideration.
- As regards the households sector, the population, number of households and average number of persons in the household, size of housing units and the number of permanently occupied housing units were taken into account. In addition to that, the thermal energy used for space heating, as well as the energy used for domestic hot water generation and cooking were specifically examined. Lastly, the energy used for household cooling was also analysed.
- With regard to the industrial sector, the analysis included direct thermal energy, that is, final heat from energy sources directly used for process applications, as well as indirect thermal energy, that is, the heat used for the generation of media (steam and domestic hot water). Indirect thermal energy is particularly interesting in respect of the consumption which can be covered through district heating systems and high-efficiency cogeneration.
- In regard to the services sector, thermal energy for heating and the energy for cooling were taken into account.

The calculation of total thermal energy needs for 2030 included thermal energy used for space heating in the households sector, indirect heat used in the industrial sector, and thermal energy used for heating in the services sector. Cooling energy was not included in the calculation because the supply of heating energy and the supply of cooling energy are not performed at the same time, given that those are seasonal processes. It is estimated that the installed capacities of cogeneration generation units would be more than sufficient to cover seasonal peak loads of the cooling needs met through potential high-efficiency cogeneration. Finally, the required theoretical thermal capacity of new high-efficiency cogeneration facilities was calculated.

It is possible that certain potential locations for new high-efficiency cogeneration facilities will require the construction of new infrastructure for the distribution of thermal energy or an upgrade of the existing one.

An overview of all potential new locations for high-efficiency cogeneration is presented in the table below.

Table 31: Overview of the potential for additional new high-efficiency cogeneration

No.	City	Thermal energy needs in 2030 (theoretical values)					
		Households	Industry	Services	Total heat consumption		Required thermal capacity
		GJ	GJ	GJ	GJ	MWh	MW _t
1	Zagreb	8 580 576	2 638 423	3 421 440	14 640 440	4 066 789	2 540
2	Đurđenovac	68 765	477 692	6 653	553 111	153 642	96
3	Velika Gorica	585 083	0	210 464	795 547	220 985	140

4	Karlovac	603 394	143 798	224 843	972 036	270 010	167
5	Županja	107 962	506 016	10 526	624 503	173 473	111
6	Koprivnica	304 657	315 615	106 959	727 231	202 009	125
7	Varaždin	491 440	338 066	294 171	1 123 677	312 132	190
8	Bjelovar	386 607	155 847	158 259	700 713	194 643	122
9	Osijek	1 184 754	1 010 453	422 692	2 617 899	727 194	454
10	Sisak	499 197	19 080	143 147	661 424	183 729	118
11	Virovitica	219 949	716 975	82 183	1 019 107	283 085	174
12	Rijeka	900 930	91 638	649 695	1 642 262	456 184	342
13	Samobor	342 501	0	124 891	467 392	129 831	82
14	Zaprešić	241 538	131 992	83 706	457 236	127 010	80
15	Belišće	107 299	1 029 174	10 622	1 147 094	318 637	199
16	Slavonski Brod	558 765	138 385	182 533	879 683	244 356	153
17	Petrinja	234 273	139 036	73 599	446 908	124 141	80
18	Požega	257 207	155 795	92 864	505 865	140 518	88
TOTAL:		15 674 896	8 007 985	6 299 247	29 982 128	8 328 369	5 262

The above table shows that there are eighteen (18) potential new locations for high-efficiency cogeneration and the corresponding infrastructure. The total theoretical value of heat consumption for all listed locations is 29 982 128 GJ, that is, 8 328 369 MWh. The corresponding thermal capacity, required for satisfying 100 % of thermal energy needs in 2030, is 5 262 MW_t.

The distribution of total thermal energy needs across Croatia is shown graphically in the figure below.

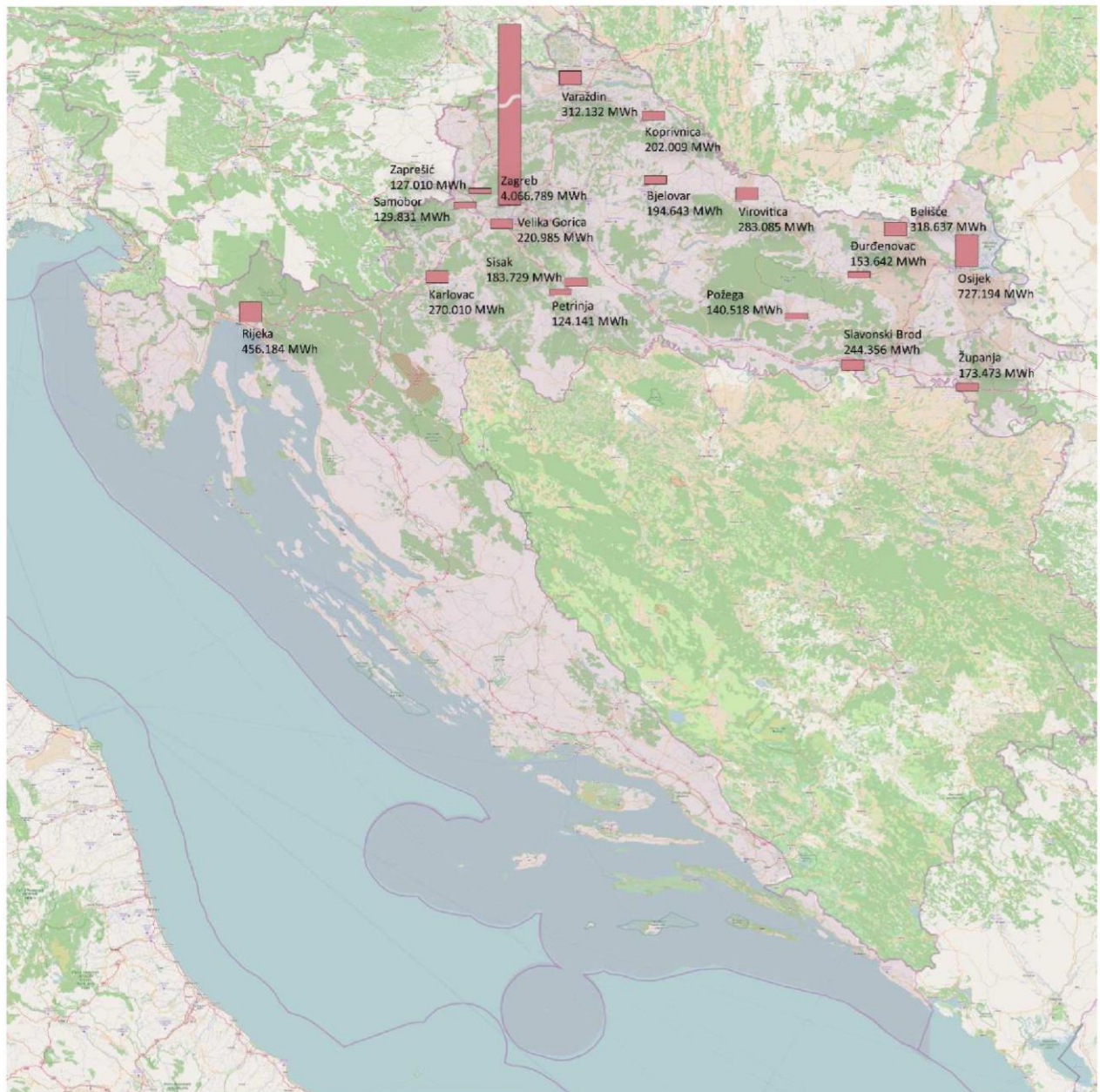


Figure 62: Distribution of total thermal energy needs in Croatia

This theoretical value of thermal energy needs in 2030 will be discussed in real terms, taking into consideration the likelihood of the application of high-efficiency cogeneration.

7. DETERMINING THE POTENTIAL TO INCREASE INFRASTRUCTURE ENERGY EFFICIENCY

7.1. INTRODUCTION

The main goal of this chapter is to define the technical and economic basis for increasing energy efficiency of developing district heating systems in urban areas with organised thermal energy production, distribution and supply already in place.

A well-conceived snapshot of the current condition of centralised supply is certainly the first step since it is essential for any attempt at both planning how to increase energy efficiency and planning the development, construction and maintenance of existing systems.

Data required for the preparation of this chapter were collected via a questionnaire, which was first sent to the Croatian Energy Regulatory Agency and subsequently to energy operators, as the main participants in the thermal energy market, with the assistance of the Ministry of the Economy. Not all requested data were obtained, so the analyses below will be limited by the quality and scope of the data supplied.

7.2. ANALYSIS OF THE CURRENT CONDITION OF ENERGY INFRASTRUCTURE

In order to determine the potential for increasing energy efficiency of the Croatian heating system infrastructure, an analysis of its current condition is required as the first step. According to the project task, the analysis of the current condition contained below includes cogeneration units and boiler plants in the thermal production system, as well as the thermal energy distribution and supply system. The analysis is based on data collected from state institutions, such as the Croatian Energy Regulatory Agency, the Ministry of the Economy and those collected by the companies operating heating systems of individual cities. The analyses conducted include available data on production systems, distribution network and heating substations, depending on the system. These data are organised in tables. Since the level of available data varies from system to system, the tables also differ by the level of detail provided.

In the territory of Croatia in 2014, 15 cities had some form of heating system, more specifically: 20 district heating systems, 55 closed heating systems and 57 stand-alone heating systems. Thermal energy is generated in production cogeneration installations and boiler plants.

Croatia has seven cogeneration installations with a capacity exceeding 20 MW which use thermal energy for heating of private and public buildings, or else thermal energy is used for other purposes, such as in industrial processes, which will be included in the analysis of the current situation below. Also, cogeneration installations increasingly use wood biomass and biogas obtained from agricultural crops and by-products. But since their capacity is rather small, such installations are not subject of this study. Having discussed cogeneration installations in more detail in the previous chapter, only basic information necessary to analyse the current situation is provided here; for more a more detailed description of cogeneration installations please refer to Chapter 6.

The analysis of the current condition of heating infrastructure below is provided as a breakdown by the cities having a heating system. Energy efficiency of heating systems can be evaluated on the basis of fuel heat consumption, and heat produced and supplied to customers. This is precisely the reason for requesting data at the level of each boiler so that optimal quality analysis might be conducted, in accordance with the project task. However, the data collected referred to the boiler room level only and were incomplete in many cases, so the scope of the analysis was somewhat limited. An analysis of the 2014 heating system energy efficiency is provided in the tables below, grouped by cities, and depending on data availability. The data source is HERA and heating sector companies.

7.2.1. Samobor

Heating systems in Samobor are operated by *HEP-Toplinarstvo d.o.o.* The heating system consists of one DHS, one CHS and two SHSs. The total network length is 3 084 m.

The Samobor heating system data are provided in Annex 14.3.1.

7.2.2. Zaprešić

Heating systems in Zaprešić are operated by *HEP-Toplinarstvo d.o.o.* The heating system consists of four CHSs and one SHS. The total network length is 1 660 m.

The Zaprešić heating system data are provided in Annex 14.3.2.

7.2.3. Velika Gorica

In the city of Velika Gorica, there are 14 heating systems owned by *HEP-Toplinarstvo d.o.o.*, more specifically: 4 DHSs, 6 CHSs and 4 SHSs.

The Velika Gorica heating system data are provided in Annex 14.3.3.

7.2.4. Sisak

Heating systems in Sisak are operated by *HEP-Toplinarstvo d.o.o.* The heating system consists of two DHSs, one of which receives its thermal energy supply from a cogeneration installation – the Sisak thermal power and heating plant (hereinafter: TE Sisak). TE Sisak generates electricity and heat. The electricity is delivered to the grid, and the heat used for the plant's own needs and to meet the heating system needs for heating of residential, commercial and other buildings in Sisak, as well as for the production of process steam for industrial purposes. The cogeneration installation consists of two blocks – Block A and Block B with the total electrical capacity of 420 MW. Block A has been in operation since 1970 and Block B since 1976. Both blocks operate on the same principle and consist of equivalent equipment. Each block has two 330 t/h steam boilers at 540 °C and pressure of 135 bar. According to the information provided, the installation uses natural gas, transported to the facility by the main gas pipeline, as fuel. A third one, Block C, as a replacement combined cogeneration installation with a rated electrical output of 230 MW and a rated thermal output of 50 MW, is currently under construction at the same location. A more detailed description of each block is provided in Chapter 6. In addition to the TE Sisak cogeneration installation, there is also a DHS named *Energana Sisak* with a total installed boiler room capacity of 125 MW. It uses natural gas as fuel. According to the information provided, the total distribution network length is 26 600 m. It supplies thermal energy to 4 139 final customers, of which 4 053 are households, while the remaining 86 are industrial operators.

The Sisak heating system data are provided in Annex 14.3.4.

7.2.5. Kutina

The city of Kutina has one cogeneration installation with a capacity of more than 20 MW; being a part of *Petrokemija d.d.* company, it is used for the production of process steam and heat for the petrochemical plant's own production purposes, with the electricity consumed exclusively within the perimeter of the installation. In order to ensure cost-effectiveness, it is used for maximum thermal energy production in the form of high-pressure 122 bar steam, and 40 bar and 4 bar process steam. The installation consists of three steam generators (K1, K2, and K3) and one steam turbine. Two steam generators are located in a common boiler room while the third is situated at another location; it was designed to be fired by waste gases from a planned carbon black factory, which was later abandoned. The rated steam output may be achieved by using medium-heavy fuel oil only or in combination with natural gas. The steam is transported by an external, approx. 1 500 m steam pipeline from the generator to a 122 bar steam distributor situated within *Energana* (boiler room with two steam generators).

Steam generators K1 and K2 are of identical technical characteristics and date back to 1981. The rated output of the steam generators is 115 MW each, with a 33.5 MW minimum load. Steam temperature is 540 °C at a pressure of 122 bar. The declared degree of utilisation of the steam generators is 0.92. Technically speaking, the steam generator K3 is identical to the steam generators K1 and K2. The steam turbine, also produced in 1981, has the rated electrical output of 35 MW and a maximum steam flow of 250 t/h. The 2014 efficiency at the level of the entire cogeneration installation was 89 %.

Technical parameters of the cogeneration installation, as well as other elements are described in detail in Chapter 6.

There is no thermal system used for heating of other public and private entities in the city.

7.2.6. Karlovac

Thermal energy supply in the city of Karlovac takes place via one DHS and one CHS as part of *Gradska Toplana d.o.o.* It may be concluded from the collected data on the calculated boiler room efficiency that the data on the thermal energy production are estimated, where the average boiler room efficiency is taken to be 0.9, which is certainly not a realistic efficiency of both boiler plants. The data obtained from Gradska Toplana d.o.o. say the average production losses at 7 % and distribution losses at 13 %.

The Karlovac heating system data are provided in Annex 14.3.5.

7.2.7. Ogulin

The city of Ogulin has two CHSs, operated by *Stambeno Komunalno Gospodarstvo d.o.o.*

The Ogulin heating system data are provided in Annex 14.3.6.

7.2.8. Varaždin

Heating systems in the city of Varaždin, i.e. two CHSs and seven SHSs, are operated by *Vartop d.o.o.*

The Varaždin heating system data are provided in Annex 14.3.7.

7.2.9. Rijeka

The heating system in the city of Rijeka consists of three DHSs, eight CHSs and four SHSs. They are operated by *Energo d.o.o.* The total installed capacity of all heating systems is 101.5 MW. Natural gas is used as production fuel in most cases, while fuel oil and extra light fuel oil are used in others. The total heating distribution network length is 16 541 m. The network supplies 10 010 end-users, of which 9 963 are households and the remaining 47 end-users are industrial and commercial consumers. According to the data obtained, the total leased connected load amounts to 74.9 MW. This leaves an average approx. 26 % of the total installed capacity of all the boiler rooms to be fully utilised. It may be concluded from the collected data on the calculated boiler room efficiency that the data on the thermal energy production are estimated, where the average boiler room efficiency is taken to be 0.9, which is certainly not a realistic efficiency of all boiler plants. The lowest average efficiency of the entire heating system is 50.8 %, with 78.5 % as the maximum. The average efficiency of the entire heating system is 69.6 %.

In Rijeka, there is also a cogeneration installation, ranking among those of more than 20 MW by size. The cogeneration installation is located within *Energana*, owned by Rijeka's INA Oil Refinery, and is used for the production process purposes within the refinery. It is used for the generation of electricity and thermal energy, where a part of the heat produced is used to drive steam turbines and rest as driving energy for other installations within the oil refinery. The temperature of the steam supplied to the steam turbine is 420 °C at a pressure of 35 bar. Steam of other temperature and pressure parameters is used for other purposes, depending on process requirements. The *Energana* power plant has four superheated high-pressure steam generators installed for the refinery's process purposes and own electricity generation. The maximum production capacity of the steam generators is 300 t/h (2x50 t/h and 2x100 t/h). The fuels used include fuel oil, refinery gas and natural gas. All generators have the option of combined combustion of those fuels. In addition to the steam generators, a CO boiler and an HGU unit are also used for steam generation. Similarly, a part of the steam is used to drive steam turbines and electricity generation, and the rest for other refinery systems purposes. The electricity generated is used for refining purposes, while any surpluses are delivered to the grid, that is, to the Croatian electric power system. Three turbo generators are installed for that purpose. The first one has an extraction option at 14 and 6 bar and 8 MW electricity generation. The second turbine features one controlled extraction at 14 bar and a 20 MW electricity generator. The third turbine has two controlled extractions and a 20 MW generator. The 2014 efficiency at the level of the entire cogeneration installation was 87.6 %. It is presented in more detail in Chapter 6.

The Rijeka heating system data are provided in Annex 14.3.8.

7.2.10. Virovitica

In Virovitica, the supply of thermal energy to customers is via five CHSs operated by the gas utility *Plin VTC d.o.o.*

The Virovitica heating system data are provided in Annex 14.3.9.

7.2.11. Slavonski Brod

The heating system in Slavonski Brod consists of one DHS, two CHSs and 18 SHSs operated by the gas utility *Brod-Plin d.o.o.* The total heating network length is 7 050 m.

The Slavonski Brod heating system data are provided in Annex 14.3.10.

7.2.12. Osijek

The city of Osijek has three DHSs and one CHS operated by *HEP-Toplinarstvo d.o.o.* In the case of one DHS, heat is produced in the *Termoelektrana-Toplana Osijek* (hereinafter: TE-TO Osijek) cogeneration installation, operated by *HEP Proizvodnja d.o.o.* The total installed boiler rooms capacity without TE-TO Osijek, which is analysed separately, is 167.6 MW. Natural gas is the predominant fuel, but fuel oil is also used, as well as extra light fuel oil to a lesser extent. The heating system consists of around 56 200 m distribution network, supplying 11 708 end-users, of which 10 432 are households and 1 266 are industrial and commercial entities. The total leased power is 193.2 MW, including the cogeneration unit production. Since some boiler rooms supply end-users jointly, the data provided do not refer to each boiler room separately, nor is possible to estimate the efficiency at the boiler room level or at the level of the entire heating system, including the production, distribution and supply of thermal energy.

The TE-TO Osijek cogeneration installation is used for thermal energy and electricity generation. The heat is used for heating and process steam supply to industrial consumers, while the electricity is delivered to the grid. The installation was built in two stages. A gas turbine power plant (TPP) and a steamblock boiler room (SBK) were built in 1976, while a thermal 45 MW Block was added in 1985. The TPP block consists of two gas turbine generation units, each with a rated electrical capacity of 25 MW. Natural gas is mostly used as fuel, but extra light fuel oil may be used as well. The TPP block was initially planned as an auxiliary source for peak loads but became a regular power source, generating electricity together with the 45 MW Block during the Homeland War. The TPP block is rarely used nowadays because of weak demand and the underdeveloped heating system, undermining its cost-effectiveness. According to available data for the observed year 2014, efficiency at the level of the TPP block was 54.2 %. The 45 MW Block is dedicated to district heating with a primary task of thermal energy, as well as electricity generation in a combined process. Thermal energy is used in the thermal system for heating and process steam production for the industry, while the electricity is delivered to the grid. The installation is also able to operate in island mode. The 45 MW Block consists of a 45 MW rated electrical power steam turbine and generator. The steam turbine is an extraction condensing type with three uncontrolled and one controlled extractions. Two high-pressure boilers with a maximum steam output of 125 t/h per boiler and 45 t/h as a minimum, are also part of the 45 MW Block. The maximum process steam output is limited to 70 t/h. The boilers are adapted for the use of natural gas or heavy fuel oil. According to the 2014 data, which are the latest available, efficiency at the level of the 45 MW Block was 68.4 %. The hot water station has three heaters. The SBK Block of TE-TO Osijek also features three Steamblock type boilers. Its main use is process steam production when the TPP Block is out of order. Each boiler has a maximum output of 18 t/h steam at a temperature of 250 °C and 18 bar pressure. They are also fired by natural gas and heavy fuel oil. Efficiency at the SBK Block level is 82.45 %. A more detailed description of the TE-TO Osijek cogeneration installation is provided in Chapter 6.

The Osijek heating system data are provided in Annex 14.3.11.

7.2.13. Belišće

Belišće has a cogeneration installation with a capacity above the 20 MW analysed. It is owned by *DS Smith Duropack Belišće d.o.o.* (formerly *Belišće d.d.*) and it used for meeting its own thermal energy and electricity needs. It consists of two steam generation units (K3 and K4). The two boilers, K3 and K4, were produced in 1975 and 1984, respectively; they were subsequently upgraded and revitalised. Both boilers are of the same technical specifications, having a rated heating capacity of 94 MW each. The temperature of the steam produced is 500 °C at a 72 bar pressure. Three steam turbines (T1, T2 and T3) are also installed at the current location. The first turbine (T1), with the rated power of 15 MW, is no longer used and is not planned to be returned to operation. The second one (T2), made in 1980,

also has nominal electrical power of 15 MW. It is a condensation turbine with two controlled extractions (at 15 bar and 7 bar) and one uncontrolled extraction. The latest turbine and generator overhaul was performed in 2012. The third turbine (T3), made in 1984, is also a condensation turbine with two controlled extractions (at 15 bar and 7 bar), and a nominal electrical power of 15 MW. The latest overhaul was in 2007, so the turbine requires another one for further operation. The installation uses a mixture of natural gas and so-called associated petroleum (captured) gas as fuel. According to the latest available data for 2014, efficiency at the power plant level was 88.2 %.

A more detailed description of the entire installation, as well as corresponding diagrams, are available in Chapter 6.

7.2.14. Vukovar

The heating system in Vukovar consists of two DHSs, three CHSs and two SHSs, operated by the utility company *Tehnostan d.o.o.* The total installed capacity of all generation installations amounts to almost 46 MW, and the fuels used are natural gas and fuel oil. The total length of all heating networks is 7 215 m.

The Vukovar heating system data are provided in Annex 14.3.12.

7.2.15. Zagreb

The biggest heating system in Croatia is in Zagreb and consists of three DHSs, 14 CHSs and 14 SHSs. Thermal energy for two of the DHSs is supplied by cogeneration installations, namely electricity and thermal power plant *Elektrana-Toplana Zagreb* and thermal power plant *Termoelektrana-Toplana Zagreb* (hereinafter: EL-TO Zagreb and TE-TO Zagreb).

EL-TO Zagreb

The first cogeneration installation, EL-TO Zagreb, began its operation in 1907 at the initial capacity of 0.8 MW. Population growth and industrial development drove an increase in electricity and heat needs, so the installation developed to keep the pace.

Cogeneration installation EL-TO Zagreb consists of four blocks: Block A, Block B, Block H and Block J. Block A, built in 1970, is the oldest production block of EL-TO Zagreb. It consists of a steam boiler (K6) and back-pressure steam turbine with the installed electrical capacity of 12 MW. Its purpose is to power process steam production and hot water heaters. The maximum thermal capacity of the block is 55 MW and 40 t/h of process steam. In 2014, as the latest year analysed, overall efficiency at Block A level was 80.5 %. Block B, built in 1979, consists of two steam boilers (K8 and K9) and a back-pressure steam turbine with the electrical power output of 30 MW. Its purpose is to supply process steam and hot water to the thermal system. The overall thermal capacity of the block is 90 MW and 42 t/h of process steam. Efficiency at the Block B level is 81.7 %. Block H and Block J are identical blocks built in 1998 by relocation of gas turbines from Dujmovača. The 25.6 MW turbine produces steam for the supply to process steam customers or heating substation. The maximum steam output of the waste heat boiler is 64 t/h. Efficiency at the boiler level is 74.8 %. There are also two 116 MW auxiliary hot water boilers (VK3 and VK4) and an auxiliary steam boiler (K7) with the maximum steam output of 80 t/h. VK3, VK4 and K7 efficiency are 88.7 %, 94.4 %, and 81.9 %, respectively.

Cogeneration installations of EL-TO Zagreb are nearing the end of their designed economic lifecycle or have already exceeded it. The Block A boiler (K6) has virtually reached the designed service life, while the Block A turbine has around 22 000 hours of operation left. Since there were some technical difficulties in the turbine operation (overspeed), and the number of startings and stoppings was certainly higher than designed, the steam turbine may have no more than a few thousand hours of operation left. Furthermore, under the requirements of Directive 2010/75/EU on industrial emissions, Block A does not comply with new air emission limit values. Given its virtually exhausted service life, no major investment in the block's modernisation would be justified, so it should remain in operation as a cold reserve only until 2018, that is, until a new block comes into operation.

Block B boilers (K8 and K9) have an average approx. 36 500 hours of operation left, and the steam turbine approx. 16 500 hours. Based on the average [annual] utilisation of 4-5 000 hours until the new block is commissioned and 2-3 000 after the new block comes into operation, Block B might remain in operation until 2025 and boilers K8 and K9 somewhat longer. But since Block B does not comply with permitted IED⁶ air emission limits either, unless elevated emissions are permitted in the future, Block B will also have to be decommissioned and become a cold reserve as early as 2018 or until the new block comes into operation.

⁶ IED – Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control) (Recast); Official Journal of the European Communities, 27.12.2010

Blocks H and J have a little more than 28 000 hours of operation left. Based on the average [annual] utilisation of around 5 000 hours until the new block is commissioned and around 2 000 hours after the new block comes into operation, Blocks H and J could remain in operation until 2023. But since these blocks do not comply with permitted IED air emissions limits, without exemptions for public heating plants they might work until the end of 2015 only. In order to be able to continue working past 2015 (with exemption for public heating plants), these blocks must reduce their NO_x emissions to below 100 mg/m³ _{sdpi5%}.

Boiler K7 is already past its service life. Not only should K7 not work, but it should not be in a cold reserve operation beyond 2018.

Hot water boiler VK3 was in operation for some 25 000 hours only and, with the current average annual utilisation, it could continue working for another 20-odd years. But on account of its age, it is not recommended to remain in operation after 2025. After the reconstruction, boiler VK3 complies with IED air emission limits.

Hot water boiler VK4 is the youngest production unit at EL-TO Zagreb, and will remain in operation after 2030. VK4 complies with IED air emission limits.

Therefore, the construction of new high-efficiency combined-cycle cogeneration installations is planned to replace the existing production facilities at EL-TO Zagreb which have reached the end of their service life.

The table below shows hours of work and planned years of decommissioning for the existing installations.

Table 32: Production facilities at EL-TO Zagreb

Production facilities			Fuel	Rated capacity	Hours of work*	Designed hours of work*	Year of commissioning	Year nominated for decommissioning
Large concrete chimney	Coupling process installations	Block A	–	12 MW _a + 55 MW _t + 40 t/h	–		1970	2018**
		K6	HFO/NG	100 t/h (115 bar / 515 °C)	242 000	200 000		
		PAT1/G-1	–	12 MW _e	202 000	200 000		
		Block B	–	30 MW _e + 90 MW _t + 42 t/h	–		1980	2018
		K8	HFO/NG	100 t/h (115 bar/515 °C)	189 550	200 000		
		K9	HFO/NG	100 t/h (115 bar/515 °C)	197 930	200 000		
		PAT2/G-2	–	30 MW _e	195 340	200 000		
	Auxiliary installations	K7	HFO/NG	80 t/h (17 bar/240 °C)	140 482	100 000	1972	2018**
		VK3	HFO/NG	116 MW _t	50 000	100 000	1991	2025
		VK4	HFO/NG	116 MW _t	2 500	100 000	2011	after 2030
PTE Zagreb	Block H	Block H	–	25 MW _e + 8 MW _t + 64 t/h	109 270		1994/1998	2023
		PT1/G-3	NG	25 MW _e		130 000		
		KU1	–	64 t/h (18 bar/235 °C)		130 000		
	Block J	Block J	–	25 MW _e + 8 MW _t + 64 t/h	107 780		1994/1998	2023
		PT1/G-3	NG	25 MW _e		130 000		
		KU1	–	64 t/h (18 bar/235 °C)		130 000		

* From commissioning until 31/12/2015

** Hours of work exceeded its designed service life.

TE-TO Zagreb

Cogeneration installation TE-TO Zagreb was put to use in 1962 on construction of two cogeneration blocks (Block A and Block B), which were initially coal-fired but were subsequently converted to liquid fuel use. As thermal energy needs increased over time, a new cogeneration unit (Block C) was put into operation, followed by the addition of a steam boiler. The first two blocks are no longer in use, having been replaced by two modern combined-cycle cogeneration blocks K and L in 2001 and 2010. Block C is a classic cogeneration installation, consisting of a steam boiler and a steam turbine connected to a 110 MW electric power generation unit. The total heat exchanger capacity is 200 MW. According to the latest data for 2014, efficiency at the Block C level was 68.5 %. Block K is a modern combined-cycle cogeneration installation, consisting of two gas turbines and power generation units with a total output of 142 MW, as well as two two-pressure waste heat boilers and one steam condensation turbine with

the maximum electrical output of 66 MW. Thermal energy is delivered to end-users in the forms of process (industrial) steam and through DHS network water heating. Efficiency at the Block K level is 69.7 %. Block L is a cogeneration installation identical to Block K, differing only in the 75 MW electric output of the gas turbine with a generator and the maximum 40 MW electrical output of the steam condensation turbine with a generator. This block also serves to supply process steam to the end-users and for DHS water heating. Its efficiency is 68.9 %. There are also four hot water boilers (VK3, VK4, VK5, and VK6) and one steam boiler (PK3), with the overall thermal input of 348 MW. The hot water boiler efficiency for 2014, as the latest year analysed, was 90.0 %, 90.0 %, 89.6 %, and 86.6 %, respectively, while the PK3 efficiency was 96.75 %.

Future utilisation of existing installations at TE-TO Zagreb will be largely dictated by environmental regulations. Because of the obligation to achieve the emission limit values for all thermal energy installations starting from 1 January 2018, the existing units require substantial investment in order to meet the emission limit values.

Combined-cycle cogeneration installations (Block K and Block L) comply with more stringent restrictive emission limit values; with regular maintenance, they can remain in operation until 2030 (Block K) and 2040 (Block L).

Block C has worked only 130 000 hours, so it could remain in operation for another 20 years or so before the end of its service life. But since it cannot be overhauled in order to meet IED requirements, it is planned to stop working when IED requirements enter into force in 2018. However, Block C will remain a cold reserve until its planned decommissioning in 2028.

Existing hot water boilers can be fitted with low NO_x burners to prolong their service life. The old, worn-out boilers VK3 and VK4 are to be completely overhauled, extending their service life until 2035. Burners on the boilers VK5 and VK6 are also to be replaced, so their service life will be extended until 2035 as well. The planned overhaul will ensure that all hot water boilers comply with the requirements of emission limit value.

Although the boiler PK3 has worked no more than some 62 000 hours and could still work, the IED air emission limits mandate that it be replaced by two new 25 t/h boilers.

The table below shows hours of work and planned years of decommissioning for the existing installations.

Table 33: Production facilities at TE-TO Zagreb

Production facilities			Fuel	Rated capacity	Hours of work*	Designed hours of work*	Year of commissioning	Year nominated for decommissioning
Large concrete chimney	Auxiliary facility	VK3	HFO/NG	58 MW _t	35 300	100 000	1977	after 2030
		VK4	HFO/NG	58 MW _t	34 400	100 000	1978	after 2030
		VK5	HFO/NG	116 MW _t	41 150	100 000	1982	2029
		VK6	HFO/NG	116 MW _t	31 250	100 000	1990	after 2030
		PK3	HFO/NG	80 t/h (20 bar/280°C)	61 900	100 000	1985	2018
	Coupling process installations	Block C		120 MW _e + 200 MW _t	128 700		1979	2028
		K3	HFO/NG	500 t/h (140 bar/560 °C)		200 000		
		PAT3/G-3	-	120 MWe		200 000		
	Block K	Block K		208 MW _e + 140 MW _t	85 000		2001	after 2030
		PT1/G-4	NG/SLFO	71 MWe		140 000		
		KU1	-	109 t/h (95 bar/539 °C) 12 t/h (10 bar/287 °C)		140 000		
		PT2/G-5	NG/SLFO	71 MWe		140 000		
		KU2	-	109 t/h (95 bar/539 °C) 12 t/h (10 bar/287 °C)		140 000		
		PAT4/G-6	-	66 MW _e		200 000		
Block L	Block L			112 MW _e + 110 MW _t	26 500		2011	after 2030
	PT3/G-7	NG	75 MW _e			140 000		
	KU3	-	107 t/h (95 bar/540 °C) 25 t/h (11 bar/280 °C)			140 000		

Production facilities		Fuel	Rated capacity	Hours of work*	Designed hours of work*	Year of commissioning	Year nominated for decommissioning
	PAT5/G-8	–	37 MW _e		200 000		

A detailed description of the above cogeneration installations is provided in Chapter 6.

The Zagreb heating system data are provided in Annex 14.3.13.

7.3. COMMENT ON ENERGY EFFICIENCY

It is evident from data on thermal systems in Croatia, broken down by cities, that aggregated data only are available for a particular installation. To analyse energy efficiency of particular components of the heating systems based on directly measured values, accurate and reliable data on consumption, production and sale of thermal energy are indispensable. Armed with such data, one can very easily determine the actual degree of utilisation not only of the entire systems but of their individual parts as well. Since this is not the case here, where aggregate data only are available, only the most basic analysis was carried out and energy efficiency was analysed at the overall level, relying solely on the comparison of the main indicators without the impact of climate conditions or taking into account the particularities affecting the indicators, such as the fact that domestic hot water generation is also a part of some systems or the distinction between day and night operating regime.

At this point, it is important to note that the only credible data concern the resulting overall heating system efficiency calculated, taking into account the energy of the fuel consumed and thermal energy supplied since the data provided may not be claimed to be absolutely accurate, both in terms of the records of fuel consumed and of thermal energy supplied and charged to final customers.

The overall efficiency indicators calculated have a wide range, so it is impossible to use them for drawing unambiguous conclusions. Such data are more useful in describing data quality itself rather than to the quality of energy processes. The figures were expected to fall between 65 % and 80 %, depending materially on the type of fuel used, structural characteristics of boilers, boiler rooms, their age and maintenance, and on the length and installation method of the hot water pipeline network. The efficiency level higher than 80 % may be expected of home boiler rooms without distribution network, and a new generation of natural gas-fired boilers.⁷

7.4. COMMENT ON THE TECHNICAL AND TECHNOLOGY CHARACTERISTICS OF INSTALLATIONS AND HEATING NETWORKS

In analysing the current condition of installations and equipment, according to data provided in Annex 14.3, one may note that partial data only were available. Such partial data, as well as graphics provided herein below, show that the year of manufacture of boilers ranges over a long period of time, with the oldest boiler dating back to 1971 and the latest one to 2013. Considerably fewer data were available for burners, but the range for their year of manufacture is identical: from 1971 to 2013.

In order to gain a better insight into the age of the installations, the average boiler age was calculated at 26 years. It is a very significant figure, which characterises the existing thermal energy production facilities in Croatia's heating systems.

⁷ Strategy of heating sector development in Croatia – Phase 1/3, 2008

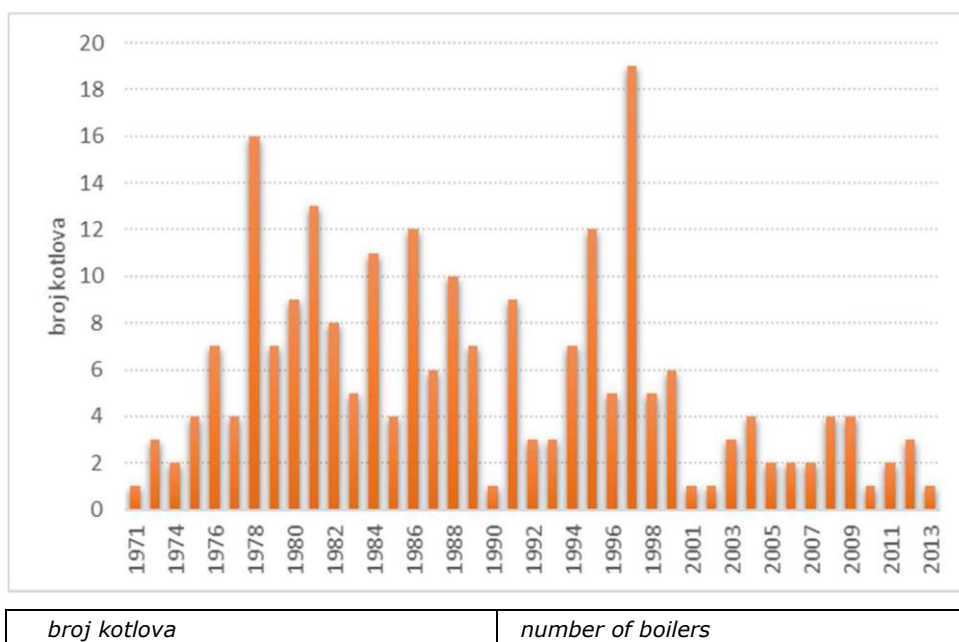


Figure 63: Age of existing boilers

The age of existing burners is provided in the chart below, showing their average age as 29 years, and even though fewer data are available, it is a good illustration of the current condition. It is important to note that the burner and boiler age data are not comparable because of incompleteness, so they are provided for information purposes only.

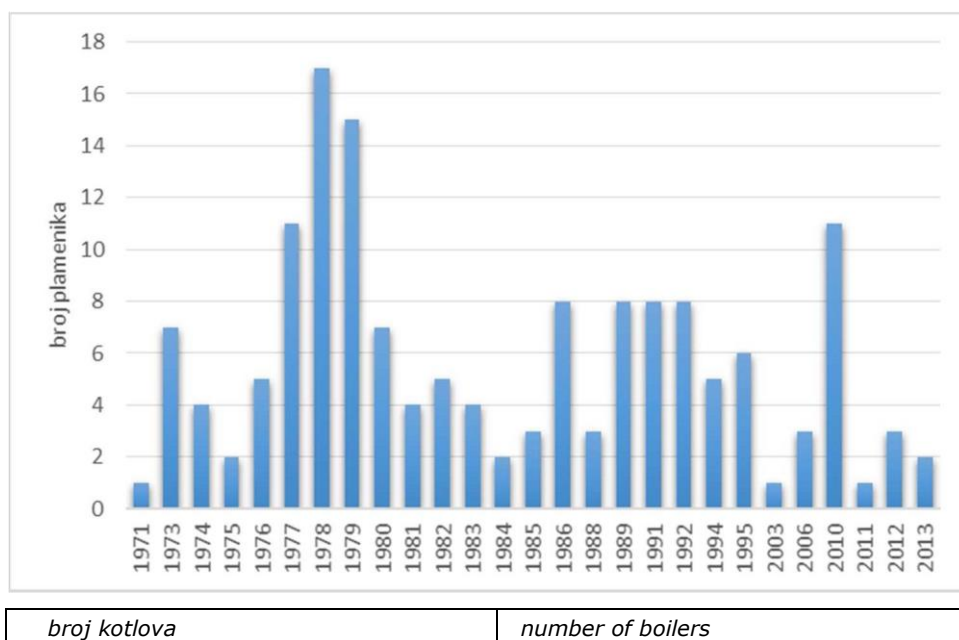


Figure 64: Age of existing burners installed in the systems

In accordance with good engineering practice, boiler plants are considered to be in a satisfactory condition if their age is up to 25 years, pumping stations up to 30 years, and the pipeline network up to 35 years old, where the condition of the equipment is consistent with its exploitation history, with only slight signs of wear visible. However, the data obtained do not lead to such a conclusion, but rather point to the fact that these installations are approaching the end of their service life in a considerable number of cases covered by the analysis.

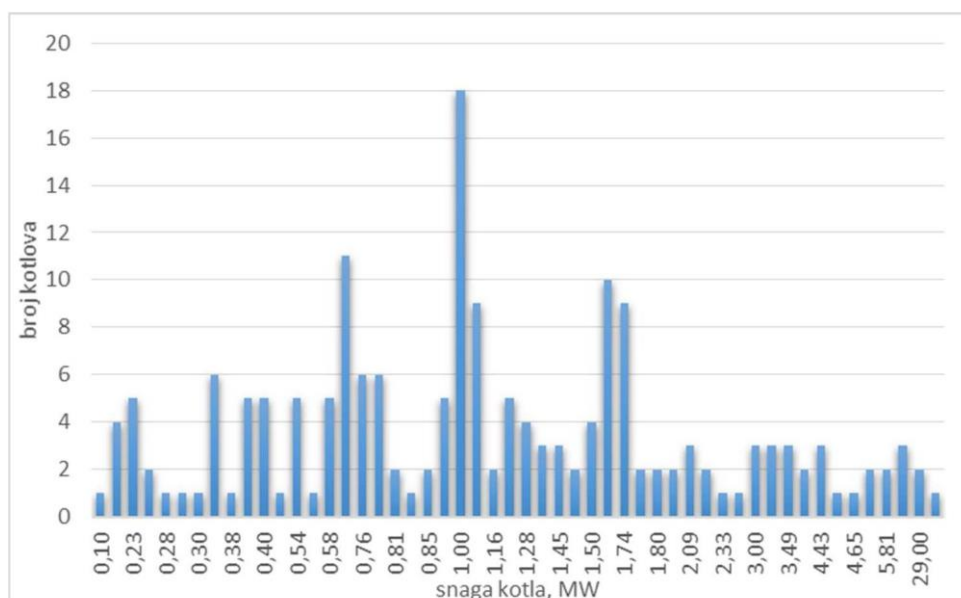
A summary of good engineering practice in assessing the condition of parts of the heating systems is provided in the table below.

Table 34: Assessment of parts of the heating systems⁸

Assessment	Equipment condition	Condition description	Age of equipment
1	Very bad	Equipment service life exhausted. General appearance poor, surface corrosion, leakages, mechanical damage, cracks, insulation damaged etc. Insufficient or no maintenance. Installation functionally deficient or works with frequent failures and outages. Major losses. Inefficiency. Obsolete technical solutions. To be replaced urgently.	Boiler plants: over 25 years Pumping installations: over 30 years Network pipelines: over 35 years
2	Bad	Equipment condition bad due to either age or poor maintenance during exploitation. General appearance poor. Equipment functioning but at a high risk of failure or outage. Obsolete technical solutions. Inferior efficiency. Losses. Major repairs or replacements required to reinstate satisfactory functionalities. Plan replacements as soon as possible.	Boiler plants: over 25 years Pumping installations: over 30 years Network pipelines: over 35 years
3	Satisfactory	Equipment condition consistent with its exploitation history. Only slight traces of wear visible. Equipment under systematic maintenance (replacements and repairs) during exploitation. Function of the equipment is at satisfactory level under increased monitoring, care and maintenance. Replacements are only necessary for efficiency improvements and application of more up-to-date solutions.	Boiler plants: up to 25 years Pumping installations: up to 30 years Pipelines network: up to 35 years
4	Good	Only slight traces of exploitation are visible. Minor defects and faults in the previous operation have always been repaired through regular maintenance. Functionality, availability and reliability of the plant are appropriate. Relatively up-to-date solutions and construction. Further exploitation possible for another 10-15 years, given proper maintenance.	Boiler plants: 10-20 years Pumping installations: 10-20 years Network pipelines: 15-25 years
5	Very good	No traces of exploitation visible. No major failures in past operation. Systematic maintenance carried out. Up-to-date technology, resulting in appropriate efficiency. Equipment virtually new and, given proper maintenance, may be used for another 15-20 years.	Boiler plants: up to 10 years Pumping installations: up to 10 years Network pipelines: up to 15 years

To get an insight into a wide range of capacities (output) of analysed boiler plants, it should be noted that individual boiler output ranges from 58 MW in Karlovac to 0.1 MW in a home boiler room in Velika Gorica, as shown in the figure below. It may be concluded that most boilers under 2 MW, or more than 80 % of all those analysed, have a heating capacity of less than 2 MW.

⁸ Strategy of Heating Sector Development in Croatia – Phase 1/3, 2008



broj kotlova	number of boilers
snaga kotla, MW	boiler output, MW

Figure 65: Capacity (output) of existing boilers

With regard to boiler manufacturer data available, the shares of particular manufacturers in existing boilers installed in heating systems are shown in the chart below. The most widely represented are Toplota and EMO with some 20 per cent.

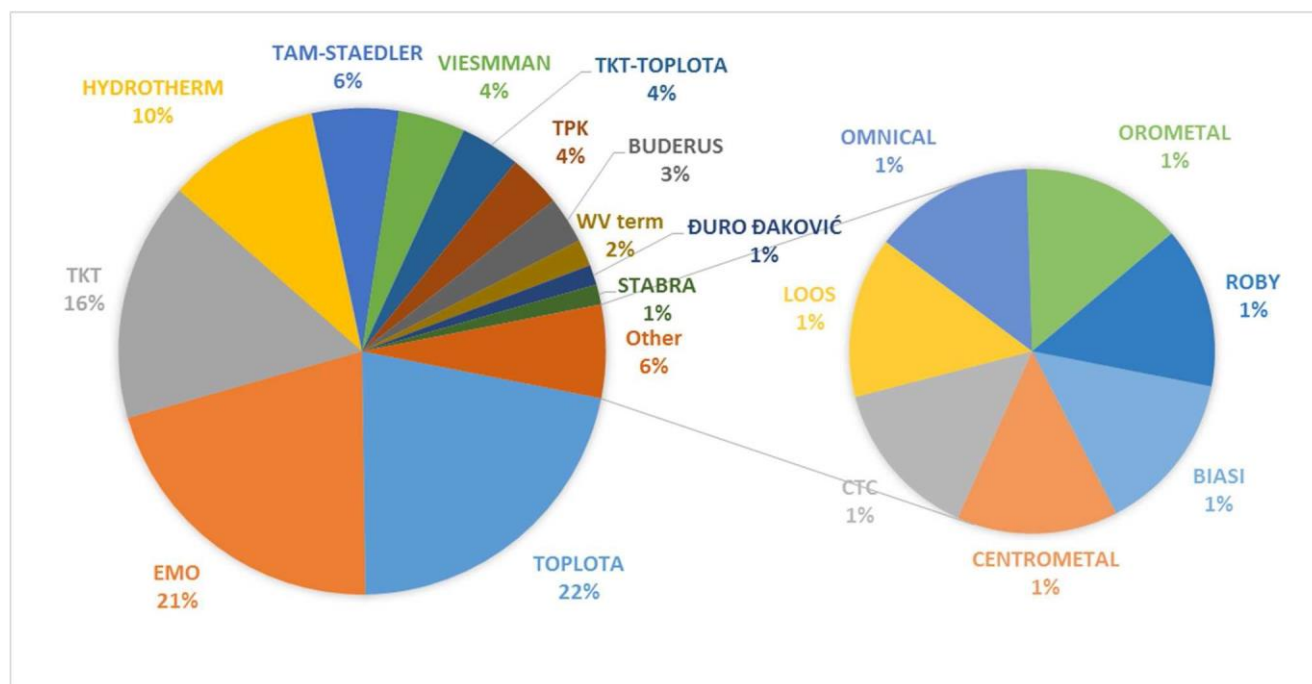


Figure 66: Proportion of boiler manufacturers in heating systems in Croatia

With regard to the manufacturers of burners installed in thermal installations in Croatia, the situation is quite different. The most widely represented are the burners made by Weishaupt, accounting for more than 90 per cent of all installed burners for which data were available.

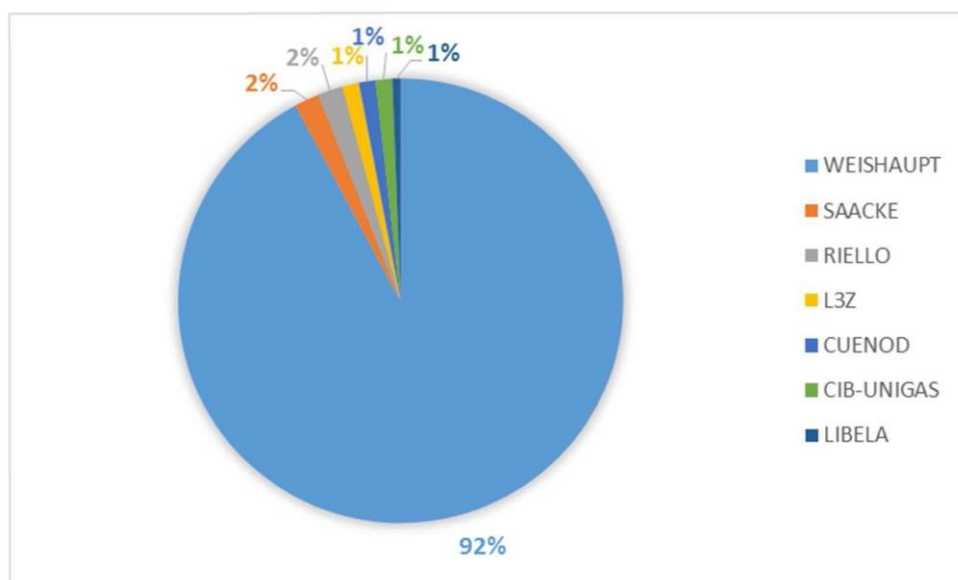


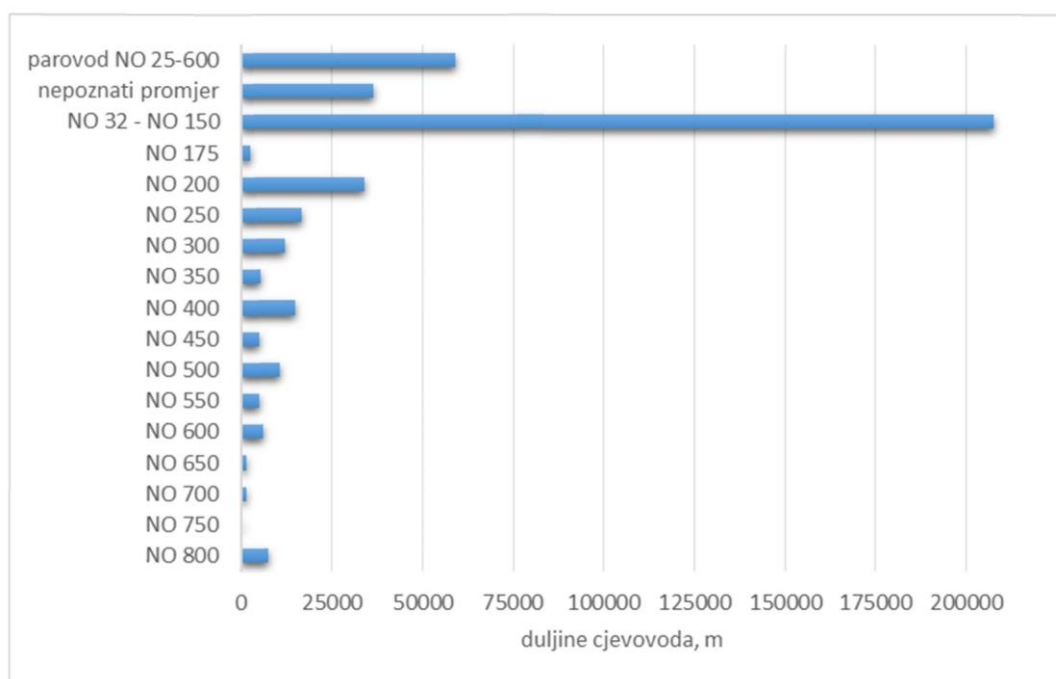
Figure 67: Shares of manufacturers of burners installed in heating systems

An overview of heating network lengths, according to their nominal diameter in respective cities is provided in the table below. It should be noted that data providing the dimensions of existing networks are partial, reflecting only those available.

Table 35: Existing thermal network by nominal diameter and city

Network diameter	Osijek	Sisak	Zagreb	Samobor	Velika Gorica	Zaprešić	Karlovac
NO 800			7 292				
NO 750			312				
NO 700			1 388				
NO 650	580		791				
NO 600			5 363				700
NO 550	4 960		0				0
NO 500	1 100		9 408				100
NO 450	0		4 827				0
NO 400	1 500		12 800				450
NO 350	1 350	1 070	2 494				270
NO 300	1 840		8 739				1 578
NO 250	4 240	586	8 857			130	2 609
NO 200	3 520	820	23 275	55	2 407	90	3 598
NO 175	0	91	1 821	0	377	0	0
NO 32-NO 150	37 110	13 104	133 299	3 029	7 037	1 440	12 691

The network length breakdown by nominal diameters of the existing pipeline is provided in the chart below.



<i>parovod NO 25-600</i>	<i>steam pipeline NO 25-600</i>
<i>nepoznati promjer</i>	<i>diameter unknown</i>
<i>duljine cjevovoda, m</i>	<i>pipeline length, m</i>

Figure 68: Network length breakdown by nominal diameters of the existing pipeline

For most existing hot water/heat/steam pipelines there was no information available on the actual pipeline construction or installation method, or on the age of particular sections; therefore no analysis was possible from the aspect of possible future savings (loss reduction) by replacing worn-out trenched pipelines with pre-insulated pipes, which has been the established practice for some time now.

Since a part of the heating networks was built at the time of boiler room construction, and taking into account that the average age of existing boiler plants is 26 years and the age of burners 29 years, even the part of the heating networks which has not been replaced to date will shortly be ready for replacement with pre-insulated pipelines, as the most commonly used nowadays. An overview of normal service life of pipeline systems by type is provide in the table below.

Table 36: Typical service life by type of piping

Piping system	Service life in years
pre-insulated pipes	20-40
overhead piping	20-50
buried piping	20-50
steel-in-steel pipes	20-40
condensate pipes	20-30

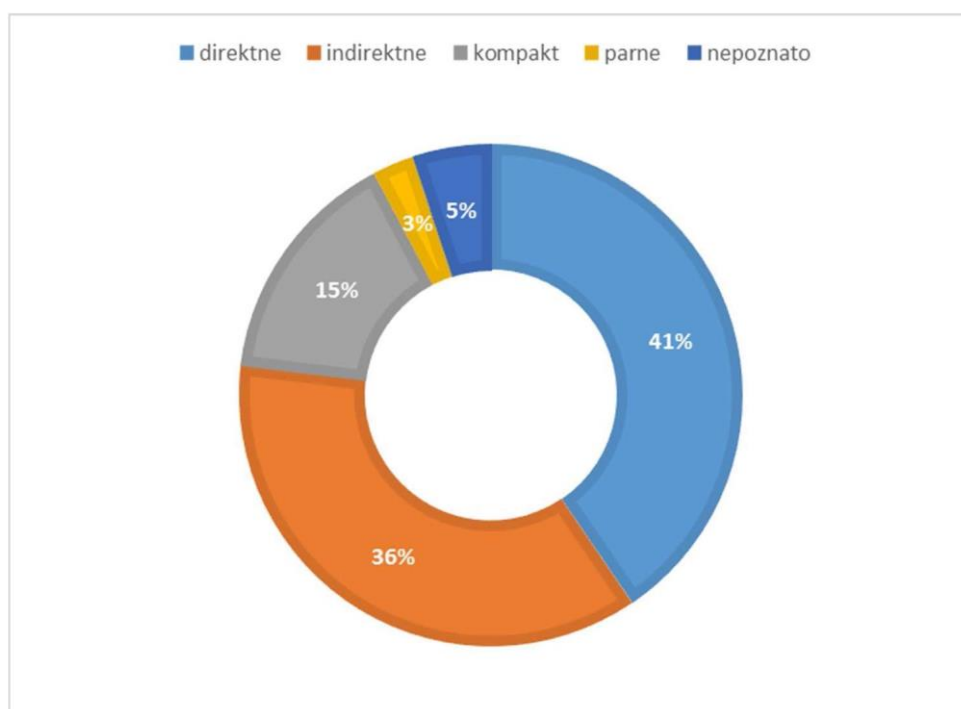
Network losses are defined as the difference between the annual amount of heat supplied to the district heating network and the annual amount of heat delivered to all customers connected to the system. In the engineering practice, losses for modern district heating networks which use pre-insulated pipes are estimated at 6-8 per cent. Older network systems often exhibit greater losses because they were designed for lower energy costs and have poor insulation.

Heating stations are used to connect consumers' home installations to the district heating network. Consumers connection may be direct or indirect. In the case of indirect connection, the heat exchanger provides hydraulic separation and in the case of a direct connection there is no heat exchanger, so the same medium (water) is used in the secondary circuit. It is recommended that directly connected systems be equipped with a fluid leak monitoring system. Today, indirect thermal connections with a heat exchanger in the heating station are mandated. Data on existing heating substations, where available, in the heating systems in Croatia are shown in the table below.

Table 37: Overview of heating stations by type

City	No of heating stations by type				
	Direct	Indirect	Compact	Steam	Total
Zagreb	898	1 301	478	120	2 797
Osijek	451	113	137		701
Sisak	67	21	77		165
Samobor	23	7	0		30
Velika Gorica	108	12	0		120
Zaprešić	22	14	0		36
Karlovac	192	0	0		192
Rijeka	0	168	0		168
Virovitica	21	0	0		21
Varaždin	38	1	0		39
Slavonski Brod		48			48
Vinkovci		54			54
Vukovar		93			93
Ogulin		12			12
Topusko		19			19

The shares of particular heating substation types in the heating systems in Croatia are provided in the chart below.



<i>direktne</i>	<i>direct</i>
<i>indirektne</i>	<i>indirect</i>
<i>kompakt</i>	<i>compact</i>
<i>parne</i>	<i>steam</i>
<i>nepoznato</i>	<i>unknown</i>

Figure 69: Shares of heating substation types in existing heating systems

Evidently, the existing heating substations of the direct type have the largest share.

7.1. COMMENT ON THE POTENTIAL TO INCREASE ENERGY EFFICIENCY OF THE EXISTING INFRASTRUCTURE

Even on the assumption that energy efficiency in the part of the buildings sector which is already connected to thermal energy supply by district heating systems increases, such measures may be said not to have a directly positive impact on further development of district heating systems. Specifically, if the energy efficiency of buildings increases through renovation and building envelope revitalisation, this will inevitably lead to a decrease in building heating needs. That fact is not favourable for the district heating systems from the commercial point of view because it implies a reduction in market demand for thermal energy as a product, and thus in revenue and profit decline. Therefore, an increase in energy efficiency of the building sector may have a negative impact on further district heating system development. However, it does not translate into impossibility of conceiving adequate economic models which will enable companies engaging in thermal energy production, distribution and supply to retain their profit levels in such cases. Among the possible solutions is the application of the so-called ESCO model, which might enable such companies to retain their profit, while also ensuring an increase in energy efficiency of the building sector. Naturally, the application of such a model requires prior detailed economic analysis.

Energy efficiency of the heating systems is related to the condition of infrastructure and energy parameters of the heating medium – water, transported through the pipeline system. A review of past development and the monitoring of trends reveals four typical generations of district heating systems. They can be distinguished the most by the heating medium temperature regime, which has undergone major changes in the course of historical development of district heating systems. But the continuous tendency to lower the flow temperature of the heating medium has always been present. The reason for it lies in the fact that the lowering of the flow temperature reduces thermal losses. In addition to reducing the flow temperature, it is desirable to maximise the temperature difference. The results are mainly positive. Specifically, by increasing the temperature difference, i.e. the difference between the flow temperature of the heating medium delivered to consumers and that of the return medium, reduces the mass flow and thus leads to a reduction in the costs of energy required to drive circulation pumps. Another positive effect is a decrease in the pipeline diameter which leads to lower capital costs when investing in a new pipeline network, as well as to a reduction in heat losses in the pipeline systems.

The distribution network, i.e. the pipeline system of district heating systems, serves primarily for transporting the thermal energy contained in the heating medium from the thermal energy source to the end-consumers. The requirements set for the distribution network include a minimisation of heat losses into the environment, operational reliability and resistance to corrosion. Furthermore, when designing or revitalising piping, not only appropriate pipeline dimensions but also suitable material need to be selected. District heating system piping is often exposed to high pressures and temperatures. This is most pronounced in so-called second generation systems, which are actually the most common in Croatia. Such piping requires a special approach to revitalisation. Pre-insulated pipes, which are placed directly into a trench in the ground, are available in the market today. A steel pipe serving for heating medium transport is coated with insulating material (most commonly, polyurethane foam of sound thermodynamic properties in terms of heat conduction). A polyethylene casing pipe, preventing moisture penetration into the insulation layer which would alter its insulation properties, is used as the outermost layer. Moisture detector wires are also installed in pre-insulated pipes to signal damage to the polyethylene or steel pipes. It may be concluded that the piping system is among the most relevant elements when seeking to increase energy efficiency of district heating systems since the replacement of old, worn out pipes laid in concrete channels reduced heat losses to the environment on the one hand, while also reducing piping leaks due to corrosion and mechanical damage, which frequently generates substantial heat losses in existing systems.

Consumers are the last link in the chain of thermal energy production, distribution and supply. End-users of thermal energy, mostly households, receive their thermal energy from heating substations. With regard to the method of connection of end-users, there are two types of heating substations. The modern method involves a so-called indirect system, in which thermal energy brought via the heating medium is delivered through the heat exchanger to the heating medium of the secondary circuit. The other method of connection is the direct type. In such systems, the heating medium flow directly from the central heating source through the heating units (radiators) of end-users. Direct systems are very rare and they are avoided for safety and environmental reasons, as well as for the purpose of simplifying the management and regulation of the entire system.

In the construction of new or revitalisation of existing systems, it is necessary to ensure optimal system operation parameters so that the district heating system may achieve the best performance in both energy and economic terms. Such systems are characterised by distinctively long transient

periods, which pose a fundamental problem in determining the dynamics, regulation and strategy of system management. Thus, for example, there is a reasonable possibility of pressure oscillations in more complex networks (e.g. branched pipeline network with various altitudes). Or else, pressure oscillations may occur in the case of incorrectly sized differential pressure controllers, which are usually located in each heating substation. Their function is to optimise the overall system heating source, coupled with the distribution, pipeline network and end-users. An integrated approach to designing the entire system leads to a synergy effect, resulting in optimum system management.

7.2. IN LIEU OF A CONCLUSION

In view of incomplete and limited data and of their questionable quality, resulting in unrealistic energy efficiency indicators, it is impossible to quantify energy savings.

Considering the high average service life of the heating systems and their components, the conclusion is that the potential for energy savings certainly exist but, given the ratio of the prices of thermal energy supplied and required investments, their economic viability is questionable.

In conclusion, it can be stated that each measure should be separately considered and evaluated.

Principal measures by which better energy efficiency of DHSs may be achieved are the following:

- installation of new generation fuel combustion (burner) systems;
- construction of cogeneration installations instead of conventional boiler or individual boiler-based heating;
- replacement of old distribution network pipes with pre-insulated pipes;
- construction of heat accumulators;
- installation of speed controlling devices on electrical engines driving pumps in heating stations and heating distribution systems;
- replacement of old heating stations with new generation stations;
- installation of thermostatic mixing valves in heating stations;
- installation of new generation control and metering equipment in new buildings;
- improvement of thermal insulation in buildings.

Although the level of expertise of professional participants is at a satisfactory level, relatively few projects for the improvement of energy efficiency of the existing Croatian district heating systems have been implemented. The reason for it lies in lack of economic justification due to a high cost of equipment and construction in comparison to relatively low energy prices in Croatia. When difficulties with collection for the thermal energy supplied, technically and technologically outdated equipment and infrastructure of most DHSs in Croatia, which operate with losses, are added to the equation, it is clear why companies engaging in thermal energy production and distribution refrain from investing in energy efficiency projects. Problem resolution should not be left to the profession alone but, in addition to the technical aspects analysed, economic and legal aspects hindering the implementation of energy efficiency measures must also be considered. Therefore, it is precisely this energy sector segment that requires financial government incentives and new legislative measures which might, altogether, result in considerable energy savings.

8. STRATEGY, POLICIES AND MEASURES

8.1. INTRODUCTION

The first part of this chapter provides an overview of relevant directives and Croatia's legal and strategic framework, including laws and implementing regulations which regulate the thermal energy market in particular, general energy regulations of relevance to the heating sector, as well as regulations and legal strategy documents that affect the rights and obligations of the entities involved in the heating sector by defining the measures to increase energy efficiency and use of renewable energy sources (RES).

The second part provides strategic guidelines which are to assist in the activities aimed at defining national energy and climate policies and measures, as regards the DHS potential for heating and cooling and its contribution to the targets set by the respective policies.

These guidelines are founded on the conclusions of the analyses of DHS development, based on an increase in energy consumption, forecast changes in the energy consumption for heating and cooling in the coming period, heat demand to be met by high-efficiency cogeneration, potential for additional high-efficiency cogeneration and energy efficiency of the infrastructure, as well as the impact of the energy markets on the development and implementation of the projects based on high-efficiency cogeneration and DHS use for heating and cooling.

8.2. ACQUIS COMMUNAUTAIRE

Although district heating and cooling are not directly regulated by EU documents, certain EU directives include special measures to regulate or affect the thermal energy production/consumption for heating and cooling. These include, primarily, Directive 2004/8/EC on the promotion of cogeneration based on a useful heat demand in the internal energy market, the Energy Efficiency Directive, the Energy Performance of Buildings Directive, the Renewable Energy Directive, the Energy Labelling Directive and the Industrial Emissions Directive.

8.2.1. Directive 2004/8/EC on the promotion of cogeneration based on useful heat demand in the internal energy market

The purpose of this Directive is to increase energy efficiency and improve supply security by creating a framework for promoting and developing high-efficiency cogeneration based on useful heat demand and primary energy savings in the internal market, taking into account the specific national circumstances especially concerning climatic and economic conditions.

This Directive governs the cogeneration efficiency criteria; conditions of guarantee of origin of electricity from high-efficiency cogeneration; analysis of national potentials for high-efficiency cogeneration; high-efficiency cogeneration support schemes; grid access and tariffs; administrative procedures or the legal framework aimed at encouraging the design of cogeneration units to match economically justifiable heat demands, reducing the regulatory and non-regulatory barriers to an increase in cogeneration, expediting administrative procedures and ensuring that the rules are objective, transparent and non-discriminatory; Member States' reporting on the analyses and evaluations carried out, as well as other matters significant for the promotion of high-efficiency cogeneration.

8.2.2. Directive 2012/27/EU on energy efficiency

This document establishes a common framework of measures for the promotion of energy efficiency within the EU in order to ensure the achievement of the Union's 2020 20 % headline target on energy efficiency and to pave the way for further energy efficiency improvements beyond that date.

This Directive lays down rules designed to remove barriers in the energy market and overcome market failures that impede efficiency in the supply and use of energy, and provides for the establishment of

indicative national energy efficiency targets for 2020. In this regard, the respective requirements concerned are minimum and do not prevent any Member State from maintaining or introducing more stringent measures.

This Directive particularly encourages efficiency in heating and cooling, committing the Member States to carry out a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling by the end of 2015.

8.2.3. Directive 2010/31/EU on the energy performance of buildings

This Directive promotes the improvement of the energy performance of buildings within the European Union, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness.

While noting they are minimum requirements and do not prevent any Member State from maintaining or introducing more stringent measures, this Directive lays down the following requirements relating to:

- the common general framework for a methodology for calculating the integrated energy performance of buildings and building units;
- the application of minimum energy performance requirements for new buildings and new building units, including the reduction of heat demand;
- national plans for increasing the number of nearly zero-energy buildings;
- energy certification of buildings or building units;
- regular inspection of heating and air-conditioning systems in buildings;
- independent control systems for energy performance certificates and inspection reports.

8.2.4. Directive 2009/28/EC on the promotion of the use of energy from renewable sources

This Directive establishes a common framework for the promotion of energy from renewable sources. It sets mandatory national targets for the overall share of energy from renewable sources in gross final consumption of energy and for the share of energy from renewable sources in transport. It also lays down rules relating to statistical transfers between Member States, joint projects between Member States and with third countries, guarantees of origin, administrative procedures, information and training, and access to the electricity grid for energy from renewable sources.

This Directive includes energy for heating and cooling in the renewable energy targets by 2020 and promotes the direct use of renewable energy sources in buildings and the use of renewable energy sources in district heating and cooling as an instrument aimed at achieving that target.

8.2.5. Directive 2010/30/EU concerning the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products.

This Directive establishes a framework for the harmonisation of national measures on end-user information, particularly by means of labelling and standard product information, including heating and cooling equipment, on the consumption of energy and, where relevant, of other essential resources during use, and supplementary information concerning energy-related products, thereby allowing end users to choose more efficient products.

8.2.6. Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control)

This Directive lays down rules on integrated prevention and control of pollution arising from industrial activities, as well as rules designed to prevent or, where that is not practicable, to reduce emissions into air, water and land and to prevent the generation of waste, in order to achieve a high level of protection of the environment taken as a whole.

8.3. LEGAL FRAMEWORK OF THE REPUBLIC OF CROATIA

In addition to the Energy Act, which lays down rules of relevance for all forms of energy, the thermal energy market is particularly regulated by the Thermal Energy Market Act and extensive implementing regulations that govern relations between thermal energy suppliers and customers using thermal energy. Some provisions with relevance for the heating sector may be found in the Energy Efficiency Act and in part also in the Renewable Energy Sources and High-Efficiency Cogeneration Act, which focuses on the promotion of power generation from renewable sources and high-efficiency cogeneration. Regulations in the field of building segment energy efficiency are a special segment of the legal framework, and they fall within the scope of competence of the ministry responsible for construction activities.

8.3.1. Thermal Energy Market Act

As a special act governing the thermal energy market, the Thermal Energy Market Act (NN Nos 80/13, 14/14, 102/14 and 95/15) regulates the measures for safe and reliable supply of thermal energy, thermal systems using thermal energy for heating and cooling, conditions for the grant of a heat distribution concession and concession for the construction of the distribution network, rules and measures for safe and reliable thermal energy generation, distribution and supply activities in the heating systems, as well as measures to achieve energy efficiency in heating systems.

This Act transposes Directive 2009/28/EC on the promotion of the use of energy from renewable sources, Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency into Croatian legislation.

The Act is organised in 11 chapters as follows:

- I. General provisions
- II. Interest to the Republic of Croatia
- III. Performance of energy activities
- IV. Thermal energy buyer activities [and] Electricity transmission
- V. Thermal energy systems
- VI. Thermal energy production
- VII. Thermal energy distribution
- VIII. Thermal energy supply
- IX. Inspection
- X. Infringement provisions
- XI. Transitional and final provisions

The Act defines the construction and development of district heating systems, the production of thermal energy in high-efficiency cogeneration installations, as well as their maintenance and use as being of interest to the Republic of Croatia. Also, heating systems are considered to be an important element of energy efficiency and are of interest for achieving Croatia's energy efficiency targets.

For that purpose, special tasks have been delegated to local self-government units, which are required to do the following:

- stimulate, plan and approve the construction of heating systems and, in accordance with energy efficiency measures, ensure that priority in construction is given to district heating systems while also providing a connection of closed heating systems to district heating systems where appropriate;
- plan the development of heating systems if there are cogeneration installations are in their territory or if they are developing RES cogeneration installations in their territory; and
- when drafting spatial planning documents, give priority to the construction and development of distribution networks, which would be used to meet thermal energy needs of households, commercial consumers and industry.

The ministry responsible for energy is responsible for the monitoring of thermal energy market supply and demand, the preparation of future consumption and current thermal energy supply estimates, the planning of the additional district heating system capacity construction and development, and the proposal and implementation of measures to be taken should the state of crisis be declared. On the basis of annual reports of local self-government units, the ministry submits a report to the Croatian Government on the state of affairs and measures to be taken for the purpose of district heating system development.

The Act regulates the status of all thermal energy market participants. Thus, a thermal energy producer is a legal or natural person licensed by the Croatian Energy Regulatory Agency to engage in the heat production energy activity. The licence is mandatory for the production of heat in a heating system with boiler rooms which have installed production capacity exceeding 2 MW.

The status of an eligible electricity and heat producer may be acquired by energy operators using an energy cogeneration installation and using waste, biodegradable portions of waste or renewable energy sources to produce thermal energy in an economically appropriate manner, in compliance with the regulations governing environmental protection and waste management. Having acquired the status of eligible producers of electricity and thermal energy from cogeneration pursuant to the Electricity Market Act, legal or natural persons are required to obtain a heat generation licence too. For the purpose of efficient use of energy sources in cogeneration installations while meeting buyers' needs for thermal energy at the same time, planned electricity generation conditional upon simultaneous thermal energy consumption for heating and/or cooling has acceptance priority in the power grid.

In planning the construction of new generation installations, the cost-benefit analysis under the Energy Efficiency Act is to be carried out if:

1. a new electricity and thermal generation installation with a total thermal input exceeding 20 MW is planned, in order to assess the cost and benefits of providing for the operation of the installation as a high-efficiency cogeneration installation;
2. an existing electricity and thermal generation installation with a total thermal input exceeding 20 MW is substantially refurbished, in order to assess the cost and benefits of converting it to high-efficiency cogeneration;
3. an industrial installation with a total thermal input exceeding 20 MW generating waste heat at a useful temperature level is planned or substantially refurbished, in order to assess the cost and benefits of utilising the waste heat to satisfy economically justified demand, including through cogeneration, and of the connection of that installation to a closed and district heating and cooling systems;
4. new closed and district heating systems are planned or, in existing closed and district heating systems, a new energy production installation with a total thermal input exceeding 20 MW is planned or an existing such installation is to be substantially refurbished, in order to assess the cost and benefits of utilising the waste heat from nearby industrial installations.

Production installations may be built by legal or natural persons if such planned production installations meet the criteria laid down in the procedure of energy approval issuing in accordance with the Electricity Market Act. The criteria governing the procedure of issuing energy approval for the construction of generation installations are public, and are based on the principles of objectivity, transparency and impartiality; some of them are also energy efficiency criteria and contribution of the capacity to the overall target for the share of RES energy and energy efficiency in 2020 gross final energy consumption in the European Union, within the scope of compliance of Croatia with its international obligations for the energy sector and in accordance with the regulations constituting the Union *acquis communautaire*. When selecting an energy solution, in deciding on the construction of production installations, the construction of a RES- and/or waste-fuelled cogeneration installation is always given priority over other types of production installations. Energy approval is not necessary for the production of thermal energy from RES or cogeneration in simple buildings, as defined by the regulations on the physical planning and construction; no energy approval is issued for the construction of or works on such buildings.

Technical requirements for thermal energy production installations are to be regulated by the rules, adopted by the minister competent for the energy sector, in cooperation with the ministry competent for construction activities.

With a view to increasing the national thermal energy potential for heating and cooling, in accordance with the Energy Efficiency Directive, an obligation has been laid down for the Croatian Government to adopt a Programme of Heating and Cooling Efficiency Potential Utilisation, and the contents of that document have been defined.

8.3.2. General Terms and Conditions of Thermal Energy Supply

General Terms and Conditions of Thermal Energy Supply (NN No 35/14) govern the relations between thermal energy producers, distributors and suppliers, duties and responsibilities of thermal energy producers, distributors and suppliers, as well as the criteria of quality and security of thermal energy supply, the conditions governing restrictions and suspension of thermal energy supply, the terms of

accounting and collection of heat charges, the procedure of switching between thermal energy suppliers, measures to protect final customers and legal protection.

8.3.3. General Terms and Conditions of Thermal Energy Delivery

General Terms and Conditions of Thermal Energy Delivery (NN No 35/14) govern the relations between thermal energy suppliers and the thermal energy buyer, the relations between the thermal energy buyer and final customers, the duties and responsibilities of thermal energy suppliers and the thermal energy buyer, duties and responsibilities of the thermal energy buyer and final customers, the terms of accounting and collection of heat charges, the conditions governing restrictions and suspension of thermal energy delivery, investment, reconstruction and maintenance of production plants and internal installations, the access to thermal energy meters and connection installations, procedure in the event of unauthorised thermal energy use, the procedure in the event of technical and other disruptions in thermal energy supply, the procedure in the event of heat redistribution to the final customer, the procedure in the event that an entire building/structure is disconnected from the thermal system, measures to protect final customers, the procedure governing a change of the thermal energy buyer, the method of informing final customers about thermal energy consumption and costs, the thermal energy buyer's obligation to inform final customers of any change in the final price of thermal energy, the right to consumption data, including the right to forward such data to another thermal energy buyer and the conditions thereof, and legal protection.

8.3.4. Network Rules of Thermal Energy Distribution

Network Rules of Thermal Energy Distribution (NN No 35/14) govern the distribution network description, development, construction and maintenance, the management and supervision of the distribution network, the conditions of connecting to the distribution network, the connection construction and connecting to the distribution network, the rights and duties of thermal energy distributors and distribution network users, the terms of metering in respect of the thermal energy delivered, the disclosure of data and exchange of information, the quality of service and security of thermal energy supply, measures to protect distribution network users, unauthorised thermal energy use, indemnification and legal protection.

8.3.5. Rules on the method of cost allocation and billing for thermal energy delivered

Rules on the method of cost allocation and billing for thermal energy supplied (NN Nos 99/14, 27/15 and 124/15) prescribe the installation of local distribution devices for the thermal energy delivered, devices to regulate heat emission and separate heat meters, in accordance with the provisions of the Thermal Energy Market Act, as well as the models of cost allocation and billing for the thermal energy delivered to a joint heat meter to the final thermal energy customers who own separate parts of a building constituting independent usable building units and register thermal energy delivered by means of local distribution devices or measure it by means of a separate thermal energy meter.

8.3.6. Decree on the amount and method of payment of a concession fee for heat distribution and a concession fee for the construction of heat distribution energy facilities

[By the] Decree on the amount and method of payment of a concession fee for heat distribution and a concession fee for the construction of heat distribution energy facilities (NN No 1/14), the Croatian Government has set the amount of concession fee for thermal energy distribution at 0.05 % of the concession holder's profit generated by the performance of the heat distribution energy activity in the previous year in the territory for which the concession is granted. In this regard, by way of exception, a concession holder that did not perform the heat distribution energy activity in the previous year in the territory for which the concession is granted, and a concession holder embarking on a concession for the construction of heat distribution facilities are to pay a fee equal to 0.05 % of planned revenue for the year in which they begin to perform the heat distribution activity, according to the offer which constitutes an integral part of the concession agreement.

8.3.7. Methodology for determining tariff item amounts for thermal energy production

The Methodology for determining tariff item amounts for heat generation (NN No 56/14) applies to DHS thermal energy producers as long as the activity of thermal energy production in a district heating system is performed as a public service. The methodology does not apply to thermal energy producers in a closed or stand-alone thermal system or to thermal energy production for primarily business purposes.

It establishes the method for calculating tariff item amounts for thermal energy production in a district heating system, the elements for determining the revenue permitted, the application procedure for determining or modifying tariff item amounts, and the formula to be used for calculating total revenue.

The methodology is based on reasonable costs of operation, maintenance, replacement, construction or reconstruction of the facilities and environmental protection, and includes the reinvestment of the proceeds of investment into energy facilities and thermal energy production equipment.

The permitted revenue of the producer should cover the costs of engaging in thermal energy production and provide an income to the producer from regulated assets.

8.3.8. Methodology for determining tariff item amounts for thermal energy distribution

The Methodology for determining tariff item amounts for thermal energy distribution (NN No 56/14) establishes the methodology for calculating tariff item amounts for thermal energy distribution, the elements for determining the revenue permitted, the application procedure for determining or modifying tariff item amounts, the formula the formula to be used for calculating total revenue, and the tables to be used for monitoring the costs and calculating the revenue permitted. The Methodology does not apply to thermal energy distribution for predominantly commercial purposes. It is also based on reasonable costs of operation, maintenance, replacement, construction or reconstruction of the facilities and environmental protection, and includes a return on investment into energy facilities and thermal energy production equipment.

The permitted revenue of the distributor should cover the costs of engaging in thermal energy distribution and provide an income to the distributor from regulated assets. Rules on the method of cost allocation and billing for thermal energy delivered.

8.3.9. Energy Act

The Energy Act (NN Nos 120/12, 14/14 and 102/15) is a general act governing the relations in the energy sector. It includes the provisions common to all energy forms by regulating the implementation of Croatia's energy policies, the performance and regulation of energy activities, energy prices, general terms and conditions of energy use and other matters of relevance to the energy sector as a whole.

The regulation of particular energy markets, including the thermal energy market, as well as the area of energy efficiency and RES utilisation, are all subject to separate acts.

The Energy Act transposes the *acquis communautaire* in the energy field, in particular, Directive 2009/72/EC concerning common rules for the internal market in electricity and Directive 2009/73/EC concerning common rules for the internal market in natural gas into the national legislation.

The Act is organised in 12 chapters as follows:

- I. General provisions
- II. Energy policies and energy development planning
- III. Energy efficiency and renewable energy sources
- IV. Performance of energy activities
- V. Energy market and public services
- VI. Energy prices
- VII. Terms and conditions of network connection and use, and of energy supply
- VIII. Final customers under special protection
- IX. Access to facilities and special conditions
- X. Inspection
- XI. Infringement provisions

XII. Transitional and final provisions

The chapter Energy policies and energy development planning determines the Energy Development Strategy, adopted by the Croatian Parliament at the proposal of the Croatian Government for a period of not less than ten years, as the basic document determining the energy policies and energy development planning.

Pursuant to the Energy Development Strategy, the Croatian Government adopted the Energy Development Strategy Implementation Programme, which lays down measures, holders responsible for various activities and the dynamics of implementation of energy policies and national energy schemes, the method of cooperation with local and regional self-government bodies in the field of energy development planning, as well as the cooperation with energy operators and international organisations, for a period of ten years.

In addition, the Croatian Government may initiate national energy schemes and development plans for separate energy sectors, in accordance with the Energy Development Strategy and the Energy Development Strategy Implementation Programme under special rules which govern particular energy activities, providing for long-term development targets and orientation of energy sectors.

Both local self-government and regional self-government units must plan the needs and the method of energy supply in their development documents, and harmonise such documents with the Energy Development Strategy and the Energy Development Strategy Implementation Programme.

Based on the described strategy and planning documents, energy operators adopt their own programmes, as well as the plans of construction, maintenance and use of energy facilities and other needs in the performance of energy activities, in compliance with the obligations arising out of international treaties.

Total energy consumption, energy demand, sources (types) of energy, as well as the ways and measures to meet such needs are determined by long-term and annual energy balances adopted by the Croatian Government.

In a special chapter entitled Energy Efficiency and Renewable Energy Sources, the Energy Act stipulates that the efficient use of energy is of interest to Croatia, and that the efficient use of energy in generation, transport, distribution, and direct consumption is to be regulated by a special act. Accordingly, the Croatian Parliament adopted the Energy Efficiency Act (NN No 127/14) and, in September 2015, as the Renewable Energy Sources and High-Efficiency Cogeneration Act (NN No 100/15), which will come into force on 1 January 2016.

The Energy Act lays down energy activities and terms and conditions of their performance – a licence to engage in energy activities issued by HERA under the terms and in the manner determined by that act, special acts for particular energy markets and the Rules on licences for energy activities and keeping the register of issued and cancelled licences for energy activities (NN Nos 88/15 and 114/15).

The energy price for final customers includes a freely contracted part and a regulated part, which may be determined by the application of the tariff system, as well as fees and other prescribed levies. The tariff system consists of the stipulated methodology and tariff item amount, both of which are aimed at stimulating the mechanisms to improve energy efficiency and consumption management, including an increased use of RES and cogeneration. The methodology, as laid down by HERA, is based on reasonable costs of operation, maintenance, replacement, construction and reconstruction of the facilities and environmental protection; it must ensure an appropriate return on reasonably invested funds, and may be based on the method of incentive regulation or another method of economic regulation. Tariff items are covered by the methodology and are laid down according to the energy service type, power/capacity, quantity, quality, and other elements related to the energy delivered; they may differ depending on the user type, delivery period and seasonal or daily delivery dynamics. The application to have tariff item amounts determined or modified is submitted to HERA by the energy operator. HERA is responsible for supervising the implementation of tariff systems and fees.

8.3.10. Tariff system for electricity generation from renewable energy resources and cogeneration

The Tariff system for electricity generation from renewable energy resources and cogeneration (NN Nos 133/13, 151/13, 20/14, 107/14, and 100/15) transposes the provisions of Directive 2009/28/EC on the promotion of the use of energy from renewable sources and Directive 2004/8/EC on the promotion of cogeneration based on useful heat demand in the internal energy market into Croatian legislation. This Tariff system sets out the incentive purchase price for the electricity generated in a RES power generation plant and cogeneration installation or delivered to the power grid, which is paid by the

market operator to the eligible electricity producer, as well as the conditions for obtaining the incentive purchase price.

8.3.11. Decree on incentive fee for electricity generation from renewable energy resources and cogeneration

The Decree on incentive fee for electricity generation from renewable energy resources and cogeneration (NN No 128/13) lays down the method of utilisation, the amount, billing, collection, allocation and payment of an incentive fee for electricity generation from RES generation plants and cogeneration installations, in accordance with the strategy objectives concerning the share of RES and cogeneration in the overall electricity consumption, taking into account the situation in the Croatian energy market and electricity generation costs in RES generation plants and cogeneration installations, as well as the share of electricity generated in RES generation plants and cogeneration installations, and which electricity generation is stimulated.

8.3.12. Rules governing the use of renewable energy resources and cogeneration

The Rules governing the use of renewable energy resources and cogeneration (NN No 88/12) define RES generation plants and cogeneration installations used for energy generation and lays down the terms, conditions and possibilities of using renewable energy sources and cogeneration installations, as well as other matters of relevance to the use of renewable energy sources and cogeneration. In addition, the Rules regulate the form, content and method of keeping a Register of RES and cogeneration projects and installations, and eligible producers (RESCEP Register).

8.3.13. Rules governing the grant of eligible electricity producer status

The Rules governing the grant of eligible electricity producer status (NN Nos 132/13, 81/14, 93/14, 24/15, 99/15, and 110/15) lay down the criteria for the grant and cancellation of the eligible electricity producer status, as well as the rights and obligations of an eligible producer and inspection of its operation.

8.3.14. Renewable Energy Sources and High-Efficiency Cogeneration Act

The Renewable Energy Sources and High-Efficiency Cogeneration Act (NN No 100/15), which enters into force on 1 January 2016, regulates the planning and promotion of generation and consumption of electricity generated in RES plants and high-efficiency cogeneration installations, incentive measures for the electricity generation through the use of RES and high-efficiency cogeneration, the system of incentives to the electricity generation from RES and high-efficiency cogeneration, the construction of RES electricity generation plants and high-efficiency cogeneration installations on state-owned land, the register of renewable energy sources and high-efficiency cogeneration for projects, project holders and eligible electricity producers, as well as the international cooperation in the RES field and other matters of relevance to the use of renewable energy sources and high-efficiency cogeneration.

The Act is organised in 13 chapters as follows:

- I. General provisions
- II. National target of RES energy use, Third National RES Action Plan, report on the progress of incentives to the use of energy from renewable sources
- III. Tender for the right to build generation installations using RES or high-efficiency cogeneration on state-owned land
- IV. Register of RES generation installations, [cogeneration] installations and eligible producers
- V. Eligible electricity producer status
- VI. Incentive measures for renewable energy sources and high-efficiency cogeneration
- VII. Fund raising and accounting for the payment of incentives
- VIII. Handover of electricity from final customers having their own generation
- IX. Demonstration projects
- X. Ecobalance group
- XI. Inspection

XII. Infringement provisions

XIII. Transitional and final provisions

This Act declared the use of renewable energy sources and high-efficiency cogeneration (abbreviated as RES and HEC, respectively) to be of interest to the Republic of Croatia. The purpose of the Act is to promote RES and HEC electricity generation, to promote RES and HEC electricity generation at the site of its consumption, to increase the shares of electricity generated from RES in the overall end-use consumption through the use of RES and HEC incentive mechanisms and regulatory framework for the use of.

The Act stipulates that the use of RES and HEC is of Croatia's interest in the field of energy, as set out in the Energy Development Strategy of the Republic of Croatia, laws and other regulations governing the performance of energy activities, especially for the purpose of: achieving the National RES energy use target with regard to the share of RES energy use in the overall end-use energy consumption in Croatia in 2020; more extensive use of own natural energy resources; long-term reduction of dependence on fuel imports; efficient energy use and a reduced environmental impact of fossil fuels; new job openings and development of entrepreneurship in the energy sector and other industries, initiated by the development of energy projects and their results in the local community; stimulation of the development of new and innovative technologies and their contribution to the local community; and finally, diversification of energy generation and increased supply security.

This Act transposes Directive 2009/28/EC on the promotion of the use of energy from renewable sources and Directive 2012/27 on energy efficiency into Croatian legislation.

It regulates the system of incentives to the electricity generation from RES and HEC.

8.3.15. Environmental Protection and Energy Efficiency Fund Act

Under the Environmental Protection and Energy Efficiency Fund Act (NN Nos 107/03 and 144/12), the Environmental Protection and Energy Efficiency Fund (EPEEF) was established as the central point for the collection and investment of extra-budgetary funds in the programmes and projects concerning environmental and nature protection, energy efficiency and RES use.

The EPEEF performs activities related to the funding of preparation, implementation and development of the programmes and projects and similar activities in the field of preservation, sustainable use, protection and improvement of the environment in the field of energy efficiency and RES use as well; in particular, professional and other activities related to the collection, management and use of EPEEF funds; intermediation with regard to the funding of environmental protection and energy efficiency from the resources of foreign countries, international organisations, financial institutions and bodies, as well as local and international legal and natural persons; keeping a database of programmes, projects and similar activities in the field of environmental protection and energy efficiency, and of the financial resources required and available, etc.

8.3.16. Energy Sector and Investment Monitoring Centre Act

The Energy Sector and Investment Monitoring Centre Act (NN Nos 25/12 and 120/12) regulates the monitoring of energy sector operations and investments; under the Act, the Energy Sector and Investment Monitoring Centre (EIC) was also established as the strategic interest of the Republic of Croatia. The Energy Efficiency Act defines EIC as the national coordinating authority for energy efficiency.

8.3.17. Energy Efficiency Act

The Energy Efficiency Act (NN No 127/14), transposing Directive 2012/27/EU on energy efficiency into Croatian legislation, has been in force since November 2014.

Similarly to the Energy Act, this Act also declares the energy efficiency to be of interest to the Republic of Croatia.

The Act is organised in eight chapters as follows:

- I. General provisions
- II. Powers of competent authorities
- III. Energy efficiency plans
- IV. Energy efficiency obligations

- V. Energy service
- VI. Inspection
- VII. Infringement provisions
- VIII. Transitional and final provisions

The Act uses a number of terms in the field of energy efficiency, where the following terms are of particular interest:

- efficient district heating and cooling: a district heating or cooling system using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat or 50 % of a combination of such energy and heat;
- efficient heating and cooling: a heating and cooling system that, compared to a baseline scenario reflecting a business-as-usual situation, measurably reduces the input of primary energy needed to supply one unit of delivered energy within a relevant system boundary in a cost-effective way, as assessed in the cost-benefit analysis in accordance with the Thermal Energy Market Act, taking into account the energy required for extraction, conversion, transport and distribution;
- efficient individual heating and cooling: an individual heating and cooling supply system that, compared to efficient district heating and cooling, measurably reduces the input of non-renewable primary energy needed to supply one unit of delivered energy within a relevant system boundary or requires the same input of non-renewable primary energy but at a lower cost, taking into account the energy required for extraction, conversion, transport and distribution.

The following institutions have been laid down as the public authorities with special legal powers in energy efficiency planning:

- Ministry of the Economy (MoE): energy efficiency preparation and policies (including the creation of the NAP, report on the NAP implementation, report to the EC on the NAP implementation, etc.)
- EPEEF: promotion of rational management of energy and energy efficiency, co-financing of the implementation of energy efficiency measures
- EIC: national coordinating authority for energy efficiency (systematic planning of energy efficiency improvements, management of the energy savings monitoring, measuring and verification system, monitoring the implementation energy efficiency measures, publication of relevant information, etc.).

Strategy and planning documents for the field of energy efficiency are the following:

- National Action Plan – NAP:
 - three-year period;
 - contents: overview and assessment of energy consumption needs, long-term goals, activity holders and time limits, measures to improve energy efficiency, plan to increase the number of zero-energy buildings, measures for the annual renovation of buildings owned by the central government, calculation of planned energy savings, NAP funding sources;
 - adopted by the Croatian Government (CG), created by the MoE, together with the Ministry of Construction and Physical Planning, the Ministry of Environmental and Nature Protection and EIC;
- Report on the NAP implementation;
- Long-term strategy for mobilising investment in the national building stock renovation by 2050 (CG):
 - Contents: overview of the national building stock, cost-effective approach to building renovation, policies and measures to promote cost-effectiveness, long-term guidelines on investments, investment assessment;
 - Update planned for 30 April 2017 and every three years thereafter, to be submitted to the European Commission.
- Energy Efficiency Action Plan:
 - adopted by LSGUs and cities,
 - three-year period,
 - harmonised with the NAP.

- Annual Energy Efficiency Plan:
 - implementing body of a regional self-government unit or city,
 - by the end of the current year for the following year,
 - harmonised with the NAP and the Action Plan.

A special chapter of the Act defines the energy efficiency obligation scheme and specifies energy efficiency obligations for energy operators, energy market regulator, product suppliers, large public sector enterprises and, in particular, the obligations with regard to energy metering and information on energy billing. The Act also establishes an energy savings monitoring, measuring and verification system.

The energy service is defined by the Act as the implementation of energy efficiency projects and other related activities under an energy performance contract with a guaranteed achievement of verifiable and measurable or assessable improvement of energy efficiency and/or energy and/or water savings under reference conditions.

The Act, in particular, regulates the public sector energy service and energy renovation of public buildings.

Energy performance contract is a contract between an energy service user and provider, which is verified and monitored throughout its term; the investment in works, equipment and services for the implementation of measures to improve energy efficiency covered by the energy service is paid in accordance with the degree of energy efficiency improvement or other criteria agreed, such as financial savings. In addition, it details an energy performance contract for apartment buildings, as well as a contract for energy renovation works on apartment buildings. Energy efficiency in public procurement is also promoted.

8.3.18. Decree on contracting and implementation of public sector energy service

The Decree on contracting and implementation of public sector energy service (NN No 11/15) lays down the method of energy service contracting for the public sector, the obligations of energy service providers and clients, the content of an energy performance contract, as well as the budgetary monitoring of the energy service for public sector energy service clients.

This Decree applies to budgetary and extra-budgetary beneficiaries of the state budget, as well as local and regional self-government units as energy service clients, and to energy service providers and the Agency for Transactions and Mediation in Immovable Properties (ATP).

8.3.19. Rules of systematic public sector energy management

The Rules of systematic public sector energy management (NN No 18/15) lays down the obligations of energy and water consumption management, consumption analysis, the method of reporting on energy and water consumption, and the methodology of systematic public sector energy management. The energy management system is a set of interrelated and active elements of a plan which sets out the energy efficiency increase target and the strategy for achieving it.

8.4. STRATEGY AND PLANNING DOCUMENTS

8.4.1. Sustainable Development Strategy

Croatia's Sustainable Development Strategy, adopted in 2009 (NN No 30/9) for a ten-year period, contains the analysis of the existing economic, social and environmental situation and lays down the guidelines for long-term action. This Strategy includes basic principles and criteria for setting targets and priorities in considering a long-term transformation towards Croatia's sustainable development.

8.4.2. Energy Development Strategy

The Energy Development Strategy (NN No 130/09) is the basic document determining Croatia's energy policies and planning its energy development. Departing from the economic development and energy demand, the Energy Development Strategy defines national energy schemes, necessary investment in the energy sector, incentives for investments in renewable sources and cogeneration and those aimed at improving environmental protection measures.

8.4.3. Croatia's Low-Emission Development Strategy – in the making

The Ministry of Environmental and Nature Protection is drafting a Low-Emission Development Strategy (LEDS) of the Republic of Croatia, as the basic document transposing the obligation to reduce greenhouse gas emissions into specific sectoral policies. The goal of the Strategy is to achieve a competitive low-carbon economy by 2050, in line with European strategic guidelines and in compliance with the obligations laid down in the United Nations Framework Convention on Climate Change (UNFCCC). The Strategy will be the fundamental document in the field of climate change mitigation, as well as an umbrella economic, developmental and environmental strategy.

The Low-Emission Development Strategy drafting was anticipated by the creation of the framework for the Low-Emission Development Strategy, implemented under a project of support to Croatia in drafting the Low-Emission Development Strategy, which is coordinated by the Ministry of Environmental and Nature Protection and the United Nations Development Programme (UNPD) for Croatia.

8.4.4. National Renewable Energy Sources Action Plan

In 2013, the Croatian Government adopted the National Renewable Energy Action Plan until 2020 (NAP). By reason of the accession of the Republic of Croatia and Croatia's Energy Development Strategy, the NAP takes into account the 20 % target for RES in gross end-use consumption by 2020, as set out in Council Directive 2013/18/EU of 13 May 2013 adapting Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources.

Together with the overall national target, the NAP also defines sectoral targets: 39 % RES in electricity generation (including major hydro plants), 10 % RES in transport and 19.6 % RES in heating and cooling energy generation. It is evident from the foregoing that the production of heating and cooling energy from RES is expected to give a significant contribution towards the achievement of the national target by 2020.

8.4.5. National Energy Efficiency Programme for 2008-2016 (NEEP)

The NEEP was prepared under the 2008 Energy Efficiency in End-Use [Consumption] Act (which ceased to have effect on the entry into force of the Energy Efficiency Act) with the aim of constituting a comprehensive basis for decision-makers in drafting other official documents related to energy efficiency, such as new legislation to transpose the *acquis communautaire* into national legislation and the National Energy Efficiency Action Plan (NEEAP).

The NEEP defines national targets, as well as targets specific to each sector, for energy efficiency improvement and provides an overview of the method and procedures to be applied in order to achieve long-term energy efficiency targets.

8.4.6. National Energy Efficiency Action Plan (1, 2 and 3)

The NEEAP is a comprehensive strategy to improve energy efficiency in Croatia. The Third plan was made for the period between 2014 and 2016, according to a template set out by the European Commission to be adhered to by EU Member States.

The NEEAP includes a report on the assessment of the state of implementation of energy efficiency policies, specifies achieved energy savings in the preceding three-year period and provides guidelines for the period that follows, detailing planned measures.

The document is submitted to the European Commission, which reviews the action plans of all Member States, including Croatia, and analyses the cumulative EU target achievement.

The adoption of this Plan contributes to the continuous performance of activities and measures laid down in the National Energy Efficiency Programme for 2008-2016; in accordance with assessments and in the case that the risk of failure to achieve the planned targets increases, current measures are reviewed and new sectoral measures are laid down in order to ensure that the 2016 target is achieved. It should particularly be noted that the Plan introduces energy efficiency obligation, in accordance with the requirements of Directive 2010/31/EU; Croatia has opted for a combined approach, including alternative policy measures and mandatory savings to be defined by the rules adopted pursuant to the new Energy Efficiency Act.

8.5. BASELINES

This section presents recommendations for possible directions to be taken in defining national energy and climate policies and improving the regulatory framework, with regard to the DHS potential for heating and cooling and its contribution to the targets set out by the respective Croatian and EU policies.

These recommendations have been prepared departing from the guidelines of the European energy and climate policy and taking into account the conclusions of the analyses covered by this study.

8.5.1. Regulatory framework

Legal and statutory obligations which may arise in project preparation and implementation are laid down by energy regulations and regulations in the fields of physical planning and construction and environmental protection, as well as the regulations governing property rights on a land, performance of economic activities, administrative procedure, etc. In this regard, technical and technological characteristics and installed plant capacity have been taken into account, which result in shortening the administrative procedure.

The procedure of preparation and implementation of plant construction requires a large number of administrative documents to be obtained and contracts to be concluded; however, if competent state authorities, bodies of local and regional self-government units and legal persons with public authority (agencies, operators etc.) comply with the set time limits, taking into account the principles of administrative proceedings, and if energy operators perform their obligations laid down in issued approvals and authorisations, the administrative proceedings to be conducted are not an obstacle which would greatly slow down the implementation of energy projects.

The absence of a systematic arrangement of the RES heating and cooling energy generation, not only with regard to generation, distribution and supply, but also with regard to defining the targets, incentives concept and system of small RES installer certification, is a specific gap in the legal framework concerning the thermal energy market.

It was thus appropriate for the new Renewable Energy Sources and High-Efficiency Cogeneration Act, which enters into force at the beginning of 2016, (or for amendments to the Thermal Energy Market Act) to set out the legal framework for systematic incentives to RES heating and cooling energy generation, which would build on to the current practice of *ad hoc* incentives through occasional public invitations and tenders, whether directly through EPEEF or in cooperation with local and regional self-government units.

8.5.2. Price and market impact

In principle, two major obstacles to a more extensive use of high-efficiency cogeneration have been recognised:

1. The first major obstacle is the broad presence of gas network in large urban settings, where the price of natural gas for households continues to be regulated, which is destimulating to cogeneration projects.
2. The second major obstacle refers to the general situation in the EU wholesale electricity market, where the price of electricity is extremely low owing to the impact of a privileged and administrative position of RES-fired electrical plants, so it does not favour high-efficiency cogeneration.

8.5.3. Determined potential

The study included an analysis of the potential for the reconstruction of existing and the construction of new energy installations, on the assumption that high-efficiency cogeneration is used.

The analysis of the current situation covered four existing cogeneration installations of *Hrvatska Elektroprivreda d.d.* and three industrial cogeneration installations with a thermal input exceeding 20 MW. The analysis determined the potential of particular blocks of *Hrvatska Elektroprivreda d.d.* cogeneration installations to meet the requirements of high-efficiency cogeneration, under appropriate operating regimes. Furthermore, the analysis established that none of the existing industrial cogeneration installations is a likely candidate for high-efficiency cogeneration.

An analysis of potential new heat consumption locations identified a total of 18 locations which, based on their theoretical potential for thermal energy needs and likelihood of the construction of necessary heat distribution infrastructure, represent a likely potential for the construction of new high-efficiency

cogeneration installations. The respective theoretical heat potential of these 18 locations is 29 982 128 GJ, or 8 328 369 MWh annually by 2030.

8.6. STRATEGIC GUIDELINES

Despite a long-term tradition of supply from the DHS system, the situation in the existing district systems is not satisfactory. The reasons behind this are numerous, e.g. age of the installations and their low efficiency, network age, high fuel prices, poor insulation in buildings using district systems, low heat manageability, and inadequate heat pricing policy, which did not cover generation costs.

Along with the EU energy policy, the policies and measures to increase the efficiency and development of district heating systems will also be affected by the following factors with clashing impact:

- economic benefit for thermal energy buyers, by making thermal energy economically more convenient than alternative energy forms;
- development of Croatia's economic situation, with citizens increasingly using energy for heating, cooling and DHW as their living standard increases;
- growth of new building construction;
- climate protection and CO₂ emissions reduction policy;
- quality of building insulation and programmes to increase building energy performance, as well as the national policy targets in the expectation of efficiency of energy consumption in residential and business buildings;
- systems to promote increase in energy efficiency and RES use.

The increase in DHS system efficiency should adhere to the following guidelines:

- construction of efficient cogeneration installations where they are not present, and substitution of district boiler rooms with DHS and construction of adequate high-efficiency cogeneration installations;
- choice of fuel, particularly aiming to reduce CO₂ emissions;
- replacement of the heat network reaching the end of its service life and connection of district boiler rooms to the DHS network;
- priority programme of energy renovation of buildings in the areas covered by DHS.

9. HIGH-EFFICIENCY COGENERATION SHARE, POTENTIAL IDENTIFIED AND PROGRESS MADE

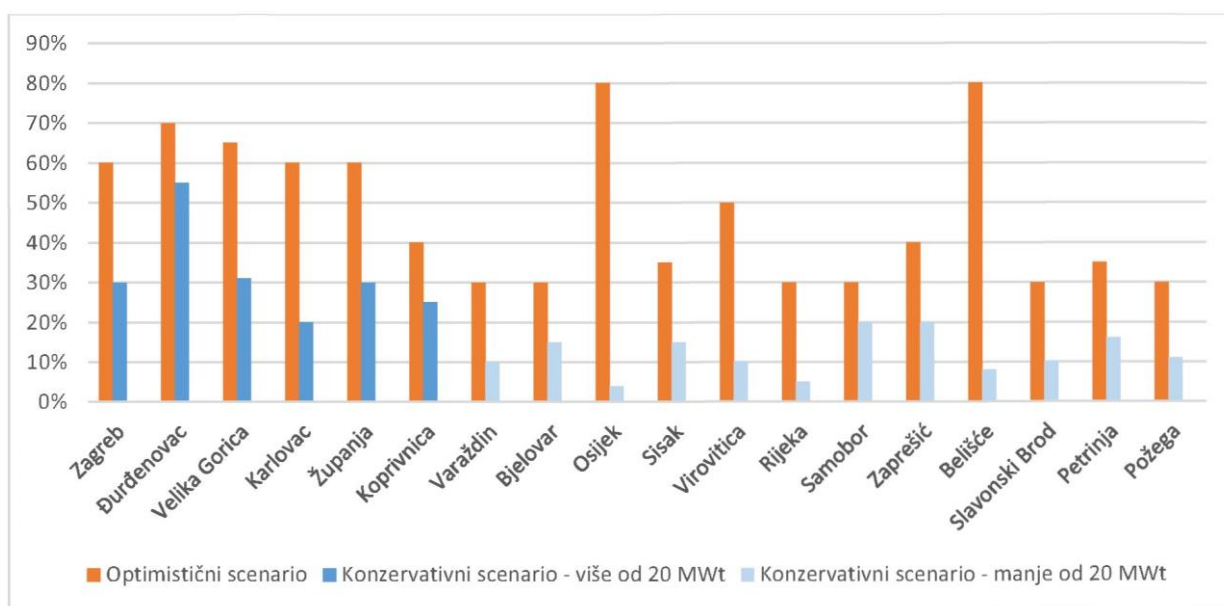
9.1. INTRODUCTION

The analysis of high-efficiency cogeneration share is based on the results of the analysis provided in Chapter 6 'Determining the potential for additional high-efficiency cogeneration'. The potential determined refers primarily to possible locations for the construction of new high-efficiency cogeneration installations, and the justification for their construction is considered under two scenarios with regard to the share of future district heating system consumers: a conservative and an optimistic scenario.

In the conservative scenario, the shares of consumers in the district heating system were estimated on the basis of existing trends identified for each potential new location, while also taking into account their respective specificities.

In the optimistic scenario, the shares of consumers in the district heating system were estimated on the basis of an optimistic projection of energy sector trends, anticipating positive developments in the Croatian economy.

A graphic showing the distribution of forecast shares of consumers supplied with thermal energy through district heating systems for each potential location in 2030 is shown in the figure below.



<i>Optimistični scenario</i>	<i>Optimistic scenario</i>
<i>Konzervativni scenario – više od 20 MW_t</i>	<i>Conservative scenario – more than 20 MW_t</i>
<i>Konzervativni scenario – manje od 20 MW_t</i>	<i>Conservative scenario – less than 20 MW_t</i>

Figure 70: Shares of future thermal energy consumers in the new DHS plants in 2030, optimistic and conservative scenarios

Both scenarios are centred around locations representing a potential with a thermal input exceeding 20 MW. Those shown in light-blue are not further discussed in the conservative scenario since they refer to a value below 20 MW_t.

The results obtained are shown graphically on the map of Croatia.

9.2. HIGH-EFFICIENCY COGENERATION SHARE IN THE CONSERVATIVE SCENARIO OF DETERMINED POTENTIAL

9.2.1. Equivalent heat consumption and thermal input

As already mentioned in the introduction, in the conservative scenario, the potential for new high-efficiency cogeneration installations and associated infrastructure is determined by multiplying the presumed conservative share of district heating system consumers in 2030 with theoretical thermal needs in that same year. Only the locations with a required thermal input exceeding 20 MW_t are taken into account.

The results of the analysis in the conservative scenario are provided in the table below.

Table 38: Conservative scenario of the potential for additional new high-efficiency cogeneration in 2030

No	City	Theoretical thermal needs in 2030			Conservative scenario in 2030			
		Total heat consumption		Required thermal input	Share of DHS consumers	Equivalent heat consumption		Equivalent thermal input
		GJ	MWh	MW _t	%	GJ	MWh	MW _t
1	Zagreb	14 640 440	4 066 789	2 540	30	4 392 132	1 220 037	762
2	Đurđenovac	553 111	153 642	96	55	304 211	84 503	53
3	Velika Gorica	795 547	220 985	140	31	246 619	68 505	43
4	Karlovac	972 036	270 010	167	20	194 407	54 002	33
5	Županja	624 503	173 473	111	30	187 351	52 042	33
6	Koprivnica	727 231	202 009	125	25	181 808	50 502	31
TOTAL:		18 312 866	5 086 907	3 178	30.1	5 506 528	1 529 591	956

The table above shows a total of six (6) potential new locations for high-efficiency cogeneration, which have been reasonably considered in terms of the development of required district heating system infrastructure.

Total equivalent thermal potential of all new potential locations of high-efficiency cogeneration installations is 5 506 528 GJ or 1 529 591 MWh. The equivalent thermal capacity, required to meet the projected thermal needs in the conservative scenario, is 956 MW.

A graphical representation of the spatial distribution of equivalent heat consumption in Croatia in 2030, in the case of the conservative scenario is provided in the figure below.

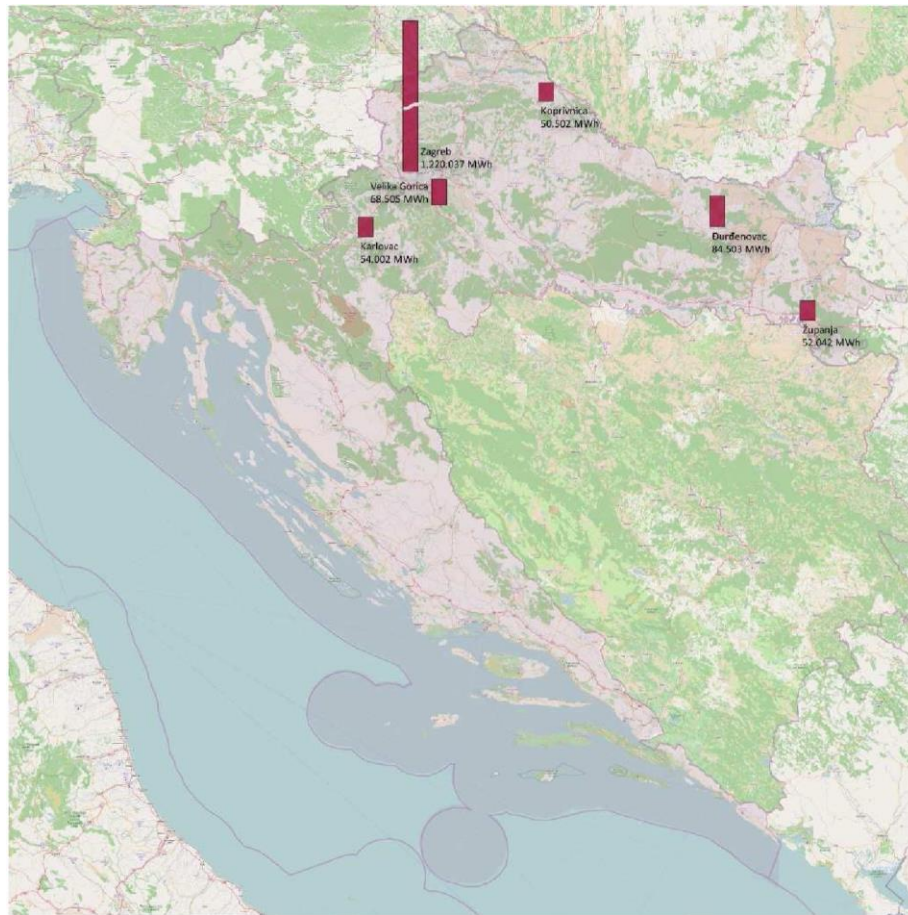


Figure 71: Distribution of equivalent heat consumption in Croatia, 2030 – conservative scenario

9.2.2. Electrical component of high-efficiency cogeneration

For the purpose of determining the amount of the electrical component in a high-efficiency cogeneration installation, the construction of an installation using the latest technology is presumed. At this point, it is likely to presume that this would be a cogeneration combined cycle gas turbine, or CCCGT, installation.

The presumed values of 55 % for electrical efficiency and 35 % for thermal efficiency have been taken as the basis for calculating, i.e. determining the electricity component of high-efficiency cogeneration. Thus, it follows that the overall efficiency of the high-efficiency cogeneration installation would be 90 %. According to known and available data on modern cogeneration installations based on a combined cycle gas turbine utilising the thermal energy produced, it can be concluded that the efficiency values range up to 95 % for the overall cogeneration installation efficiency, while standing at 60 % or 35 % for electrical and thermal efficiency, respectively. Since these latest values above constitute technical characteristics of the most advanced cogeneration installations, the values estimated for the purpose of this analysis are somewhat more conservative, as previously mentioned. An additional reason for reducing above maximum efficiency values in modern cogeneration installations lies in the fact that the thermal needs at the six locations could not be met by a single major cogeneration installation optimised for large rated thermal outputs, but rather by multiple smaller installations which regularly achieve lower electrical and heat efficiency values.

The estimated electrical and thermal efficiency values of a high-efficiency cogeneration installation and specific amounts of thermal energy to be produced at cogeneration installations, coupled with district heating systems, served as a basis for determining the amount of electricity which can be generated by such cogeneration installations, where the installation management strategy is defined by the principle that thermal needs must be met in full. The results of the analysis are provided in the table below.

Table 39: High-efficiency cogeneration electricity potential based on the conservative scenario, 2030

No	City	Conservative scenario in 2030	
		Potential electricity output	
		GJ	MWh
1	Zagreb	6 901 921.6	1 917 200.4
2	Đurđevovac	478 045.5	132 790.4
3	Velika Gorica	387 544.8	107 651.3
4	Karlovac	305 496.9	84 860.2
5	Županja	294 408.4	81 780.1
6	Koprivnica	285 697.8	79 361.5
TOTAL:		8 653 115.0	2 403 643.1

Total equivalent annual electricity output potential of all new potential locations of high-efficiency cogeneration installations is 8 653 115 GJ or 2 406 643 MWh.

The electricity generated may be used on site and/or be delivered to the Croatian power system.

A graphical representation of the spatial distribution of potential electricity output from high-efficiency cogeneration installations in Croatia in 2030, in the case of the conservative scenario, is provided in the figure below.

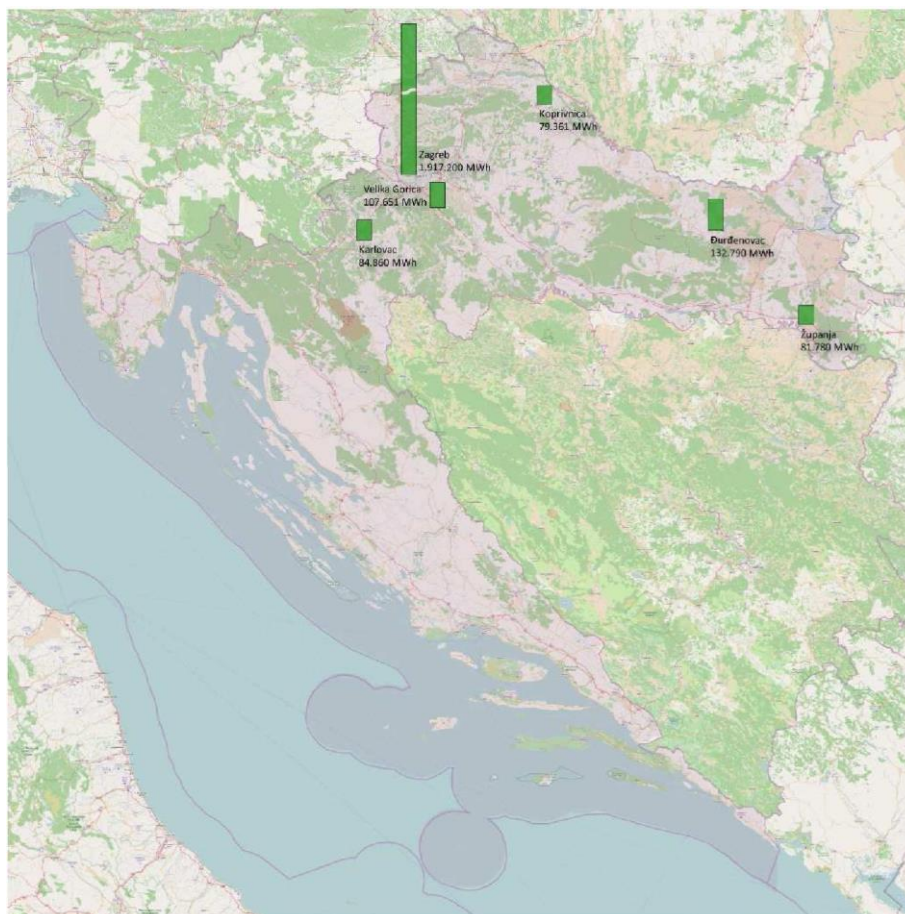


Figure 72: Distribution of electricity potential from high-efficiency cogeneration in Croatia, 2030 – conservative scenario

9.3. HIGH-EFFICIENCY COGENERATION SHARE IN THE OPTIMISTIC SCENARIO OF DETERMINED POTENTIAL

9.3.1. Equivalent heat consumption and thermal input

The optimistic scenario was prepared using the same methodology as in the conservative scenario. The results of the optimistic scenario analysis are provided in the table below. Only the locations with a required thermal input exceeding 20 MW_t are presented.

Table 40: Optimistic scenario of the potential for additional new high-efficiency cogeneration in 2030

No	City	Theoretical thermal needs in 2030			Optimistic scenario in 2030			
		Total heat consumption		Required thermal input	Share of DHS consumers	Equivalent heat consumption		Equivalent thermal input
		GJ	MWh	MW _t	%	GJ	MWh	MW _t
1	Zagreb	14 640 440	4 066 789	2 540	60	8 784 264	2 440 073	1 524
2	Osijek	2 617 899	727 194	454	80	2 094 319	581 755	363
3	Belišće	1 147 094	318 637	199	80	917 675	254 910	159
4	Rijeka	1 642 262	456 184	342	30	492 679	136 855	103
5	Karlovac	972 036	270 010	167	60	583 221	162 006	100
6	Velika Gorica	795 547	220 985	140	65	517 105	143 640	91
7	Virovitica	1 019 107	283 085	174	50	509 554	141 543	87
8	Đurđenovac	553 111	153 642	96	70	387 177	107 549	67
9	Županja	624 503	173 473	111	60	374 702	104 084	67
10	Varaždin	1 123 677	312 132	190	30	337 103	93 640	57
11	Koprivnica	727 231	202 009	125	40	290 892	80 803	50
12	Slavonski Brod	879 683	244 356	153	30	263 905	73 307	46
13	Sisak	661 424	183 729	118	35	231 499	64 305	41
14	Bjelovar	700 713	194 643	122	30	210 214	58 393	37
15	Zaprešić	457 236	127 010	80	40	182 894	50 804	32
16	Petrinja	446 908	124 141	80	35	156 418	43 449	28
17	Požega	505 865	140 518	88	30	151 760	42 155	26
18	Samobor	467 392	129 831	82	30	140 218	38 949	25
TOTAL:		29 982 128	8 328 369	5 262	55	16 625 599	4 618 222	2 903

The table above shows a total of eighteen (18) potential new locations for high-efficiency cogeneration, which have been reasonably considered in terms of the development of required district heating system infrastructure.

Total equivalent thermal potential of all new potential locations of high-efficiency cogeneration installations is 16 625 599 GJ or 4 618 222 MWh. The equivalent thermal capacity, required to meet the projected thermal needs in the optimistic scenario, is 2 903 MW_t.

A graphical representation of the spatial distribution of equivalent heat consumption in Croatia in 2030, in the case of the optimistic scenario, is provided in the figure below.

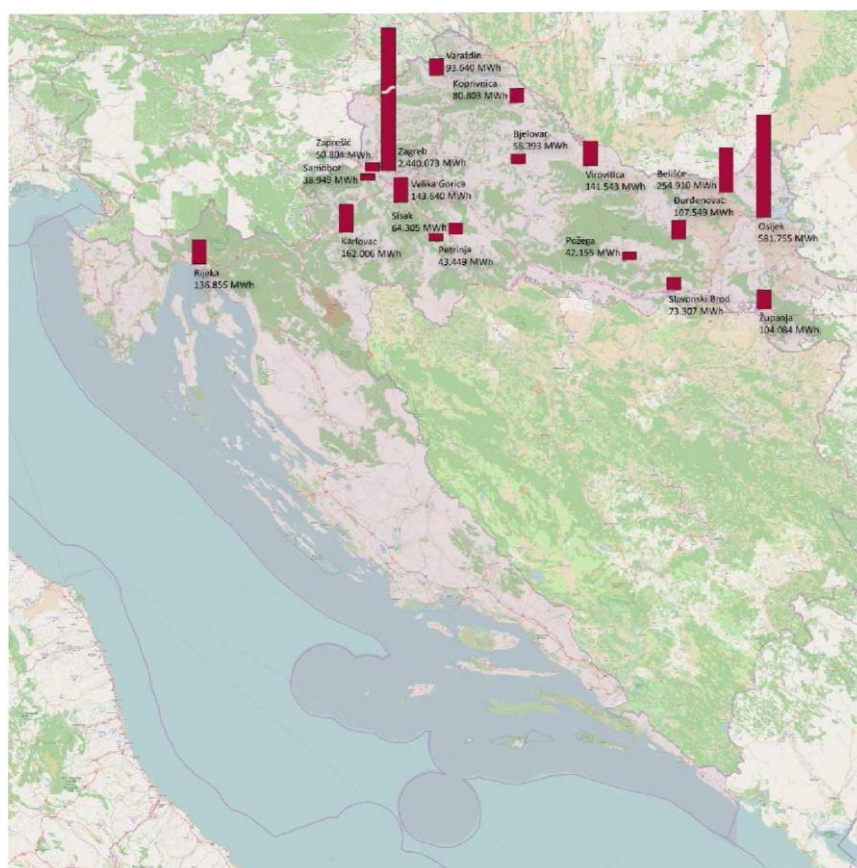


Figure 73: Distribution of equivalent heat consumption in Croatia, 2030 – optimistic scenario

9.3.2. Electrical component of high-efficiency cogeneration

The amount of the electrical component in a high-efficiency cogeneration installation was determined using the same methodology and selecting the same technology as in the conservative scenario.

The results of high-efficiency cogeneration electrical component determination are shown in the table below.

Table 41: High-efficiency cogeneration electricity potential based on the optimistic scenario, 2013

No	City	Optimistic scenario in 2030	
		Potential electricity output	
		GJ	MWh
1	Zagreb	13 803 843.2	3 834 400.9
2	Osijek	3 291 073.4	914 187.1
3	Belišće	1 442 061.5	400 572.6
4	Karlovac	916 490.7	254 580.7
5	Velika Gorica	812 594.0	225 720.6
6	Virovitica	800 727.2	222 424.2
7	Rijeka	774 209.3	215 058.1
8	Đurđevac	608 421.6	169 006.0
9	Županja	588 816.7	163 560.2
10	Varaždin	529 733.3	147 148.1
11	Koprivnica	457 116.5	126 976.8
12	Slavonski Brod	414 707.8	115 196.6
13	Sisak	363 783.4	101 050.9
14	Bjelovar	330 336.3	91 760.1

No	City	Optimistic scenario in 2030	
		Potential electricity output	
		GJ	MWh
15	Zaprešić	287 405.5	79 834.9
16	Petrinja	245 799.3	68 277.6
17	Požega	238 479.4	66 244.3
18	Samobor	220 342.1	61 206.1
TOTAL:		26 125 941.2	7 257 205.9

Total equivalent annual electricity output potential of all new potential locations of high-efficiency cogeneration installations is 26 125 941 GJ or 7 257 206 MWh.

The electricity generated may be used on site and/or be delivered to the Croatian power system.

A graphical representation of the spatial distribution of potential electricity output from high-efficiency cogeneration installations in Croatia in 2030, in the case of the optimistic scenario, is provided in the figure below.

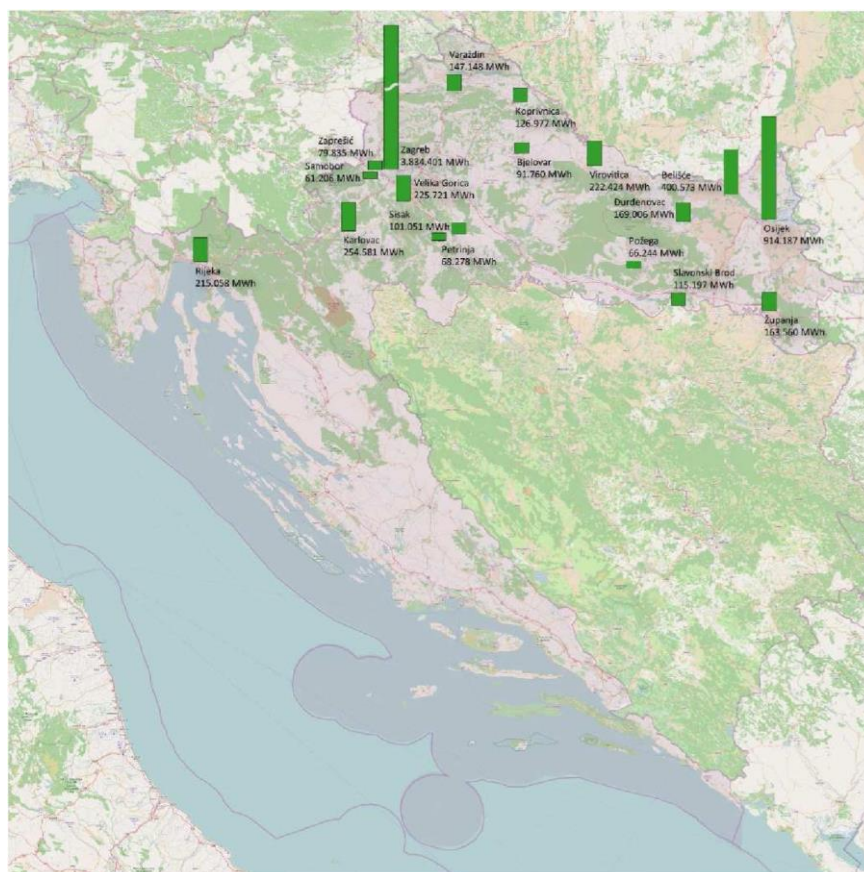


Figure 74: Spatial distribution of electricity potential from high-efficiency cogeneration in Croatia, 2030 – optimistic scenario

9.4. PROGRESS MONITORING

For the purpose of monitoring programme implementation, as well as evaluation of the results achieved and, finally, reporting to the Croatian Government on these results and recommendations, the Ministry of the Economy ought to establish a system of Programme implementation evaluation and monitoring through regular cooperation and reporting by HERA, which supervises the performance of energy activities and the functioning of energy markets, and by local self-government units which are, among other things, obligated to encourage, plan and approve the construction of heating systems.

10. ESTIMATE OF EXPECTED SAVINGS

10.1. INTRODUCTION

As has been stated in the previous chapters, thermal energy accounts for a substantial share of Croatia's energy balance. The Croatian Government adopts energy balances for each individual form of energy, defining methods and measures to meet the aforementioned energy needs. Furthermore, a special chapter of the Energy Act relating to energy efficiency and renewable energy sources stipulates that the efficient use of energy is of interest to Croatia, and that the efficient use of energy in generation, transport, distribution, and direct consumption will be regulated by a special act. For that purpose, the Croatian Parliament passed the new Renewable Energy Sources and High-Efficiency Cogeneration Act (NN No 100/15), which enters into force on 1 January 2016.

As part of this project, an analysis of the energy required to meet heating and cooling needs in the household, industry and services sectors is of interest. District heating systems are considered the most acceptable method of meeting the energy needs in terms of using the primary fuel energy. District heating systems very often have greater installed capacity and use cogeneration installations as a source of thermal energy. Cogeneration installations imply simultaneous generation of thermal energy and electricity. Modern cogeneration installations are considered high-efficiency installations if they achieve primary energy savings of at least 10 %, in accordance with the methodology laid down by the Rules governing the grant of eligible electricity producer status (NN Nos 132/2013, 81/14, 93/14, 24/15, 99/15, and 110/15). The high-efficiency cogeneration installations have also been declared of interest to Croatia and, together with thermal systems, they are considered an important element for increasing energy efficiency.

Considerable responsibility for this lies with local self-government units, which are required to plan, promote and approve the construction of thermal systems, in particular if there are cogeneration units in an area being analysed. Similarly, it is essential to provide for the construction of the necessary district heating system infrastructure in spatial plans.

10.2. ANALYSIS OF THE EXISTING SITUATION

In accordance with the analyses conducted in preceding chapters, the level of savings was estimated on the assumption of a maximised use of energy in thermal systems and implementation of energy efficiency measures, as well as all identified adequate high-efficiency cogeneration installations.

Final energy consumption was analysed in three sectors: households, services and industry. The analysis covered only cities, municipalities and settlements with a total population exceeding 10 000. In addition to analysing the energy needed for air treatment, i.e. for the purposes of space heating, an analysis of the energy needed for domestic hot water generation was also carried out.

In 2013, total energy consumption in the household sector was 103.7 PJ. The predominant energy source was firewood with a share of some 48 %, followed by electricity (21 %), natural gas (19 %), thermal energy (5 %), and oil and fuel oil (7 %). Furthermore, the analysis distinguished between three specific energy consumption regions in Croatia: central, continental and southern Croatia. These specific regions were found to differ considerably in the amount and manner of energy consumption, justifying such an approach. Based on the initial results of the preliminary analysis of useful energy consumption for heating, it was concluded that the total useful energy consumed in centrally-heated dwellings was some 22.7 PJ, while useful energy consumed in room-heated dwellings was about 1.5 PJ. Useful energy obtained from district heating systems was 6.6 PJ. The analysis was designed on the basis of parameters such as: the total floor area of the housing space and its heated area, and the standards of useful energy consumption determined specifically for different heating methods of various heating methods, in combination with fuels used for that purpose. In Croatia, the average energy consumption standard in centrally-heated residential units is about 180 kWh/m² of the heated area, while in the case of room-heated residential units the standard is about 124 kWh/m² of the heated area.

A similar analysis was carried out for the services sector. The analysis also covered cities, municipalities and settlements with a population exceeding 10 000. The services sector was divided into sub-sectors such as: education, health, governance and administration, trade, tourism, and hotels and restaurants. Heating and cooling energy consumption standards were defined for each sector, along with standards for other forms of energy consumption. Total energy consumption in the services sector in 2013 was about 29 PJ, with thermal energy accounting for about 48 % and cooling energy for

15 %. The fuels used (in descending order in terms of their share in consumption) were as follows: natural gas, electricity, extra light fuel oil, thermal energy, liquefied petroleum gas.

An analysis of consumption in the industry sector is the most demanding because the industrial installations use thermal energy of different parameters and from different energy sources. It is important to distinguish between direct thermal energy (resulting from direct fuel combustion) and indirect thermal energy (produced in boiler rooms and used subsequently in technological processes). The 2013 total useful thermal energy produced by industrial installations amounted to 22.7 PJ, of which direct thermal energy accounted for 12.3 PJ and indirect thermal energy for 10.4 PJ.

10.3. ESTIMATE OF FUTURE USEFUL ENERGY CONSUMPTION

Future useful energy consumption was estimated using an end-use model, i.e. the MAED software. It covered the impact of all relevant energy consumption determinants, such as demographic changes, population mobility, domestic product growth and structure, housing standard, climatological characteristics of the area, efficiency of energy use, habits, etc. The main idea of the end-use model is to determine the specific energy consumption based on the structural analysis of the energy consumption achieved. It serves as the basis for preparing development scenarios for individual determinants and specific consumptions, and total future energy consumption is eventually created.

The analysis has found that, in the case of the household sector in the specific energy consumption region of northern Croatia, energy consumption is expected to decrease to about 40 PJ in 2030 not only as a direct consequence of an increase in household sector energy efficiency, but also of a decrease in the size of the population. In the specific region North, useful thermal energy consumption is expected to fall to about 1.6 PJ, while in the specific region South, a modest increase in thermal energy consumption is expected. That increase is primarily explained as the result of a rising living standard and a greater need for cooling energy.

In the services sector, an increase in the total useful energy consumption is expected. It is primarily due to a rise in the number of employees in that sector and an increase in the heated/cooled areas in which services sector activities are performed. The analysis found that thermal energy consumption would be about 11.2 PJ in 2030. As for the consumption of energy for space cooling, energy consumption for such purposes is expected to increase at an annual rate of 2.4 %.

Given the specific characteristics of the industry sector, two categories of useful consumption have been defined: useful thermal energy and electricity for non-thermal needs. Among other things, useful energy consumption in the industry sector is modelled on a projection of GDP growth by 2030, strategic documents for economic and industrial development, and recommendations and analyses by international organisations on economic trends in the period under observation. By 2030, total useful thermal energy consumption in the industry sector is expected to increase from almost 23 PJ in 2013 to almost 30 PJ in 2030. The analysis included the consumption of both direct thermal energy and indirect thermal energy.

10.4. ACHIEVING SAVINGS IN ENERGY CONSUMPTION

In Croatia in 2013, 9 678 TJ of thermal energy was supplied to final customers for the purposes of thermal heating systems. For thermal purposes, a total of 1 800 MW of thermal power was installed in cogeneration installations, heating plants, small heating plants and block or home boiler rooms, as well as a total of 410 km of pipeline distribution network in 18 cities. In Croatia, according to information provided by HERA, the activity of thermal energy generation, distribution and supply is performed by 11 economic operators. A more detailed overview of the main indicators relating to the economic operators engaging in heating sector activities and to the heating systems themselves is provided in Chapter 1 and Chapter 7.

Energy savings based, among other things, on increased energy efficiency is one of the imperatives for further development of the heating sector in Croatia. In addition, it is necessary to increase the reliability and security of supply by using advanced modern technologies, such as high-efficiency cogeneration plants, the use of biomass and waste as fuel, the replacement of existing, inefficient piping with new, modern pre-insulated piping. Furthermore, if savings are to be made in any of the ways mentioned above, it is essential to improve the existing legislative framework, which very often does not provide sufficient support in the implementation of various measures.

The use of natural gas for heating purposes, as the main competitor to thermal systems, is among major obstacles to further development of the heating sector and, consequently, to achieving energy savings (in terms of primary energy savings). In addition, the absence of major investments in this sector, which is a consequence of inadequate systematic energy planning, is also a considerable obstacle.

It should be noted here that one of the main preconditions for increasing energy savings is raising public awareness of energy efficiency measures. Citizens' awareness and their attitude with regard to energy consumption are important because thermal energy consumption is firmly linked to the habits and customs of citizens, as predominant thermal energy users. Considering thermal systems, energy efficiency may be viewed from two aspects:

- building sector;
- thermal systems.

Increasing energy efficiency in the buildings sector has a direct impact on energy consumption savings. By retrofitting or improving the thermodynamic characteristics of building envelopes, considerable savings in thermal energy consumption for space heating and cooling may be achieved. Admittedly, the reduction of thermal energy required by final customers does not have a direct positive impact on thermal system development, so new models need to be proposed for economically justifiable improvement of these systems. Increasing the energy efficiency of the distribution network leads to a reduction in heat losses during thermal energy distribution. Savings can be achieved primarily by installing pre-insulated pipes with moisture detectors, as a modern method of thermal energy distribution. Furthermore, adequate metering and regulating equipment needs to be installed in end-user substations to ensure adequate amounts of thermal energy for each end user. End users, i.e. consumers also need to be taken into account in estimating possible savings. By the manner in which they use energy, end users can considerably contribute to reducing consumption, so it is necessary to develop appropriate plans for their education.

Considerable potential for energy savings lies in energy sources themselves. Most of the existing heat sources are hot water boilers and cogeneration installations with a poor degree of effectiveness. By replacing them with modern technologies, such as heat pumps of great installed power, biomass and waste boilers, considerable savings in primary energy consumption may be achieved.

Naturally, for the purpose of further district heating system development and achieving energy consumption savings, it is necessary to consider all options and adopt an integral solution to achieve the most favourable results. In doing so, it is neither necessary nor possible to achieve a less favourable [sic – the most favourable is likely meant] solution in every segment of the system. The fact that without systematic planning and management it is impossible to achieve significant positive changes should be kept in mind. It is necessary to anticipate trends and technologies which will be economically acceptable in the period of next 10 years or more and, based on those assumptions, design the entire system and determine achievable savings.

10.5. POTENTIAL ENERGY SAVINGS

Heating energy savings in Croatia to be achieved by 2030 have been determined on the basis of the results of all the analyses conducted in the following chapters:

- Chapter 2 – Forecast changes in energy consumption for heating and cooling in the next 10 years;
- Chapter 4 – Determining thermal energy demand which can be met through high-efficiency cogeneration;
- Chapter 6 – Determining the potential for additional high-efficiency cogeneration;
- Chapter 7 – Determining the potential to increase infrastructure energy efficiency;
- Chapter 9 – High-efficiency cogeneration share, potential identified and progress made.

In Chapter 2 – Forecast changes in energy consumption for heating and cooling in the next 10 years, account has been taken of energy efficiency measures in the form of increased energy efficiency in the building sector, as well as applicable legal regulation defining the criteria for new-builds in the future and, indirectly, energy needs for heating and cooling. In addition, the potential for implementing additional high-efficiency cogeneration and infrastructure necessary for the use of thermal systems have been analysed.

In Chapter 9 – High-efficiency cogeneration share, potential identified and progress made, two scenarios of future thermal energy needs: conservative and optimistic have been defined. In addition to thermal needs based on the proportion of consumers connected to district heating systems, potent electricity output has been determined for each scenario. Six locations were singled out and analysed in the conservative scenario and 18 potential locations for new high-efficiency cogeneration installations in the optimistic scenario. The results of the analysis, namely the determined heat consumption and potential electricity output, refer to projections for 2030. To meet the needs thus identified, the necessary amount of primary fuel energy was also determined.

Based on the determined fuel consumption and electricity and thermal energy output values, as well as the presumed electricity and heat efficiency of a cogeneration installation, primary fuel energy savings are determined in accordance with the methodology defined in the Rules governing the grant of eligible electricity producer status.

10.5.1. Primary energy savings in the conservative high-efficiency cogeneration scenario

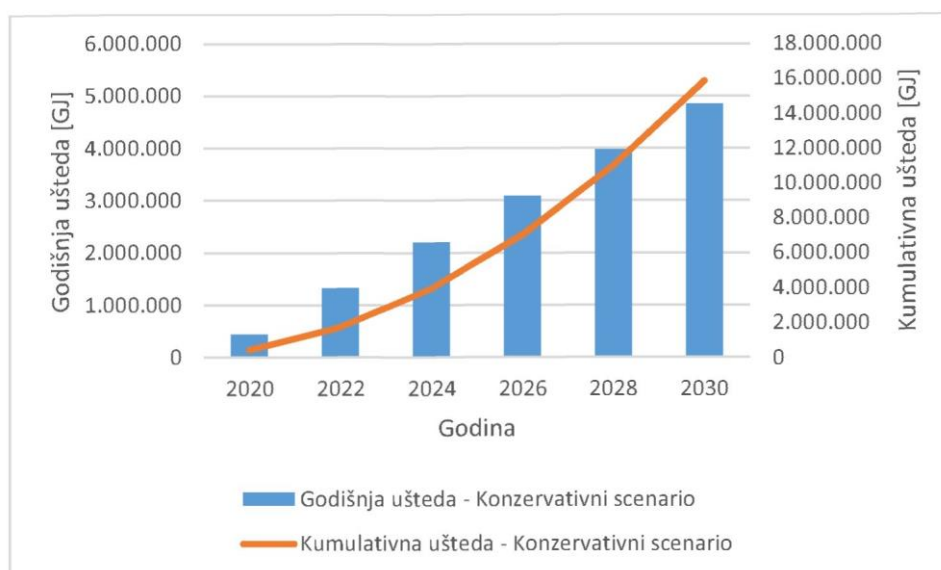
The projection of fuel consumption to meet thermal and electricity needs as part of high-efficiency cogeneration, and primary energy savings determined according to the aforementioned methodology, are provided in the table below. These primary energy savings refer to potential savings in 2030.

Table 42: Estimate of primary energy savings in 2030 – conservative scenario

No	City	Conservative scenario in 2030				
		Fuel consumption		Primary energy savings	Primary energy savings	
		MWh	GJ	%	MWh	GJ
1	Zagreb	3 485 819.0	12 548 948.3	30.83	1 074 518.7	3 868 267.3
2	Đurđenovac	241 437.1	869 173.7	30.80	74 354.7	267 677.0
3	Velika Gorica	195 729.7	704 627.0	30.81	60 297.1	217 069.4
4	Karlovac	154 291.4	555 448.9	30.79	47 501.9	171 006.9
5	Županja	148 691.1	535 287.9	30.85	45 877.4	165 158.5
6	Koprivnica	144 291.8	519 450.6	30.78	44 409.6	159 874.4
TOTAL:		4 370 260.1	15 732 936.4	30.82	1 346 959.3	4 849 053.6

Potential primary energy savings can be achieved, among other things, by building and commissioning of high-efficiency cogeneration installations. It is not realistic to expect the entire potential for thermal energy to be satisfied by building cogeneration installations within a short period of time or in the near future. The potential primary energy savings shown in the table above refer to projections for 2030. Therefore, to determine cumulative primary energy savings by 2030, it was presumed that potential primary energy savings would only be achieved starting from 2020 and would grow linearly until 2030, when a saving of 4 849 054 GJ is expected at an annual level. The reason for this lies in the time needed to build and put into operation high-efficiency cogeneration installations and necessary infrastructure.

The following figure shows expected primary energy savings in the period between 2020 and 2030 based on linear approximation, as explained above. In addition to expected savings in the given years, it also shows cumulative primary energy savings, i.e. overall primary energy savings achieved, for the period under observation.



Godišnja ušteda [GJ]	Annual savings [GJ]
----------------------	---------------------

<i>Kumulativna ušteda [GJ]</i>	<i>Cumulative savings [GJ]</i>
<i>Godina</i>	<i>Year</i>
<i>Godišnja ušteda – Konzervativni scenario</i>	<i>Annual savings – conservative scenario</i>
<i>Kumulativna ušteda – Konzervativni scenario</i>	<i>Cumulative savings – conservative scenario</i>

Figure 75: Overview of annual and cumulative primary energy savings, 2020-2030 – conservative scenario

The following two figures show fuel consumption for the purposes of powering potential high-efficiency cogeneration installations in 2030 in Croatia, and primary energy savings in the conservative scenario.



Figure 76: Distribution of fuel consumption for high-efficiency cogeneration installations in Croatia, 2030 – conservative scenario

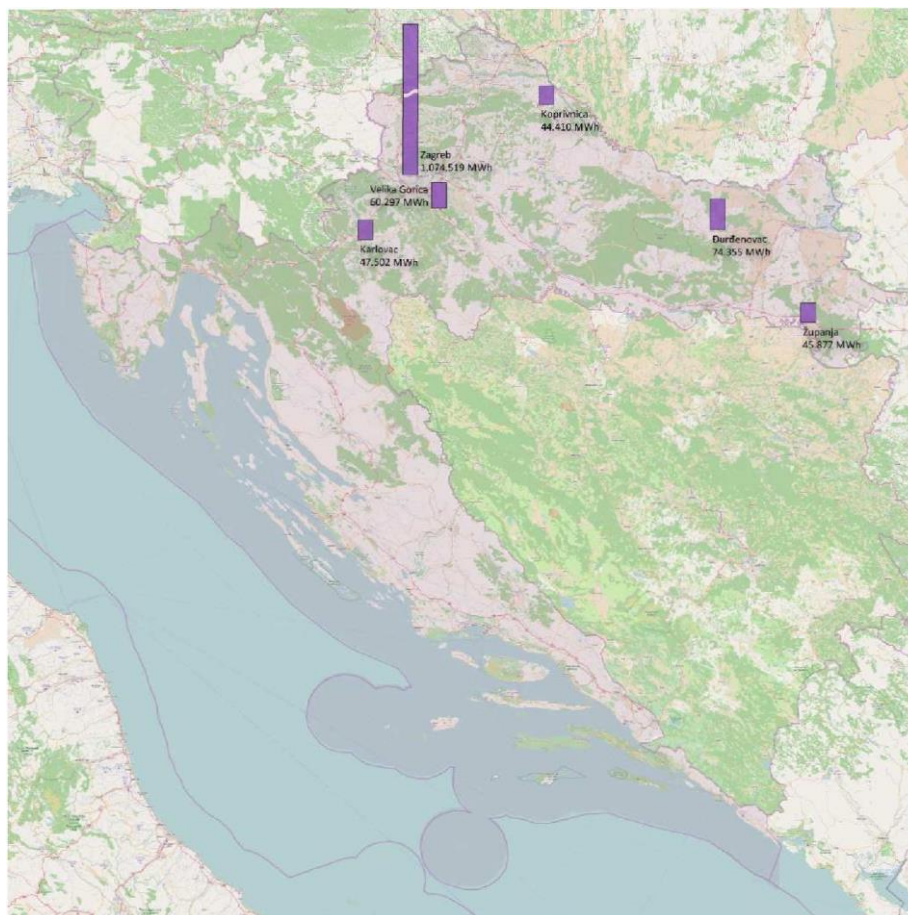


Figure 77: Distribution of primary energy savings for high-efficiency cogeneration installations in Croatia, 2030 – conservative scenario

10.5.2. Primary energy savings in the optimistic high-efficiency cogeneration scenario

By analogy with the analysis carried out for the conservative scenario, an analysis for the optimistic scenario in 2030 has been conducted in this chapter. The basic difference between the two scenarios is the assumption of the share of thermal needs satisfied by district heating systems, as explained in greater detail in Chapter 9 – High-efficiency cogeneration share, potential identified and progress made.

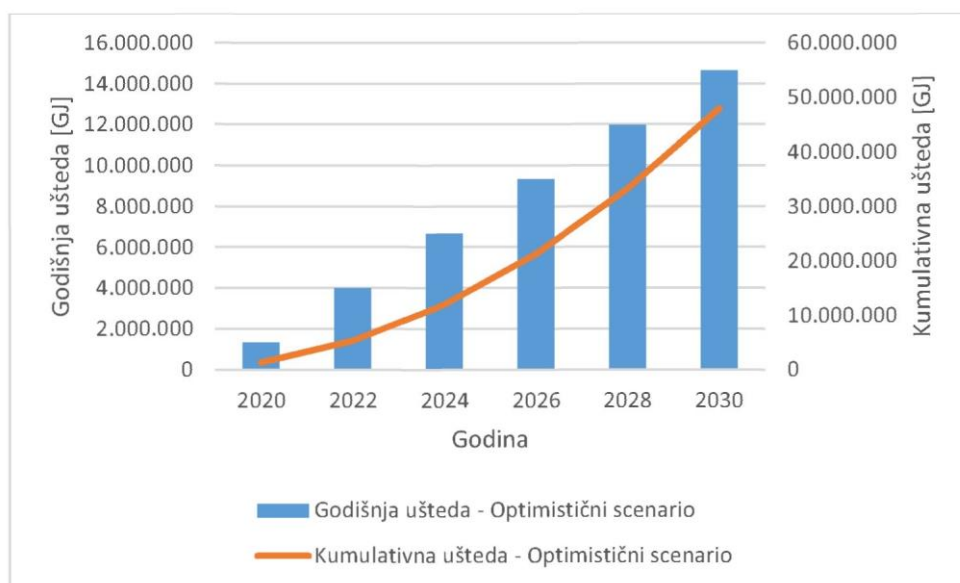
Estimates of primary energy savings at 18 locations in Croatia where thermal needs will suffice for the construction of high-efficiency cogeneration installations with thermal input exceeding 20 MWt are provided in the figure below. An overview of expected fuel consumption is also given.

Table 43: Estimate of primary energy savings in 2030 – optimistic scenario

No	City	Optimistic scenario in 2030				
		Fuel consumption		Primary energy savings	Primary energy savings	
		MWh	GJ	%	MWh	GJ
1	Zagreb	6 971 638.0	25 097 896.7	30.83	2 149 037.4	7 736 534.6
2	Đurđevac	1 662 158.3	5 983 769.9	30.80	511 890.3	1 842 805.2
3	Velika Gorica	728 313.9	2 621 929.9	30.79	224 227.2	807 217.7
4	Karlovac	391 014.8	1 407 653.2	30.79	120 382.3	433 376.4
5	Županja	462 874.1	1 666 346.7	30.85	142 815.8	514 137.0
6	Koprivnica	410 401.0	1 477 443.6	30.78	126 311.6	454 721.6
7	Varaždin	404 407.7	1 455 867.6	30.76	124 389.6	447 802.6
8	Bjelovar	307 283.6	1 106 221.0	30.82	94 692.1	340 891.5

No	City	Optimistic scenario in 2030				
		Fuel consumption		Primary energy savings	Primary energy savings	
		MWh	GJ	%	MWh	GJ
9	Osijek	297 382.2	1 070 575.9	30.83	91 669.3	330 009.6
10	Sisak	267 542.1	963 151.5	30.84	82 496.6	296 987.8
11	Virovitica	230 866.9	831 121.0	30.80	71 099.5	255 958.0
12	Rijeka	209 448.4	754 014.2	31.10	65 145.5	234 523.7
13	Samobor	183 729.0	661 424.4	30.05	55 208.5	198 750.7
14	Zaprešić	166 836.5	600 611.4	30.82	51 412.1	185 083.6
15	Belišće	145 154.3	522 555.5	30.83	44 744.4	161 080.0
16	Slavonski	124 141.1	446 907.9	30.82	38 255.1	137 718.5
17	Petrinja	120 444.1	433 598.9	30.81	37 104.4	133 575.7
18	Požega	111 283.9	400 622.0	30.81	34 282.4	123 416.8
TOTAL:		13 194 919.8	47 501 711.3	30.82	4 065 164.2	14 634 591.1

Since these savings cannot be achieved within a short period of time, this analysis presumed that primary energy savings increase linearly until 2030, and that savings would only begin to be achieved in 2020 and grow linearly until 2030, when a saving of 14 634 591 GJ at an annual level is expected. Based on these assumptions, an analysis of annual and cumulative primary energy savings was carried out, as shown in the following figure.



<i>Godišnja ušteda [GJ]</i>	<i>Annual savings [GJ]</i>
<i>Kumulativna ušteda [GJ]</i>	<i>Cumulative savings [GJ]</i>
<i>Godina</i>	<i>Year</i>
<i>Godišnja ušteda – Optimistični scenario</i>	<i>Annual savings – optimistic scenario</i>
<i>Kumulativna ušteda – Optimistični scenario</i>	<i>Cumulative savings – optimistic scenario</i>

Figure 78: Overview of annual and cumulative primary energy savings, 2020-2030 – optimistic scenario

The following two figures show fuel consumption for the purposes of powering potential high-efficiency cogeneration installations in 2030 in Croatia, and primary energy savings in the optimistic scenario.

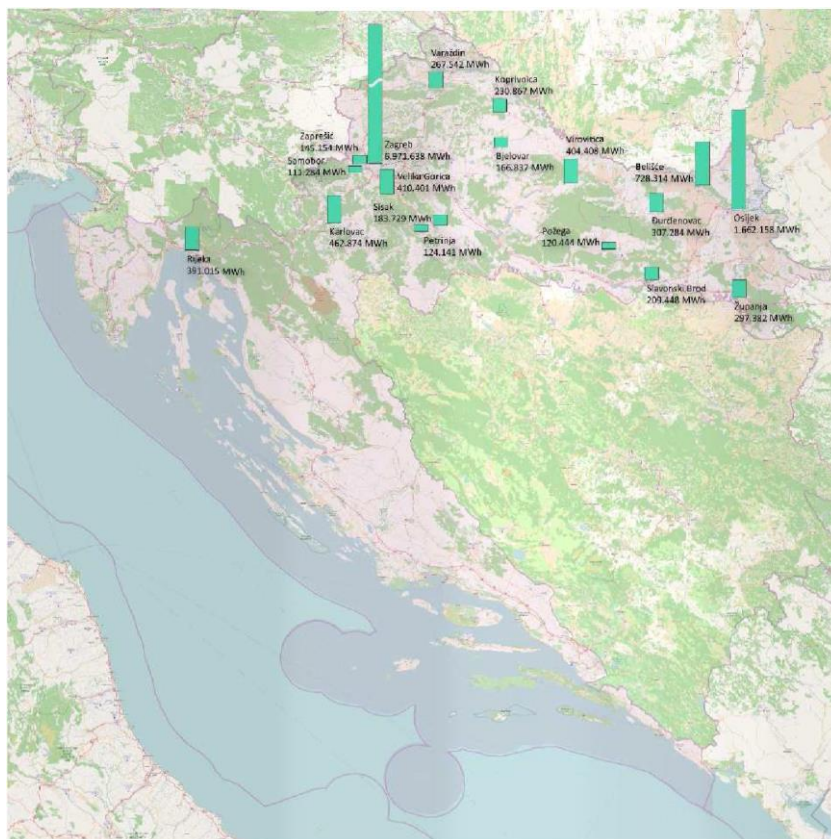


Figure 79: Distribution of fuel consumption for high-efficiency cogeneration installations in Croatia, 2030 – optimistic scenario

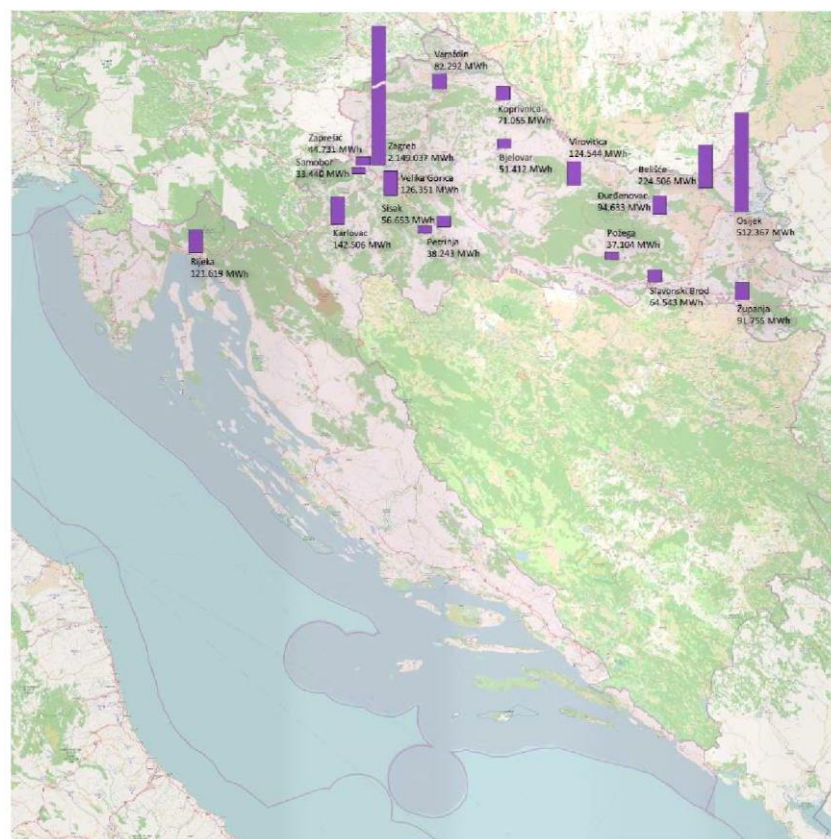


Figure 80: Distribution of primary energy savings for high-efficiency cogeneration installations in Croatia, 2030 – optimistic scenario

11. ESTIMATE OF PUBLIC SUPPORT MEASURES FOR HEATING AND COOLING

11.1. ANALYSIS OF RELEVANT REGULATIONS (TREATIES, DIRECTIVES, REGULATIONS AND GUIDELINES) ALLOWING THE GRANT OF STATE AID

11.1.1. Treaty on the Functioning of the European Union

The Treaty on the Functioning of the European Union (hereinafter: TFEU) is the basic document by which the signatories founded the European Union, to which the Member States delegate powers to achieve their common goals.

The TFEU established the internal market with the aim of developing Europe's internal market. Article 107(1) of the TFEU prohibits any aid granted by a Member State or aid granted through State resources which distorts competition.

Article 107 (2) sets out the following types of aid which are not contradictory to the internal market:

- aid having a social character, granted to individual consumers, provided that such aid is granted without discrimination related to the origin of the products concerned;
- aid to make good the damage caused by natural disasters or exceptional occurrences;
- aid granted to the economy of certain areas of the Federal Republic of Germany affected by the division of Germany, in so far as such aid is required in order to compensate for the economic disadvantages caused by that division. Five years after the entry into force of the Treaty of Lisbon, the Council, acting on a proposal from the Commission, may adopt a decision repealing this point.

Article 107(3) of the TFEU sets out the following types of aid which may be considered compatible with the internal market:

- aid to promote the economic development of areas where the standard of living is abnormally low or where there is serious underemployment, and of the regions referred to in Article 349, in view of their structural, economic and social situation;
- aid to promote the execution of an important project of common European interest or to remedy a serious disturbance in the economy of a Member State;
- aid to facilitate the development of certain economic activities or of certain economic areas, where such aid does not adversely affect trading conditions to an extent contrary to the common interest;
- aid to promote culture and heritage conservation where such aid does not affect trading conditions and competition in the Union to an extent contrary to the common interest;
- such other categories of aid as may be specified by decision of the Council on a proposal from the Commission.

Article 108 of the TFEU defines actions by the European Commission regarding the grant of State aid. The Commission is required to keep all systems of State aid under review, in cooperation with Member States. If the Commission finds that a certain type of aid is not compatible with the functioning of the internal market, it may decide that such State aid must be abolished or altered within a period of time. If the Member State concerned does not comply with the Commission's decision on State aid, the Commission or any other interested Member State may refer the matter to the Court of Justice of the European Union.

The Council of Ministers may unanimously decide that aid is considered to be compatible with the internal market if justified by exceptional circumstances.

11.1.2. Guidelines on State Aid for environmental protection and energy 2014-2020

The Guidelines on State aid for environmental protection and energy 2014-2020 apply to State aid granted for environmental protection or energy objectives in all sectors to which the TFEU applies.

These Guidelines have established that, under certain conditions, the following aid may be compatible with the internal market:

- aid for going beyond Union standards or increasing the level of environmental protection in the absence of Union standards (including aid for the acquisition of new transport vehicles);
- aid for early adaptation to future Union standards;
- aid for environmental studies;
- aid for the remediation of contaminated sites;
- aid for energy from renewable sources;
- aid for energy-efficiency measures, including cogeneration and district heating and district cooling;
- aid for resource efficiency and, in particular, for waste management;
- aid for CO₂ capture, transport and storage including individual elements of the Carbon Capture Storage (CCS) chain;
- aid in the form of reductions in or exemptions from environmental taxes;
- aid in the form of reductions in funding support for electricity from renewable sources;
- aid for energy infrastructure;
- aid for generation adequacy measures;
- aid involved in tradable permits;
- aid for the relocation of undertakings.

Point 6 explicitly states explicitly that aid for district heating and cooling is compatible with the internal market under certain conditions.

The Guidelines define district heating and cooling as district heating and cooling which satisfies the definition of efficient district heating and cooling system as set out in Article 2(41) and (42) of Directive 2012/27/EU (26). The definition includes the heating/cooling production plants and the network (including related facilities) necessary to distribute the heat/cooling from the production units to the customer premises.

Individual aid granted on the basis of a notified aid scheme remains subject to the notification obligation pursuant to Article 108(3) of the TFEU if the aid exceeds the notification thresholds set out in the Guidelines and is not granted on the basis of a competitive bidding process. The thresholds are defined in detail in Article 20 of the Guidelines.

State aid for environmental protection and energy objectives will be considered compatible with the internal market within the meaning of Article 107(3)(c) of the Treaty if, on the basis of the common assessment principles set out in this section, it leads to an increased contribution to the Union environmental or energy objectives without adversely affecting trading conditions to an extent contrary to the common interest. The specific handicaps of assisted areas will be taken into account.

Furthermore, the Guidelines clarify how the Commission will apply the common assessment principles set out in the Guidelines when assessing aid measures falling within the scope of these Guidelines and, where applicable, lay down specific conditions for individual aid. They also set out and define the general conditions for the grant of State aid applicable to all aid specified in the Guidelines.

The Guidelines define aid the following specific conditions applicable to aid for energy-efficiency measures, including cogeneration and district heating and district cooling: In order to ensure that aid contributes to a higher level of environmental protection, aid for district heating and district cooling and cogeneration of heat and electricity (CHP) will only be considered compatible with the internal market if granted for investment, including upgrades, to high-efficient CHP and energy-efficient district heating and district cooling. For measures co-financed by the European Structural and Investments Funds, Member States may rely on the reasoning in the relevant Operational Programmes.

11.1.3. Commission Regulation (EU) No 651/2014 of 17 June 2014 declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty on the Functioning of the European Union

In accordance with Article 108(4) of the Treaty, the Commission adopted the Regulation declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the TFEU which apply to those categories of State aid. This Regulation should allow for better prioritisation of State aid enforcement activities, greater simplification and should enhance transparency, effective evaluation and the control of compliance with the State aid rules at national and Union levels.

This Regulation applies to the following categories of aid: regional aid; aid to SMEs in the form of investment aid, operating aid and SMEs' access to finance; aid for environmental protection; aid for research and development and innovation; training aid; recruitment and employment aid for disadvantaged workers and workers with disabilities; aid to make good the damage caused by certain natural disasters; social aid for transport for residents of remote regions; aid for broadband infrastructures; aid for culture and heritage conservation; aid for sport and multifunctional recreational infrastructures; and aid for local infrastructures.

This Regulation also defines district heating and cooling according to Article 2(41) and (42) of Directive 2012/27/EU. The definition includes the heating/cooling production plants and the network (including related facilities) necessary to distribute the heat/cooling from the production units to the customer premises. This definition is classified among the definitions applicable to environmental protection aid, in accordance with this Regulation.

The Regulation further contains provisions regulating notification thresholds, transparency of aid, incentive effect, aid intensity and eligible costs, cumulation of aid, publication and information, and monitoring the granting of aid.

It governs in detail the grant of investment aid for the installation of energy-efficient district heating and cooling systems. The Regulation specifies that such aid is compatible with the internal market within the meaning of Article 107(3) of the TFEU provided that the conditions laid down in this Regulation are fulfilled.

It defines the costs which are eligible for such installations, the aid intensity and the amount of aid eligible for the distribution network.

Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC,

Directive 2012/27/EU of the European Parliament and of the Council [sic – likely repetition of the title] establishes a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's 2020 20 % headline target on energy efficiency and to pave the way for further energy efficiency improvements beyond that date.

The Directive lays down rules designed to remove barriers in the energy market and overcome market failures that impede efficiency in the supply and use of energy, and provides for the establishment of indicative national energy efficiency targets for 2020.

This Directive defines efficient district heating and cooling as a district heating or cooling system using at least 50 % renewable energy, 50 % waste heat, 75 % cogenerated heat or 50 % of a combination of such energy and heat.

Under the Directive, efficient district heating and cooling is a way for Member States to establish an energy efficiency obligation scheme. The Directive provides clear guidance on monitoring and promoting energy efficiency, and efficient district heating and cooling is an important part of it.

The Directive stipulates that, by 31 December 2015, Member States are to carry out and notify to the Commission a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling.

11.1.4. Commission Regulation (EU) No 1407/2013 of 18 December 2013 on the application of Articles 107 and 108 of the Treaty on the Functioning of the European Union to *de minimis* aid

The Regulation on the application of Articles 107 and 108 of the Treaty on the Functioning of the European Union to *de minimis* aid applies to aid granted to undertakings in all sectors. The following aid is exempt from the application of this Regulation: aid granted to undertakings active in the fishery and aquaculture sector; aid granted to undertakings active in the primary production of agricultural products; aid to export-related activities towards third countries or Member States, namely aid directly linked to the quantities exported, to the establishment and operation of a distribution network or to other current expenditure linked to the export activity; and aid contingent upon the use of domestic over imported goods.

If aid measures fulfil the conditions laid down in this Regulation, they are deemed not to meet all the criteria referred to in Article 107(1) of the TFEU, and are therefore exempt from the notification requirement in Article 108(3) of the TFEU. The total amount of *de minimis* aid granted per Member State to a single undertaking must not exceed EUR 200 000 over any period of three fiscal years.

This Regulation defines methods for the calculation, culmination [sic – cumulation, instead of culmination, is meant] and monitoring of *de minimis* aid.

11.2. OVERVIEW OF POSSIBLE WAYS OF GRANTING STATE AID FOR DISTRICT HEATING AND COOLING

11.2.1. State aid in accordance with the *de minimis* rules

Small amounts of aid to one undertaking, i.e. less than EUR 200 000 over any period of three years, are considered to be so small as not to have any significant effect on competition or trade and, under the *de minimis* rule, these are exempt from the general ban on State aid.

However, *de minimis* payments to one undertaking under different measures or schemes have to cumulatively observe the EUR 200 000 limit, and Member States have to closely monitor small payments to ensure that the EUR 200 000 limit is not breached.

De minimis aid can be given for most purposes, including operating aid. However, it cannot be given for export-related activities (except attendance at trade fairs), agriculture and fisheries or aid favouring domestic over imported products. Aid measures for district heating and cooling can be consistent with the *de minimis* rules, provided that they observe the EUR 200 000 limit.

11.2.2. State aid under Regulation 651/2014, according to which certain categories of aid are compatible with the EU's internal market

A block exemption allows Member States to bring certain State aid schemes into place without prior notification to the European Commission, provided that they are within the parameters set out in the block exemption.

Member States are required send a summary information sheet with a list of aid measures to the Commission via the State Aid Notification Interactive (SANI) system within 20 working days after the entry into force of the aid scheme.

However, before the scheme enters into force or a notification of it is sent via SANI, a summary of measures needs to be drawn up for distribution through other channels. This summary document must be published at an easily accessible location, for example on a website for interested parties for information purposes, and must remain accessible for the entire duration of the scheme. The website must be specified in the summary, which in turn must be notified via SANI.

The following aid categories covered by the block exemption will be subject to an evaluation if they have an average annual budget exceeding EUR 150 million:

- regional aid (except operating aid);
- aid for SMEs;
- aid for access to finance for SMEs;

- aid for research and development;
- aid for environmental protection (except reductions of environmental taxes under Directive 2003/96/EC);
- aid for broadband infrastructures.

The schemes covered by the General Block Exemption Regulation, but belonging to other categories not listed above, will not be subject to evaluation requirements, regardless of their budget.

The schemes covered by the Regulation that are subject to evaluation can be implemented without prior notification to the Commission as per the 20 day SANI notification requirement. However, an evaluation plan must be submitted to and agreed with the Commission within six months.

The evaluation plan should contain some standard information (e.g. objectives of the aid scheme, result indicators, envisaged methodology, timeline of the evaluation).

11.3. SPECIFIC NOTIFICATION

If a measure does not fit in the block exemption or is not applied in compliance with the *de minimis* rules, the scheme must be notified to the Commission. This can be a lengthy process and should therefore be regarded as a last resort.

More straightforward cases can be resolved within 6-9 months. More complex cases can be expected to take longer. Aid cannot be given until final approval has been received from the Commission.

Notification process for measures not covered by the block exemption

The first step is cooperation with the Commission on the proposal concerned. A useful step is to seek similar measures for aid from other Member States. If there is a similar aid measure in other States, the terms of that measure should be replicated in order to increase the chances of the Commission approving the aid measure.

After the implementation of this initial step, a pre-notification (i.e. a draft notification) can be sent to the Commission. The pre-notification is to be submitted to the Commission via SANI.

In most cases, the Commission will respond with a request for further information and/or to arrange a discussion. There can be a series of rounds of questions and answers, and refinement of the proposal until the Commission is satisfied that it can be approved. However, there is no guarantee that the Commission will give consent to the proposal for the grant of State aid.

In the end, the Commission will invite the Member State to submit the final notification via SANI, and final approval and/or consent is normally given within two months.

12. PLANS FOR DISTRICT HEATING SECTOR DEVELOPMENT

12.1. INTRODUCTION

This chapter provides an analysis of development plans for energy companies in the district heating sector and an additional analysis conducted to determine their financial potential for future investments. Furthermore, it analyses applicable spatial planning acts with a major impact on heating systems, including a short overview of the current situation in the thermal energy market according to relevant sources (HERA; *Energija u RH* (Energy in Croatia)).

12.2. ANALYSIS OF DEVELOPMENT PLANS FOR EXISTING ENERGY OPERATORS IN THE HEATING SECTOR

In order to analyse the development plans, requests for information on the current development plans were sent to energy operators engaging in thermal energy generation and distribution in the Croatian thermal energy market.

The analysis covers available three-year development plans and data obtained via a questionnaire, including the following three-year period data:

- financial statements: balance sheet/profit and loss account/cash flow statement – to determine the financial potential of each district heating company in terms of future development investments;
- data on annual thermal energy generation;
- investment in existing infrastructure or expansion.

Since not all data requested in the questionnaire were obtained at the time of preparing this report, the analyses were conducted based on the available data.

12.2.1. Annual thermal energy generation in 2012, 2013 and 2014

The available data suggest a declining trend of total thermal energy generation in the majority of cities in the last three years, as shown in the figure and table below. Increased thermal energy generation can be observed only in Sisak in 2014.

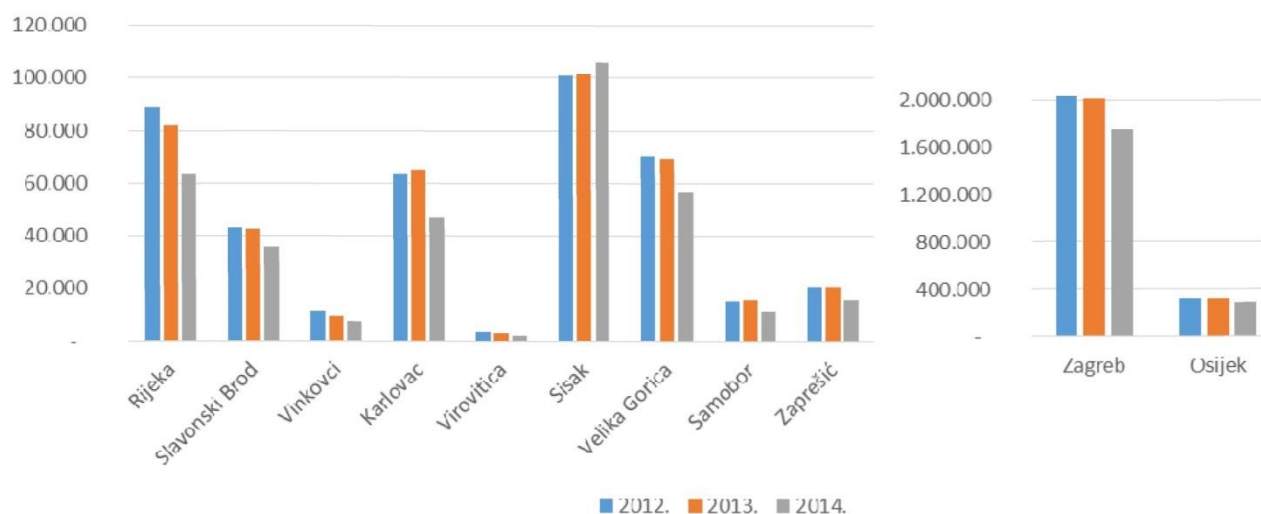


Figure 81: Annual thermal energy generation

Table 44: Annual thermal energy generation

Company	City/year	Thermal energy generated, MWh		
		2012	2013	2014
Energo	Rijeka	89 055	82 079	63 409
Brod Plin	Slavonski Brod	43 242	42 476	35 477
GTG	Vinkovci	10 961	9 320	7 189
Gradska Toplana	Karlovac	63 562	65 286	47 070
Plin VTC	Virovitica	3 629	3 422	2 357
HEP Toplinarstvo	Sisak	101 496	101 628	105 773
	Velika Gorica	70 482	69 349	56 938
	Samobor	15 308	15 785	11 151
	Zaprešić	20 788	21 036	15 608
	Zagreb	2 034 214	2 016 677	1 744 344
	Osijek	315 122	319 260	283 583

12.2.2. Investments in heating systems implemented in 2012, 2013 and 2014

The data on the implementation of maintenance and investment plans in 2012, 2013 and 2014 obtained are incomplete. Most companies conducted only corrective maintenance for the purpose of maintaining heating system functionality. Data on investment maintenance carried out by individual companies in the last three years are provided in the table below.

Table 45: Implemented investments in the existing infrastructure or system expansion

Company	City	Implemented investments in the existing infrastructure or expansion, HRK			Work description
		2012	2013	2014	
Energo	Rijeka	–	–	–	
Brod Plin	Slavonski Brod	2 764 556		877 529	replacement of boilers, other boiler equipment, substation, thermal capacity increase, pumping installation and
GTG	Vinkovci	–	–		
Gradska Toplana	Karlovac	1 500 000	1 500 000	1 500 000	emergency interventions due to hot water pipeline rupture and hot water network replacement, boiler installation repairs
Plin VTC	Virovitica	–	–	–	
HEP Toplinarstvo	Sisak	11 719 298	5 092 879	6 323 331	boiler room replacement and reconstruction, hot water pipeline replacement and reconstruction, hot water network revitalisation, steam pipeline replacement and reconstruction, new hot water pipeline connections, new steam pipeline connections, heating station replacement and reconstruction, calorimeter and metering system
	Velika Gorica	3 624 377	1 157 918	52 602	heating network revitalisation, block boiler room replacement and reconstruction, heating station replacement and reconstruction, exchanger replacement and reconstruction, new heating station facilities, calorimeter and metering system replacement and reconstruction,

Company	City	Implemented investments in the existing infrastructure or expansion, HRK			Work description
		2012	2013	2014	
	Samobor	1 583 951	130 731	–	installation of gas in boiler rooms, hot water pipeline revitalisation, block boiler room replacement and reconstruction, heating station replacement and
HEP Toplinarstvo	Zaprešić	2 662 033	161 763	32 246	heating network revitalisation, block boiler room replacement and reconstruction, heating station replacement and reconstruction, exchanger replacement and reconstruction, calorimeter and
	Zagreb	66 023 538	53 396 133	28 697 469	hot water pipeline replacement, hot water pipeline revitalisation and retrofits, steam pipeline repairs, exchanger replacement, heating station revitalisation, calorimeter and metering system replacement, new
	Osijek	15 223 786	11 051 888	12 219 270	block boiler room replacement and reconstruction, hot water pipeline replacement and reconstruction, steam pipeline network revitalisation, new hot

According to the submitted documents and records of investments made, it can be concluded that the majority of investment in production facilities and distribution networks was implemented to maintain the functionality of heating systems, while only a small portion went towards system improvements and development and to connect new consumers.

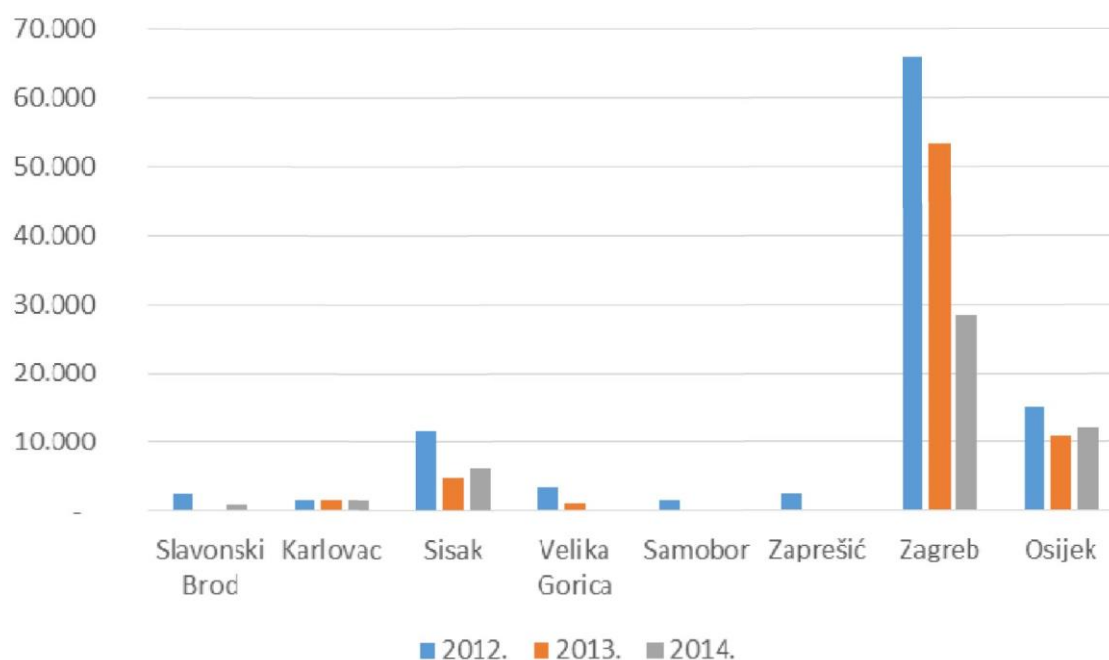


Figure 82: Investment in the existing infrastructure

12.2.3. Three-year development plans

Three-year development plans of the following companies have been analysed: *Energo d.o.o.* Rijeka, *Brod Plin d.o.o.* Slavonski Brod, *Gradska toplana d.o.o.* Karlovac and *HEP Toplinarstvo d.o.o.* They include plans for the development, construction and reconstruction of energy facilities and thermal energy generation equipment, as well as plans for the development, construction and reconstruction of distribution networks. They refer to the district heating systems in Rijeka, Slavonski Brod, Karlovac, Zagreb, Osijek and Sisak.

Information on three-year investment plans for 2015-2017, as well as subsequent years in the case of particular companies, is provided in the tables below, stating investment amounts, planned funding sources and a general description of investments.

Table 46: Planned investments in energy facilities and thermal energy generation equipment

Company	City	Planned investments in energy facilities and thermal energy generation equipment, in HRK 000				Funding sources	Description
		2015	2016	2017	2018 and beyond		
Energo	Rijeka	1 650	27 380	1 750	3 260	EBRD	heating plant relocation and new energy block construction, heating station reconstruction, remote control and supervision system implementation, new boiler installation, boiler dismantling and installation works, exchanger installation
Brod Plin	Slavonski Brod	1 500	500	500	n/a	EBRD, own funds	boiler no 3, water softening, expansion system, chimney repairs at the Slavonija boiler
GTG	Vinkovci	n/a	n/a	n/a	n/a	–	–
Gradska Toplana	Karlovac	500	600	470	3 258	City of Karlovac, EPEEF, own	boiler repairs, installation of VKLM-25 boiler gas
Plin VTC	Virovitica	–	–	–	–	–	no plans for new
HEP Toplinarstvo	Sisak	130	–	–	–	own funds	boiler room replacement and reconstruction
	Velika Gorica	1 685	–	20 000	20 000	own funds	DHS construction – production facility, investment documentation
	Samobor	632	–	8 100	8 100	own funds	DHS construction – production facility, investment documentation
	Zaprešić	840	–	12 150	12 150	own funds	DHS construction – production facility, investment documentation
	Zagreb	39	–	–	–	own funds	personal transport vehicles, tools and
	Osijek	–	–	–	–	–	–

Table 47: Planned investment in the distribution network

Company	City	Planned investment in the distribution network, in HRK 000				Funding sources	Description
		2015	2016	2017	2018 and beyond		
Energo	Rijeka	6 500	9 150	3 400	80	EBRD	Reconstruction of a part of the existing hot water pipeline
Brod Plin	Slavonski Brod	5 000	5 600	–	n/a	Loan	worn-out 2 571 m hot water pipeline replacement
GTG	Vinkovci	n/a	n/a	n/a	n/a	–	–

Company	City	Planned investment in the distribution network, in HRK 000				Funding sources	Description
		2015	2016	2017	2018 and beyond		
Gradska Toplana	Karlovac	1 000	4 550	3 150	3 000	City of Karlovac, EPEEF, own funds	partial hot water pipeline system repairs
Plin VTC	Virovitica	–	–	–	–	–	no plans for new construction
HEP Toplinarstvo	Sisak	6 669	3 400	3 400	–	own funds	revitalisation of the third phase of pipe distribution around heating station 2 – Caprag, revitalisation of heating station 3 and the first phase of distribution – Caprag, calorimeter and metering system replacement, steam pipeline replacement and reconstruction, hot water
HEP Toplinarstvo	Velika Gorica	1 113	6 000	12 950	18 736	own funds	hot water network revitalisation, remote reading system installation, DHS hot water network construction
	Samobor	35	–	2 680	2 680	own funds	remote reading system installation DHS hot water network construction
	Zaprešić	920	–	4 020	4 020	own funds	DHS hot water network construction, new hot water pipeline facilities
	Zagreb	62 399	211 869	192 423	480 000	own funds, EU funds, World Bank, investors	planned revitalisation of hot water pipeline, connection of the Dubrava district, hot water network revitalisation in Dubrava, remote reading system installation, steam pipeline repairs, calorimeter and metering system replacement, new
	Osijek	12 169	35 133	35 133	41 543	own funds, investors	revitalisation of hot water and steam networks, remote reading system installation, replacement of the connecting steam pipeline from TE-TO Osijek to the heating plant, new connections

12.2.4. Analysis of the financial potential

It is important to note that without detailed information and in-depth analysis, it is impossible to perform a detailed examination of the financial potential of the companies observed. A brief overview is provided below.

Brod Plin

In the 2013-2014 period, *Brod Plin d.o.o.* generated revenue of HRK 113 million and HRK 94 million respectively, as well as a profit of HRK 2.3 million and HRK 2 million respectively. Balance sheet analysis showed the value of fixed assets at HRK 75 million. Trade receivables amounted to HRK 27 million and 23 million respectively. In terms of liabilities, *Brod Plin d.o.o.* recorded HRK 16 million and HRK 11 million in non-current liabilities to financial institutions respectively, as well as HRK 41 million

and HRK 40 million in current liabilities (mainly to suppliers, but also to financial institutions) for the respective years.

According to data provided, the company invested the following amounts in boiler rooms: HRK 2.76 million in 2012, HRK 50 155 in 2013 and HRK 877 528 in 2014. In the upcoming period between 2015 and 2017, the company plans to invest HRK 2.5 million in the reconstruction of energy facilities and HRK 10.6 million in worn-out hot water pipeline replacement. The company plans to cover the investments partly with its own funds and partly with a loan from the European Bank for Reconstruction and Development.

Energo

Summarised three-year financial information provided by the company shows a record of accounting losses in all three years observed (2012-2014). In addition, a review of cash flows in the three-year period of 2012-2014 revealed a continuous decrease in net cash flow. Furthermore, balance sheet analysis found a significant amount of non-current and current liabilities. In the forthcoming period, the company plans to undertake certain significant investments to be financed, according to its announcements, by the European Bank for Reconstruction and Development and by European funds from the Operational Programme Competitiveness and Cohesion 2014-2020, considering that the company has no economic potential to finance the said investments by itself.

Gradska Toplana Karlovac

The heating plant *Gradska Toplana Karlovac* submitted accounting information for the period 2012-2014. While recording a significant loss of HRK 369 000 in 2012, the company generated minimum accounting profit in the two subsequent years.

The company also submitted its Three-year Plan for the Construction of New Facilities and Upgrade or Reconstruction of the Existing Facilities. According to the plan, the total value of the planned works relating to retrofits or replacement of the existing assets is HRK 10.93 million; *Gradska Toplana d.o.o.* will contribute more than 28 % of the total amount, while the remaining amount will be covered by the Environmental Protection and Energy Efficiency Fund and the City of Karlovac.

GTG Vinkovci

The company submitted its balance sheet and profit and loss account. According to the analysed data for the period between 2011 and 2014, it recorded accounting losses for all but the last year. The company failed to provide information on planned investments.

Plin Virovitica

The company submitted its profit and loss account and balance sheet for the period between 2012 and 2014. It recorded accounting losses in all the years observed. The company failed to provide information on planned investments in system development, only mentioning the necessary maintenance of the existing condition.

Stambeno Komunalno Gospodarstvo

The company submitted its financial statements (a profit and loss account and a balance sheet) for the period between 2011 and 2014. It recorded accounting profit in all the years observed. The company failed to provide additional information on planned investments or investments made in the previous period.

Termalna Voda d.o.o.

The company provided accounting information for the 2011-2012 period for *Termalna Voda*, which is registered as a thermal energy distributor. The company recorded an accounting profit of HRK 88 000 in 2011 and a loss of HRK 46 000 in 2012.

HEP Toplinarstvo d.o.o.

The company provided financial information for the period between 2011 and 2014. It recorded accounting losses in all the years observed. In addition, the company submitted the Three-Year Plan For Distribution Network Development, Construction And Reconstruction for 2015-2017, which includes plans to invest a total of HRK 1 137.3 million. About 45 % of the planned investments are to be covered by own funds, 53 % by EU funds and the rest by investor funding. The company also submitted a Three-Year Plan For The Development, Construction And Reconstruction Of Energy Facilities And Equipment For Thermal Energy Generation between 2015 and 2017. The amount of HRK 83.8 million in own funding is intended to cover planned investments in production, namely, the construction of district heating systems in Samobor, Zaprešić and Velika Gorica.

12.3. ANALYSIS OF SPATIAL PLANNING DOCUMENTS OF RELEVANCE TO HEATING SYSTEMS

According to applicable legislation governing spatial planning, spatial planning documents regulate the purposeful organisation, use and allocation of space, as well as standards and guidelines for planning and protection of spaces belonging to the State, counties, cities and municipalities. Spatial planning documents are adopted at state, regional and local levels. Spatial plans have the legal effect and nature of an implementing regulations.

In accordance with the Spatial Planning Act (NN No 153/13), spatial plans of a county, city and municipality are the basic strategy documents defining the purposeful organisation, use and allocation of space at regional (county) and local (city) self-government unit level. The applicable documents relating to spatial planning at regional and local level and affecting the development of heating systems will be summarised below.

The county plan defines the conditions for the development of spatial plans for municipalities, cities and other units. As a strategic document, a county's spatial plan defines, for example, the system of central settlements, the economic structure of the county, the basis of the allocation of space for particular purposes, the basis of transport, public and other infrastructure, etc. A county's spatial plan defines the focal points of the county's future development.

The spatial plan of a large city⁹, city or municipality defines a course of development for business activities, the allocation of space and the conditions for sustainable and balanced development of the area covered by the plan. This strategic document defines, for example, the surface areas of settlements, the distribution of business activities in the area, and the basis of transport, public, utility and other infrastructure, as well as the boundaries of building areas.

District heating systems are mostly used in larger and more densely populated areas. From the aspect of settlement development at county level, the process of spatial planning starts with defining the system of central settlements. Then, the required surface area for the development of settlements is determined according to the projected population count and planned population density. The boundaries of areas intended for the construction and development of settlements are defined at city level. Within these boundaries, individual spatial units are formed in accordance with their purpose (housing, business, commercial, tourism, etc.). Furthermore, one of the main goals of spatial planning is to develop communal energy infrastructure in the areas intended for construction, in order to secure suitable locations and corridors for its siting in the area. This is precisely the significance of spatial planning for the development of district heating supply with regard to defining the spatial structure of heat consumption and securing a suitable location for infrastructure. Other provisions of spatial planning documents define the environment in which this kind of system will be developed, with regard to the of planning communal energy infrastructure. For instance, planned electricity infrastructure development will have an impact on the application of cogeneration technologies in thermal energy generation and on the possibility of selling the electricity generated to the electric power system. The development of gas supply in the area will result in an increased supply of available fuels for thermal energy generation, but also in competition in the form of individual thermal energy supply. The same applies to the use of renewable energy sources.

In terms of content, each of the mentioned spatial planning documents consists of basic starting points, goals and guidelines for development, as well as implementing provisions based on which these goals are to be accomplished. On examination of these documents, it has been concluded that the common guideline in all the documents is to promote further development of the electricity and natural gas supply. Therefore, the following considerations are targeted at provisions concerning the development of thermal energy supply systems.

The description of provisions of a county spatial plan (CSP) is focused on the elements of demographic development and population concentration in settlements (population and settlements), as well as the basic elements of heating system development (energy infrastructure – thermal energy). For each county, the two largest cities in terms of population are mentioned.

The description of provisions of a city spatial plan and a general urban development or master plan (CSP and GUDP, respectively) also refers to the basic elements of heating system development (energy infrastructure – thermal energy).

⁹ The term 'large city' is in accordance with the provisions of the Local and Regional Self-government Act (NN Nos 33/01, 60/01, 129/05, 109/07, 125/08, 36/09, 36/09, 150/11, 144/12, 19/13), which define new local self-government units: cities, which are also economic, financial, cultural, health care, transport and science centres of development in a wide area, and have a population of more than 35 000.

Apart from these, the list below outlines companies, ordered by county, engaging in energy activities of generation, distribution and supply, and operating pursuant to the Thermal Energy Market Act (NN Nos 80/13, 14/14, 102/14 and 95/15), according to data received from HERA.

The HERA register shows that out of 27 energy operators registered for the activities of thermal energy generation, distribution and supply, nine are registered for all three activities, while the other companies perform only one or two of these activities. These companies are registered in 12 out of the 20 counties in Croatia, including the City of Zagreb. The largest number, i.e. six of them, is registered in the City of Zagreb. According to data for the year 2013, some form of registered heating system existed in 18 Croatian cities.

12.3.1. Zagreb County

General information on the county

Zagreb County lies in the north-western part of Croatia, territorially encircling the City of Zagreb from three sides. Apart from the City of Zagreb, it borders six counties: Krapina-Zagorje County, Varaždin County, Koprivnica-Križevci County, Bjelovar-Bilogora County, Sisak-Moslavina County and Karlovac County, as well as the neighbouring Republic of Slovenia. Because of its position and connections with the adjoining counties, it represents an important link between the capital city and other territorial parts of Croatia. It is the fastest-growing economic region. The area of Zagreb County measures 3 060 km², constituting about 5.4 % of the total territory of Croatia. According to the latest census (of 2011), the county has a population of 317 606, or about 7.4 % of the total population of Croatia, and an average population density of 103.8 inhabitants per square kilometre, which is above the national average population density. The administrative centre of Zagreb County is Zagreb. Apart from Zagreb, it includes eight cities, of which two are large ones, and 25 municipalities consisting of 697 settlements.

Current thermal energy situation

Apart from the City of Zagreb, which constitutes a separate entity, four cities in Zagreb County have some form of heating system, namely Velika Gorica, Zaprešić, Samobor and Ivanić Grad. With the exception of the City of Zagreb, only one company registered in Zagreb County is licensed for thermal energy generation, distribution and supply, and that is *Ivakop d.o.o.* of Ivanić Grad. The company provides thermal energy generation, distribution and supply services in parts of Ivanić Grad which have the necessary infrastructure and to such economic operators with which it has signed contracts for the sale of thermal energy. In the other cities, namely Velika Gorica, Zaprešić and Samobor, generation, distribution and supply activities are performed by *HEP Toplinarstvo d.o.o.*, which also covers the territory of the City of Zagreb.

For the purposes of this chapter, the Zagreb County Spatial Plan (published in the Zagreb County Gazette No 3/2002, consolidated version published in No 14/2012) has been examined as the key document of the county. However, the document makes no reference to the current situation in respect of thermal energy generation, distribution and supply.

Thermal energy plans

An examination of the Zagreb County Spatial Plan and its sections relating to energy has found no reference to development plans concerning thermal energy generation, distribution and supply within the county.

12.3.1.1. City of Velika Gorica

An examination of the Velika Gorica Spatial Plan, according to the Decision on the Adoption of the Velika Gorica Spatial Plan, Official Gazette No 8 of 13 December 2014, consolidated version, has found a reference to installations for the use of renewable energy sources and cogeneration in a section relating to energy buildings of special importance to the State and county.

The Spatial Plan mentions the existence of a heating network in the cities. The supply of thermal heat from public heating plants is planned for the part of Velika Gorica in which there is a public hot water pipeline network, while other areas of Velika Gorica and other settlements may use smaller common or individual building heating systems. In order to preserve air quality and increase energy efficiency, integration and centralisation of individual neighbourhood heating systems is encouraged throughout Velika Gorica, using renewable energy sources or natural gas as the basic fuel. In Velika Gorica proper, this Plan allows for the expansion of the public hot water pipeline network and for a connection of the existing and new buildings to it. It also encourages the closure of the existing public heating plants during the integration of the heating networks or their reconstruction for the purpose of using

renewable energy sources or natural gas. The siting of electricity and/or thermal energy generation facilities may be planned for within building areas intended for commercial and utility infrastructure purposes, provided that they solely use renewable energy sources or natural gas as the basic fuel.

12.3.1.2. City of Samobor

An analysis of the 2007 Samobor Spatial Plan and the Samobor Master Plan of February 2007 has found no reference to the existence of heating networks or plans concerning thermal energy generation, distribution or supply.

12.3.1.3. City of Zaprešić

An examination of the Zaprešić Spatial Plan, according to the Decision adopting the Zaprešić Spatial Plan of April 2005 and its amendments of 2007 and 2011, has found no mention of heating systems or plans for their development.

12.3.1.4. City of Ivanić Grad

An analysis of the Ivanić Grad Spatial Plan, according to the Official Gazette of the City of Ivanić Grad Nos 06/05, 10/09, 11/09 and 10/10, has found no provisions concerning heating systems or plans concerning thermal energy generation, distribution or supply.

12.3.2. Krapina-Zagorje County

General information on the county

Krapina-Zagorje County lies in the north-western part of Croatia. Territorially, it borders the City of Zagreb, the neighbouring Republic of Slovenia, and two counties: Varaždin County and Zagreb County. Its position and road infrastructure make it an important link, via Slovenia, to other European countries. Measuring 1 229 km² in area, it is among smaller counties, constituting about 2.2 % of the total area of Croatia. According to the latest census, the county has a population of 132 892, or about 3.1 % of the total population of Croatia. The population density of the county is 108.1 inhabitants per square kilometre, which makes it one of the more densely populated counties. The administrative centre of the county is Krapina. Apart from the county seat, the county comprises six more cities and 25 municipalities, including 422 settlements.

Current thermal energy situation

In Krapina-Zagorje County, according to official information published by HERA, there is not a single company engaging in thermal energy generation, distribution and supply services. Also, no form of thermal energy system exists in the county. An examination of the Krapina-Zagorje County Spatial Plan of 2002 and its amendments has found no mention of thermal energy being used for heating public and private buildings. A reference is made to the existence of geothermal springs, which would need to be explored to ascertain the potential for their use.

Thermal energy plans

The Krapina-Zagorje County Spatial Plan makes no mention of plans concerning thermal energy generation, distribution or supply. A reference is made only to the existence of geothermal springs, which would need to be explored to ascertain the potential for their use.

12.3.2.1. City of Krapina

The Krapina Spatial Plan of 2002, its corrigendum of 2003 and amendments of 2004, 2007 and 2011 have been analysed. They make no mention of thermal energy supply or development plans in respect of thermal energy generation, distribution and supply in the cities.

The Krapina Master Plan of 2002 and its amendments of 2004, 2007, 2009 and 2010 have also been examined and no reference is made therein to heating systems, nor is provision made for their development.

12.3.3. Sisak-Moslavina County

General information on the county

Sisak-Moslavina County is situated in the central part of Croatia and, with an area of 4 468 km², it is one of the largest Croatian counties, constituting about 7.9 % of the land area of Croatia. Territorially,

it borders five counties: Karlovac County, Zagreb County, Bjelovar-Bilogora County, Požega-Slavonia County and Slavonski Brod-Posavina County, as well as the neighbouring state of Bosnia and Herzegovina. According to the latest census, the county has a population of 172 439, constituting about 4 % of the total population of Croatia; with 38.6 inhabitants per square kilometre it is one of the less populous counties. Nevertheless, because of its historical and territorial advantages, Sisak-Moslavina County is one of the most densely built-up industrial counties. The administrative centre of the county is Sisak and, apart from it, the county comprises six more cities and 12 municipalities.

Current thermal energy situation

In Sisak-Moslavina County, there are currently three companies which, according to the HERA register, are registered for one of the activities in the field of thermal energy: two of them are registered for the provision of thermal energy generation services and one for thermal energy supply. According to the information available, heating systems exist in two cities in the county: Sisak and Topusko. In Sisak, there is a district heating system which is operated by the company *HEP Toplinarstvo d.o.o.*, which engages in generation, distribution and supply services. In Topusko, there is a heating system within a thermal spa, being supplied with energy by *Top-Terre d.o.o.* An analysis of the Sisak-Moslavina County Spatial Plan of 2001 and its amendments has found no mention of thermal energy being used for heating public and private buildings. A reference is made to the existence of geothermal springs which would need to be explored to ascertain the potential for their use.

Thermal energy plans

The Sisak-Moslavina County Spatial Plan mentions the need for increased use of geothermal energy and solar energy. There are no other plans in respect of thermal energy.

12.3.3.1. City of Sisak

An examination of the Sisak Spatial Plan, according to the city's Official Gazette Nos 11/02, 12/06, 3/13 and 6/13, has found a reference to a new combined block in the Sisak thermal power plant as a structure of special importance to the State. Furthermore, the Plan allows for the construction of energy structures using renewable energy sources (wind, sun, biomass, geothermal energy, etc.). It may be observed that the Spatial Plan makes no mention of the existence of heating networks in Sisak or of plans concerning thermal energy generation, distribution or supply.

The Sisak Master Plan of 2002 provides for the construction of a district heating system in the cities, along with the construction of hot water pipelines and heating substations based on the project entitled 'Conceptual design for the supply of thermal energy to Sisak by 2005', in order to raise the standard of living in the cities and for environmental reasons. Commercial, public and social facilities, business premises, apartment buildings and blocks are planned to be connected to the hot water pipeline network. Low-density mixed-use zones, used predominantly for residential purposes, are not covered by the thermal energy supply project because investment costs are too high relative to consumption. A new steam pipeline (NO 250) with a condensate recovery pipeline (NO 150) is planned to serve for the supply of Sisak's district heating system to meet the thermal energy needs of its Caprag neighbourhood. The construction of new steam and hot water pipelines is foreseen at several locations.

12.3.4. Karlovac County

General information on the county

Karlovac County lies in the central part of Croatia and represents a link between the north and south of the country; it is also a junction of the most important roads linking Europe with the Adriatic Sea. The area of the county measures 3 626 km², constituting about 6.4 % of the total territory of Croatia. It borders four counties: Zagreb County, Sisak-Moslavina County, Lika-Senj County and Primorje-Gorski Kotar County, as well as two neighbouring states: Slovenia and Bosnia and Herzegovina. According to available data in the 2011 census, Karlovac County has a population of 128 899, which constitutes about 3 % of the total population of Croatia, and has an average population density of about 35.5 inhabitants per square kilometre. The administrative centre of the county is Karlovac, and apart from Karlovac, the county comprises four more cities and 17 municipalities. The information above puts it among medium-sized counties, less populous than the national average and with a negative natural population growth rate.

Current thermal energy situation

Three companies are currently registered in Karlovac County of which two can provide all three services in the thermal energy field (generation, distribution and supply). In Karlovac County, there is a heating system in Karlovac operated by *Gradska toplana d.o.o.*, and in Ogulin, where it is operated

by *Stambeno Komunalno Gospodarstvo d.o.o.* The description of the existing situation in the Karlovac County Spatial Plan of 2001 lacks information on the current thermal energy situation.

Thermal energy plans

The Karlovac County Spatial Plan of 2001 and its amendments of 2008 do not contain any specific plans regarding thermal energy. They only suggest that new thermal energy generation installations should be planned on the basis of cogeneration, while the existing installations should be retained and may be technologically upgraded to transform them into electricity generation installations. New cogeneration installations to be implemented in commercial and communal zones, and cogeneration installations of up to 1 MW in capacity which may be planned in other zones, are also mentioned.

12.3.4.1. City of Karlovac

The Karlovac Spatial Plan of 2002 omits information on the existing thermal energy supply systems in the cities although they exist and does not specify plans concerning thermal energy generation, distribution and supply.

The Karlovac Master Plan of 2007 recommends the use of renewable energy sources where appropriate. It further determines the existence of a hot water pipeline system, including: thermal energy generation installations (the existing heating plant with installed thermal capacity of 116 MW, connected load of 70 MW and possible 30 MW connection; a planned TE-TO Karlovac heating plant) and a distribution network – the existing and planned hot water pipelines. It recommends laying underground hot water pipelines, while above-ground hot water pipelines may also be laid inside the heating plant compound and industrial complexes, if so required by technical or technological reasons. The network extension and siting of new hot water pipeline network structures within the area covered by the Master Plan is possible, subject to approval of other legal persons with public authority for the proposed route or location. The new thermal energy generation installation (TE-TO Karlovac) is planned in a commercial area (K) north of the railway station, subject to the following building conditions: construction of a planned 110 kV cable from the Dubovac transformer station to connect it to the electricity supply system, construction of a gas compressor installation inside the TE-TO complex to increase the pressure to 28-30 bar for the purpose of connecting it to the existing high-pressure gas pipeline, construction of a well to supply water for the cooling system. The new thermal energy generation installation (TE-TO Karlovac) on the basis of cogeneration is planned, while the existing thermal energy generation installation will be retained in the form necessary for heat distribution and may be technologically upgraded (cogeneration) to transform it into an electricity generation installation.

12.3.5. Varaždin County

General information on the county

Varaždin County is situated in the north-western part of Croatia. Territorially, it borders four counties: Međimurje County, Koprivnica-Križevci County, Zagreb County and Krapina-Zagorje County, as well as the neighbouring Republic of Slovenia. With an area of 1 262 km², which constitutes merely 2.2 % of the total area of Croatia, it is one of the smallest counties. According to the 2011 census, the county is home to 175 951 inhabitants, or 4.1 % of the total population of Croatia. The average population density is 139.4 inhabitants per square kilometre, which makes it one of the most densely populated counties in Croatia. Apart from Varaždin, as the administrative centre of Varaždin County, the county comprises five more cities and 22 municipalities, numbering 302 settlements.

Current thermal energy situation

Two companies operating in Varaždin County are currently registered with HERA as thermal energy generation and supply service providers. In Varaždin County, there is only one heating system which, since the bankruptcy of *Grijanje Varaždin d.o.o.*, has been operated by a new company, *VARTOP d.o.o.* For the purposes of this chapter, the Varaždin County Spatial Plan of 2000 has been examined; while not including information on the current thermal energy situation, it makes note of the potential for geothermal energy exploitation.

Thermal energy plans

The Varaždin County Spatial Plan does not specify any plans concerning thermal energy, but makes reference to great potential for the exploitation of geothermal resources, notably in the area of Ludbreg area and Varaždinske Toplice spa, as well as Topličica, where thermal water was once used for recreational purposes. Thermal water can be used in cogeneration to produce electricity and thermal energy, which in turn could be used for different purposes: the tourism and recreation industry, agriculture, commercial and residential buildings, etc.

12.3.5.1. City of Varaždin

The Varaždin Spatial Plan of 2005 states that a portion of buildings in Varaždin proper are heated via a district heating system; more details are available in the Master Plan. Plans for the development of the heating network are provided separately and the network will be expanded within Varaždin proper; in case an incinerator is built, it may be used as an energy source and the network may be expanded further.

An analysis of the Varaždin Master Plan of 2006 has found no description of existing thermal energy supply systems; however, reference is made to a plan to develop a district heating system, taking into account the rational use of energy. In building a boiler room or a heating plant, account should be taken of the possibility of using renewable fuels (biomass). In distribution, hot water distribution pipelines should be separated from internal building heating systems, using thermal substations as well. Heating projects should provide for heat consumption metering for each consumer separately. Expansion of the existing system with a steam and hot water pipeline network is planned in Varaždin proper. Furthermore, the Plan says that additional energy sources can be provided by using geothermal energy and by optimally relying on and constructing buildings for the passive use of solar energy. Other supplementary energy sources, such as gas, biodiesel, etc., may also be used.

12.3.6. Koprivnica-Križevci County

General information on the county

Koprivnica-Križevci County, situated in the north-western part of Croatia, is among the counties of central Croatia. Territorially, it borders the neighbouring Republic of Hungary and five counties: Varaždin County, Međimurje County, Virovitica-Podravina County, Bjelovar-Bilogora County and Zagreb County. With an area of 1 748 km², which is about 3.1 % of the total area of Croatia, it ranks among smaller counties. According to the latest census of 2011, it has a population of 115 584, which constitutes about 2.7 % of the total population of Croatia. The average population density is 66.1 inhabitants per square kilometre, which is below the Croatian average. The administrative centre of the county is Koprivnica. Apart from Koprivnica, the county has two more cities and 22 municipalities, numbering 264 settlements.

Current thermal energy situation

According to the HERA register, there are no registered companies engaging in thermal energy generation, distribution and/or supply services in Koprivnica-Križevci County. There is no type of heating system in the county either. An analysis of the Koprivnica-Križevci County Spatial Plan of 2001 and its subsequent amendments of 2007 and 2012 has found no reference in the description of the existing situation to the thermal energy situation.

Thermal energy plans

A further examination of the Koprivnica-Križevci County Spatial Plan and its amendments has found no significant plans concerning thermal energy. The Spatial Plan only mentions the planned use of geothermal resources in the Kutnjak and Molve geothermal fields. It provides for the exploitation of the existing and conversion of old oil and gas wells into geothermal ones, for which necessary studies need to be prepared first. A study entitled 'Concept and feasibility of the programme for the commercial use of geothermal energy at Lunjkovec-Kutnjak' set out a comprehensive programme for the commercial use of geothermal energy. It recommends the use of geothermal energy for electricity generation (power plant), agricultural production (greenhouses), industrial processing of agricultural products (dryer), fish farming (fish ponds), tourism (spa, tourist complex and supporting amenities) and the supply of thermal energy to urban areas.

12.3.6.1. City of Koprivnica

The Koprivnica Spatial Plan of 2006 and its amendments of 2012 and 2015 have been analysed. In the description of the existing situation, there is no reference to the city's thermal energy supply systems. Also, thermal energy supply is not specifically referred to in the description of development plans either. There are no planning provisions concerning the development of heating systems in Koprivnica.

The Koprivnica Master Plan of 2008 and its amendments of 2014 and 2015 have been examined. The provisions of the existing Plan do not contain a description of the existing thermal energy supply situation. Furthermore, the Plan contains no planning provisions concerning the development of heating systems in Koprivnica.

12.3.7. Bjelovar-Bilogora County

General information on the county

Bjelovar-Bilogora County is situated in the north-western part of Croatia and is among a group of counties belonging to the central part of Croatia. It borders five counties, namely Zagreb County, Koprivnica-Križevci County, Virovitica-Podravina County, Požega-Slavonia County and Sisak-Moslavina County. The area of the county measures 2 640 km², or 4.66 % of the total land area of Croatia, which makes it a medium-sized county. Because of its position, it belongs among agriculturally and economically more developed counties. According to the latest census, the county is home to 119 764 inhabitants, or 2.8 % of the total population of Croatia. With the total population density of 45.4 inhabitants per square kilometre, it belongs to a group of counties with below-average density. The administrative centre of the county is Bjelovar, and apart from it, the county has four more cities and 18 municipalities, numbering 323 settlements.

Current thermal energy situation

According to the HERA register, there is only one company registered solely for thermal energy generation in Bjelovar-Bilogora County. Available information shows that there are currently no heating systems in the county. An analysis of the Bjelovar-Bilogora County Spatial Plan of 2001 has found that thermal energy is not specifically covered and no description of the current situation in this field either.

Thermal energy plans

The Bjelovar-Bilogora County Spatial Plan does not specifically cover thermal energy plans. It only mentions the need for further exploration of the geothermal potential, with identification of the locations of geothermal springs, as well as exploitation and its impact on the environment.

12.3.7.1. City of Bjelovar

The Bjelovar Spatial Plan of 2003 and its amendments of 2009 have been analysed. In the description of the existing situation, there is no reference to existing thermal energy supply systems in the city. With regard to the use of renewable energy sources, the existence of geothermal resources has been recorded in the Bjelovar area, but that such resources have not been utilised sufficiently or at all for energy purposes. A further examination of the existing sources and explorations for new ones are necessary in order to examine the possibility of using this (in the estimate of the Plan's authors) relatively favourable and environmentally acceptable energy source. On the outskirts of Bjelovar, a geothermal spring with a water temperature of 170 °C in a proposed exploitation field measuring 290 m x 250 m was discovered in the settlements of Patkovac and Ciglana using two exploration wells in each settlement. After the examination, the exploration wells were closed and remain unused owing to lack of funding for planned methods of exploitation for energy purposes. The use of water is planned in several phases: first, for the construction of a geothermal power plant, then for a heating plant, for recreational purposes, etc., as well as the expansion of the well's capacity by building new wells. The Plan also mentions a study, which has been drawn up but is considered not to have sufficient parameters because no long-term surface temperature testing has been carried etc. A problem has been observed in the form of fairly large amounts of dissolved minerals and salts which hamper production and can only be eliminated chemically. The presence of a lot of dissolved gases, in particular CO₂ which should also be separated from the water, has also been mentioned. The Plan identifies the Velika Ciglana thermal water exploitation field.

The Bjelovar Master Plan of 2004 and its amendments of 2009 and 2012 have also been examined. In the description of the existing situation, there is no reference to heating systems. Thermal energy supply at city level is not specifically covered. There are no planning provisions concerning the development of thermal energy supply or plans for thermal energy supply in the cities in general. In the context of environmental protection, it is determined that future development of the energy sector in Bjelovar should be based on energy generation and consumption in accordance with human healthcare requirements and quality of the local and global environment. The environmental protection goals and strategy are defined in accordance with the basic guidelines at national level.

12.3.8. Primorje-Gorski Kotar County

General information on the county

Primorje-Gorski Kotar County lies in the western part of Croatia. The area of the county measures 3 588 km², or 6.3 % of the total area of Croatia, which is above the Croatian average. It borders the neighbouring Republic of Slovenia and three adjoining counties: Istria County, Karlovac County and Lika-Senj County. Because of its infrastructure connections, tourism and natural resources, it is one of Croatia's most developed regions. It has a population of 296 195, or 6.9 % of the total population of Croatia. The average population density of the county is 82.6 inhabitants per square kilometre, which makes it a county of above-average density. The administrative centre of the county is Rijeka, and apart from it, the county has 13 other cities, 22 municipalities and 536 settlements.

Current thermal energy situation

In Primorje-Gorski Kotar County, there is only one company registered with HERA for all three activities, namely thermal energy generation, distribution and supply. There is only one heating system in Primorje-Gorski Kotar County, the one in Rijeka which is operated by *ENERGO d.o.o.* An analysis of the Primorje-Gorski Kotar County Spatial Plan of 2013 has found that it contains no description of the current thermal energy situation. It only mentions plans in that field.

Thermal energy plans

The Primorje-Gorski Kotar County Spatial Plan makes reference to the heating sector and plans for further development of the hot water pipeline system. In particular, it encourages the use of wood biomass-fired cogeneration installations in the Gorski Kotar area and trigeneration installations in the coastal areas and on the islands, implying the development of a hot water pipeline network. The use of heat pumps in the heating sector by utilising the heat of the sea, lakes, streams, industrial wastewater streams, restaurants and tourism facilities, households, and the heat of the soil is encouraged as well. There are also plans for further development of the existing hot water pipeline system in Rijeka, where natural gas will continue to be used as the primary fuel. In particular, the use of decentralised renewable energy sources in which Primorje-Gorski Kotar County abounds is emphasised. In order to reduce pollution from boiler rooms and other thermal sources for heating, the Plan emphasises the need to promote the use of gas in all sources or a connection to centralised heat sources, especially in the central part of Rijeka, saying that all boiler rooms using fuel oil as the primary fuel need to use fuels with a maximum 1 % m/m of sulphur.

Furthermore, it says that the use of renewable energy sources and energy efficiency are two very important development goals in the energy sector. The Plan provides for the rational use of energy by utilising renewable energy sources, depending on the energy and economic potential of particular areas. The term 'renewable energy sources' means the energy of water (small hydroelectric power plants of up to 10 MW), sun, wind, geothermal energy, energy from biomass (within the scope of its natural regeneration/growth), as well as industrial and waste heat, according to local circumstances. It further states that the sea and other watercourses abound in energy potential which, by using heat pumps, may be used for heating and cooling in coastal buildings, for electricity generation, as well as for processing equipment.

The Plan supports the use of solar energy of small-capacity installations for thermal energy and electricity generation on the roofs of the existing and new residential, commercial and public buildings, as well as on roof overhangs, in parking lots and other areas suitable for their installation. The construction of wood biomass-fired cogeneration/trigeneration installations is planned. The municipalities and cities need to determine the annual allowable cut in their respective areas, define the general purposes of the wood concerned and plan the construction of biomass-fired energy facilities and their size accordingly. The occupation of agricultural land to cultivate crops to be used for the production of biodiesel or any other biofuel is prohibited.

12.3.8.1. City of Rijeka

For the purposes of this chapter, the Rijeka Spatial Plan of 2003 and its amendments of 2005 and 2013 have been analysed. The description of the current heat supply situation says that the heating system of Rijeka consists of the city's heating plants and boiler rooms used to generate thermal energy. Thermal energy is generated by the city's 14 heating plants and boiler rooms with a combined installed capacity of 120 MW. Thermal energy is used for heating about 500 000 m² of residential and commercial space, and about 380 000 m³ of hot water annually.

As regards thermal infrastructure development, the Plan encourages the production of electricity and thermal energy in cogeneration, as well as of electricity, thermal and cooling energy in trigeneration, because of its economic and environmental justification; the utilisation of excess thermal energy from

the *INA-Maziva* industrial energy installations at Mlaka for the supply of heating energy to the surrounding parts of the city; the rational consumption of all forms of energy and the revitalisation and utilisation of the existing unused energy facilities located in the city centre (a paper factory) for the purpose of generating thermal energy and electricity in a combined process; and the use of different renewable energy sources (solar energy and the thermal energy of the sea).

The Plan further mentions the following possibilities of increasing energy efficiency of the existing heating system in Rijeka:

- connect new consumers to the existing unused installations;
- increase the utilisation of the waste heat of flue gases from gas-fired boiler units (by installing recovery boilers);
- improve the automatic regulation and control system in order to increase the degree of system efficiency and fuel saving and reduce harmful emissions;
- replace two-stage burners with modulating burners and use new burning technologies;
- DHW generation and waste heat use;
- enable thermal energy consumption metering and regulation for each consumer;
- develop studies and pilot projects on the possibilities of building and using small thermal power plants, operating on the basis of cogeneration, for thermal energy and electricity supply.

In reference to the measures to prevent air pollution, it says that the adverse impact of the population and commercial facilities, in particular in the city centre, will be prevented by prohibiting the use of coal, switching from individual heating to heating via local heating plants, expanding the heat and gas network in neighbourhoods, systematic control of the boiler room operation, reducing thermal losses, improving the thermal insulation of buildings, etc.

The Rijeka Master Plan, adopted in 2007, and its amendments of 2013, 2014, and 2015 have also been examined. They provide a description of the heating systems in Rijeka which are operated by *K.D. ENERGO*. The conclusion is that the installed boiler units do not require replacement in the next 20 to 30 years. The installed capacity of the heating plants is assessed to be utilised at only 40 % of the average heating plant load. The Plan says that the Mlaka Refinery has two medium-pressure boilers in normal operating condition as cold reserve which represent possible excess capacity. According to data given in the Plan, this energy installation has been revitalised for the most part and reconstructed to replace the consumption of liquid fuel with gas (mixed gas). It is estimated that the operation of one of the boilers can be made available to external consumption units, whereby a thermal capacity of 11-14 MW may be achieved. Finally, thanks to its location at the centre of utility consumption, this installation is assessed to represent a significant potential source of thermal energy supply. The Plan goes on to say that the city's thermal supply (heating plants and hot water pipelines) is available in some parts only, covering no more than 20 % of the city's possible consumers.

Thermal energy supply at neighbourhood level is covered separately. Development goals are consistent with those presented in the city's Spatial Plan. The assessment of Rijeka's existing thermal system identified possibilities for increasing energy efficiency. In order to achieve the measured increase, the following is required:

- connect new consumers to the existing unused installations;
- increase the utilisation of the waste heat of flue gases (by installing recovery boilers) on gas-fired boiler units;
- improve the automatic regulation and control system in order to increase the degree of system efficiency and fuel saving and reduce harmful emissions;
- replace the existing burners with new modulating and low NOx burners and use new furnace, DHW generation and waste heat utilisation technologies;
- enable thermal energy consumption metering and regulation for each consumer; develop studies and pilot projects on the possibilities of building and using small thermal power plants, operating on the basis of cogeneration, for thermal energy and electricity supply;
- substitute fuel oil with mixed (natural) gas.

The Plan provides for drawing up an energy development strategy for Rijeka based on studies and pilot projects for the purpose of rationalising energy consumption, utilising excess thermal energy and unused existing energy facilities, and increasing energy efficiency.

It allows the use of renewable energy sources, in particular the use of solar energy and the energy of the environment (sea).

12.3.9. Lika-Senj County

General information on the county

Lika-Senj County is geographically situated in the central part of Croatia, representing an important link between Croatia's three largest cities: Zagreb, Split and Rijeka. The area of the county measures 5 353 km², or 9.5 % of the country's total land area, which makes it the largest county in Croatia. Territorially, it borders neighbouring Bosnia and Herzegovina and three adjoining counties: Primorje-Gorski Kotar County, Karlovac County and Zadar County. The county has a population of 50 927, or 1.2 % of the total population; with an average population density of 9.5 inhabitants per square kilometre, it is the most sparsely populated county in Croatia. The administrative centre of the county is Gospić. Apart from Gospić, there are three more cities and eight municipalities consisting of 255 settlements.

Current thermal energy situation

In Lika-Senj County, there is not a single registered company engaging in thermal energy generation, distribution and/or supply services. Also, no form of thermal energy system exists in the county. An examination of the Lika-Senj County Spatial Plan of 2015 has found no description of the current thermal energy situation.

Thermal energy plans

The Lika-Senj County Spatial Plan suggests planning for new heating installations based on cogeneration, while the existing thermal energy generating installations should be retained and transformed into installations for the simultaneous electricity generation. New cogeneration installations may be built in commercial and communal zones as part of building areas in settlements. In other zones, cogeneration installations of up to 1 MW in capacity may be planned.

12.3.9.1. City of Gospić

The Gospić Spatial Plan of 2005 and amendments to its Implementing Provisions of 2009 and 2015 have been analysed. The description of the existing situation, lacks reference to thermal energy supply systems in the city. Thermal energy supply at city level is not specifically covered, and there are no provisions on thermal system planning.

12.3.10. Virovitica-Podravina County

General information on the county

For the purposes of this chapter, the most important county documents have been used: the Virovitica-Podravina County Spatial Plan (consolidated version), 2010, and the Virovitica-Podravina County Spatial Plan (5th amendment – Vol. 1), 2013.

Virovitica-Podravina County lies in the continental part of Croatia at a meeting point of central and eastern Croatia. The area of the county measures 2 024 km², or 3.6 % of the total land area of Croatia, ranking it among smaller counties. Territorially, it borders the neighbouring Republic of Hungary and four adjoining counties, namely Koprivnica-Križevci County, Osijek-Baranja County, Požega-Slavonia County and Bjelovar-Bilogora County. The county has a population of 84 836, or about 2 % of the total population of Croatia. With an average population density of 41.9 inhabitants per square kilometre, it is among the less populous counties. The administrative centre of the county is Virovitica. Apart from Virovitica, the county includes two more cities and 13 municipalities with 188 settlements.

Current thermal energy situation

In Virovitica-Podravina County there is only one company with all three activities (thermal energy generation, distribution and supply) registered with HERA, that is *Plin VTC d.o.o.* The company operates the county's only district heating system, which is located in Virovitica. Even though there is a heating system in the county, an analysis of the Virovitica-Podravina County Spatial Plan of 2010 (consolidated version) and its amendments of 2013 has found no description of the current situation with regard to thermal energy supply. It only mentions the existence of thermal water springs which should be exploited.

Thermal energy plans

The Virovitica-Podravina County Spatial Plan mentions the existence of several thermal water springs. Favourable results of the geothermal water exploration indicate possible development of that area partly based on that resource, notably for the purpose of cogeneration (simultaneous generation of electricity and thermal energy), development of health and recreational tourism, expansion of the tertiary sector and, consequently, the development of other branches of the economy. The Plan also

says that geothermal energy may be exploited locally, as well as in a wider area if interest is shown and its utilisation proves cost-effective. For that purpose, it is necessary to provide for the possibility of planning drilling wells, heat pumps, pipelines and hot water pipelines, and other necessary installations for geothermal energy exploitation. Apart from geothermal energy, planning for the exploitation of renewable sources, such as wood biomass, agricultural and industrial waste, in cogeneration units is also mentioned.

12.3.10.1. City of Virovitica

The Virovitica Spatial Plan of 2005 has been examined. In the description of the current situation, there is no reference to existing thermal energy supply systems in the city(if any). Thermal energy supply at city level is not specifically covered. There are no provisions concerning thermal energy supply planning in the city.

The Virovitica Master Plan of 2005 and its amendments of 2007 have been analysed. The description of the current situation lacks reference to existing thermal energy supply systems in the city (even though they exist). Thermal energy supply at neighbourhood level is not specifically covered. There are no planning provisions concerning the development of centralised thermal energy supply or plans for thermal energy supply in the city in general.

In order to improve the situation and prevent further deterioration in air quality, in particular in areas intended for residential building, appropriate protection measures need to be taken. One such measure is to determine, through targeted research, the possibility of reducing emissions from all sources of air pollution in the city and examine the feasibility of possible solutions, appliances, and to envisage the use of low-sulphur fuel oil or gas for boiler rooms.

12.3.11. Požega-Slavonia County

General information on the county

Požega-Slavonia County lies in the continental part of Croatia and constitutes a link between eastern and central Croatia. The area of the county measures 1 823 km², or 3.2 % of the total land area of Croatia, ranking it among medium-sized counties. It borders five adjoining counties: Bjelovar-Bilogora County, Virovitica-Podravina County, Osijek-Baranja County, Slavonski Brod-Posavina County, and Sisak-Moslavina County. According to the latest census of 2011, the county has a population of 78 034, accounting for 1.8 % of the total population of Croatia. The average population density is 42.8 inhabitants per square kilometre, which makes Požega-Slavonia County a less populous county. The administrative centre of the county is Požega. Apart from Virovitica, the county includes four other cities and five municipalities with 277 settlements.

Current thermal energy situation

In Požega-Slavonia County, there are currently two companies with registered activities in the field of thermal energy. One company is registered for the provision of thermal energy distribution services, and the other for the provision of generation and supply services. According to available data, there is only one heating system in the county, namely in Požega, and it is operated by the company *Tekija d.o.o.*

For the purposes of this chapter, the key county document, the Požega-Slavonia County Spatial Plan of 2002 and its amendments of 2011, has been examined. They provide no description of the existing heating system in the county.

Thermal energy plans

The aforementioned documents of the Požega-Slavonia County Spatial Plan mention the heating potential of geothermal springs and the need to develop conceptual designs and investment studies for geothermal energy exploitation. Furthermore, cogeneration plants and small cogeneration plants are foreseen for the purpose of processing waste resulting from industrial production and processing. Thermal energy from cogeneration is used in various production processes or for heating individual buildings and even entire settlements. One of the ways of using cogeneration is trigeneration, where some of the energy is used for cooling. In Požega-Slavonia County, the most common waste is wood (bio) waste, generated by large wood processing and treatment plants and a number of small and large sawmills. However, chemical, construction, metal processing, meat, pharmaceutical, textile, printing, confectionery, tobacco, paper, alcohol, non-metal, leather and footwear industries, breweries, bakeries, dryers, oil mills, machine building and other industries may also be planned to use cogeneration in the future. In the territory of the county, at least two, and even more such structures are planned if possible (one in the Požega area and the other in the Pakrac area, along with the reconstruction of the existing potential), specifically inside the complexes producing large amounts of

waste or in their immediate vicinity, and which would collect and exploit the energy potential of wood and waste from various producers.

12.3.11.1. City of Požega

The Požega Spatial Plan of 2005 has been examined. The description of the existing situation makes no reference to thermal energy supply systems in the city. Thermal energy supply at city level is not specifically covered, nor are there any planning provisions concerning the development of heating systems or plans for thermal energy supply in the city.

The Požega Master Plan of 2005 and its amendments of 2007 and 2011 have been analysed. The description of the existing situation lacks reference to the existence of heating systems in the city (even though they exist). Thermal energy supply at neighbourhood level is not specifically covered, nor are there any planning provisions concerning the development of heating systems or plans for thermal energy supply in the city. It has been established that, in accordance with the Požega-Slavonia County Spatial Plan, the construction of small cogeneration plants for the exploitation of waste from the wood processing industry is possible in the industrial production zone, subject to fulfilment of environmental protection requirements.

12.3.12. Slavonski Brod-Posavina County

General information on the county

For the purposes of this chapter, the key county documents have been examined: the Slavonski Brod-Posavina County Spatial Plan of 2001 and the Decisions amending the Slavonski Brod-Posavina County Spatial Plan of 2005, 2008, 2010 and 2012.

Slavonski Brod-Posavina County is situated along the southern edge of the Slavonia plain. With an area of 2 030 km², which constitutes about 3.6 % of the total land area of Croatia, it ranks among smaller counties. It borders neighbouring Bosnia and Herzegovina and four counties: Sisak-Moslavina County, Požega-Slavonia County, Osijek-Baranja County and Vukovar-Syrmia County. According to the 2011 census, the county is home to 158 575 inhabitants, or 3.7 % of the total population of Croatia. With an average population density of 78.1 inhabitants per square kilometre, it is slightly above the national average. The administrative centre of the county is Slavonski Brod. Apart from it, the county includes one more city and 26 municipalities, consisting of 185 settlements.

Current thermal energy situation

In Slavonski Brod-Posavina County, three companies are currently registered with HERA for the activities of thermal energy generation, distribution or supply. According to available data, a heating system exists only in Slavonski Brod and is operated by *Brod plin d.o.o.* The heating network is covered separately in the Slavonski Brod-Posavina County Spatial Plan of 2001. Despite the fact that there are no integral heating systems in the county to supply thermal energy to customers in the cities as a whole, the existing heating network is referred to as an energy structure of relevance to the county; the existing heating networks in Slavonski Brod and Nova Gradiška¹⁰ are partial and comprise individual block boiler rooms, from which heat distribution pipelines lead to large individual buildings or groups of buildings. Also, where they needed thermal energy, industrial consumers built systems for their own use only. The existing heating network in the county currently meets the needs in Slavonski Brod and to a lesser extent in Nova Gradiška. Basic preconditions, namely the size and density of consumption and the necessary funding for construction and maintenance, have not been met in other settlements. The possibilities for the Slavonski Brod and Nova Gradiška heating network development depend on the agreed concept of development of the two cities, and they differ from each other.

Thermal energy plans

The Slavonski Brod-Posavina County Spatial Plan makes reference to hot water pipelines, which are foreseen in building areas of large urban settings only. These hot water pipelines are planned to be built using underground piping, for which corridors need to be provided. The routes of the planned hot water pipelines need to be planned within the existing infrastructure corridors and areas for the sake of protection and rational use of space. The main goal of development of the thermal energy system is to provide quality heating energy supply to customers in larger cities, Slavonski Brod in particular.

Despite the fact that the gas network in Slavonski Brod covers a large area of the city, there are preconditions for the reconstruction and integration of the already built networks. The planned continuation of urbanisation of the city centre through construction of multi-storey residential and commercial buildings and economic development will increase the need for thermal energy to an extent

¹⁰ Data on the heating network in Nova Gradiška are not available anywhere other than the Spatial Plan; therefore, that system, if existing at all, has not been covered here.

that it is necessary to consider building a thermal power/heating plant of appropriate size. In Nova Gradiška, in the next planning period consumption is not expected to increase so much as to warrant the construction of a single heating system. It will be possible to effectively meet the needs for heating energy using a combination of block boiler rooms and a gas network.

12.3.12.1. City of Slavonski Brod

The Slavonski Brod Spatial Plan of 2004 and its amendments of 2007 and 2014 have been analysed. The existing heating network in Slavonski Brod is described as a partial network, comprising individual block boiler rooms with hot water pipelines. Industrial consumers built their own hot water pipeline systems mostly for themselves. The Slavonski Brod-Posavina County Spatial Plan provides for the construction of a thermal power/heating plant in the wider area of Slavonski Brod and a hot water pipeline system that would integrate most of the existing local systems, as well as its extension where necessary. The assessment is that, considering the current circumstances, the construction of a thermal power/heating plant is questionable. Furthermore, thermal energy supply at city level is covered separately. The city's energy supply is based on gas and electricity supply. The Slavonski Brod-Posavina County Spatial Plan indicates a possibility, but also the need to explore the siting of a thermal power plant and a heating plant in the industrial zone and port of Bjeliš. In previous planning documents, the construction programme was based on port functions and a gas pipeline construction. The construction of this thermal power plant is not expected in the planning period of the Slavonski Brod Spatial Plan because, according to the Plan, there are no interested customers for now. The good gas and electricity supply network speaks in favour of that. A reduction and change in industrial production programmes, as well as the introduction of gas as fuel, have reduced electricity consumption and the existing capacity is estimated to meet current and future needs.

According to the document, justification for the construction of a hot water pipeline system in Slavonski Brod which would integrate most existing local systems needs to be explored, and upgrade it for new customers as necessary. Deciding on the justification for the construction of this system is related to deciding on the construction of a thermal power/heating plant. In this regard, the Plan notes that no alternative energy sources are used in Slavonski Brod. From a spatial planning point of view, alternative energy sources are desirable and are divided into two groups: those for which no additional space needs to be provided (plant waste, biomass and biogas) and those for which it is necessary to provide additional space (small hydroelectric power plants and larger units for the exploitation of solar energy). At the time the Spatial Plan was prepared, a possibility and justification for the construction of a small thermal power/heating plant fired by biomass and organic waste within the Bjeliš industrial zone and port was being explored.

Implementing provisions say that the city's supply with thermal energy and its use will be provided through the appropriate use of space and establishment of corridors for the distribution network upgrading, connection of the thermal power/heating plant networks, laying of the underground hot water pipeline, construction of buildings for the passive use of solar energy, construction of buildings for the use of wind energy, construction of buildings for the use of alternative energy sources. The Spatial Plan undertakes to explore the siting of the thermal power/heating plant in the wider area of the city. Construction and landscaping conditions are defined in greater detail by the Slavonski Brod Master Plan.

The provisions governing the implementation of the Slavonski Brod Master Plan of 2005 and its amendments of 2008 are analysed below. Thermal energy supply at neighbourhood level is covered separately. The city's supply with thermal energy and its use are planned to be provided through the appropriate use of space and establishment of corridors for the distribution network upgrading, connection of the thermal power/heating plant networks, laying of the underground hot water pipeline, construction of buildings for the passive use of solar energy, construction of buildings for the use of wind energy, construction of buildings for the use of alternative energy sources. Accordingly, areas and corridors for the development of the thermal energy system have been defined.

12.3.13. Zadar County

General information on the county

For the purposes of this chapter, the following key documents of the county have been considered: The Zadar County Spatial Plan – consolidated version of 2006 and its amendments of 2014.

Zadar County lies in the central part of Adriatic Croatia. Thanks to its position, it is an important infrastructure link between the two largest Croatian cities, Zagreb and Split, and it also provides ferry connections to neighbouring Italy. It shares land borders with neighbouring Bosnia and Herzegovina and two counties: Lika-Senj County and Šibenik-Knin County. With a land area of 3 646 km², or 6.4 % of the total land area of Croatia, it ranks among large Croatian counties. According to the 2011 census,

the county has a population of 170 017, accounting for approximately 4 % of the total population of Croatia. With an average population density of 46.6 inhabitants per square kilometre, it belongs to the category of sparsely populated counties compared to the national average. The administrative centre of the county is the Zadar, and the county consists of five other cities and 28 municipalities composed of 229 settlements.

Current thermal energy situation

According to data available in the HERA register, Zadar County has no registered companies providing any services in the field of thermal energy. In addition, according to available data, there is no form of heating system within the county. The Zadar County Spatial Plan does not specifically cover thermal energy. It only states that resolving the issue of heating/cooling energy utilisation in Zadar County, particularly in the City of Zadar, is important for the county.

Thermal energy plans

The Zadar County Spatial Plan includes no plans regarding thermal energy generation, distribution of supply, or any form of heating system in general.

12.3.13.1. City of Zadar

The Zadar Spatial Plan of 2004 and its amendments of 2008 and 2011 have been analysed. Thermal energy supply at city level is not specifically covered, nor are there any planning provisions concerning the development of heating systems or plans for thermal energy supply in the city. The Plan states the following measures for the improvement of air quality in Zadar:

- adopt measures to reduce air pollution in all major industrial plants;
- use low-sulphur fuel oil with a sulphur content of up to 1 %, or another fuel in all boiler rooms using fuel oil in Zadar;
- prohibit coal use in home boiler rooms in Zadar.

12.3.14. Osijek-Baranja County

General information on the county

For the purposes of this chapter, the most important county document, the Osijek-Baranja County Spatial Plan of 2002 with amendments of 2012 and 2013, has been examined. Osijek-Baranja County lies in the eastern part of Croatia, encompassing the whole Croatian part of Baranja and a part of Slavonia. It borders the neighbouring republics of Hungary and Serbia, as well as four other counties: Virovitica-Podravina County, Vukovar-Syrmia County, Brod-Posavina County and Požega-Slavonia County. With an area of 4 155 km², or 7.3 % of the total land area of Croatia, the country belongs to the group of large Croatian counties in terms of area. According to the latest census, it has a population of 305 032, or 7.1 % of the total population of Croatia. The county has an average population density of 73.4 inhabitants per square kilometre, making it a county of average population density. The administrative centre is the city of Osijek, and the county consists of six other cities and 35 municipalities composed of 263 settlements.

Current thermal energy situation

In Osijek-Baranja County, a heating system exists only in Osijek and is operated by *HEP Toplinarstvo d.o.o.* Since *HEP Toplinarstvo d.o.o.* is registered in the City of Zagreb, the county has no registered companies engaging in any type of thermal energy activity. The Osijek-Baranja County Spatial Plan provides a separate thermal energy analysis, stating that within the county, a district heating system was only built in Osijek, while other cities and settlements meet their heat needs by block boiler rooms or each user arranges heat supply individually. The development of DHS in Osijek began in 1963. DHS components include a thermal source, a heating network, heating stations and domestic heating installations at consumers' homes. Total consumption is divided into three groups of consumers: technological (industrial), commercial and residential. A description of each individual DHS component is also provided. DHS thermal sources comprise the facilities of the *Toplana* heating plant, the *Termoelektrana-Toplana* thermal power/heating plant and block boiler rooms. The heating network consists of steam and hot water pipeline networks. The hot water pipeline system is a double-pipe system, with most pipes laid underground, and is used primarily to heat facilities requiring a lower temperature level. The Plan also states that the hot water pipeline network should meet the needs of Osijek for a longer period. The steam pipeline network of the heating system is primarily used to meet the industrial consumers' needs for process steam.

Thermal energy plans

The Osijek-Baranja County Spatial Plan points out the need for using alternative energy sources, inclusion of cogeneration installations, use and introduction of DHSs in settlements, as well as the improvement of thermal insulation of existing and new facilities in order to increase efficiency or reduce thermal energy losses. It also states that, while the existing DHS successfully meets the consumers' needs, substantial investment funding needs to be planned for future reconstruction of certain DHS components.

Apart from the conventional energy sources in Osijek-Baranja County, the use of alternative energy sources is also possible. These are primarily wood and waste wood, vegetable residues and other biomass, biogas and geothermal energy, which are abundant in Osijek-Baranja County. Apart from the above, the use of solar energy for space heating and domestic hot water generation is also mentioned.

12.3.14.1. City of Osijek

The Osijek Spatial Plan of 2005 and its amendments of 2009, 2010 and 2012 have been analysed. The provisions of the Plan envisage possible development of heating and alternative systems, stating that the thermal network should be built according to the requirements of thermal energy distributors.

The document named Amendments to the Osijek Master Plan of 2010 is analysed below. The document provides for thermal energy supply in the area covered by the Plan to be ensured by building two new KTE Osijek combined thermal power plants for electricity generation, one of which may be built as an extension to the existing KTE Osijek, and by developing the steam and hot water distribution network. It says that the distribution network should be built according to the requirements of thermal energy distributors. Furthermore, the Plan allows for the construction of other plants for electricity and/or thermal energy generation using renewable energy sources (solar energy, outside heat, ground heat).

12.3.15. Šibenik-Knin County

General information on the county

For the purposes of this chapter, the following key documents of the county have been considered: The Šibenik-Knin County Spatial Plan – consolidated version of 2012 and amendments of 2013.

Šibenik-Knin County is located in the central part of Dalmatia. It shares land borders with neighbouring Bosnia and Herzegovina, and with two counties: Zadar County and Split-Dalmatia County. With an area of 2 984 km², or 5.3 %, it belongs among average-sized counties. According to the 2011 census, the county is home to 109 375 inhabitants, or 2.6 % of the total population of Croatia. With an average population density of 36.7 inhabitants per square kilometre, Šibenik-Knin County ranks among sparsely populated counties. The administrative centre of the county is Šibenik. The county consists of four other cities, 15 municipalities and 199 settlements.

Current thermal energy situation

In Šibenik-Knin County, there are no registered companies engaging in any thermal energy activity. There are no heating systems within the county either. The Šibenik-Knin County Spatial Plan does not specifically cover thermal energy or make reference to it.

Thermal energy plans

The Šibenik-Knin County Spatial Plan includes no plans concerning heating systems or thermal energy.

12.3.15.1. City of Šibenik

The analysed Šibenik Spatial Plan of 2003 does not specifically address thermal energy supply at city level or include planning provisions related to thermal energy supply in the city.

The analysis of the Šibenik Master Plan of 2012 found that thermal energy supply at city level is not specifically covered.

12.3.16. Vukovar-Syrmia County

General information on the county

For the purposes of this chapter, the Vukovar-Syrmia County Spatial Plan of 2002 and its amendments of 2007, 2011 and 2014 have been examined.

Vukovar-Syrmia County lies in the far north-eastern part of continental Croatia and occupies parts of eastern Slavonia and western Syrmia. It shares borders with neighbouring Serbia and two other counties: Brod-Posavina County and Osijek-Baranja County. The area of the county measures

2 454 km², or 4.3 % of the total land area of Croatia, ranking it among medium-sized Croatian counties. According to the latest census, the county is home to 179 521 inhabitants, or 4.2 % of the total population of Croatia. The average population density is 73.2 inhabitants per square kilometre, at the level of the national average. The administrative centre of the county is Vukovar. Apart from Vukovar, the county consists of four other cities, 26 municipalities and 85 settlements.

Current thermal energy situation

Vukovar-Syrmia County has two registered companies engaging in thermal energy generation, distribution and supply services. Both companies are registered for all three activities and provide services to Vukovar and Vinkovci, which have heating systems. The heating system in Vukovar is operated by *Tehnostan d.o.o.* and the one in Vinkovci by *GTG Vinkovci d.o.o.* The description of the current situation in the County Spatial Plan lacks information on thermal energy supply systems in the county, although they do exist in Vinkovci and Vukovar.

Thermal energy plans

No plans are mentioned with regard to thermal energy supply at county level. Eastern Croatia is noted to be among priority locations for the construction of a thermal power plant under Croatia's proposed Spatial Planning Strategy. According to the Plan, a thermal power plant can be built in the area intended for port development, but the decision on the final location can be made only on conducting a study and assessing alternative locations. In that regard, the county is interested in the construction of a TE-TO, which would greatly contribute to its development but which requires an examination of possible locations in the wider area of Vukovar. The study should determine the justification for TE construction in the wider area, and analyse the justification for the use of alternative fuels from local resources.

12.3.16.1. City of Vukovar

The Vukovar Spatial Plan of 2006 and its amendments of 2007, 2011 and 2014 have been analysed. According to the description of the current situation, a certain number of buildings in Vukovar are heated by the district heating system. The thermal energy supply system consists of several smaller subsystems. The largest ones are located in Borovo Naselje and Olajnica (by the River Vuka). The others are small and are used to supply up to four or five buildings. Overall, some 1 800 apartments and a certain number of office buildings are heated. Two boiler rooms, 4 km of hot water pipeline and 1.1 km of pipeline network were renovated. Given that the system sustained considerable damage, and was further damaged by corrosion following a number of years out of service, there are substantial investments and interventions to improve the situation. Thus, the boiler rooms, heating stations and substations have undergone repairs, which restored their basic function. Almost all the piping (around 1 500 m) in Olajnica needs to be replaced. The disadvantage is that there is no indirect heating system, but only a direct one. The internal system of the buildings is not separated from the external one.

As for planning, the Vukovar Spatial Plan includes a separate analysis of thermal energy supply at city level. There are plans to expand the existing heating system with a hot water pipeline network in Vukovar proper. The implementing provisions state that parts of Vukovar will be supplied with thermal energy from the new heating plant in Olajnica. It will have a capacity of 20 MW and will use gas as fuel, while extra light fuel oil will be used as reserve fuel. Apart from biogas, renewable fuel (biomass) should be planned as a fuel for new heating plants for thermal energy generation, where possible. Hot water distribution pipelines and internal heating systems of buildings should be separated by heating substations. When designing heating systems at the locations of thermal energy consumers, heat consumption metering should be planned for each consumer individually.

The Vukovar Master Plan of 2007 and its amendments of 2012 are analysed below. A description is provided of the existing thermal energy supply system in Vukovar proper. According to the description, the heating system consists of several smaller subsystems. The largest ones are located in Borovo Naselje and Olajnica. The other subsystems are small and are used to supply up to four or five buildings. Overall, the thermal energy supply system provides heating to a total of 600 apartments and commercial facilities. Given that the system sustained considerable damage, and was further damaged by corrosion following a number of years out of service, there are substantial investments and interventions to improve the situation. Thus, the boiler rooms, heating stations and substations have undergone repairs, which restored their basic function. Apart from the required replacement of almost all the piping (phase 1: around 1050 m from the Vuka boiler room to the one in Olajnica, phase 2: around 150 m from the Vuka boiler room to the one at J.J. Strossmayera 5b, phase 3: around 300 m from the Blok Centar boiler room to the Vuka boiler room), a major drawback is that the boiler rooms are directly connected to the distribution system. Therefore, the substations should be reconstructed and converted to an indirect type (a total of eight substations at the following addresses: Olajnica 5, 6, 12 and bb, Županijska ulica 106, 110 and 114, as well as Ulica J.J. Strossmayera 5b).

In respect of planning provisions in the Vukovar Master Plan, thermal energy supply at neighbourhood level is covered separately. The Plan envisages maintaining the existing separate subsystems for thermal energy supply. The Plan provides for the development of the district heating system, taking into account rational energy use. It is specified that, during boiler room or heating plant construction, the use of renewable energy sources (biomass) should be anticipated where possible. In distribution, hot water distribution pipelines should be separated from internal building heating systems, using thermal substations as well. Further plans for system retrofit interventions envisage continued replacement of almost all hot water pipelines, which were severely damaged by corrosion following several years out of service, and also by war circumstances. Heating projects should provide for heat consumption metering for each consumer separately. The Plan provides for the expansion of the existing steam and hot water pipeline system, with the largest ones located in Borovo Naselje and Olajnica. The construction of a new heating plant with a thermal input of 20 MW in Olajnica is planned to provide thermal energy for a wider area of the city. A location for the new Olajnica heating plant has been designated.

In addition to heating systems based on heating the water in heating stations and on the hot water pipeline network, the Plan also anticipates other systems for heating the interior of buildings. Storey-based systems are to be installed in individual residential buildings, with natural gas foreseen as a primary source of driving energy, or electricity, where not feasible.

When it comes to buildings of mixed, commercial, manufacturing, IT and other purposes, the installation of absorption cooling/heating systems running on hot water, steam, solar energy, natural gas, biomass heat, liquid fuel heat, etc. is assessed as rational. Wherever there is a source of waste heat, e.g. in industrial facilities, health care institutions etc., the application of absorption cooling technology is considered economically cost-effective.

Additional energy sources may be provided by using geothermal energy and optimal building orientation and construction, in order to enable passive utilisation of solar energy, as well as by using small hydroelectric power plants and other additional energy sources.

12.3.16.2. City of Vinkovci

The Vinkovci Spatial Plan of 2004 has been analysed, and its description of the current situation does not include information on the existing thermal energy supply systems in the city (although they do exist). Furthermore, with regard to planning, thermal energy supply at city level is not covered separately. There are no planning provisions concerning the development of centralised thermal energy supply or plans for thermal energy supply in the city in general.

The analysed Vinkovci Master Plan of 2006 has been analysed states that, to date, thermal energy consumers in the city have met their thermal energy needs individually. The issue of thermal energy supply has not been addressed systematically by building of a district heating system. There are only thermal energy units (boiler rooms), built to supply thermal energy to designated buildings.

Thermal energy supply at neighbourhood level is covered separately. The construction of a district heating system in Vinkovci is assessed as being technically feasible, but not economically justified. Cities the size and population density of Vinkovci, on account of their too low heat consumption and consumer density, are generally considered to require too much financial investment, which is currently not justifiable. Gas installation also poses a limitation to district heating system construction, and according to an assessment given in the Plan, this type of thermal energy supply requires considerably lower investment, while enabling more rational fuel consumption and enabling a better and more flexible consumption control, which results in a lower thermal energy unit price.

Therefore, the only realistic possibility proposed is the construction of individual energy units for particular large consumers (large residential and office buildings, public or commercial facilities) or a block boiler room for a group of buildings constructed close together and connected by a heating network. This need me be more pronounced particularly if such consumers are located in the vicinity of each other. To meet the needs for thermal energy and sanitary hot water of a group of users, it is more cost-effective to build a single block boiler room. Natural gas is planned as the main fuel, with extra light oil (fuel oil) as the mandatory reserve fuel. A boiler room for a building or a group of buildings should be constructed within the building with the highest heat consumption value or within the first building to be constructed in that group of buildings. The energy unit should be built and dimensioned so as to enable sanitary hot water supply.

A heating network is planned for the purpose of thermal energy distribution from the block boiler room to surrounding users. Heating network piping should be built in an underground pipeline system in a public area in general or, if necessary, on the users' building parcels. The heating network pipeline system should be built in a single area from the boiler room to the surrounding users and, if necessary,

on the users' building parcels, with underground pipelines laid in concrete channels or directly in the trench.

12.3.17. Split-Dalmatia County

General information on the county

For the purposes of this chapter, the main county document – the Split-Dalmatia County Spatial Plan of 2003 with amendments of 2004, 2005, 2006, 2007 and 2013 – have been analysed.

Split-Dalmatia County is located in the central part of the Adriatic coast. It shares land borders with neighbouring Bosnia and Herzegovina, as well as with two counties: Šibenik-Knin County and Dubrovnik-Neretva County. The area of the county measures 4 540 km², or 8 % of the total land area of Croatia, ranking it the second largest in Croatia. The country is home to 454 798 inhabitants, or 10.6 % of the total population, making it the most populated county in Croatia, with the exception of the City of Zagreb. With an average population density of 100.2 inhabitants per square kilometre, it ranks among most densely populated counties, mostly thanks to the contribution of the second largest Croatian city of Split. The administrative centre is the city of Split, and the county consists of 15 other cities, 39 municipalities and 368 settlements.

Current thermal energy situation

Until recently, Split-Dalmatia County had only one company registered with HERA for the activities of thermal energy generation and distribution, namely *Hvidra d.o.o.* That company ceased operation, and the heating system in Split was the only one in the county. The Split-Dalmatia County Spatial Plan includes no description of the current situation regarding thermal energy.

Thermal energy plans

The Split-Dalmatia County Spatial Plan only mentions the promotion of connection to the district heating system. There are no other plans regarding thermal energy supply in the county.

Thermal energy supply at county level is not specifically covered. Concerning the use of renewable energy sources, the Solar Energy Utilisation Program includes plans for the construction of solar electricity/heating plants driven by solar energy, and the Plan specifies the following locations to be examined: Žeževačka Ljut (Šestanovac municipality) and Kozjak-Malačka, the area located to the east towards Sv. Ivan (City of Kaštela), which is shown in the graphic part of the plan. As stated, due to specific requirements (area size, water, vicinity of roads, etc.), construction criteria need to be determined in greater detail in the Spatial Plan of the area foreseen for the construction of solar electricity/heating plants. These facilities may be built outside the boundaries of the building zone. Areas for the construction of solar electricity/heating plants will be defined within the designated macro locations in the graphic part of the Plan. The terms and criteria for designating these areas have been defined.

In order to improve air quality, the need to promote the use of gas in all sources in the city centre or a connection to district heating sources is outlined. For the same purpose, it is assessed that laying down the use of fuel oil with a sulphur content of up to 1 %, or the use of gas in all boiler rooms using fuel oil, may be necessary. As stated, boiler rooms running on solid fuels should be converted to use liquid or gaseous fuel, or be connected to a district supply system. The Programme also mandates a ban on the use of coal in home boiler rooms in central Split and retail sale of coal with a sulphur content greater than 0.55 g/MJ.

12.3.17.1. City of Split

The Split Spatial Plan of 2005 has been analysed. The description of the current energy systems condition lacks information on the existing systems of thermal energy supply in the city (although they existed at the time of its preparation). Thermal energy supply at city level is not specifically covered. The Split Spatial Plan envisages the rational use of energy by using additional sources, primarily solar energy. The installation of solar collectors is allowed on all buildings outside the zones protected as historical heritage, or on individual buildings not categorised as cultural monuments. Furthermore, the Plan identifies the need to promote the use of gas in all the sources in the urban area of Split or connection to district heating systems; lay down the use of fuel oil with a sulphur content of up to 1 %, or the use of gas; and prohibit the use of coal in home boiler rooms in the urban area of Split and retail sale of coal with a sulphur content greater than 0.55 g/MJ. Potential air polluters (household furnaces and small boiler rooms) are required to keep a record in accordance with regulations and submit it to the competent administrative department of the City of Split for the purpose of keeping an environmental emissions inventory.

The analysed Split Master Plan of 2005 provides no information on the existing systems of thermal energy supply either. Thermal energy supply at neighbourhood level is not specifically covered. There are no planning provisions concerning the development of centralised thermal energy supply or plans for thermal energy supply in the city in general. Air protection against pollution is planned to be ensured by expanding the heating network and building a gas network, as well as by systematic control of the operation of small boiler rooms.

12.3.18. Istria County

General information on the county

For the purposes of this chapter, the following key documents of the county have been considered: Decision adopting the Istria County Spatial Plan, 2002; Decision adopting the Istria County Spatial Plan, consolidated version, 2005; and Decision adopting the Istria County Spatial Plan, consolidated version, 2011. Istria County is the westernmost county in Croatia, encompassing most of the Istria peninsula. It shares land borders with neighbouring Slovenia and with Primorje-Gorski Kotar County. The county's land area measures 2 813 km², or around 5 %, corresponding to the Croatian average in terms of size. According to the latest census of 2011, Istria County is home to 208 055 inhabitants, or 4.9 % of the total population of Croatia. The average population density is 74 inhabitants per square kilometre, ranking around the Croatian average. The administrative centre of the county is Pazin, and the county consists of nine more cities, 31 municipalities and 655 settlements.

Current thermal energy situation

Istria County currently has no registered companies providing any thermal energy services. Similarly, there is no form of heating system in the county. In the Istria County Spatial Plan and its later amendments, thermal energy is not specifically covered and no description of the current situation regarding thermal energy or heating system is provided.

Thermal energy plans

The Istria County Spatial Plan makes no reference to plans regarding thermal energy or heating systems.

12.3.18.1. City of Pula

The analysed Pula Spatial Plan of 2006 does not specifically address thermal energy supply at city level or include planning provisions related to thermal energy supply in the city.

An analysis of the Pula Master Plan of 2008 has found that thermal energy supply is not separately covered at city level.

12.3.19. Dubrovnik-Neretva County

General information on the county

For the purposes of this chapter, the key document of the county, Amendments to the County Spatial Plan (Dubrovnik-Neretva County Institute for Physical Planning), 2015, has been examined. Dubrovnik-Neretva County is the southernmost county in Croatia. Its land area is divided into two parts, separated by the border with neighbouring Bosnia and Herzegovina. It also shares land borders with neighbouring Montenegro and with Split-Dalmatia County. With an area of 1 718 km², or 3.2 % of the total land area of Croatia, it belongs to the category of smaller Croatian counties. The county has a population of 122 568, or 2.9 % of the total population of Croatia. The average population density is 68.82 inhabitants per square kilometre, placing it just below the Croatian average. The administrative centre of the county is Dubrovnik, and the county consists of four more cities, 17 municipalities and 230 settlements.

Current thermal energy situation

Dubrovnik-Neretva County currently has no registered companies providing any thermal energy services. Similarly, there is no form of heating system in the county. In the Dubrovnik-Neretva County Spatial Plan and its amendments, thermal energy is not specifically covered and no description of the current situation regarding thermal energy or heating system is provided.

Thermal energy plans

The Dubrovnik-Neretva County Spatial Plan makes no reference to plans regarding thermal energy or heating systems.

12.3.19.1. City of Dubrovnik

An analysis of the Dubrovnik Spatial Plan of 2005 has found no reference to thermal energy supply at city level, nor are there any planning provisions concerning thermal energy supply in the city either.

An analysis of the Dubrovnik Master Plan of 2005 has shown that thermal energy supply is not separately covered at city level.

12.3.20. Međimurje County

General information on the county

For the purposes of this chapter, the key document of the county, the Međimurje County Spatial Plan (Međimurje County Institute for Physical Planning) of 2001 with Amendments to the Međimurje County Spatial Plan (Međimurje County Institute for Physical Planning) of 2010, has been considered. Međimurje County lies in the northern part of Croatia. It borders with the neighbouring republics of Slovenia and Hungary, as well as two counties: Varaždin County and Koprivnica-Križevci County. With an area of 729 km², or 1.3 % of the total land area of Croatia, it is the smallest Croatian county. According to the latest census, Međimurje County has a population of 113 804, which accounts for 2.7 % of the total population of Croatia. With an average population density of 156.1 inhabitants per square kilometre, it is the most densely populated Croatian county. The administrative centre of the county is Čakovec, and the county consists of two more cities, 22 municipalities and 131 settlements.

Current thermal energy situation

In Međimurje County, there is only one company registered with HERA for all three thermal energy activities (generation, distribution and supply). According to available data, currently there are no district heating systems in the county. The Međimurje County Spatial Plan does not specifically cover thermal energy. There is also no mention of the current situation in that area.

Thermal energy plans

The Međimurje County Spatial Plan includes no separate analysis of thermal energy, and no plans are mentioned regarding the issue.

12.3.20.1. City of Čakovec

For the purposes of this chapter, the Čakovec Spatial Plan of 2003 and its amendments of 2009, 2012 and 2014 have been considered. The description of the current state of the energy infrastructure lacks information on thermal energy supply systems in the city. As regards planning provisions, thermal energy supply at city level is not specifically covered. There are no planning provisions concerning the development of centralised thermal energy supply or plans for thermal energy supply in the city in general.

The Čakovec Master Plan of 2005 and its amendments of 2009, 2011 and 2014 have been analysed. In the description of the existing situation, there is no reference to any existing thermal energy supply systems in the city. Thermal energy supply at city level is not specifically covered, nor are there any planning provisions concerning the development of district thermal energy supply or plans for thermal energy supply in Čakovec in general.

12.3.21. City of Zagreb

General information on the City of Zagreb

For the purposes of this chapter, the key document of the city has been considered, namely, the Zagreb Spatial Plan – amendments of 2014. The City of Zagreb is a separate regional entity and as the capital of Croatia it is the administrative, economic, cultural, transport and scientific centre of Croatia. With an area of 641 km², or 1.1 % of the total land area of Croatia, the City of Zagreb is the smallest regional entity if compared to the counties. The City of Zagreb has a population of 790 017, or 18.4 % of the total population Croatia. As the largest city in Croatia, it has an average population density of 1 232.5 inhabitants per square kilometre, making it the most densely populated region in Croatia. It consists of 17 districts and 70 neighbourhoods.

Current thermal energy situation

Zagreb currently has six registered companies capable of providing at least one thermal energy service, but only one of them provides all three – thermal energy generation, distribution and supply. The company in question is *HEP Toplinarstvo d.o.o.* It operates the district heating system in Zagreb,

which is the largest in Croatia. The Zagreb Spatial Plan covers thermal energy as a separate unit and sets out plans in that area, but provides no description of the current situation.

Thermal energy plans

The Zagreb Spatial Plan of 2014 states that the establishment of a comprehensive district heating system is possible by consolidating the local heating networks, individual separate heating plants and individual boiler rooms by replacing liquid fuel with natural gas, connecting local heating networks to the DHS and converting the existing separate heating plants into small cogeneration installations. Using renewable energy sources, such as the sun, wind, biogas and geothermal water, as an additional source of thermal energy is also planned. The Plan states that the development of the city's basic energy systems in the heating sector should aim to limit any major expansion of the DHS and that the heating sector development should be based on a radical rationalisation of DHS operation, including the revitalisation and replacement of plants nearing the end of their service life and an increase in the coverage of home heating plants (special heating plants) by the system. The Plan also provides for organised and systematic care of energy efficiency in the heating sector based on the national energy programme KUENcts/Energy Efficiency Programme for District Heating Systems. Based on the assessment that thermal energy consumption in the western part of Zagreb will increase, following an analysis of the production potential of the existing installations and taking into account the need and likelihood of building combined cycle gas power plants, the Plan provides for the extension and/or construction of new facilities at the EL-TO Zagreb location. Comparative technical energy and economic analyses of the TE-TO Zagreb location show the replacement of worn-out blocks with a new combined cycle cogeneration plant as the most favourable solution. Despite dating from as recently as 2014, some elements of the Zagreb Spatial Plan may be said to be outdated since most of them have already been implemented or rejected.

The Zagreb Master Plan of 2007 and its amendments of 2013 and 2015 have been analysed. The Plan states that the supply of thermal energy to the city and its use will be ensured by adequate space utilisation and by defining corridors for the following:

- distribution network extension;
- connection of TE-TO and EL-TO networks;
- construction of pumping stations;
- underground installation of steam pipelines;
- construction of new buildings on TE-TO and EL-TO locations;
- geothermal energy utilisation;
- construction of new buildings for the passive use of solar energy;
- use of energy from a future thermal waste treatment plant;
- use of an energy source preferable to consumers in parts of the city where other energy sources exist or are planned in addition to the DHS.

The district heating system distribution network (hot water pipelines, steam pipelines) are laid underground in accordance with special regulations. The corridor required for laying down the district heating system distribution network (hot water pipelines and steam pipelines), depending on the piping type, is 2 m to 4 m. In certain cases, the existing and planned district heating system distribution network (hot water pipelines and steam pipelines) may be laid down, generally on the same route, on all types of surface, depending on the local technical conditions, in accordance with the provisions of Articles 22 and 56 of this decision. The construction and mounting of devices for the exploitation of solar energy is allowed, provided that they have no negative impact on the neighbourhood, while taking account of the limitations arising from the Measures for the Preservation and Protection of Landscape and Natural Values and Immovable Cultural Property.

12.4. FINAL OBSERVATIONS

The following final observations refer to the provisions of the above-mentioned county and city spatial planning documents concerning the development of the energy infrastructure related to thermal energy supply.

With regard to the analysis of the development plans of the energy operators in the district heating sector and their financial potential for future investments, only scant data were obtained. In total, eight energy companies submitted business data for the past several years. The level of the data submitted is low, that is, the Programme authors had access only to the aggregate annual data on the main accounting categories.

Based on the data processed, a vast majority of the companies were found to have operated with a loss. In addition, most companies did not state any plans on the development of their activities, and

most investments to date (if any) were primarily aimed at regular or emergency system maintenance so as to maintain heating system functionalities. It should be noted that the planned investments largely refer to the construction and reconstruction of distribution networks (approx. HRK 1 179 million), while a considerably smaller amount is intended for the construction and reconstruction of energy facilities and equipment for thermal energy generation (approx. HRK 125 million). Several companies mentioning plans for future investments intend to finance them either from European funds, if the planned investments are substantial (e.g. *HEP Toplinarstvo d.o.o.*) or with the help of the local community and domestic sources, such as the Environmental Protection and Energy Efficiency Fund (e.g. *Gradska Toplana d.o.o.* Karlovac).

Thermal energy supply at county level is elaborated only in four county spatial plans, as follows: Primorje-Gorski Kotar County, Brod-Posavina County, Osijek-Baranja County, and to a lesser extent Lika-Senj County spatial plans. At the city spatial plan level, this topic is elaborated in the plans of seven cities, as follows: Velika Gorica, Varaždin, Rijeka, Slavonski Brod, Osijek, Vukovar, and Zagreb. In city master plans, heat supply is analysed as a separate field in nine cities: Sisak, Karlovac, Varaždin, Rijeka, Slavonski Brod, Osijek, Vukovar, Vinkovci, and Zagreb. In the remaining counties/cities, the issue of thermal energy supply is mentioned only in the context of future use of cogeneration, renewable energy sources and environmental protection measures.

From the point of view of space allocation, due to the technical characteristics of district heating system distribution networks, and apart from allowing district heating systems in general (if they are mentioned at all), the spatial plans failed to achieve the objective of promoting the development of district heating systems as an alternative in thermal energy supply. None of the spatial plans mention a distribution network for cooling energy, as an alternative to individual cooling systems.

A better elaboration of district heating systems is possible at master plan level. A significant number of master plans are older than 10 years and, hence, do not incorporate more recent guidelines concerning district systems development. The spatial plans and master plans have significant potential for strengthening the role of district heating systems.

The regulations regarding energy efficiency in buildings which lay down stricter requirements for buildings of nearly zero-energy level (all new-builds as of 2018, or 2020) with a defined share of renewable energy sources and a limited possibility for cost optimisation, and especially limited possibilities to apply the renewable energy sources on a building, compel these buildings to rely more extensively on district systems for the supply of energy from renewable sources or that having an adequate ratio between renewable and non-renewable energy sources. Other regulations regarding environmental protection – e.g. noise protection – may give further advantage to district systems by eliminating the unwanted impact of equipment installed on the buildings themselves.

Apart from the cities and counties with substantial construction activity, requiring spatial plans to be amended in accordance with the requirements of space users, it is necessary to intensify the updating of all spatial plans also by including alternative and renewable energy sources, and providing space to include renewable energy sources into district heating systems. The plans should anticipate spatial needs for such systems and their role in the development of intelligent networks and the supply of spatial units with renewable energy sources, while complying with applicable regulations.

An overview of the applicable spatial planning documents and provisions directly concerning thermal energy supply, for each of the cities, is provided in the table below.

Table 48: Overview of the spatial planning documents and provisions concerning thermal energy supply

County	Zagreb				Krapina-Zagorje	Sisak-Moslavina	Karlovac	Varaždin	Koprivnica-Križevci	Bjelovar-Bilogora	Primorje-Gorski Kotar	Lika-Senj	Virovitica-Posravina	Požega-Slavonia	Slavonski Brod-Posavina	Zadar	Osijek-Baranja	Šibenik-Knin	Vukovar-Syrmia	Split-Dalmatia	Istria	Dubrovnik-Neretva	Međimurje	City of Zagreb	
City	Velika Gorica	Samobor	Zaprešić	Ivanić Grad	Krapina	Sisak	Karlovac	Varaždin	Koprivnica	Bjelovar	Rijeka	Gospić	Virovitica	Požega	Slavonski Brod	Zadar	Osijek	Šibenik	Vukovar	Vinkovci	Split	Pula	Dubrovnik	Čakovec	Zagreb
Year of adoption of the act																									
County spatial plan	2002 *2012				2002	2001	2001 *2008	2000	2001 *2004 *2012	2001	2013	2015	2010 *2013	2002 *2011	2001 *2005 *2008 *2010 *2012	2006 *2014	2002 *2012 *2013	2012 *2013	2002 *2007 *2011 *2014	2003 *2004 *2005 *2006 *2007 *2013	2002 *2005 *2011	2015	2001 *2010	-	
City spatial plan	2014	2007	2005 *2007 *2011	2005 *2009 *2010	2002 2003 *2004 *2007 *2011	2002 2006 *2013	2002	2005	2006 *2012 *2015	2003 *2009	2003 *2005 *2013	2005 *2009 *2015	2005	2005	2004 *2007 *2014	2004 *2008 *2011	2005 *2009 *2010 *2012	2003	2006 *2007 *2011 *2014	2004	2005	2006	2005	2003 *2009 *2012 *2014	2014
City master plan	-	2007	-		2002 *2004 *2007 *2009 *2010	2002	2007	2006	2008 *2014 *2015	2004 *2009 *2012	2007 *2013 *2014 *2015	-	2005 *2007	2005 *2007 *2011	2005 *2008	-	2010	2012	2007 *2012	2006	2005	2008	2005	2005 *2009 *2011 *2014	2007 *2013 *2015
Are there provisions in place which directly relate to thermal energy supply or planning?																									
County SP	no				no	no	no	no	no	no	yes	yes	no	no	yes	no	yes	no	no		no	no	no	no	-
City SP	yes	no	no	no	no	no	no	yes	no	no	yes	no	no	no	yes	no	yes	no	yes	no	no	no	no	no	yes
GUDP	-	no	-	no	no	yes	yes	yes	no	no	yes	-	no	no	yes	-	yes	no	yes	yes	no	no	no	no	yes
Other provisions	res, cogen, ng	-	-	-	geo	geo	cogen, res,	geo	geo	geo	cogen, res,	cogen,	res,	cogen,	res, cogen,	emi	res, cogen,		cogen, res,		res, ng	res,	res,	geo	cogen, res

13. FINAL OBSERVATIONS

The analysis of total energy consumption in 2013 showed the following:

- Total energy consumption in the household sector amounted to 103.7 PJ in 2013. In the structure of final energy fuels, firewood holds the largest share in consumption with 48 per cent, followed by electricity with 21 per cent, natural gas with 19 per cent, heat with 5 per cent, and fuel oil and liquefied petroleum with 4 and 3 per cent, respectively.
- Total energy consumption in the service sector was 29 118 TJ. The share of thermal energy in total consumption was 48 per cent, while cooling energy accounted for 15 per cent. In the structure of thermal energy consumption, natural gas was the prevalent [fuel] with a 42 per cent share, followed by electricity with 24 per cent, extra light fuel oil with 18 per cent, heat with 12 per cent, and liquefied petroleum gas with 4 per cent.
- Total energy consumption at industrial plants amounted to 22.73 PJ, of which 12.28 PJ was direct thermal energy and 10.45 PJ indirect thermal energy.

The results of modelling the projections of future thermal energy needs show the following:

- Throughout Croatia, except in coastal areas, thermal energy consumption in the household sector is expected to decrease, largely as a result of an expected population decline in these parts of Croatia, but also of an anticipated improvement of building energy performance. In the coastal areas of Croatia, that is, zone South, a slight increase in thermal energy needs prompted by a rising standard of living and increased energy needs for cooling, is foreseen, along with expected population growth.
- In the services sector, a modest increase of useful thermal energy and a substantially greater increase in energy needed for cooling are expected as a result of economic development.
- In the industry sector, an increase of thermal energy needs by up to almost 30 PJ is expected; also, it is important to distinguish between direct thermal energy (heat caused by direct fuel combustion and used in the production process) and indirect thermal energy (heat produced in boiler rooms and heating plants), since only indirect thermal energy can be substituted by heat from high-efficiency cogeneration.

According to the analysis of the current condition of thermal energy installations, covering four existing cogeneration installations of *Hrvatska elektroprivreda* and three industrial cogeneration installations with a thermal input exceeding 20 MW, individual blocks of HEP cogeneration installations can meet high-efficiency cogeneration needs under certain exploitation conditions, but none of the analysed industrial cogeneration installations is a viable candidate to meet high-efficiency cogeneration requirements.

An analysis of potential new heat consumption locations identified a total of 18 locations which, based on their theoretical potential for thermal energy needs and likelihood of the construction of necessary heat distribution infrastructure, represent a likely potential for the construction of new high-efficiency cogeneration installations. The respective theoretical thermal potential of these 18 locations is 29 982 128 GJ, or 8 328 369 MWh annually by 2030.

The conservative scenario regarding the share of district heating system consumers, presumed on the basis of the current trends identified for each potential new location, singled out six (6) potential new locations for high-efficiency cogeneration. Their total equivalent thermal potential is 5 506 528 GJ, or 1 529 591 MWh annually by 2030. The corresponding total equivalent potential of the electrical component of high-efficiency cogeneration, based on modern CCCG technology, in the conservative scenario amounts 8 653 115 GJ or 2 403 643 MWh.

The conservative scenario regarding the share of district heating system consumers, presumed on the basis of the current trends identified for each potential new location, singled out eighteen (18) potential new locations for high-efficiency cogeneration. Their total equivalent thermal potential is 16 625 599 GJ, or 4 618 222 MWh annually by 2030. The corresponding total equivalent potential of the electrical component of high-efficiency cogeneration in the optimistic scenario amounts to 26 125 941 GJ or 7 257 206 MWh.

The potential for primary energy savings by 2030, presuming the application of high-efficiency cogeneration, is 4 849 053 GJ in the conservative scenario and 14 634 591 GJ in the optimistic scenario regarding the share of future district heating system consumers.

Despite a long tradition of DHS system supply in Croatia, the situation in the existing district systems is not satisfactory for a number of reasons, such as: old plants and their low efficiency, old networks, high fuel prices, poor insulation of buildings using district systems, poor manageability of heat consumption, and inadequate policy of heat pricing, which failed to cover production costs.

The development of new district systems will also depend on the efficiency of the existing ones, so upgrading the latter should be treated as a priority. If wholesale fuel prices are excluded as unmanageable, since they depend on the market, there are four remaining essential components to be prioritised among the activities aimed at increasing DHS system efficiency:

- construction of efficient cogeneration installations where they are not present, and substitution of district boiler rooms with DHS and construction of adequate high-efficiency cogeneration installations;
- choice of fuel, particularly aiming to reduce of CO₂ emissions;
- replacement of the heat network reaching the end of its service life and connection of district boiler rooms to the DHS network;
- priority programme of energy renovation of buildings in the areas covered by DHS.

The plans for DHS development should take account of the fact that, in addition to the development of planning and expert analyses by competent institutions, the procedure for preparation and implementation of plant construction requires a number of administrative documents to be obtained and contracts – envisaged by the complex legal framework in the field of energy, physical planning and construction, environmental protection, etc. – to be concluded. However, if competent state authorities, bodies of local and regional self-government units and legal persons with public authority (agencies, operators etc.) comply with the prescribed time limits, taking into account the principles of administrative proceedings, and if energy entities fulfil their obligations under issued consents and approvals, administrative proceedings to be conducted should not slow down the implementation of such projects.

The new Renewable Energy Sources and High-Efficiency Cogeneration Act, entering into force on 1 January 2016, does not cover the issue of incentives to RES heating and cooling energy generation. Since the thermal market represents great potential for achieving the energy targets relating to the use of renewable energy sources, lack of systematic consideration of this area is recognised as a major drawback of the existing legal framework.

State aid for district heating and cooling may be granted in accordance with the provisions of the General Block Exemption Regulation (No 651/2014). The condition is to meet all the requirements under Regulation No 651/2014, and three ways of enabling state aid to be granted have been determined.

1. The first is to grant state aid in accordance with the *de minimis* rule, which means aid to a single company not exceeding EUR 200 000 over any period of three years. Aid measures for district heating and cooling may be in compliance with the *de minimis* rules, provided that the ceiling of EUR 200 000 over a three-year period is respected.
2. The second way is to grant state aid in accordance with Regulation No 651/2014, declaring certain categories of aid compatible with the internal EU market. This block exemption allows Member States to adopt certain state aid schemes without prior notification of the European Commission, and aid measures for district heating and cooling may be included in the block exemption if they meet the requirements of Regulation No 651/2014.
3. The third way to allocate state aid is via notification of a state aid allocation scheme to the Commission. This procedure may be long and uncertain, and no state aid may be allocated before final approval of the Commission.

For the purpose of monitoring programme implementation, as well as evaluating the results achieved and reporting to the Croatian Government on these results and recommendations, the Ministry of the Economy ought to establish a system of Programme implementation evaluation and monitoring through regular cooperation and reporting by HERA, which supervises the performance of energy activities and the functioning of energy markets, and by local self-government units which are, among other things, obligated to encourage, plan and approve the construction of heating systems.

14. ANNEXES

14.1. HEAT CONSUMPTION DEVELOPMENT UNTIL 2030 – POTENTIAL FOR HIGH-EFFICIENCY COGENERATION

Table 49: Characteristics of settlements according to heat consumption projections until 2030

County	City/municipality	No of persons	No of households	Avg. No of persons per household	Housing units area	Permanently occupied housing units	Share of permanently occupied %	2015	2020	2025	2030
City of Zagreb	Zagreb	781 272	303 441	2.57	25 789 993	299 977	30.47	300 691	306 470	311 953	317 718
Sisak-Moslavina	Kutina	22 683	7 959	2.85	770 773	7 804	0.79	7 823	7 973	8 116	8 266
Osijek-Baranja	Osijek	107 225	41 972	2.55	3 821 383	41 384	4.20	41 482	42 280	43 036	43 831
Osijek-Baranja	Bellšće	10 776	3 848	2.80	351 482	3 748	0.38	3 757	3 829	3 898	3 970
Primorje-Gorski Kotar	Rijeka	127 645	52 890	2.41	4 099 933	52 056	10.90	52 805	54 137	55 494	56 949
Virovitica-Podravina	Virovitica	21 247	7 700	2.76	768 576	7 577	0.77	7 595	7 741	7 879	8 025
Varaždin	Varaždin	46 115	17 021	2.71	1 543 109	16 735	1.70	16 775	17 097	17 403	17 725
Split-Dalmatia	Split	176 552	63 007	2.80	5 029 394	61 662	12.91	62 549	64 126	65 735	67 458
Karlovac	Karlovac	55 106	21 266	2.59	1 895 862	20 855	2.12	20 905	21 306	21 688	22 088
Slavonski Brod-Posavina	Slavonski Brod	58 662	20 137	2.91	1 929 946	19 631	1.99	19 678	20 056	20 415	20 792
Koprivnica-Križevci	Koprivnica	30 422	10 713	2.84	1 101 100	10 517	1.07	10 542	10 745	10 937	11 139
Vukovar-Syrmia	Županja	12 065	4 008	3.01	426 938	3 861	0.39	3 870	3 945	4 015	4 089
Zagreb	Velika Gorica	63 258	20 944	3.02	2 088 031	20 752	2.11	20 801	21 201	21 580	21 979
Osijek-Baranja	Đurđenovac	6 750	2 452	2.75	220 049	2 402	0.24	2 408	2 454	2 498	2 544
Bjelovar-Bilogora	Bjelovar	39 372	13 686	2.88	1 422 139	13 580	1.38	13 612	13 874	14 122	14 383
Sisak-Moslavina	Sisak	47 316	18 203	2.60	1 682 775	17 997	1.83	18 040	18 387	18 715	19 061
Požega-Slavonia	Požega	25 722	9 143	2.81	953 435	9 027	0.92	9 048	9 222	9 387	9 561
Zadar	Zadar	74 443	27 461	2.71	2 753 285	27 153	5.68	27 544	28 238	28 946	29 705
Zagreb	Zaprešić	25 152	8 638	2.91	774 989	8 567	0.87	8 587	8 752	8 909	9 074
Sisak-Moslavina	Petrinja	24 331	8 603	2.83	931 863	8 446	0.86	8 466	8 629	8 783	8 946
Istria	Pula – Pola	56 627	22 934	2.47	1 959 977	22 640	4.74	22 966	23 545	24 135	24 768
Međimurje	Čakovec	26 817	8 948	3.00	962 987	8 799	0.89	8 820	8 989	9 150	9 319
Zagreb	Samobor	37 556	12 286	3.06	1 355 992	12 148	1.23	12 177	12 411	12 633	12 866

County	City/municipality	No of persons	No of households	Avg. no of persons per household	Housing units area	Permanently occupied housing units	Share of permanently occupied %	2015	2020	2025	2030
Vukovar-Syrmia	Vinkovci	34 888	12 147	2.87	1 200 207	11 999	1.22	12 028	12 259	12 478	12 709
Vukovar-Syrmia	Vukovar	27 549	10 894	2.53	1 066 728	10 682	1.09	10 707	10 913	11 108	11 314
Zagreb	Vrbovec	14 560	4 367	3.33	493 013	4 312	0.44	4 322	4 405	4 484	4 567
Šibenik-Knin	Šibenik	45 742	17 311	2.64	1 584 693	17 183	3.60	17 430	17 870	18 318	18 798
Osijek-Baranja	Đakovo	27 328	8 757	3.12	938 531	8 579	0.87	8 599	8 765	8 921	9 086
Zagreb	Brdovec	11 106	3 466	3.20	379 987	3 446	0.35	3 454	3 521	3 584	3 650
Koprivnica-Križevci	Križevci	20 958	6 866	3.05	699 116	6 749	0.69	6 765	6 895	7 018	7 148
Varaždin	Ivanec	13 606	4 057	3.35	386 470	4 004	0.41	4 014	4 091	4 164	4 241

Table 50: Projections of household heating and cooling consumption until 2030

County	City/municipality	Heating, GJ				Domestic hot water and cooking, GJ				Cooling, GJ			
		2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
City of Zagreb	Zagreb	11 309 048	10 543 888	9 628 488	8 580 576	2 667 815	2 704 048	2 737 119	2 772 110	476 597	646 238	821 152	1 002 697
Sisak-Moslavina	Kutina	285 298	265 995	242 902	216 466	69 404	70 347	71 207	72 117	12 786	17 337	22 030	26 900
Osijek-Baranja	Osijek	1 561 484	1 455 836	1 329 443	1 184 754	368 044	373 043	377 605	382 433	65 695	89 078	113 188	138 212
Osijek-Baranja	Belišće	141 418	131 850	120 403	107 299	33 332	33 785	34 198	34 636	5 950	8 067	10 251	12 517
Primorje-Gorski Kotar	Rijeka	991 587	982 199	952 128	900 930	469 483	490 108	511 405	534 052	108 692	126 172	144 446	163 738
Virovitica-Podravina	Virovitica	289 889	270 275	246 810	219 949	67 385	68 300	69 136	70 020	11 862	16 084	20 438	24 956
Varaždin	Varaždin	647 709	603 886	551 458	491 440	148 831	150 852	152 697	154 649	25 898	35 117	44 622	54 487
Split-Dalmatia	Split	866 487	858 283	832 006	787 267	556 118	580 548	605 776	632 602	174 525	202 594	231 936	262 913
Karlovac	Karlovac	795 263	741 456	677 084	603 394	185 472	187 991	190 290	192 723	32 758	44 417	56 440	68 918
Slavonski Brod-Posavina	Slavonski Brod	736 442	686 615	627 005	558 765	174 586	176 957	179 122	181 412	31 344	42 500	54 003	65 943
Koprivnica-Križevci	Koprivnica	401 532	374 365	341 863	304 657	93 532	94 802	95 962	97 188	16 499	22 372	28 427	34 712
Vukovar-Syrmia	Županja	142 291	132 664	121 146	107 962	34 337	34 804	35 229	35 680	6 275	8 509	10 812	13 202
Zagreb	Velika Gorica	771 129	718 955	656 537	585 083	184 556	187 062	189 350	191 771	33 450	45 356	57 632	70 374
Osijek-Baranja	Đurđinovac	90 631	84 499	77 163	68 765	21 362	21 652	21 917	22 197	3 813	5 170	6 570	8 022
Bjelovar-Bilogora	Bjelovar	509 542	475 067	433 822	386 607	120 772	122 413	123 910	125 494	21 678	29 394	37 350	45 608
Sisak-Moslavina	Sisak	657 933	613 418	560 162	499 197	160 054	162 228	164 212	166 312	29 486	39 982	50 803	62 035
Požega-Slavonia	Požega	338 994	316 058	288 619	257 207	80 281	81 371	82 366	83 419	14 398	19 523	24 807	30 291
Zadar	Zadar	419 506	415 535	402 812	381 152	244 888	255 646	266 755	278 568	69 901	81 143	92 895	105 302
Zagreb	Zaprešić	318 343	296 804	271 036	241 538	76 190	77 225	78 169	79 168	13 809	18 724	23 792	29 052
Sisak-Moslavina	Petrinja	308 768	287 877	262 884	234 273	75 114	76 134	77 065	78 050	13 838	18 763	23 842	29 113
Istria	Pula - Pola	400 955	397 159	384 999	364 297	204 186	213 156	222 418	232 268	50 844	59 022	67 570	76 594
Međimurje	Čakovec	340 543	317 502	289 937	258 382	78 253	79 316	80 286	81 312	13 617	18 465	23 462	28 649
Zagreb	Samobor	451 410	420 868	384 330	342 501	108 037	109 504	110 844	112 261	19 581	26 551	33 737	41 196
Vukovar-Syrmia	Vinkovci	442 205	412 286	376 492	335 517	106 712	108 161	109 484	110 884	19 501	26 443	33 600	41 029
Vukovar-Syrmia	Vukovar	393 669	367 034	335 169	298 691	94 999	96 290	97 467	98 713	17 361	23 541	29 912	36 525
Zagreb	Vrbovec	160 231	149 390	136 420	121 573	38 348	38 869	39 345	39 848	6 950	9 424	11 975	14 623
Šibenik-Knin	Šibenik	268 844	266 298	258 145	244 264	154 970	161 778	168 808	176 284	43 680	50 705	58 049	65 802
Osijek-Baranja	Đakovo	323 699	301 798	275 597	245 602	76 296	77 333	78 278	79 279	13 619	18 466	23 464	28 652
Zagreb	Brdovec	128 051	119 387	109 022	97 157	30 647	31 063	31 443	31 845	5 555	7 532	9 570	11 686
Koprivnica-Križevci	Križevci	257 672	240 238	219 381	195 505	60 022	60 837	61 581	62 368	10 588	14 357	18 243	22 276
Varaždin	Ivanec	154 970	144 485	131 941	117 581	35 609	36 093	36 534	37 001	6 196	8 402	10 676	13 036

Table 51: Projections of industry heating consumption until 2030

County	City/municipality	2015		2020		2025		2030	
		Direct, GJ	Indirect, GJ	Direct, GJ	Indirect, GJ	Direct, GJ	Indirect, GJ	Direct, GJ	Indirect, GJ
City of Zagreb	Zagreb	847 791	2 038 606	889 025	2 137 759	976 234	2 347 463	1 097 235	2 638 423
Sisak-Moslavina	Kutina	79 778	3 377 358	83 658	3 541 624	91 865	3 889 041	103 251	4 371 075
Osijek-Baranja	Osijek	289 180	780 738	303 245	818 711	332 992	899 022	374 266	1 010 453
Osijek-Baranja	Belišće	42 418	795 202	44 482	833 879	48 845	915 678	54 899	1 029 174
Primorje-Gorski Kotar	Rijeka	35 874	70 805	37 619	74 248	41 309	81 532	46 429	91 638
Virovitica-Podravina	Virovitica	52 299	553 979	54 842	580 923	60 222	637 909	67 686	716 975
Varaždin	Varaždin	239 330	261 210	250 970	273 915	275 589	300 785	309 748	338 066
Split-Dalmatia	Split	44 670	11 078	46 843	11 616	51 438	12 756	57 814	14 337
Karlovac	Karlovac	100 973	111 107	105 884	116 511	116 271	127 940	130 682	143 798
Slavonski Brod-Posavina	Slavonski Brod	108 623	106 925	113 906	112 125	125 080	123 124	140 583	138 385
Koprivnica-Križevci	Koprivnica	302 397	243 863	317 105	255 724	348 212	280 809	391 371	315 615
Vukovar-Syrmia	Županja	142 662	390 978	149 601	409 995	164 276	450 213	184 637	506 016
Zagreb	Velika Gorica	9 638	0	10 107	0	11 098	0	12 474	0
Osijek-Baranja	Đurđenovac	3 070	369 094	3 220	387 046	3 536	425 013	3 974	477 692
Bjelovar-Bilogora	Bjelovar	142 508	120 417	149 439	126 273	164 098	138 660	184 437	155 847
Sisak-Moslavina	Sisak	118 454	14 743	124 215	15 460	136 400	16 976	153 307	19 080
Požega-Slavonia	Požega	179 561	120 377	188 294	126 231	206 765	138 614	232 393	155 795
Zadar	Zadar	18 716	100	19 626	105	21 552	115	24 223	130
Zagreb	Zaprešić	57 357	101 985	60 147	106 945	66 047	117 436	74 234	131 992
Sisak-Moslavina	Petrinja	8 998	107 427	9 435	112 652	10 361	123 703	11 645	139 036
Istria	Pula - Pola	1 294 118	3 603	1 357 060	3 778	1 490 181	4 149	1 674 885	4 663
Međimurje	Čakovec	112 776	66 776	118 261	70 024	129 862	76 893	145 958	86 423
Zagreb	Samobor	38 180	0	40 037	0	43 965	0	49 414	0
Vukovar-Syrmia	Vinkovci	118 276	0	124 029	0	136 195	0	153 076	0
Vukovar-Syrmia	Vukovar	19 826	0	20 790	0	22 829	0	25 659	0
Zagreb	Vrbovec	21 685	123 550	22 739	129 559	24 970	142 268	28 065	159 902
Šibenik-Knin	Šibenik	163 857	3 036	171 826	3 184	188 681	3 496	212 068	3 930
Osijek-Baranja	Đakovo	108 047	0	113 302	0	124 416	0	139 837	0
Zagreb	Brdovec	27 038	86 895	28 353	91 122	31 135	100 060	34 994	112 463
Koprivnica-Križevci	Križevci	32 478	0	34 058	0	37 399	0	42 035	0
Varaždin	Ivanec	20 665	50 013	21 670	52 445	23 795	57 590	26 745	64 728

Table 52: Projections of service sector heating and cooling consumption until 2030

County	City/ municipality	Heating, GJ				Cooling, GJ				Heating and Cooling, GJ			
		2015	2020	2025	2030	2015	2020	2025	2030	2015	2020	2025	2030
City of Zagreb	Zagreb	3 274 273	3 320 584	3 369 597	3 421 440	1 057 504	1 231 643	1 441 830	1 696 927	4 331 777	4 552 227	4 811 427	5 118 368
Sisak-Moslavina	Kutina	65 381	66 306	67 284	68 320	21 116	24 594	28 791	33 884	86 497	90 899	96 075	102 204
Osijek-Baranja	Osijek	404 511	410 232	416 288	422 692	130 646	152 160	178 127	209 642	535 157	562 392	594 414	632 335
Osijek-Baranja	Belišće	10 165	10 309	10 461	10 622	3 283	3 824	4 476	5 268	13 448	14 132	14 937	15 890
Primorje-Gorski Kotar	Rijeka	621 749	630 543	639 850	649 695	200 809	233 876	273 788	322 228	822 558	864 419	913 638	971 923
Virovitica-Podravina	Virovitica	78 648	79 761	80 938	82 183	25 401	29 584	34 633	40 760	104 049	109 345	115 571	122 943
Varaždin	Varaždin	281 518	285 499	289 714	294 171	90 923	105 895	123 967	145 900	372 441	391 395	413 680	440 071
Split-Dalmatia	Split	560 177	568 101	576 486	585 355	180 923	210 715	246 675	290 318	741 100	778 816	823 161	875 673
Karlovac	Karlovac	215 172	218 215	221 436	224 843	69 495	80 939	94 751	111 515	284 667	299 154	316 188	336 359
Slavonski Brod-Posavina	Slav. Brod	174 682	177 153	179 767	182 533	56 418	65 708	76 921	90 531	231 099	242 860	256 689	273 064
Koprivnica-Križevci	Koprivnica	102 359	103 807	105 339	106 959	33 059	38 503	45 074	53 049	135 418	142 310	150 413	160 008
Vukovar-Syrmia	Županja	10 073	10 215	10 366	10 526	3 253	3 789	4 436	5 220	13 326	14 004	14 802	15 746
Zagreb	Velika Gorica	201 411	204 260	207 275	210 464	65 051	75 762	88 692	104 384	266 462	280 022	295 967	314 847
Osijek-Baranja	Đurđenovac	6 367	6 457	6 553	6 653	2 056	2 395	2 804	3 300	8 424	8 852	9 356	9 953
Bjelovar-Bilogora	Bjelovar	151 452	153 594	155 861	158 259	48 915	56 970	66 692	78 492	200 367	210 564	222 553	236 751
Sisak-Moslavina	Sisak	136 990	138 927	140 978	143 147	44 244	51 530	60 324	70 996	181 234	190 457	201 301	214 143
Požega-Slavonia	Požega	88 869	90 126	91 456	92 864	28 702	33 429	39 134	46 057	117 572	123 555	130 590	138 921
Zadar County	Zadar	249 977	253 512	257 254	261 212	80 736	94 031	110 078	129 553	330 713	347 543	367 332	390 766
Zagreb	Zaprešić	80 105	81 238	82 437	83 706	25 872	30 132	35 274	41 515	105 977	111 370	117 712	125 221
Sisak-Moslavina	Petrinja	70 433	71 429	72 484	73 599	22 748	26 494	31 015	36 503	93 181	97 923	103 499	110 102
Istria	Pula - Pola	342 145	346 984	352 105	357 523	110 504	128 700	150 664	177 320	452 648	475 684	502 769	534 843
Međimurje	Čakovec	155 351	157 548	159 874	162 333	50 174	58 436	68 409	80 512	205 525	215 985	228 283	242 846
Zagreb	Samobor	119 519	121 210	122 999	124 891	38 602	44 958	52 630	61 942	158 121	166 168	175 629	186 833
Vukovar-Syrmia	Vinkovci	116 653	118 303	120 049	121 896	37 676	43 880	51 368	60 457	154 329	162 183	171 418	182 353
Vukovar-Syrmia	Vukovar	92 122	93 425	94 804	96 263	29 753	34 652	40 566	47 743	121 875	128 077	135 370	144 006
Zagreb	Vrbovec	11 603	11 767	11 941	12 124	3 747	4 365	5 109	6 013	15 350	16 131	17 050	18 138
Šibenik-Knin	Šibenik	164 887	167 219	169 688	172 298	53 254	62 024	72 608	85 455	218 141	229 243	242 296	257 753
Osijek-Baranja	Đakovo	103 064	104 522	106 065	107 697	33 287	38 768	45 385	53 414	136 351	143 291	151 449	161 111
Zagreb	Brdovec	8 841	8 966	9 098	9 238	2 855	3 325	3 893	4 582	11 696	12 291	12 991	13 820
Koprivnica-Križevci	Križevci	70 491	71 488	72 543	73 659	22 767	26 516	31 041	36 533	93 257	98 003	103 584	110 192
Varaždin	Ivanec	20 775	21 068	21 379	21 708	6 710	7 815	9 148	10 767	27 484	28 883	30 527	32 475

Table 53: Consumption potential for determining high-efficiency cogeneration share until 2030

County	City/municipality	Households – space heating, GJ	Industry – indirect, heating, GJ	Services – heating, GJ	Heating 2030 total, GJ	Equiv. installed power in 2030, MW _t	Share of consumers with high-efficiency DHS, %	Equiv. installed power of high-eff. cogen., MW _t	Equiv. heat transmitted from high-eff. cogen., MWh
City of Zagreb	Zagreb	8 580 576	2 638 423	3 421 440	14 640 440	2 540	60	1 524	2 440 073
Osijek-Baranja	Osijek	1 184 754	1 010 453	422 692	2 617 899	454	80	363	581 755
Osijek-Baranja	Belišće	107 299	1 029 174	10 622	1 147 094	199	80	159	254 910
Primorje-Gorski Kotar	Rijeka	900 930	91 638	649 695	1 642 262	342	30	103	136 855
Virovitica-Podravina	Virovitica	219 949	716 975	82 183	1 019 107	174	50	87	141 543
Varaždin	Varaždin	491 440	338 066	294 171	1 123 677	190	30	57	93 640
Karlovac	Karlovac	603 394	143 798	224 843	972 036	167	60	100	162 006
Slavonski Brod-Posavina	Slavonski Brod	558 765	138 385	182 533	879 683	153	30	46	73 307
Koprivnica-Križevci	Koprivnica	304 657	315 615	106 959	727 231	125	40	50	80 803
Vukovar-Syrmia	Županja	107 962	506 016	10 526	624 503	111	60	67	104 084
Zagreb	Velika Gorica	585 083	0	210 464	795 547	140	65	91	143 640
Osijek-Baranja	Đurđenovac	68 765	477 692	6 653	553 111	96	70	67	107 549
Bjelovar-Bilogora	Bjelovar	386 607	155 847	158 259	700 713	122	30	37	58 393
Sisak-Moslavina	Sisak	499 197	19 080	143 147	661 424	118	35	41	64 305
Požega-Slavonia	Požega	257 207	155 795	92 864	505 865	88	30	26	42 155
Zagreb	Zaprešić	241 538	131 992	83 706	457 236	80	40	32	50 804
Sisak-Moslavina	Petrinja	234 273	139 036	73 599	446 908	80	35	28	43 449
Zagreb	Samobor	342 501	0	124 891	467 392	82	30	25	38 949
TOTAL:		15 674 896	8 007 985	6 299 247	29 982 128	5 262	–	2 903	4 618 222

14.2. RESULTS OF CALCULATION OF PREFERENTIAL ELECTRICITY PRODUCER STATUS

Table 54: Calculation of high-efficiency cogeneration criteria status – EL-TO Zagreb

Methodology for grant of preferential electricity producer status			$Q_{f, \text{fuel 1}}$	$Q_{f, \text{fuel 2}}$	E_i	E_L	Q_{cogen}	H_b	H_p	H_g	η_u	TEST Cogeneration?	η_e	η_t	$\eta_{R,e}$	$\eta_{ref,e}$	$\eta_{ref,t}$	PES	TEST: HEC?
			MJ	MJ	MWh _e	MWh _e	MJ	MJ	MJ	MJ	%		%	%	%	%	%	%	
			Annual cogeneration plant fuel consumption (type 1)	Annual cogeneration plant fuel consumption (type 2)	Total annual electricity delivered, measured at the point of cogen. plant connection to the grid	Electricity consumed on site	Useful heat produced in cogeneration process at cogen. plant	Heat produced outside cogeneration process at cogen. plant = peak heat production	Heat recovery = total heat recovery from recovered condensate	Heat losses due to cogeneration, through techn. justified losses	Total cogen. plant efficiency	Test of compliance with cogeneration criteria	Average annual efficiency of cogen. plant electricity generation	Average annual efficiency of cogen. plant heat generation	Uncorrected elect. efficiency value of reference power plant	Electr. efficiency of the reference power plant	Heat efficiency of the reference boiler room	PRIMARY ENERGY SAVINGS	Test of compliance with high-efficiency cogeneration criteria
EL-TO ZAGREB	Block A	2012	158 427 253	103 545 747	6 901	859.46	195 326 403	0	0	0	85.224	YES	10.664	74.560	45.929	45.384	89.605	6.285	NO
		2013	106 497 469	2 618 552	-1 211	725.88	82 110 599	0	0	0	73.651	NO	0.000	75.251	49.753	0.000	89.976	0.000	NO
		2014	166 486 101	26 373 596	2 400	1 411.79	146 544 779	0	0	0	83.100	YES	7.115	75.985	48.591	47.737	89.863	-0.541	NO
	Block B	2012	1 068 770 897	325 095 608	59 970	3 369.24	1 094 789 207	0	0	0	94.902	YES	16.359	78.543	47.598	47.079	89.767	18.197	YES
		2013	1 216 922 059	219 034 606	55 249	2 091.84	1 035 828 597	0	0	0	86.511	YES	14.376	72.135	48.429	47.992	89.847	9.289	NO
		2014	1 135 303 502	146 068 860	50 023	9 523.33	866 727 667	0	0	0	84.370	YES	16.729	67.641	48.826	48.173	89.886	9.074	NO
	Block H	2012	1 750 813 280	0	123 538	3 123.14	741 497 587	0	0	0	68.396	YES	23.293	42.352	50.000	49.471	90.000	-6.223	NO
		2013	1 807 438 111	0	131 181	2 239.68	817 924 121	0	0	0	71.828	YES	24.889	45.253	50.000	49.558	90.000	0.501	NO
		2014	1 406 067 951	0	105 360	9 587.38	674 553 024	0	0	0	77.405	YES	29.430	47.974	50.000	49.403	90.000	11.408	YES
	Block J	2012	2 188 744 258	0	155 316	3 751.66	918 913 187	0	0	0	68.147	YES	23.091	41.984	50.000	49.473	90.000	-7.155	NO
		2013	2 073 166 818	0	151 863	2 489.23	934 891 714	0	0	0	71.898	YES	24.802	45.095	50.000	49.559	90.000	0.151	NO
		2014	1 352 023 059	0	102 007	9 181.18	641 974 930	0	0	0	77.088	YES	29.606	47.483	50.000	49.403	90.000	11.257	YES

Table 55: Calculation of high-efficiency cogeneration criteria status – TE-TO Zagreb and TE-TO Osijek

Methodology for grant of preferential electricity producer status			$Q_{f, \text{fuel 1}}$	$Q_{f, \text{fuel 2}}$	E_i	E_L	Q_{cogen}	H_b	H_p	H_g	η_u	TEST Cogeneration ?	η_e	η_t	$\eta_{R,e}$	$\eta_{ref,e}$	$\eta_{ref,t}$	PES	TEST: HEC?
			MJ	MJ	MWh _e	MWh _e	MJ	MJ	MJ	MJ	%		%	%	%	%	%	%	
			Annual cogeneration plant fuel consumption (type 1)	Annual cogeneration plant fuel consumption (type 2)	Total annual electricity delivered, measured at the point of cogen. plant connection to the grid	Electricity consumed on site	Useful heat produced in cogeneration process at cogen. plant	Heat produced outside cogeneration process at cogen. plant = peak heat production	Heat recovery = total heat recovery from recovered condensate	Heat losses due to cogeneration, through techn. justified losses	Total cogen. plant efficiency	Test of compliance with cogeneration criteria	Average annual efficiency of cogen. plant electricity generation	Average annual efficiency of cogen. plant heat generation	Uncorrected elect. efficiency value of reference power plant	Electr. efficiency of the reference power plant	Heat efficiency of the reference boiler room	PRIMARY ENERGY SAVINGS	Test of compliance with high-efficiency cogeneration criteria
TE-TO ZAGREB	Block C	2012	462 324 794	1 236 109 800	110 669	39 119.43	718 269 873	0	0	0	74.039	YES	19.031	42.290	42.504	41.889	89.272	-7.755	NO
		2013	1 579 725 397	513 555 000	129 610	39 119.43	956 680 450	0	0	0	74.720	YES	20.566	45.702	47.473	46.864	89.755	-5.481	NO
		2014	3 188 858 005	349 900 800	216 641	39 119.43	1 642 522 000	0	0	0	72.434	YES	20.887	46.415	48.982	48.333	89.901	-5.436	NO
	Block K	2012	10 290 894 801	0	1 254 709	10 920.23	1 780 005 500	0	0	0	61.572	YES	16.432	17.297	51.700	51.162	90.000	-94.793	NO
		2013	7 046 943 797	0	831 879	10 920.23	1 455 198 500	0	0	0	63.705	YES	19.618	20.650	51.700	51.236	90.000	-63.310	NO
		2014	969 877 965	0	83 874	10 920.23	374 277 630	0	0	0	73.776	YES	35.186	38.590	51.700	51.041	90.000	10.566	YES
	Block L	2012	4 700 498 755	0	570 494	10 182.72	896 132 019	0	0	0	63.537	YES	18.111	19.065	52.500	51.940	90.000	-78.404	NO
		2013	3 494 112 275	0	401 650	10 182.72	841 058 760	0	0	0	66.502	YES	22.867	24.071	52.500	52.011	90.000	-41.421	NO
		2014	914 740 891	0	89 306	10 182.72	309 052 450	0	0	0	72.940	YES	32.097	33.786	52.500	51.841	90.000	-0.550	NO
TE-TO OSIJEK	Block 45 MW	2012	1 482 477 550	101 415 756	81 046	15 827.41	832 915 922	0	0	0	74.605	YES	22.018	52.587	49.340	48.704	89.936	3.549	NO
		2013	1 406 980 108	112 896 993	75 787	14 754.62	843 920 541	0	0	0	76.971	YES	21.446	55.526	49.235	48.621	89.926	5.531	NO
		2014	1 182 023 929	261 073 647	72 601	15 425.92	726 008 266	0	0	0	72.269	YES	21.959	50.309	48.137	47.462	89.819	2.228	NO
		2015	950 330 570	75 306 835	53 147	9 259.27	513 859 624	0	0	0	72.006	YES	21.905	50.101	49.244	48.615	89.927	0.765	NO
	Blok PTA 1	2012	409 104 838	0	29 324	1 146.80	124 195 636	0	0	0	57.172	YES	16.697	30.358	50.000	49.478	90.000	-48.199	NO
		2013	374 659 250	0	27 008	1 121.28	106 128 155	0	0	0	55.355	YES	15.580	28.327	50.000	49.496	90.000	-58.854	NO
		2014	251 190 456	0	17 747	809.91	72 131 279	0	0	0	55.312	YES	15.794	28.716	50.000	49.423	90.000	-56.586	NO
		2015	0	0	0	195.70	0	0	0	0	0.000	NO	0.000	0.000	0.000	0.000	0.000	0.000	NO
	Blok PTA 2	2012	0	0	0	179.97	0	0	0	0	0.000	NO	0.000	0.000	0.000	0.000	0.000	0.000	NO
		2013	59 705 767	0	4 304	421.24	16 912 602	0	0	0	56.818	YES	15.580	28.327	50.000	49.446	90.000	-58.775	NO
		2014	191 555 364	0	13 534	676.73	55 006 601	0	0	0	55.423	YES	15.794	28.716	50.000	49.419	90.000	-56.580	NO

Table 56: Calculation of high-efficiency cogeneration criteria status – TE Sisak

Methodology for grant of preferential electricity producer status			$Q_{f, \text{fuel 1}}$	$Q_{f, \text{fuel 2}}$	E_i	E_L	Q_{cogen}	H_b	H_p	H_g	η_u	TEST Cogeneration?	η_e	η_t	$\eta_{R,e}$	$\eta_{\text{ref},e}$	$\eta_{\text{ref},t}$	PES	TEST: HEC?
			MJ	MJ	MWh _e	MWh _e	MJ	MJ	MJ	MJ	%		%	%	%	%	%	%	
			Annual cogeneration plant fuel consumption (type 1)	Annual cogeneration plant fuel consumption (type 2)	Total annual electricity delivered, measured at the point of cogen. plant connection to the grid	Electricity consumed on site	Useful heat produced in cogeneration process at cogen. plant	Heat produced outside cogeneration process at cogen. plant = peak heat production	Heat recovery = total heat recovery from recovered condensate	Heat losses due to cogeneration, through techn. justified losses	Total cogen. plant efficiency	Test of compliance with cogeneration criteria	Average annual efficiency of cogen. plant electricity generation	Average annual efficiency of cogen. plant heat generation	Uncorrected elect. efficiency value of reference power plant	Electr. efficiency of the reference power plant	Heat efficiency of the reference boiler room	PRIMARY ENERGY SAVINGS	Test of compliance with high-efficiency cogeneration criteria
TE SISAK	Block A	2012	197 394 071	777 124 600	89 113	7 634.63	0	0	0	0	35.740	NO	0.000	0.000	41.786	41.359	89.203	0.000	NO
		2013	37 809 970	264 390 600	23 635	7 634.63	0	0	0	0	37.250	NO	0.000	0.000	40.989	40.487	89.125	0.000	NO
		2014	0	0	0	0.00	0	0	0	0	0.000	NO	0.000	0.000	0.000	0.000	0.000	0.000	NO
	Block B	2012	0	0	0	0.00	0	0	0	0	0.000	NO	0.000	0.000	0.000	0.000	0.000	0.000	NO
		2013	0	0	0	0.00	0	0	0	0	0.000	NO	0.000	0.000	0.000	0.000	0.000	0.000	NO
		2014	0	0	0	0.00	0	0	0	0	0.000	NO	0.000	0.000	0.000	0.000	0.000	0.000	NO
	Block H	2012	0	0	0	0.00	0	0	0	0	0.000	NO	0.000	0.000	0.000	0.000	0.000	0.000	NO
		2013	0	0	0	0.00	0	0	0	0	0.000	NO	0.000	0.000	0.000	0.000	0.000	0.000	NO
		2014	0	0	0	0.00	0	0	0	0	0.000	NO	0.000	0.000	0.000	0.000	0.000	0.000	NO

Table 57: Calculation of high-efficiency cogeneration criteria status – Industrial power plant

Methodology for grant of preferential electricity producer status		$Q_{f, \text{fuel 1}}$	$Q_{f, \text{fuel 2}}$	E_i	E_L	Q_{cogen}	H_b	H_p	H_g	η_u	TEST Cogeneration?	η_e	η_t	$\eta_{R,e}$	$\eta_{ref,e}$	$\eta_{ref,t}$	PES	TEST: HEC?
		MJ	MJ	MWh _e	MWh _e	MJ	MJ	MJ	MJ	%		%	%	%	%	%	%	
		Annual cogeneration plant fuel consumption (type 1)	Annual cogeneration plant fuel consumption (type 2)	Total annual electricity delivered, measured at the point of cogen. plant connection to the grid	Electricity consumed on site	Useful heat produced in cogeneration process at cogen. plant	Heat produced outside cogeneration process at cogen. plant = peak heat production	Heat recovery = total heat recovery from recovered condensate	Heat losses due to cogeneration, through techn. justified losses	Total cogen. plant efficiency	Test of compliance with cogeneration criteria	Average annual efficiency of cogen. plant electricity generation	Average annual efficiency of cogen. plant heat generation	Uncorrected elect. efficiency value of reference power plant	Electr. efficiency of the reference power plant	Heat efficiency of the reference boiler room	PRIMARY ENERGY SAVINGS	Test of compliance with high-efficiency cogeneration criteria
Belišće d.d. Belišće	2012	595 477 404	1 202 327 086	48 762	13 072.99	1 108 051 312	23 617 758	59 966 114	0	75.329	YES	12.382	59.612	50.000	48.723	90.000	-9.113	NO
	2013	575 533 032	457 525 995	16 353	7 396.22	542 980 711	190 753 919	53 004 002	0	79.302	YES	8.276	65.895	50.000	48.843	90.000	-10.913	NO
	2014	549 382 826	428 195 427	12 663	6 188.99	441 459 095	352 957 834	75 673 940	0	88.206	YES	6.943	73.523	50.000	48.792	90.000	-4.253	NO
Petrokemija Kutina d.d.	2012	4 477 816 009	0	69 593	1 980.00	3 355 572 640	0	131 709 060	0	80.692	YES	5.754	71.996	50.000	48.538	90.000	-8.872	NO
	2013	4 725 490 538	0	93 422	3 180.00	3 667 445 360	0	149 749 110	0	84.969	YES	7.359	74.441	50.000	48.592	90.000	-2.190	NO
	2014	4 535 906 142	0	80 198	5 431.00	3 726 845 060	0	155 568 840	0	88.959	YES	6.796	78.733	50.000	48.526	90.000	1.465	NO
INA Rijeka Oil Refinery	2012	3 539 038 695	1 150 894 945	102 244	19 932.36	2 905 181 171	0	1 031 596 284	0	71.323	YES	9.378	39.949	42.228	39.180	89.245	-45.561	NO
	2013	2 644 545 944	1 161 431 893	77 709	18 935.13	1 966 940 353	519 223 086	735 650 333	0	74.464	YES	9.141	45.994	42.843	39.816	89.305	-34.299	NO
	2014	2 484 729 826	1 025 578 844	89 962	19 035.51	2 279 629 220	403 023 040	916 880 876	0	87.600	YES	11.178	50.302	42.709	39.609	89.292	-18.264	NO

14.3. INFORMATION ON THE CURRENT ENERGY INFRASTRUCTURE CONDITION

14.3.1. Samobor

Table 58: Heating system data for the city of Samobor

Production unit data	Unit	DHS	CHS	SHS		SUM
Production unit's name (address)		Slavonska 6	Matoševa 1a	Ljudevita Gaja 6	Basaričekova 9	
Total installed boiler room power	kW	11 800	4 800	930	1 220	18 750
Natural gas consumption	m ³	1 038 871	367 274	0	0	1 406 145
Extra light fuel oil consumption	l	0	0	41 486	79 501	120 987
Total fuel energy input	kWh	10 018 114	3 538 816	388 145	743 814	14 688 889
Transmitted heating energy data						
Thermal energy generated	kWh	8 014 491	2 654 112	148 000	334 100	11 150 703
Distribution network/external installation length	m	2 134	950	0	0	3 084
Number of heating substations – TOTAL	pcs	20	8	1	1	30
Number of heating substations with DHW (of total)	pcs	18	6	0	1	25
Number of final customers						
Households	–	1 019	219	56	58	1 352
Industry and commercial consumers (hot/warm water)	–	14	8	1	2	25
Industry and commercial consumers (steam)	–	0	0	0	0	0
Total heated area						
Households	m ²	47 540.51	12 233.06	3 715.52	3 281.80	66 770.89
Industry and commercial consumers (hot/warm water)	m ²	2 014.63	722.63	47.12	281.21	3 065.59
Industry and commercial consumers (steam)	m ²	0.00	0.00	0.00	0.00	0.00
Installed/leased power		6 871	2 654	466	542	10 534
Households	kW	6 586	1 402	455	504	8 947
Industry and commercial consumers (hot/warm water)	kW	285	1 252	11	38	1 586
Industry and commercial consumers (steam)	kW	0	0	0	0	0
Thermal energy delivered		7 175 000	2 345 000	148 000	334 100	10 002 100
Households – heating and DHW	kWh	6 936 808	1 520 736	145 433	318 000	8 920 977
Industry and commercial consumers – heating and DHW	kWh	238 192	824 264	2 567	16 100	1 081 123

Production unit data	Unit	DHS	CHS	SHS		SUM
Industry and commercial consumers (steam)	kWh	0	0	0	0	0
Calculated efficiency						
Boiler room efficiency	–	0.800	0.750	0.381	0.449	0.759
Distribution efficiency	–	0.895	0.884	1.000	1.000	0.897
Heating system efficiency	–	0.716	0.663	0.381	0.449	0.681
Boiler room availability						
Available boiler room capacity	kW	4 929	2 146	464	678	8 216
Available boiler room capacity	%	41.8	44.7	49.9	55.6	43.8

14.3.2. Zaprešić

Table 59: Heating system data for the city of Zaprešić

Production unit data	Unit	CHS				SHS				SUM
Production unit's name (address)		A. Mihanovića 28	Mokrička 61	Trg mladosti 6	Trg mladosti 10	Drage Kodrmana 13	Franje Krajačića 1	Trg žrtava fašizma 6	Pavla Lončara 6	
Total installed boiler room power	kW	4 530	4 400	3 300	2 400	1 200	1 700	1 500	1 330	20 360
Natural gas consumption	m³	478 084	631 802	317 554	318 690	0	94 069	0	0	1 840 199
Extra light fuel oil consumption	l	0	0	0	0	76 721	0	79 165	56 704	212 590
Total fuel energy input	kWh	4 607 637	6 092 923	3 061 388	3 073 425	717 805	905 909	740 671	530 525	19 730 282
Transmitted heating energy data										
Thermal energy generated	kWh	3 686 110	4 874 338	2 449 110	2 458 740	634 000	683 000	428 000	395 000	15 608 298
Distribution network/external installation length	m	450	915	220	75	0	0	0	0	1 660
Number of heating substations – TOTAL	pcs	9	14	6	3	1	1	1	1	36
Number of heating substations with DHW (of total)	pcs	5	14	4	3	0	0	0	1	27
Number of final customers										
Households	–	526	626	295	347	149	137	121	79	2 280
Industry and commercial consumers (hot/warm water)	–	5	7	15	39	0	19	4	0	89
Industry and commercial consumers (steam)	–	0	0	0	0	0	0	0	0	0

Production unit data	Unit	CHS				SHS				SUM
Total heated area										
Households	m²	25 348.88	25 355.75	16 768.63	15 490.94	6 113.16	6 033.29	4 993.31	2 595.10	102 699.06
Industry and commercial consumers (hot/warm water)	m²	323.29	254.19	1 602.75	1 451.86	0.00	1 186.97	1 150.89	0.00	5 969.95
Industry and commercial consumers (steam)	m²	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installed/leased power		4 004	3 259	2 527	1 824	1 084	943	806	400	14 846
Households	kW	3 958	3 231	2 303	1 625	1 084	943	806	400	14 350
Industry and commercial consumers (hot/warm water)	kW	46	27	224	199	0	0	0	0	496
Industry and commercial consumers (steam)	kW	0	0	0	0	0	0	0	0	0
Thermal energy delivered		3 520 000	4 039 000	2 193 220	2 363 000	634 000	683 000	428 000	395 000	14 255 220
Households – heating and DHW	kWh	3 487 400	3 995 246	2 140 750	2 185 157	634 000	537 000	313 000	395 000	13 687 553
Industry and commercial consumers – heating and DHW	kWh	32 600	43 754	52 470	177 843	0	146 000	115 000	0	567 667
Industry and commercial consumers (steam)	kWh	0	0	0	0	0	0	0	0	0
Calculated efficiency										
Boiler room efficiency	–	0.800	0.800	0.800	0.800	0.883	0.754	0.578	0.745	0.791
Distribution efficiency	–	0.955	0.829	0.896	0.961	1.000	1.000	1.000	1.000	0.913
Heating system efficiency	–	0.764	0.663	0.716	0.769	0.883	0.754	0.578	0.745	0.723
Boiler room availability										
Available boiler room capacity	kW	526	1 141	773	576	116	757	694	930	5 514
Available boiler room capacity	%	11.6	25.9	23.4	24.0	9.7	44.5	46.3	69.9	27.1

14.3.3. Velika Gorica

Table 60: Heating system data for the city of Velika Gorica (1/2)

Production unit data	Unit	DHS				CHS			
Production unit's name (address)		Cvjetno naselje 18	Vladimira Vidriča 1	Magdalenićeva 3	Kr. D. Zvonimira 9	Dr J. Dobrile 40a	Dr J. Dobrile 8	E. Laszowskog 35	Trg K. Tomislava 34
Total installed boiler room power	kW	5 232	19 779	18 498	8 326	4 359	2 727	1 200	2 268
Natural gas consumption	m ³	0	5 388 113	0	0	0	0	0	0
Extra light fuel oil consumption	l	26 999	0	101 951	0	670 983	218 499	65 411	190 349
Light fuel oil consumption	l	0	0	29 850	0	0	0	0	0

Production unit data	Unit	DHS				CHS			
Total fuel energy input	kWh	252 604	51 671 269	1 233 135	0	6 277 742	2 044 285	611 988	1 780 912
Transmitted heating energy data									
Thermal energy generated	kWh	189 453	42 370 441	965 343	0	4 708 306	1 533 214	458 991	1 335 684
Distribution network/external installation length	m	470	3 973	3 110	405	1 260	50	150	50
Number of heating substations – TOTAL	pcs	11	26	37	12	11	2	6	2
Number of heating substations with DHW (of total)	pcs	11	26	21	12	6	2	5	2
Number of final customers									
Households	–	312	1 741	1 872	416	461	173	40	59
Industry and commercial consumers (hot/warm water)	–	11	50	89	15	36	9	0	9
Industry and commercial consumers (steam)	–	0	0	0	0	0	0	0	0
Total heated area									
Households	m ²	16,742.52	89 008.97	87 430.42	23 994.42	21 919.20	8 113.78	2 975.03	3 102.37
Industry and commercial consumers (hot/warm water)	m ²	975.86	3 793.52	11 309.22	481.09	1 164.14	391.30	0.00	4 851.01
Industry and commercial consumers (steam)	m ²	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installed/leased power		2 243	13 558	15 594	4 458	2 544	1 526	389	1 192
Households	kW	2 080	12 309	12 010	3 339	2 338	1 483	389	432
Industry and commercial consumers (hot/warm water)	kW	162	1 249	3 584	1 119	1 164	391	0	4 851
Industry and commercial consumers (steam)	kW	0	0	0	0	0	0	0	0
Thermal energy delivered		2 520 262	15 717 958	15 544 812	5 262 000	3 508 768	1 259 244	408 108	1 104 000
Households – heating and DHW	kWh	2 421 292	14 705 581	12 797 841	3 842 752	3 288 182	1 210 481	408 108	554 435
Industry and commercial consumers – heating and DHW	kWh	98 970	1 012 377	2 746 971	1 419 248	220 586	48 763	0	549 565
Industry and commercial consumers (steam)	kWh	0	0	0	0	0			
Calculated efficiency									
Boiler room efficiency	–	0.750	0.820	0.783	/	0.750	0.750	0.750	0.750
Distribution efficiency	–	13.303	0.371	16.103	/	0.745	0.821	0.889	0.827
Heating system efficiency	–	9.977	0.304	12.606	/	0.559	0.616	0.667	0.620
Boiler room availability									
Available boiler room capacity	kW	2 989	6 221	2 904	3 868	1 815	1 201	811	1 076
Available boiler room capacity	%	57.1	31.5	15.7	46.5	41.6	44.1	67.5	47.4

Table 61: Heating system data for the city of Velika Gorica (2/2)

Production unit data	Unit	CHS		SHS				SUM
Production unit's name (address)		D. Domjanića 3	Šibenska	Zagrebačka c. 12	Zagrebačka c. 19	Zagrebačka c. 71	Zagrebačka c. 126	
Total installed boiler room power	kW	2 200	1 628	100	295	1 000	2 000	69 612
Natural gas consumption	m ³	0	187 136	0	0	0	0	5 575 249
Extra light fuel oil consumption	l	313 208	0	7 981	19 426	52 712	199 437	1 866 956
Light fuel oil consumption	l	0	0	0	0	0	0	29 850
Total fuel energy input	kWh	2 930 386	1 793 574	74 671	181 750	493 175	1 865 940	71 211 431
Transmitted heating energy data								
Thermal energy generated	kWh	2 197 789	1 434 859	66 045	144 645	362 000	1 171 000	56 937 771
Distribution network/external installation length	m	120	233	0	0	0	0	9 821
Number of heating substations – TOTAL	pcs	3	6	1	1	1	1	120
Number of heating substations with DHW (of total)	pcs	3	6	0	0	1	1	96
Number of final customers								
Households	–	212	144	12	26	39	145	5 652
Industry and commercial consumers (hot/warm water)	–	6	0	2	4	6	4	241
Industry and commercial consumers (steam)	–	0	0	0	0	0	0	0
Total heated area								
Households	m ²	10 714.21	7 343.63	560.43	1 247.70	2 493.55	6 381.93	282 028.16
Industry and commercial consumers (hot/warm water)	m ²	472.00	0.00	99.28	305.50	465.15	270.09	24 578.16
Industry and commercial consumers (steam)	m ²	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installed/leased power		1 738	1 366	108	261	372	927	46 276
Households	kW	1 673	1 366	94	219	308	889	38 931
Industry and commercial consumers (hot/warm water)	kW	472	0	14	42	64	38	13 150
Industry and commercial consumers (steam)	kW	0	0	0	0	0	0	0
Thermal energy delivered		2 028 000	1 200 520	66 045	144 645	362 000	1 171 000	50 297 362
Households – heating and DHW	kWh	1 946 786	1 200 520	53 000	109 875	310 000	1 131 652	43 980 505
Industry and commercial consumers – heating and DHW	kWh	81 214	0	13 045	34 770	52 000	39 348	6 316 857
Industry and commercial consumers (steam)	kWh			0	0	0	0	0

Production unit data	Unit	CHS		SHS				SUM
Calculated efficiency								
Boiler room efficiency	–	0.750	0.800	0.884	0.796	0.734	0.628	0.800
Distribution efficiency	–	0.923	0.837	1.000	1.000	1.000	1.000	0.883
Heating system efficiency	–	0.692	0.669	0.884	0.796	0.734	0.628	0.706
Boiler room availability								
Available boiler room capacity	kW	462	262	/	34	628	1 073	23 336
Available boiler room capacity	%	21.0	16.1	/	11.5	62.8	53.6	33.5

14.3.4. Sisak

Table 62: Heating system data for the city of Sisak

Production unit data	Unit	DHS		SUM
Production unit's name (address)		TE SISAK Čret b.b. Caprag	Energana Sisak	
Total installed boiler room power	kW	0	124 950	124 950
Natural gas consumption	m³	11 107 092	72 155	11 179 247
Extra light fuel oil consumption	l	0	0	0
Light fuel oil consumption	l	0	0	0
Total fuel energy input	kWh	106 148 401	693 285	106 841 686
Transmitted heating energy data				
Thermal energy generated	kWh	105 466 486	307 000	105 773 486
Distribution network/external installation length	m	26 600		26 600
Number of heating substations – TOTAL	pcs	165		165
Number of heating substations with DHW (of total)	pcs	142		142
Number of final customers				
Households	–	4 053		4 053
Industry and commercial consumers (hot/warm water)	–	86		86
Industry and commercial consumers (steam)	–	0		0

Production unit data	Unit	DHS		SUM
Total heated area				
Households	m²	229 158.89		229 158.89
Industry and commercial consumers (hot/warm water)	m²	3 800.23		3 800.23
Industry and commercial consumers (steam)	m²	0.00		0.00
Installed/leased power		39 820		39 820
Households	kW	31 128		31 128
Industry and commercial consumers (hot/warm water)	kW	8 692		8 692
Industry and commercial consumers (steam)	kW	0		0
Thermal energy delivered		51 408 199	170 387	51 578 586
Households – heating and DHW	kWh	43 637 732	142 341	43 780 073
Industry and commercial consumers – heating and DHW	kWh	7 770 467	28 046	7 798 513
Industry and commercial consumers (steam)	kWh	0	0	0
Calculated efficiency				
Boiler room efficiency	–	0.994	0.443	0.990
Distribution efficiency	–	0.487	0.555	0.488
Heating system efficiency	–	0.484	0.246	0.483
Boiler room availability				
Available boiler room capacity	kW	/	/	85 130
Available boiler room capacity	%	/	/	68.1

14.3.5. Karlovac

Table 63: Heating system data for the city of Karlovac

Production unit data	Unit	DHS	CHS	SUM
Production unit's name (address)		Tina Ujevića 7	Baščinska cesta 41	
Total installed boiler room power	kW	116 000	1 628	117 628
Natural gas consumption	m ³	6 530 284	87 946	6 618 230
Extra light fuel oil consumption	l	0	0	0
Light fuel oil consumption	l	0	0	0

Production unit data	Unit	DHS	CHS	SUM
Total fuel energy input	kWh	61 254 064	824 934	62 078 998
Transmitted heating energy data				
Thermal energy generated	kWh	55 128 658	742 440	55 871 098
Distribution network/external installation length	m	42 000	400	42 400
Number of heating substations – TOTAL	pcs	177	8	185
Number of heating substations with DHW (of total)	pcs	0	0	0
Number of final customers				
Households	–	7 557	128	7 685
Industry and commercial consumers (hot/warm water)	–	319	0	319
Industry and commercial consumers (steam)	–	0	0	0
Total heated area				
Households	m ²	400 933.89	7 483.00	408 416.89
Industry and commercial consumers (hot/warm water)	m ²	97 438.74	0.00	97 438.74
Industry and commercial consumers (steam)	m ²	0.00	0.00	0.00
Installed/leased power		65 751	998	66 749
Households	kW	51 179	998	52 176
Industry and commercial consumers (hot/warm water)	kW	14 572	0	14 572
Industry and commercial consumers (steam)	kW	0	0	0
Thermal energy delivered		49 003 251	701 194	49 704 445
Households – heating and DHW	kWh	39 202 601	701 194	39 903 795
Industry and commercial consumers – heating and DHW	kWh	9 800 650	0	9 800 650
Industry and commercial consumers (steam)	kWh	0	0	0
Calculated efficiency				
Boiler room efficiency	–	0.900	0.900	0.900
Distribution efficiency	–	0.889	0.944	0.890
Heating system efficiency	–	0.800	0.850	0.801
Boiler room availability				
Available boiler room capacity	kW	50 249	630	50 879
Available boiler room capacity	%	43.3	38.7	43.3

14.3.6. Ogulin

Table 64: Heating system data for the city of Ogulin

Production unit data	Unit	CHS		SUM
Production unit's name (address)		V. I. Marinkovića	Ljudevita Gaja	
Total installed boiler room power	kW	2 000	2 400	4 400
Natural gas consumption	m ³	0	0	0
Extra light fuel oil consumption	l	0	0	0
Light fuel oil consumption	l	0	0	0
Total fuel energy input	kWh	1 136 237	649 960	1 786 197
Transmitted heating energy data				
Thermal energy generated	kWh	1 136 237	649 960	1 786 197
Distribution network/external installation length	m	225	223	448
Number of heating substations – TOTAL	pcs	6	6	12
Number of heating substations with DHW (of total)	pcs	0	0	0
Number of final customers				
Households	–	69	32	101
Industry and commercial consumers (hot/warm water)	–	0	0	0
Industry and commercial consumers (steam)	–	0	0	0
Total heated area				
Households	m ²	3 320.58	1 817.61	5 138.19
Industry and commercial consumers (hot/warm water)	m ²	0.00	0.00	0.00
Industry and commercial consumers (steam)	m ²	0.00	0.00	0.00
Installed/leased power		525	599	1 125
Households	kW	432	240	672
Industry and commercial consumers (hot/warm water)	kW	0	0	0
Industry and commercial consumers (steam)	kW	0	0	0
Thermal energy delivered		706 260	555 810	1 262 070
Households – heating and DHW	kWh	598 739	260 120	858 859
Industry and commercial consumers – heating and DHW	kWh	107 522	295 690	403 212
Industry and commercial consumers (steam)	kWh	0		0

Production unit data	Unit	CHS		SUM
Calculated efficiency				
Boiler room efficiency	–	1.000	1.000	1.000
Distribution efficiency	–	0.622	0.855	0.707
Heating system efficiency	–	0.622	0.855	0.707
Boiler room availability				
Available boiler room capacity	kW	1 475	1 801	3 275
Available boiler room capacity	%	73.7	75.0	74.4

14.3.7. Varaždin

Table 65: Heating system data for the city of Varaždin (1/2)

Production unit data	Unit	CHS		SHS		
Production unit's name (address)		Zagrebačka 19	Trakošćanska Bb	Rudera Boškovića 18	Koprivnička 9	Miroslava Krleža 1a
Total installed boiler room power	kW	10 290	10 470	675	675	1 500
Natural gas consumption	m ³	312 100	366 746	43 800	37 688	64 661
Extra light fuel oil consumption	l	0	0	0	0	0
Light fuel oil consumption	l	0	0	0	0	0
Total fuel energy input	kWh	3 329 338	3 934 049	456 719	394 058	691 643
Transmitted heating energy data						
Thermal energy generated	kWh	0	0	0	0	0
Distribution network/external installation length	m	296	1 274	0	0	0
Number of heating substations – TOTAL	pcs	5	25	1	1	1
Number of heating substations with DHW (of total)	pcs	5	4	1	1	1
Number of final customers						
Households	-	365	502	66	72	97
Industry and commercial consumers (hot/warm water)	-	0	0	0	0	0
Industry and commercial consumers (steam)	-	0	0	0	0	0
Total heated area						
Households	m ²	20 776.77	23 968.79	3 917.10	4 202.25	5 970.70
Industry and commercial consumers (hot/warm water)	m ²	0.00	0.00	0.00	0.00	0.00

Production unit data	Unit	CHS		SHS		
Industry and commercial consumers (steam)	m ²	0.00	0.00	0.00	0.00	0.00
Installed/leased power		2 688	2 958	478	546	776
Households	kW	2 518	2 761	478	546	776
Industry and commercial consumers (hot/warm water)	kW	0	0	0	0	0
Industry and commercial consumers (steam)	kW	0	0	0	0	0
Thermal energy delivered		1 524 055	2 415 130	260 170	294 450	437 310
Households – heating and DHW	kWh	1 409 503	1 618 908	260 170	294 450	437 310
Industry and commercial consumers – heating and DHW	kWh	114 552	796 222	0	0	0
Industry and commercial consumers (steam)	kWh	0	0	0	0	0
Calculated efficiency						
Boiler room efficiency	–	/	/	/	/	/
Distribution efficiency	–	/	/	/	/	/
Heating system efficiency	–	0.458	0.614	0.570	0.747	0.632
Boiler room availability						
Available boiler room capacity	kW	7 602	7 512	197	129	724
Available boiler room capacity	%	73.9	71.8	29.2	19.1	48.3

Table 66: Heating system data for the city of Varaždin (2/2)

Production unit data	Unit	SHS				SUM
Production unit's name (address)		Ivana Meštrovića 2-4	Stjepana Vukovića 2	Stjepana Vukovića 4	Braće Radić 6	
Total installed boiler room power	kW	1 164	675	675	975	27 099
Natural gas consumption	m ³	26 849	13 684	17 554	18 448	901 530
Extra light fuel oil consumption	l	0	0	0	0	0
Light fuel oil consumption	l	0	0	0	0	0
Total fuel energy input	kWh	278 497	142 029	182 189	191 490	9 600 012
Transmitted heating energy data						
Thermal energy generated	kWh	0	0	0	0	0
Distribution network/external installation length	m	0	0	0	0	1 570
Number of heating substations – TOTAL	pcs	3	1	1	1	39

Production unit data	Unit	SHS				SUM
Number of heating substations with DHW (of total)	pcs	0	1	1	1	15
Number of final customers						
Households	–	103	66	66	64	1 401
Industry and commercial consumers (hot/warm water)	–	0	0	0	0	0
Industry and commercial consumers (steam)	–	0	0	0	0	0
Total heated area						
Households	m ²	4 426.15	3 931.60	2 021.80	3 564.05	72 779.21
Industry and commercial consumers (hot/warm water)	m ²	0.00	0.00	0.00	0.00	0.00
Industry and commercial consumers (steam)	m ²	0.00	0.00	0.00	0.00	0.00
Installed/leased power		460	511	513	466	9 397
Households	kW	460	511	513	466	9 030
Industry and commercial consumers (hot/warm water)	kW	0	0	0	0	0
Industry and commercial consumers (steam)	kW	0	0	0	0	0
Thermal energy delivered		163 240	104 180	148 370	129 820	5 476 725
Households – heating and DHW	kWh	163 240	104 180	148 370	129 820	4 565 951
Industry and commercial consumers – heating and DHW	kWh	0	0	0	0	910 774
Industry and commercial consumers (steam)	kWh	0	0	0	0	0
Calculated efficiency						
Boiler room efficiency	–	/	/	/	/	/
Distribution efficiency	–	/	/	/	/	/
Heating system efficiency	–	0.586	0.734	0.814	0.678	0.570
Boiler room availability						
Available boiler room capacity	kW	704	164	162	509	17 702
Available boiler room capacity	%	60.4	24.3	24.0	52.3	65.3

14.3.8. Rijeka

Table 67: Heating system data for the city of Rijeka (1/2)

Production unit data	Unit	DHS			CHS				
Production unit's name (address)		Gornja Vežica	Vojak	Krnjevo	Kozala	Škurinje	Podmurvice	Po-48	V-44
Total installed boiler room power	kW	18 450	14 490	10 620	9 000	9 000	4 000	9 000	3 000
Natural gas consumption	m ³	1 867 268	0	276 782	645 464	929 830	181 099	909 281	0
Extra light fuel oil consumption	l	0	0	0	0	0	0	800	0
Fuel oil consumption	l	0	1 107 480	0	0	0	0	0	113 400
Total fuel energy input	kWh	17 513 293	12 293 028	2 595 966	6 053 871	8 720 969	1 698 546	8 536 261	1 258 740
Transmitted heating energy data									
Thermal energy generated	kWh	15 761 964	11 063 725	2 336 369	5 448 484	7 848 872	1 528 691	7 682 635	1 132 866
Distribution network/external installation length	m	3 854	3 502	2 240	939	1 130	548	788	488
Number of heating substations – TOTAL	pcs	25	42	9	10	17	5	11	5
Number of heating substations with DHW (of total)	pcs	0	0	0	0	0	0	0	0
Number of final customers									
Households	–	2 594	1 113	706	648	1 002	427	1 071	196
Industry and commercial consumers (hot/warm water)	–	6	7	–	1	3	–	2	1
Industry and commercial consumers (steam)	–	–	–	–	–	–	–	–	–
Total heated area									
Households	m ²	130 820.00	61 480.00	38 830.00	41 780.00	63 594.00	23 493.00	59 625.00	9 857.00
Industry and commercial consumers (hot/warm water)	m ²	8 426.00	8 208.00	–	3 500.00	1 712.00	–	1 840.00	1 482.00
Industry and commercial consumers (steam)	m ²	–	–	–	–	–	–	–	–
Installed/leased power		18 103	9 061	5 048	5 887	8 482	3 054	7 991	1 474
Households	kW	17 008	7 994	5 048	5 432	8 260	3 054	7 752	1 282
Industry and commercial consumers (hot/warm water)	kW	1 095	1 067	–	3 500	1 712	–	1 840	1 482
Industry and commercial consumers (steam)	kW	–	–	–	–	–	–	–	–
Thermal energy delivered		12 145 681	8 655 048	1 601 510	4 155 718	6 329 102	1 058 080	6 505 990	820 614
Households – heating and DHW	kWh	11 751 113	5 613 458	1 593 324	3 857 180	6 222 298	1 054 272	6 249 710	691 571
Industry and commercial consumers – heating and DHW	kWh	394 568	3 041 590	8 186	298 538	106 804	3 808	256 280	129 043
Industry and commercial consumers (steam)	kWh	–	–	–	–	–	–	–	–

Production unit data	Unit	DHS			CHS				
Calculated efficiency									
Boiler room efficiency	–	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
Distribution efficiency	–	0.771	0.782	0.685	0.763	0.806	0.692	0.847	0.724
Heating system efficiency	–	0.694	0.704	0.617	0.686	0.726	0.623	0.762	0.652
Boiler room availability									
Available boiler room capacity	kW	347	5 429	5 572	3 113	518	946	1 009	1 526
Available boiler room capacity	%	1.9	37.5	52.5	34.6	5.8	23.6	11.2	50.9

Table 68: Heating system data for the city of Rijeka (2/2)

Production unit data	Unit	CHS			SHS				SUM
Production unit's name (address)		Zamet	Malonji	Srdoči	Neboder	Po-18	N. Tesla	I. Marinkov.	
Total installed boiler room power	kW	9 000	4 000	6 000	720	2 850	990	380	101 500
Natural gas consumption	m ³	0	250 142	378 064	0	168 688	0	29 846	5 636 464
Extra light fuel oil consumption	l	0	0	0	36 393	0	26 626	0	63 819
Fuel oil consumption	l	539 140	0	0	0	0	0	0	1 760 020
Total fuel energy input	kWh	5 984 454	2 346 107	3 545 900	365 022	1 582 142	267 059	279 929	73 041 286
Transmitted heating energy data									
Thermal energy generated	kWh	5 386 009	2 111 496	3 191 310	328 520	1 423 927	240 353	251 936	65 737 157
Distribution network/external installation length	m	1 051	343	1 658	–	–	–	–	16 541
Number of heating substations – TOTAL	pcs	9	5	26	1	1	1	1	168
Number of heating substations with DHW (of total)	pcs	0	0	0	0	0	0	0	0
Number of final customers									
Households	–	845	310	777	8	229	–	37	9 963
Industry and commercial consumers (hot/warm water)	–	–	–	–	12	–	15	–	47
Industry and commercial consumers (steam)	–	–	–	–	–	–	–	–	0
Total heated area									
Households	m ²	44 200.00	19 132.00	41 134.00	1 378.80	6 676.00	–	2 021.00	544 020.80
Industry and commercial consumers (hot/warm water)	m ²	–	–	–	2 068.20	–	4 971.00	–	32 207.20
Industry and commercial consumers (steam)	m ²	–	–	–	–	–	–	–	0.00

Production unit data	Unit	CHS			SHS				SUM
Installed/leased power		5 747	2 487	5 349	448	868	646	263	74 910
Households	kW	5 747	2 487	5 349	179	868	–	263	70 723
Industry and commercial consumers (hot/warm water)	kW	–	–	–	269	–	646	–	11 612
Industry and commercial consumers (steam)	kW	–	–	–	–	–	–	–	0
Thermal energy delivered		3 951 056	1 680 020	2 089 687	261 754	1 242 078	195 800	142 080	50 834 218
Households – heating and DHW	kWh	3 949 236	1 680 020	2 089 687	177 274	1 242 078	–	142 080	46 313 301
Industry and commercial consumers – heating and DHW	kWh	1 820	–	–	84 480	–	195 800	–	4 520 917
Industry and commercial consumers (steam)	kWh	–	–	–	–	–	–	–	0
Calculated efficiency									
Boiler room efficiency	–	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
Distribution efficiency	–	0.734	0.796	0.655	0.797	0.872	0.815	0.564	0.773
Heating system efficiency	–	0.660	0.716	0.589	0.717	0.785	0.733	0.508	0.696
Boiler room availability									
Available boiler room capacity	kW	3 253	1 513	651	272	1 982	344	117	26 590
Available boiler room capacity	%	36.1	37.8	10.8	37.8	69.5	34.7	30.8	26.2

14.3.9. Virovitica

Table 69: Heating system data for the city of Virovitica

Production unit data	Unit	CHS					SUM
Production unit's name (address)		Slavonija Mihanovićeve 1	P+5 Trq Bana J. Jelačića	P+7 Pejačevićeva 3	P+8 Rusanova 1	Obrtnik Trq A. Starčevića	
Total installed boiler room power	kW	1 200	2 200	3 000	1 200	2 200	9 800
Natural gas consumption	m ³	45 506	63 816	98 268	46 812	88 081	342 483
Extra light fuel oil consumption	l	0	0	0	0	0	0
Light fuel oil consumption	l	0	0	0	0	0	0
Total fuel energy input	kWh	441 841	619 826	954 443	454 625	855 379	3 326 114
Transmitted heating energy data							
Thermal energy generated	kWh	–	–	–	–	–	0
Distribution network/external installation length	m	30	180	200	40	450	900

Production unit data	Unit	CHS					SUM
Number of heating substations – TOTAL	pcs	2	4	4	2	7	19
Number of heating substations with DHW (of total)	pcs	0	0	0	0	0	0
Number of final customers							
Households	–	56	99	153	35	93	436
Industry and commercial consumers (hot/warm water)	–	5	7	10	18	5	45
Industry and commercial consumers (steam)	–	0	0	0	0	0	0
Total heated area							
Households	m ²	2 641.02	5 614.22	8 439.59	1 587.35	5 248.02	23 530.20
Industry and commercial consumers (hot/warm water)	m ²	1 277.20	379.83	372.42	2 541.13	1 919.26	6 489.84
Industry and commercial consumers (steam)	m ²	0.00	0.00	0.00	0.00	0.00	0.00
Installed/leased power		522	784	1 149	562	951	3 969
Households	kW	343	731	1 097	206	682	3 060
Industry and commercial consumers (hot/warm water)	kW	1 277	380	372	2 541	1 919	6 490
Industry and commercial consumers (steam)	kW	0	0	0	0	0	0
Thermal energy delivered		333 391	432 861	675 569	373 744	541 285	2 356 850
Households – heating and DHW	kWh	333 391	432 861	675 569	373 744	541 285	2 356 850
Industry and commercial consumers – heating and DHW	kWh	0	0	0	0	0	0
Industry and commercial consumers (steam)	kWh	0	0	0	0	0	0
Calculated efficiency							
Boiler room efficiency	–	/	/	/	/	/	/
Distribution efficiency	–	/	/	/	/	/	/
Heating system efficiency	–	0.755	0.698	0.708	0.822	0.633	0.709
Boiler room availability							
Available boiler room capacity	kW	678	1 416	1 851	638	1 249	5 831
Available boiler room capacity	%	56.5	64.4	61.7	53.1	56.8	59.5

14.3.10. Slavonski Brod

Table 70: Heating system data for the city of Slavonski Brod (1/3)

Production unit data	Unit	DHS	CHS		SHS				
Production unit's name (address)		Slavonija 1	Mikrorajon	Kralj Tomislav	A. Hebrang 4-S	A. Hebrang 4-J	A. Hebrang 5-S	A. Hebrang 5-J	A. Hebrang 6
Total installed boiler room power	kW	10 500	3 260	3 960	1 020	1 080	1 020	1 020	2 250
Natural gas consumption	m ³	1 822 588	349 363	290 082	123 591	110 478	135 775	131 441	353 340
Extra light fuel oil consumption	l	0	0	0	0	0	0	0	0
Light fuel oil consumption	l	0	0	0	0	0	0	0	0
Total fuel energy input	kWh	17 548 447	3 362 706	2 791 745	1 189 554	1 063 215	1 307 082	1 265 246	3 401 863
Transmitted heating energy data									
Thermal energy generated	kWh	15 404 450	2 865 100	2 416 300	1 032 420	1 031 909	1 174 709	1 116 799	2 551 940
Distribution network/external installation length	m	4 097	1 208	865	0	0	0	0	880
Number of heating substations – TOTAL	pcs	27	10	7	0	0	0	0	4
Number of heating substations with DHW (of total)	pcs	22	9	4	0	0	0	0	4
Number of final customers									
Households	–	1 058	331	315	137	126	153	138	290
Industry and commercial consumers (hot/warm water)	–	44	3	7	2	4	5	10	21
Industry and commercial consumers (steam)	–	0	0	0	0	0	0	0	0
Total heated area									
Households	m ²	54 578.10	12 024.44	14 996.85	7 025.15	6 538.09	7 833.74	7 191.83	14 503.04
Industry and commercial consumers (hot/warm water)	m ²	16 361.50	161.72	432.20	98.67	331.01	187.56	663.30	1 005.13
Industry and commercial consumers (steam)	m ²	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installed/leased power		9 757	1 650	1 987	680	733	831	872	1 702
Households	kW	7 252	1 621	1 920	657	672	802	770	1 560
Industry and commercial consumers (hot/warm water)	kW	2 505	162	432	23	61	28	102	142
Industry and commercial consumers (steam)	kW	0	0	0	0	0	0	0	0
Thermal energy delivered		12 401 301	1 716 450	1 553 410	581 250	621 230	606 040	610 310	1 368 429
Households – heating and DHW	kWh	9 775 574	1 692 973	1 505 429	564 315	574 579	591 035	544 557	1 255 430
Industry and commercial consumers – heating and DHW	kWh	2 625 726	23 477	47 981	16 934	46 651	15 005	65 752	112 999

Production unit data	Unit	DHS	CHS		SHS				
Industry and commercial consumers (steam)	kWh	0	0	0	0	0	0	0	0
Calculated efficiency									
Boiler room efficiency	–	0.878	0.852	0.866	0.868	0.971	0.899	0.883	0.750
Distribution efficiency	–	0.805	0.599	0.643	0.563	0.602	0.516	0.546	0.536
Heating system efficiency	–	0.707	0.510	0.556	0.489	0.584	0.464	0.482	0.402
Boiler room availability									
Available boiler room capacity	kW	743	1 610	1 973	340	347	189	148	548
Available boiler room capacity	%	7.1	49.4	49.8	33.3	32.1	18.6	14.5	24.4

Table 71: Heating system data for the city of Slavonski Brod (2/3)

Production unit data	Unit	SHS							
Production unit's name (address)		A. Hebrang 7-S	A. Hebrang 7-J	Jelas	Centar 2	Centar 4	Centar 6	I.B. Mažuranić	Cipelarski Trg
Total installed boiler room power	kW	1 350	1 200	1 400	780	780	780	330	520
Natural gas consumption	m ³	160 963	171 684	94 957	86 805	77 220	83 221	28 224	32 358
Extra light fuel oil consumption	l	0	0	0	0	0	0	0	0
Light fuel oil consumption	l	0	0	0	0	0	0	0	0
Total fuel energy input	kWh	1 549 676	1 652 414	912 901	835 541	743 661	801 188	271 333	311 034
Transmitted heating energy data									
Thermal energy generated	kWh	1 180 920	1 306 600	875 140	685 921	585 390	653 001	221 980	245 060
Distribution network/external installation length	m	0	0	0	0	0	0	0	0
Number of heating substations – TOTAL	pcs	0	0	0	0	0	0	0	0
Number of heating substations with DHW (of total)	pcs	0	0	0	0	0	0	0	0
Number of final customers									
Households	–	127	133	135	88	83	83	29	56
Industry and commercial consumers (hot/warm water)	–	13	3	1	5	2	3	4	7
Industry and commercial consumers (steam)	–	0	0	0	0	0	0	0	0
Total heated area									
Households	m ²	6 326.13	7 583.19	6 227.68	3 675.07	3 593.24	3 487.34	1 485.89	2 249.98
Industry and commercial consumers (hot/warm water)	m ²	451.61	311.75	211.45	167.68	84.87	179.72	450.92	588.19

Production unit data	Unit	SHS							
Industry and commercial consumers (steam)	m ²	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installed/leased power		941	1 087	879	505	471	481	253	347
Households	kW	867	1 017	842	476	460	452	184	284
Industry and commercial consumers (hot/warm water)	kW	74	70	37	29	11	29	70	63
Industry and commercial consumers (steam)	kW	0	0	0	0	0	0	0	0
Thermal energy delivered		638 660	709 980	875 140	439 410	306 280	402 490	221 980	245 060
Households – heating and DHW	kWh	595 899	682 482	842 437	417 281	296 715	382 765	168 923	196 494
Industry and commercial consumers – heating and DHW	kWh	42 761	27 498	32 703	22 130	9 565	19 726	53 057	48 566
Industry and commercial consumers (steam)	kWh	0	0	0	0	0	0	0	0
Calculated efficiency									
Boiler room efficiency	–	0.762	0.791	0.959	0.821	0.787	0.815	0.818	0.788
Distribution efficiency	–	0.541	0.543	1.000	0.641	0.523	0.616	1.000	1.000
Heating system efficiency	–	0.412	0.430	0.959	0.526	0.412	0.502	0.818	0.788
Boiler room availability									
Available boiler room capacity	kW	409	113	521	275	309	299	77	173
Available boiler room capacity	%	30.3	9.4	37.2	35.3	39.6	38.3	23.3	33.3

Table 72: Heating system data for the city of Slavonski Brod (3/3)

Production unit data	Unit	SHS					SUM
Production unit's name (address)		Zrinska	Vatrenka	Lutvinka	H. Badalića 1	H. Badalića 2	
Total installed boiler room power	kW	390	520	1 820	330	390	34 700
Natural gas consumption	m ³	20 867	63 144	139 035	24 012	18 811	4 317 959
Extra light fuel oil consumption	l	0	0	0	0	0	0
Light fuel oil consumption	l	0	0	0	0	0	0
Total fuel energy input	kWh	200 575	606 767	1 336 358	230 850	180 814	41 562 970
Transmitted heating energy data							
Thermal energy generated	kWh	168 490	486 930	1 145 000	189 310	140 030	35 477 401
Distribution network/external installation length	m	0	0	0	0	0	7 050
Number of heating substations – TOTAL	pcs	0	0	0	0	0	48

Production unit data	Unit	SHS					SUM
Number of heating substations with DHW (of total)	pcs	0	0	0	0	0	39
Number of final customers							
Households	–	34	45	191	24	38	3 614
Industry and commercial consumers (hot/warm water)	–	7	5	7	0	0	153
Industry and commercial consumers (steam)	–	0	0	0	0	0	0
Total heated area							
Households	m ²	1 434.48	2 121.36	8 786.63	1 227.68	1 520.17	174 410.08
Industry and commercial consumers (hot/warm water)	m ²	196.22	648.56	318.55	0.00	0.00	22 850.61
Industry and commercial consumers (steam)	m ²	0.00	0.00	0.00	0.00	0.00	0.00
Installed/leased power		219	406	1 198	162	204	25 365
Households	kW	185	284	1 142	162	204	21 811
Industry and commercial consumers (hot/warm water)	kW	34	122	56	0	0	4 051
Industry and commercial consumers (steam)	kW	0	0	0	0	0	0
Thermal energy delivered		168 490	486 930	1 145 000	189 310	140 030	25 427 181
Households – heating and DHW	kWh	153 435	362 935	1 100 222	189 310	140 030	22 032 820
Industry and commercial consumers – heating and DHW	kWh	15 055	123 995	44 778	0	0	3 394 361
Industry and commercial consumers (steam)	kWh	0	0	0	0	0	0
Calculated efficiency							
Boiler room efficiency	–	0.840	0.802	0.857	0.820	0.774	0.854
Distribution efficiency	–	1.000	1.000	1.000	1.000	1.000	0.717
Heating system efficiency	–	0.840	0.802	0.857	0.820	0.774	0.612
Boiler room availability							
Available boiler room capacity	kW	171	114	622	168	186	9 335
Available boiler room capacity	%	43.9	21.8	34.2	50.9	47.8	26.9

14.3.11. Osijek

Table 73: Heating system data for the city of Osijek

Production unit data	Unit	DHS			CHS	SUM
Production unit's name (address)		Te-To Osijek Martina Divalta 203	Toplana - Cara Hadrijana	Kotlovnica V. Nazor (Grijanje Iz Cts-A)	Kotlovnica Jug	
Total installed boiler room power	kW	0	160 110	3 750	3 750	167 610
Natural gas consumption	m³	25 024 128	108 299	119 506	355 685	25 607 618
Extra light fuel oil consumption	l	0	2 983	0	0	2 983
Fuel oil consumption	l	3 299 380	269 200	0	0	3 568 580
Total fuel energy input	kWh	280 363 803	4 037 230	1 107 000	3 295 000	288 803 033
Transmitted heating energy data						
Thermal energy generated	kWh	276 306 479	3 138 350	1 059 410	3 012 030	283 516 269
Distribution network/external installation length	m	54 451		588	1 161	56 200
Number of heating substations – TOTAL	pcs	680		11	10	701
Number of heating substations with DHW (of total)	pcs	0		11	10	21
Number of final customers						
Households	–	10 100		0	332	10 432
Industry and commercial consumers (hot/warm water)	–	1 254		0	5	1 259
Industry and commercial consumers (steam)	–	17		0	0	17
Total heated area						
Households	m²	585 731.46		0.00	17 056.83	602 788.29
Industry and commercial consumers (hot/warm water)	m²	514 301.31		0.00	249.14	514 550.45
Industry and commercial consumers (steam)	m²	0.00		0.00	0.00	0.00
Installed/leased power		189 619		3 543		193 162
Households	kW	85 708		3 511		89 219
Industry and commercial consumers (hot/warm water)	kW	74 408		32		74 440
Industry and commercial consumers (steam)	kW	29 503		0		29 503
Thermal energy delivered		237 116 193	2 539 520	3 474 931		243 130 644
Households – heating and DHW	kWh	89 174 061	492 074	3 437 942		93 104 077
Industry and commercial consumers – heating and DHW	kWh	65 082 925	392 063	36 989		65 511 977
Industry and commercial consumers (steam)	kWh	82 859 207	1 655 383	0		84 514 590

Production unit data	Unit	DHS			CHS	SUM
Calculated efficiency						
Boiler room efficiency	–	0.986	0.777	/	/	0.982
Distribution efficiency	–	0.858	0.809	/	/	0.858
Heating system efficiency	–	0.846	0.629	/	/	0.842
Boiler room availability						
Available boiler room capacity	kW	/	/	/	/	/
Available boiler room capacity	%	/	/	/	/	/

14.3.12. Vukovar

Table 74: Heating system data for the city of Vukovar

Production unit data	Unit	DHS		CHS			SHS		SUM
Production unit's name (address)		Dom. rata 3	Olajnica 18	Županijska 96	Dunavska 5	R. Perešina 3a	Hrv zrak. 45	Trg Slavija 1	
Total installed boiler room power	kW	22 700	15 600	2 800	2 800	1 120	570	350	45 940
Natural gas consumption	m ³	1 193 550	504 989	173 576	0	71 185	0	12 331	1 955 631
Extra light fuel oil consumption	l	0	0	0	0	0	0	0	0
Fuel oil consumption	kg	0	0	1 115	67 127	0	43 061	0	111 303
Total fuel energy input	kWh	11 491 258	4 854 863	1 683 105	782 950	685 483	502 300	118 519	20 118 478
Transmitted heating energy data									
Thermal energy generated	kWh	10 947 400	4 547 500	1 561 300	706 140	610 790	455 100	112 972	18 941 202
Distribution network/external installation length	m	2 035	4 335	315	210	320	0	0	7 215
Number of heating substations – TOTAL	pcs	54	22	8	4	3	1	1	93
Number of heating substations with DHW (of total)	pcs	47	4	5	0	3	1	0	60
Number of final customers									
Households	–	2 110	834	278	142	142	66	49	3 621
Industry and commercial consumers (hot/warm water)	–	18	29	1	2	0	0	0	50
Industry and commercial consumers (steam)	–	0	0	0	0	0	0	0	0
Total heated area									
Households	m ²	115 629.93	41 356.96	13 182.03	5 627.52	4 044.41	4 104.36	2 396.99	186 342.20

Production unit data	Unit	DHS		CHS			SHS		SUM
Industry and commercial consumers (hot/warm water)	m ²	5 243.78	11 335.64	51.20	1 346.43	0.00	0.00	0.00	17 977.05
Industry and commercial consumers (steam)	m ²	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installed/leased power		13 808	5 999	1 843	1 053	485	287	253	23 728
Households	kW	13 110	4 436	1 838	687	485	287	253	21 094
Industry and commercial consumers (hot/warm water)	kW	698	1 564	51	1 346	0	0	0	3 660
Industry and commercial consumers (steam)	kW	0	0	0	0	0	0	0	0
Thermal energy delivered		8 556 924	3 755 227	1 339 793	652 752	485 324	439 628	80 125	15 309 773
Households – heating and DHW	kWh	7 711 737	2 761 706	1 339 166	383 972	485 324	439 628	80 125	13 201 658
Industry and commercial consumers – heating and DHW	kWh	845 187	993 521	627	268 780	0	0	0	2 108 115
Industry and commercial consumers (steam)	kWh	0	0	0	0	0	0	0	0
Calculated efficiency									
Boiler room efficiency	–	0.953	0.937	0.928	0.902	0.891	0.906	0.953	0.941
Distribution efficiency	–	0.782	0.826	0.858	0.924	0.795	0.966	0.709	0.808
Heating system efficiency	–	0.745	0.773	0.796	0.834	0.708	0.875	0.676	0.761
Boiler room availability									
Available boiler room capacity	kW	8 892	9 601	957	1 747	635	283	97	22 212
Available boiler room capacity	%	39.2	61.5	34.2	62.4	56.7	49.7	27.8	48.4

14.3.13. Zagreb

Table 75: Heating system data for the City of Zagreb (1/4)

Production unit data	Unit	COGENERATION		DUBRAVA DHS	DUBRAVA CHS				
Production unit's name (address)		TE-TO Zagreb, Kuševčka 10a, Zagreb	EL-TO Zagreb, Zagorska 1, Zagreb	M.GAVAZZDA 3	ALEJA LIPA 1A	MIRKA DEANOVIĆA 15	DUBRAVA 37	M.GAVAZZIJA 21	KOLEDINEČKA 5
Total installed boiler room power	kW	0		13 296	4 530	2 908	3 000	1 080	6 279
Natural gas consumption	m ³	160 912 720		1 471 407	506 243	337 543	308 611	103 507	585 227
Extra light fuel oil consumption	l	0		0	0	0	0	0	0
Fuel oil consumption	kg	14 352 932		0	0	0	0	0	0
Total fuel energy input	kWh	1 703 718 202		14 072 679	4 848 826	3 233 286	2 956 814	989 490	5 608 522

Production unit data	Unit	COGENERATION	DUBRAVA DHS	DUBRAVA CHS				
Transmitted heating energy data								
Thermal energy generated	kWh	1 672 267 314	12 102 504	4 121 502	2 583 325	2 362 430	790 581	4 767 244
Distribution network/external installation length	m	265 560	3 260	145	80	95	85	200
Number of heating substations – TOTAL	pcs	2 672	40	2	1	4	2	3
Number of heating substations with DHW (of total)	pcs	0	0	2	1	3	0	3
Number of final customers								
Households	–	87 627	1 530	366	374	158	191	404
Industry and commercial consumers (hot/warm water)	–	4 045	35	33	0	20	0	14
Industry and commercial consumers (steam)	–	61	0	0	0	0	0	0
Total heated area								
Households	m²	4 823 048.85	71 170.47	21 345.87	12 489.86	9 052.57	5 464.28	22 631.01
Industry and commercial consumers (hot/warm water)	m²	511 846.89	7 972.15	3 007.97	0.00	4 858.14	0.00	1 570.82
Industry and commercial consumers (steam)	m²	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installed/leased power		1 127 060	11 438	3 060	1 853	1 796	1 088	3 500
Households	kW	606 962	9 655	2 622	1 853	1 109	1 088	3 278
Industry and commercial consumers (hot/warm water)	kW	402 356	1 783	3 008	0	4 858	0	1 571
Industry and commercial consumers (steam)	kW	117 741	0	0	0	0	0	0
Thermal energy delivered		1 405 891 294	10 996 333	4 064 000	2 280 000	2 203 000	747 000	4 655 000
Households – heating and DHW	kWh	836 885 642	8 877 734	3 707 000	2 280 000	1 644 647	747 000	4 459 822
Industry and commercial consumers – heating and DHW	kWh	403 879 504	2 118 599	357 000	0	558 353	0	195 178
Industry and commercial consumers (steam)	kWh	165 126 148	0	0	0	0	0	0
Calculated efficiency								
Boiler room efficiency	–	0.982	0.860	0.850	0.799	0.799	0.799	0.850
Distribution efficiency	–	0.841	0.909	0.986	0.883	0.933	0.945	0.976
Heating system efficiency	–	0.825	0.781	0.838	0.705	0.745	0.755	0.830
Boiler room availability								
Available boiler room capacity	kW	/	1 858	1 470	1 055	1 204	/	2 779
Available boiler room capacity	%	/	14.0	32.4	36.3	40.1	/	44.3

Table 76: Heating system data for the City of Zagreb (2/4)

Production unit data	Unit	DUBRAVA CHS		FERENČICA CHS				PREČKO CHS	SUSEDGRAD CHS	CENTAR CHS
Production unit's name (address)		Gjуре Prejca 5	Vile Velebita 40	Ferenčica 74a	Ivekovičeva 19	Ježevska 7a	I Ferenčica 49	Remetin. gaj 27b	Ilica 510	Heinzeloва 47a
Total installed boiler room power	kW	2 560	1 080	3 000	1 500	3 200	5 580	2 900	2 094	3 600
Natural gas consumption	m ³	373 082	100 106	317 271	216 663	503 389	512 210	0	201 916	431 455
Extra light fuel oil consumption	l	0	0	0	0	0	0	268 112	0	0
Fuel oil consumption	kg	0	0	0	0	0	0	0	0	0
Total fuel energy input	kWh	3 575 468	956 767	3 040 318	2 073 805	4 825 413	4 906 447	2 508 466	1 933 736	4 132 040
Transmitted heating energy data										
Thermal energy generated	kWh	2 856 721	764 436	2 429 148	1 762 734	3 855 400	4 170 480	2 004 210	1 545 013	3 301 410
Distribution network/external installation length	m	175	55	650	43	575	155	142	70	105
Number of heating substations – TOTAL	pcs	4	2	7	1	10	3	3	3	3
Number of heating substations with DHW (of total)	pcs	4	0	7	1	10	3	3	2	3
Number of final customers										
Households	–	247	193	251	148	405	412	135	100	292
Industry and commercial consumers (hot/warm water)	–	6	1	0	7	9	0	10	7	18
Industry and commercial consumers (steam)	–	0	0	0	0	0	0	0	0	0
Total heated area										
Households	m ²	13 047.03	5 593.41	13 346.67	7 965.07	20 521.96	23 457.79	7 473.50	5 099.48	15 730.79
Industry and commercial consumers (hot/warm water)	m ²	422.29	37.85	0.00	864.93	269.57	0.00	833.96	1 091.15	3 582.13
Industry and commercial consumers (steam)	m ²	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installed/leased power		2 119	1 108	1 929	1 345	2 990	3 171	1 734	1 023	2 754
Households	kW	2 059	1 102	1 929	1 222	2 951	3 171	1 028	739	2 247
Industry and commercial consumers (hot/warm water)	kW	422	38	0	865	270	0	834	1 091	3 582
Industry and commercial consumers (steam)	kW	0	0	0	0	0	0	0	0	0
Thermal energy delivered		2 422 000	739 000	2 096 000	1 742 000	3 487 000	4 090 000	1 828 000	1 220 679	3 223 000
Households – heating and DHW	kWh	2 376 693	735 182	2 096 000	1 596 240	3 453 321	4 090 000	1 220 600	1 030 679	2 617 694
Industry and commercial consumers – heating and DHW	kWh	45 307	3 818	0	145 760	33 679	0	607 400	190 000	605 306
Industry and commercial consumers (steam)	kWh	0	0	0	0	0	0	0	0	0

Production unit data	Unit	DUBRAVA CHS		FERENČICA CHS				PREČKO CHS	SUSEDGRAD CHS	CENTAR CHS
Calculated efficiency										
Boiler room efficiency	–	0.799	0.799	0.799	0.850	0.799	0.850	0.799	0.799	0.799
Distribution efficiency	–	0.848	0.967	0.863	0.988	0.904	0.981	0.912	0.790	0.976
Heating system efficiency	–	0.677	0.772	0.689	0.840	0.723	0.834	0.729	0.631	0.780
Boiler room availability										
Available boiler room capacity	kW	441	/	1 071	155	210	2 409	1 166	1 071	846
Available boiler room capacity	%	17.2	/	35.7	10.4	6.6	43.2	40.2	51.2	23.5

Table 77: Heating system data for the City of Zagreb (3/4)

Production unit data	Unit	DUBRAVA SHS						FERENŠČICA SHS	
Production unit's name (address)		Dubrava 218	Grižanska 21	Hrvatskog proljeća 28	Hrvatskog proljeća 32	Hrvatskog proljeća 36	Hrvatskog proljeća 40	Ivanićgradska 62	Ivanićgradska 59b
Total installed boiler room power	kW	3 141	1 200	3 688	3 688	3 688	3 200	1 500	2 094
Natural gas consumption	m ³	418 388	121 326	262 826	270 480	178 069	247 101	209 635	204 969
Extra light fuel oil consumption	l	0	0	0	0	0	0	0	0
Fuel oil consumption	kg	0	0	0	0	0	0	0	0
Total fuel energy input	kWh	4 008 697	1 163 697	2 516 663	2 588 985	1 706 017	2 365 068	2 007 903	1 963 888
Transmitted heating energy data									
Thermal energy generated	kWh	2 515 000	889 000	1 549 000	1 908 272	775 000	1 289 839	1 396 000	1 403 000
Distribution network/external installation length	m	0	0	0	0	0	0	0	0
Number of heating substations – TOTAL	pcs	1	1	1	1	1	1	1	1
Number of heating substations with DHW (of total)	pcs	1	1	1	1	1	1	1	1
Number of final customers									
Households	–	282	84	121	121	121	122	135	142
Industry and commercial consumers (hot/warm water)	–	16	3	12	1	5	16	6	1
Industry and commercial consumers (steam)	–	0	0	0	0	0	0	0	0
Total heated area									
Households	m ²	19 960.89	4 414.58	7 341.71	7 391.08	7 347.77	7 412.69	7 463.08	8 079.73
Industry and commercial consumers (hot/warm water)	m ²	1 213.60	219.00	4 949.64	7 095.44	836.08	3 506.31	626.98	337.25
Industry and commercial consumers (steam)	m ²	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Production unit data	Unit	DUBRAVA SHS						FERENŠČICA SHS	
Installed/leased power		1 903	664	1 702	2 048	1 148	1 461	1 541	1 479
Households	kW	1 731	633	1 001	1 044	1 029	965	1 452	1 432
Industry and commercial consumers (hot/warm water)	kW	172	31	700	1 004	118	496	89	48
Industry and commercial consumers (steam)	kW	0	0	0	0	0	0	0	0
Thermal energy delivered		2 515 000	889 000	1 549 000	1 908 272	775 000	1 289 839	1 396 000	1 403 000
Households – heating and DHW	kWh	2 326 910	850 776	977 472	1 243 272	693 000	897 778	1 265 000	1 375 029
Industry and commercial consumers – heating and DHW	kWh	188 090	38 224	571 528	665 000	82 000	392 061	131 000	27 971
Industry and commercial consumers (steam)	kWh	0	0	0	0	0	0	0	0
Calculated efficiency									
Boiler room efficiency	–	0.627	0.764	0.615	0.737	0.454	0.545	0.695	0.714
Distribution efficiency	–	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Heating system efficiency	–	0.627	0.764	0.615	0.737	0.454	0.545	0.695	0.714
Boiler room availability									
Available boiler room capacity	kW	1 238	536	1 986	1 640	2 540	1 739	/	615
Available boiler room capacity	%	39.4	44.7	53.9	44.5	68.9	54.3	/	29.3

Table 78: Heating system data for the City of Zagreb (4/4)

Production unit data	Unit	PREČKO SHS	SUSEDGRAD SHS	CENTAR SHS				SUM
Production unit's name (address)		Remetinečka C. 75	Crnojezerska 18	Belostenčeva 3	Trg Bana J. Jelačića 3	Vilka Šefera 10	Slavka Kolara	
Total installed boiler room power	kW	1 711	2 000	400	1 114	2 400	2 676	89 107
Natural gas consumption	m ³	0	0	34 021	0	181 686	273 235	169 283 086
Extra light fuel oil consumption	l	199 660	211 349	0	113 884	0	0	793 005
Fuel oil consumption	kg	0	0	0	0	0	0	14 352 932
Total fuel energy input	kWh	1 868 026	1 977 389	325 546	1 065 503	1 740 232	2 617 967	1 791 295 860
Transmitted heating energy data								
Thermal energy generated	kWh	1 313 000	1 568 000	266 000	873 645	1 371 000	1 968 000	1 740 769 208
Distribution network/external installation length	m	0	0	0	0	0	0	271 395
Number of heating substations – TOTAL	pcs	1	1	1	1	1	1	2 774
Number of heating substations with DHW (of total)	pcs	1	1	0	1	1	1	55

Production unit data	Unit	PREČKO SHS	SUSEDGRAD SHS	CENTAR SHS				SUM
Number of final customers								
Households	–	146	138	36	40	111	226	94 658
Industry and commercial consumers (hot/warm water)	–	45	12	1	12	11	0	4 346
Industry and commercial consumers (steam)	–	0	0	0	0	0	0	61
Total heated area								
Households	m²	7 167.47	8 156.44	1 718.18	3 964.03	8 427.57	12 459.17	5 188 743.00
Industry and commercial consumers (hot/warm water)	m²	2 046.89	1 111.29	128.65	2 873.18	889.90	0.00	562 192.06
Industry and commercial consumers (steam)	m²	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Installed/leased power		1 402	1 192	292	874	1 485	1 657	1 186 815
Households	kW	1 113	1 035	274	543	1 359	1 657	658 285
Industry and commercial consumers (hot/warm water)	kW	289	157	18	331	126	0	424 258
Industry and commercial consumers (steam)	kW	0	0	0	0	0	0	117 741
Thermal energy delivered		1 313 000	1 568 000	266 000	873 645	1 371 000	1 968 000	1 470 769 062
Households – heating and DHW	kWh	1 065 389	1 377 319	249 402	596 569	1 285 490	1 968 000	893 989 660
Industry and commercial consumers – heating and DHW	kWh	247 611	190 681	16 598	277 076	85 510	0	411 653 254
Industry and commercial consumers (steam)	kWh	0	0	0	0	0	0	165 126 148
Calculated efficiency								
Boiler room efficiency	–	0.703	0.793	0.817	0.820	0.788	0.752	0.972
Distribution efficiency	–	1.000	1.000	1.000	1.000	1.000	1.000	0.845
Heating system efficiency	–	0.703	0.793	0.817	0.820	0.788	0.752	0.821
Boiler room availability								
Available boiler room capacity	kW	309	808	108	240	915	1 019	/
Available boiler room capacity	%	18.0	40.4	27.0	21.5	38.1	38.1	/

15. LIST OF FIGURES

Figure 1:	Structure of thermal energy delivered in Croatia in 2013	17
Figure 2:	Share of fuels for thermal energy generation in the heating sector in Croatia in 2013 (excl. cogeneration units)	17
Figure 3:	Distribution of installed thermal capacity in 2014	19
Figure 4:	Total final energy consumption in the Republic of Croatia, 2013-2035	28
Figure 5:	Structure of thermal energy consumption by sector	29
Figure 6:	Structure of household sector end-use consumption by region	34
Figure 7:	Final household energy consumption by Croatian counties	35
Figure 8:	Population projections by climate zones until 2030	37
Figure 9:	Estimate of useful thermal energy for climate zone – North	39
Figure 10:	Estimate of useful thermal energy for climate zone – centre	40
Figure 11:	Estimate of useful thermal energy for climate zone – South	40
Figure 12:	Employee structure by service sub-sectors	41
Figure 13:	Structure of service sector final energy and thermal energy consumption in 2013 ..	42
Figure 14:	Projected increase in service sector energy consumption for heating and cooling purposes, 2013-2030	43
Figure 15:	Share of individual types of useful energy in industry	44
Figure 16:	Estimate of useful thermal energy in industry until 2030	46
Figure 17:	Map of household thermal energy consumption for heating (2020)	50
Figure 18:	Map of household thermal energy consumption for cooling (2020)	51
Figure 19:	Map of total household thermal energy consumption (2020)	52
Figure 20:	Map of direct thermal energy consumption in industry (2020)	53
Figure 21:	Map of indirect thermal energy consumption in industry (2020)	54
Figure 22:	Map of service sector thermal energy consumption (2020)	55
Figure 23:	Map of service sector thermal energy consumption for cooling (2020)	56
Figure 24:	Map of household thermal energy consumption for heating (2025)	57
Figure 25:	Map of household thermal energy consumption for cooling (2025)	58
Figure 26:	Map of total household thermal energy consumption (2025)	59
Figure 27:	Map of direct thermal energy consumption in industry (2025)	60
Figure 28:	Map of indirect thermal energy consumption in industry (2025)	61
Figure 29:	Map of service sector thermal energy consumption (2025)	62
Figure 30:	Map of service sector thermal energy consumption for cooling (2025)	63
Figure 31:	Map of household thermal energy consumption for heating (2030)	64
Figure 32:	Map of household thermal energy consumption for cooling (2030)	65
Figure 33:	Map of total household thermal energy consumption (2030)	66
Figure 34:	Map of direct thermal energy consumption in industry (2030)	67
Figure 35:	Map of indirect thermal energy consumption in industry (2030)	68
Figure 36:	Map of service sector thermal energy consumption (2030)	69
Figure 37:	Map of service sector thermal energy consumption for cooling (2030)	70
Figure 38:	Representation of the interactive web map graphic interface	71
Figure 39:	Diagram of steam condensing turbine cogeneration	78
Figure 40:	Diagram of back pressure steam turbine cogeneration	78

Figure 41: Diagram of gas turbine cogeneration with heat recovery boiler.....	79
Figure 42: Principal diagram of combined cycle cogeneration	81
Figure 43: Growth of district cooling energy supplied in selected countries by various statistics	84
Figure 44: Natural gas price for households, services and industry (HRK/kWh, VAT included) Source: Energy in Croatia, EIHP, 2013.....	91
Figure 45: Principal schematic representation of Block A.....	95
Figure 46: Principal schematic representation of Block B.....	96
Figure 47: Principal schematic representation of blocks H and J	97
Figure 48: Principal simplified schematic representation of Block C	100
Figure 49: Principal simplified schematic representation of Block K	101
Figure 50: Principal simplified schematic representation of Block L.....	102
Figure 51: Principal schematic representation of the GPP block.....	104
Figure 52: Principal schematic representation of the 45 MW block.....	105
Figure 53: Layout of the Belišće North industrial zone and the location of DS Smith.....	108
Figure 54: Schematic representation of the industrial cogeneration facility in Belišće	110
Figure 55: Layout of Petrokemija d.d.	112
Figure 56: Schematic representation of the Petrokemija d.d. power plant	113
Figure 57: Phase 2 cooling towers	115
Figure 58: Location of the power plant in the Rijeka Oil Refinery.....	117
Figure 59: Schematic representation of the Rijeka Oil Refinery cogeneration installation	118
Figure 60: Rijeka Oil Refinery steam generators	119
Figure 61: Sea water pump station of the Rijeka Oil Refinery	120
Figure 62: Distribution of total thermal energy needs in Croatia	130
Figure 63: Age of existing boilers	139
Figure 64: Age of existing burners installed in the systems	139
Figure 65: Capacity (output) of existing boilers	141
Figure 66: Proportion of boiler manufacturers in heating systems in Croatia	141
Figure 67: Shares of manufacturers of burners installed in heating systems	142
Figure 68: Network length breakdown by nominal diameters of the existing pipeline	143
Figure 69: Shares of heating substation types in existing heating systems	144
Figure 70: Shares of future thermal energy consumers in the new DHS plants in 2030, optimistic and conservative scenarios	161
Figure 71: Distribution of equivalent heat consumption in Croatia, 2030 – conservative scenario	163
Figure 72: Distribution of electricity potential from high-efficiency cogeneration in Croatia, 2030 – conservative scenario	164
Figure 73: Distribution of equivalent heat consumption in Croatia, 2030 – optimistic scenario	166
Figure 74: Spatial distribution of electricity potential from high-efficiency cogeneration in Croatia, 2030 – optimistic scenario	167
Figure 75: Overview of annual and cumulative primary energy savings, 2020-2030 – conservative scenario.....	172
Figure 76: Distribution of fuel consumption for high-efficiency cogeneration installations in Croatia, 2030 – conservative scenario	172
Figure 77: Distribution of primary energy savings for high-efficiency cogeneration installations in Croatia, 2030 – conservative scenario	173
Figure 78: Overview of annual and cumulative primary energy savings, 2020-2030 – optimistic scenario	174
Figure 79: Distribution of fuel consumption for high-efficiency cogeneration installations in Croatia, 2030 – optimistic scenario	175

Figure 80: Distribution of primary energy savings for high-efficiency cogeneration installations in Croatia, 2030 – optimistic scenario	175
Figure 81: Annual thermal energy generation	181
Figure 82: Investment in the existing infrastructure.....	183

16. LIST OF TABLES

Table 1: Basic indicators relating to the Croatian district heating sector	16
Table 2: Data on energy operators in Croatia's heating sector in 2013	18
Table 3: Main indicators – HEP-Toplinarstvo d.o.o.	19
Table 4: Main indicators – Gradska Toplana d.o.o.....	20
Table 5: Main indicators – Tehnostan d.o.o.	21
Table 6: Main indicators – Vartop d.o.o./Grijanje Univerzal d.o.o.	22
Table 7: Main indicators – Plin VTC d.o.o.	23
Table 8: Main indicators – SKG d.o.o.	23
Table 9: Main indicators – Energo d.o.o.	24
Table 10: Main indicators – Brod-Plin d.o.o.	25
Table 11: Main indicators – GTG Vinkovci d.o.o.....	26
Table 12: Main indicators – Top-Terme d.o.o.	26
Table 13: Household, dwelling and population distribution in cities with more 10 000 inhabitants	33
Table 14: Estimate of useful thermal energy needs in cities and municipalities with more than 10 000 inhabitants until 2030.....	38
Table 15: Projected thermal energy increase in 10 largest Croatian cities by 2030	43
Table 16: Useful thermal energy needs in industry, 2013	44
Table 17: Basic characteristics of the cogeneration process	76
Table 18: Basic technical data on blocks A, B, H and J	94
Table 19: Basic technical data of auxiliary sources at EL-TO Zagreb location.....	98
Table 20: Basic technical data on blocks C, K and L	99
Table 21: Basic technical data on blocks D, E, F, G and H	102
Table 22: Basic technical data on Block C under construction	107
Table 23: Features of the steam generators installed in the Rijeka Oil Refinery	118
Table 24: Primary energy savings of EL-TO Zagreb	122
Table 25: Primary energy savings of TE-TO Zagreb	123
Table 26: Primary energy savings of TE-TO Osijek	
Table 27: Primary energy savings of TE Sisak.....	125
Table 28: Primary energy savings of Belišće d.o.o.	126
Table 29: Primary energy savings of Petrokemija d.d.....	126
Table 30: Primary energy savings of the Rijeka Oil Refinery.....	127
Table 31: Overview of the potential for additional new high-efficiency cogeneration	128
Table 32: Production facilities at EL-TO Zagreb	136
Table 33: Production facilities at TE-TO Zagreb.....	137
Table 34: Assessment of parts of the heating systems	140
Table 35: Existing thermal network by nominal diameter and city.....	142
Table 36: Typical service life by type of piping	143
Table 37: Overview of heating stations by type.....	144
Table 38: Conservative scenario of the potential for additional new high-efficiency cogeneration in 2030	162
Table 39: High-efficiency cogeneration electricity potential based on the conservative scenario, 2030	164

Table 40: Optimistic scenario of the potential for additional new high-efficiency cogeneration in 2030	165
Table 41: High-efficiency cogeneration electricity potential based on the optimistic scenario, 2013	166
Table 42: Estimate of primary energy savings in 2030 – conservative scenario	171
Table 43: Estimate of primary energy savings in 2030 – optimistic scenario	173
Table 44: Annual thermal energy generation	182
Table 45: Implemented investments in the existing infrastructure or system expansion	182
Table 46: Planned investments in energy facilities and thermal energy generation equipment	184
Table 47: Planned investment in the distribution network	184
Table 48: Overview of the spatial planning documents and provisions concerning thermal energy supply	209
Table 49: Characteristics of settlements according to heat consumption projections until 2030	212
Table 50: Projections of household heating and cooling consumption until 2030	214
Table 51: Projections of industry heating consumption until 2030	215
Table 52: Projections of service sector heating and cooling consumption until 2030	216
Table 53: Consumption potential for determining high-efficiency cogeneration share until 2030	217
Table 54: Calculation of high-efficiency cogeneration criteria status – EL-TO Zagreb	218
Table 55: Calculation of high-efficiency cogeneration criteria status – TE-TO Zagreb and TE-TO Osijek	219
Table 56: Calculation of high-efficiency cogeneration criteria status – TE Sisak	220
Table 57: Calculation of high-efficiency cogeneration criteria status – Industrial power plant	221
Table 58: Heating system data for the city of Samobor	222
Table 59: Heating system data for the city of Zaprešić	223
Table 60: Heating system data for the city of Velika Gorica (1/2)	224
Table 61: Heating system data for the city of Velika Gorica (2/2)	226
Table 62: Heating system data for the city of Sisak	227
Table 63: Heating system data for the city of Karlovac	228
Table 64: Heating system data for the city of Ogulin	230
Table 65: Heating system data for the city of Varaždin (1/2)	231
Table 66: Heating system data for the city of Varaždin (2/2)	232
Table 67: Heating system data for the city of Rijeka (1/2)	234
Table 68: Heating system data for the city of Rijeka (2/2)	235
Table 69: Heating system data for the city of Virovitica	236
Table 70: Heating system data for the city of Slavonski Brod (1/3)	238
Table 71: Heating system data for the city of Slavonski Brod (2/3)	239
Table 72: Heating system data for the city of Slavonski Brod (3/3)	240
Table 73: Heating system data for the city of Osijek	242
Table 74: Heating system data for the city of Vukovar	243
Table 75: Heating system data for the city of Zagreb (1/4)	244
Table 76: Heating system data for the city of Zagreb (2/4)	246
Table 77: Heating system data for the city of Zagreb (3/4)	247
Table 78: Heating system data for the city of Zagreb (4/4)	248

17. REFERENCES

- [1] Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration based on a useful heat demand in the internal energy market and amending Directive 92/42/EEC, OJ L 52, 21.2.2004, p. 50-60;
- [2] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, OJ L 140, 5.6.2009, p. 16-62;
- [3] Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings, OJ L 153, 18.6.2010, p. 13-35;
- [4] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control), OJ L 334, 17.12.2010, p. 17-119;
- [5] Directive 2012/27/EU of the European Parliament and the Council of 25 October 2012 on energy-efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC, OJ L 315, 14.11.2012, p. 1-56;
- [6] Council Directive 2013/18/EU of 13 May 2013 adapting Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources, by reason of the accession of the Republic of Croatia, OJ L 158, 10.6.2013, p. 230-230;
- [7] Directive on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products, OJ L 153, 18.6.2010, p. 1-12;
- [8] Energy Development Strategy of the Republic of Croatia (NN No 130/09);
- [9] Physical Planning Strategy of the Republic of Croatia of 27 June 1997;
- [10] Energy Development Strategy of the Republic of Croatia (NN No 30/09);
- [11] National Renewable Energy Action Plan until 2020;
- [12] Decision amending the Physical Planning Strategy of the Republic of Croatia (NN No 86/13);
- [13] Decision on the preparation of the Spatial Development Strategy of the Republic of Croatia (NN No 143/13) National Energy Efficiency Programme for 2008-2016;
- [14] Decision requiring the producer of natural gas to sell natural gas to the supplier on the gas wholesale market (NN No 29/14);
- [15] Decision setting the price at which the natural gas producer is obliged to sell natural gas produced in Croatia to the supplier on the gas wholesale market (NN No 28/15);
- [16] Decision setting the price at which the supplier on the gas wholesale market is obliged to sell gas to public service suppliers who supply gas to households (NN No 28/15);
- [17] Decision setting the price at which the natural gas producer is obliged to sell natural gas produced in Croatia to the supplier on the gas wholesale market (NN No 29/14);
- [18] Decision setting the price at which the supplier on the gas wholesale market is obliged to sell gas to public service suppliers who supply gas to households (NN No 29/14);
- [19] Decision setting the purchase price of gas for tariff customer suppliers (NN No 49/12);
- [20] Decision implementing a special measure for mitigating the increase in household natural gas prices in 2011 (NN No 148/10);
- [21] Decision implementing a special measure for mitigating the increase in household natural gas prices in 2010 (NN No 158/09);
- [22] Decision setting the purchase price of gas for tariff customer suppliers (NN No 77/07);
- [23] Decision setting the purchase price of gas for tariff customer suppliers (NN No 153/09);
- [24] National Energy Efficiency Action Plans(1, 2 and 3);
- [25] The Energy Act (NN Nos 80/13, 14/14, 102/14, and 95/15);
- [26] The Energy Act (NN Nos 120/12, 14/14, 95/15, and 102/15);
- [27] Energy Activities Regulation Act (NN No 120/12);
- [28] Electricity Market Act (NN Nos 22/13, 95/15 and 102/15);

- [29] Gas Market Act (NN No 28/13 and 14/14);
- [30] Renewable Energy Sources and High-Efficiency Cogeneration Act (NN No 105/15);
- [31] Energy Sector and Investment Monitoring Centre Act (NN Nos 25/12 and 120/12);
- [32] Energy Efficiency Act (NN No 127/14);
- [33] Environmental Protection and Energy Efficiency Fund Act (NN Nos 107/03 and 144/12) ;
- [34] State Aid Act (NN No 47/14);
- [35] Official Statistics Act (NN Nos 103/03, 75/09, 59/12, and 12/13 – consolidated version);
- [36] Physical Planning Act (NN No 153/13);
- [37] Construction Act (NN Nos 153/13);
- [38] Official Statistics Act (NN Nos 103/03, 75/09, 59/12, and 12/13 – consolidated version);
- [39] General Terms and Conditions of Thermal Energy Supply (NN No 129/06) – for the procedures initiated before 1 September 2014;
- [40] General Terms and Conditions of Thermal Energy Supply (NN No 35/14) – for the procedures initiated after 1 September 2014;
- [41] Tariff system for electricity generation from renewable energy resources and cogeneration (NN Nos 133/13, 151/13, 20/14, 107/14, and 100/15);
- [42] Decree on incentive fee for electricity generation from renewable energy resources and cogeneration (NN No 128/13);
- [43] The Decree on contracting and implementation of public sector energy service (NN No 11/15);
- [44] Decree on the amount and method of payment of a concession fee for heat distribution and a concession fee for the construction of heat distribution energy facilities (NN No 1/14) ;
- [45] Commission Regulation (EU) No 651/2014 of 17 June 2014 declaring certain categories of aid compatible with the internal market in application of Articles 107 and 108 of the Treaty, OJ L 187, 26.6.2014, p. 1-78;
- [46] Regulation (EC) No 1099/2008 of the European Parliament and of the Council of 22 October 2008 on energy statistics, OJ L 304, 14.11.2008, p. 1-62;
- [47] Tariff system for the services of thermal energy generation, distribution and supply, with no tariff amounts (NN Nos 65/07, 154/08, 22/10, 46/10, 50/10, and 86/11);
- [48] Tariff system for the services of thermal energy generation and supply, with no tariff amounts (NN No 86/11);
- [49] Decision on tariff item amounts in the Tariff system for heat generation, distribution and supply activities (NN No 154/08);
- [50] Methodology for determining tariff item amounts for thermal energy distribution (NN No 56/14);
- [51] Methodology for determining tariff item amounts for heat generation (NN No 56/14);
- [52] Network Rules of Thermal Energy Distribution (NN No 35/14);
- [53] The Rules governing the use of renewable energy resources and cogeneration (NN No 88/12);
- [54] Rules governing the grant of eligible electricity producer status (NN Nos 132/13, 81/14, 93/14, 24/15, 99/15, and 110/15) Rules of systematic public sector energy management (NN No 18/15);
- [55] Rules on the method of cost allocation and billing for thermal energy delivered (NN Nos 99/14, 27/15 and 124/15);
- [56] Rules on licences for energy activities and keeping the register of issued and cancelled licences for energy activities (NN No 88/15);
- [57] Zagreb County – Decision adopting the Zagreb County Spatial Plan (consolidated version), 2012;
- [58] Krapina-Zagorje County – Krapina-Zagorje County Spatial Plan, 2002;
- [59] Sisak-Moslavina County – Sisak-Moslavina County Spatial Plan, 2001;
- [60] Karlovac County – Karlovac County Spatial Plan – amendments, 2008;
- [61] Varaždin County – Varaždin County Spatial Plan, 2000;
- [62] Koprivnica-Križevci County – Decision adopting the Koprivnica-Križevci County Spatial Plan (Official Gazette of Koprivnica-Križevci County), 2001; Amendment to the Koprivnica-Križevci County Spatial Plan, 2007; 2nd Amendment to the Koprivnica-Križevci County Spatial Plan, 2012;
- [63] Bjelovar-Bilogora County – various data sources;

- [64] Primorje-Gorski Kotar County – Primorje-Gorski Kotar Spatial Plan (Implementing provisions), 2013;
- [65] Lika-Senj County – Decision adopting the Lika-Senj County Spatial Plan (consolidated version), Lika-Senj County Gazette, 2015;
- [66] Virovitica-Podravina County – Virovitica-Podravina County Spatial Plan (consolidated version), 2010; Virovitica Podravina County Spatial Plan (5th amendment – Vol. 1), 2013;
- [67] Požega-Slavonia County – various data sources;
- [68] Brod-Posavina County – Brod-Posavina County Spatial Plan (Physical Planning Institute of Brod-Posavina County, in cooperation with the Institute of Spatial Planning, Osijek), 2001; Decision amending the Brod-Posavina County Spatial Plan (Official Gazette of Brod-Posavina County), 2005; Brod-Posavina County Spatial Plan (Physical Planning Institute of Brod-Posavina County, in cooperation with the Institute of Spatial Planning, Osijek) – consolidated version, 2008; Decision adopting 3rd Amendment to the Brod-Posavina County Spatial Plan (Official Gazette of Brod-Posavina County), 2010; Decision adopting 4th Amendment to the Brod-Posavina County Spatial Plan (Official Gazette of Brod-Posavina County), 2012;
- [69] Zadar County – Zadar County Spatial Plan (Institute of Spatial Planning) – consolidated version, 2006; Zadar County Spatial Plan – amendments (Institute of Spatial Planning), 2014;
- [70] Osijek-Baranja County – Osijek-Baranja County Spatial Plan (Physical Planning Institute of Osijek-Baranja County);
- [71] Šibenik-Knin County – Šibenik-Knin County Spatial Plan (Official Gazette of Šibenik-Knin County) – consolidated version, 2012; Šibenik-Knin County Spatial Plan – amendments, 2013;
- [72] Vukovar-Syrmia County – various data sources;
- [73] Split-Dalmatia County – Decision adopting the Split-Dalmatia County Spatial Plan, 2003;
- [74] Istria County – Decision adopting the Istria County Spatial Plan, 2002; Decision adopting the Istria County Spatial Plan, consolidated version, 2005; [sic – should come under separate numer] Decision adopting the Istria County Spatial Plan, consolidated version, 2011;
- [75] Dubrovnik-Neretva County – Amendments to the County Spatial Plan (Physical Planning Institute of Dubrovnik-Neretva County), 2015;
- [76] Međimurje County – the Međimurje County Spatial Plan (Physical Planning Institute of Međimurje County) of 2001 with Amendments to the Međimurje County Spatial Plan (Physical Planning Institute of Međimurje County), 2010;
- [77] City of Zagreb – City of Zagreb Spatial Plan – amendments, 2014;
- [78] Guidance note on Directive 2012/27/EU, Article 14: Promotion of efficiency in heating and cooling, EU Commission, 2013;
- [79] Background Report on EU-27 District Heating and Cooling Potentials, Barriers, Best Practice and Measures of Promotion, European Commission, Joint Research Centre, 2012;
- [80] EU District Cooling Market and Trends, RESCUE, IEE, 2014;
- [81] Census of Population, Households and Dwellings 2011, Croatian Bureau of Statistics, 2013;
- [82] Population projections for the Republic of Croatia, 2010-2061, Croatian Bureau of Statistics, 2011;
- [83] Wertheimer-Baletić, A.; Akrap, A. Spatial aspects of demographic potentials in Croatia, 2011-2051, 2014;
- [84] Croatia's Industrial Strategy 2014-2020, NN No 126/2014;
- [85] World Development Indicators 2015, World Bank, 2015;
- [86] World Economic Outlook 2015, International Monetary Fund, 2015;
- [87] various other strategic planning documents for the energy sector, energy efficiency and heating sector;
- [88] other EIHP studies and projects.

