Energy Institute Hrvoje Požar

Comprehensive assessment of the potential for efficiency in heating and cooling in Croatia under Annex VIII to Directive 2012/27/EU

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LIST OF ABBREVIATIONS

BAU	reference or baseline scenario (business-as-usual)
CBA	cost-benefit analysis
WMC	waste management centre
DHS	district heating system
CBS	Croatian Bureau of Statistics
DHC	district heating and cooling
EIHP	Energy Institute Hrvoje Požar
ESCO	energy service company
ESI	European Structural and Investment Funds
RDF	refuse-derived fuel
CAEN	Croatian Agency for the Environment and Nature
HEP ODS	*Hrvatska Elektroprivreda – Operator Distribucijskog Sustava* [state-owned power company – distribution system operator]
HERA	Croatian Energy Regulatory Agency
HROTE	Croatian Energy Market Operator
IEA	International Energy Agency
IEC	Energy Certification Information System
JRC	Joint Research Centre
MBT	mechanical biological waste treatment
MESD	Ministry of the Economy and Sustainable Development
NECP	National Energy and Climate Plan
NAC	National Classification of Activities
NRRP	National Recovery and Resilience Plan
NPV	net present value
RES	renewable energy source
DHW	domestic hot water
SPF	seasonal performance factor of a heat pump
LPG	liquefied petroleum gas
CHS	closed heating system
SIM	scenario with integrated measures
HEC	high-efficiency cogeneration
CWMC	County Waste Management Centre

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EXECUTIVE SUMMARY

Heating and cooling systems are the most important final energy consumers with an energy consumption of about 50% of total energy requirements in the European Union. Buildings account for 80% of the energy consumed. To ensure the energy transition at every administrative level within the EU, it is necessary to:

- identify energy efficiency potential to achieve savings across all Member States; and;
- align policies.

Under Article 14 of **Directive 2012/27/EU** of the European Parliament and of the Council of 25 October 2012 **on energy efficiency** (EED), as of 31 December 2015, Member States are required to carry out **a comprehensive assessment of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling** (hereinafter: comprehensive assessment) and notify it to the Commission.

As part of the comprehensive assessment, Member States adopt policies which encourage due taking account of the possibilities of using efficient heating and cooling systems, particularly high-efficiency cogeneration systems, at local and regional levels, also taking into account the potential for local and regional heat market development.

The comprehensive assessment is updated at the request of the Commission and notified to the Commission every 5 years.

Croatia's first comprehensive assessment, entitled *Programme of Exploiting Heating and Cooling Efficiency Potential for 2016–2030*, was prepared in November 2015.

This Comprehensive Assessment is structured in line with Annex VIII to the Commission Delegated Regulation (EU) 2019/826 of 4 March 2019 amending Annexes VIII and IX to Directive 2012/27/EU of the European Parliament and of the Council on the contents of comprehensive assessments of the potential for efficient heating and cooling [5]:

PART I: OVERVIEW OF HEATING AND COOLING

PART II: OBJECTIVES, STRATEGIES AND POLICY MEASURES

PART III: ANALYSIS OF THE ECONOMIC POTENTIAL FOR EFFICIENT HEATING AND COOLING

PART IV: POTENTIAL NEW STRATEGIES AND POLICY MEASURES

Part I of the Comprehensive Assessment provides an overview of delivered and useful heating/cooling energy, broken down by main sectors (households, services, industry) at the level of municipalities, towns and cities, and City of Zagreb districts in 2019. The delivered and useful heating/cooling energy is then shown at those levels on a map of Croatia. Maps also show the existing district heating systems in Croatia (generation facilities and distribution network), points of supply of the industrial facilities generating waste heat, and existing and potential sources of geothermal energy. At the end of Part I, forecast trends in the annual useful [energy] for heating/cooling delivered and required are provided for the baseline scenario and a scenario with integrated measures for the period up to 2050. In 2019, total annual energy delivered for heating/cooling purposes to household, service and industrial sectors in Croatia amounted to 33 505.18 GWh, while the annual useful energy needed for heating/cooling in those sectors totalled 32 366.55 GWh. The share of energy from renewable sources in district heating systems was declared at 4.9% in 2019.

Part II specifies the existing objectives, strategies and policy measures, that is, Croatia's planned contribution with its national objectives, targets and contributions to the five closely-related dimensions of the Energy union: energy security, internal energy market, energy efficiency, decarbonisation, as well as research, innovation and competitiveness. Croatia has already adopted its national objectives and targets relating to the five dimensions of the Energy union in the Integrated National Energy and Climate Plan (NECP) for 2021–2030. With regard to heating and cooling, it is crucial to note that the target share of renewable energy sources (RES) in gross final energy consumption for heating and cooling has been set at 47.8% for 2030, compared to a 36.8% share in 2020. Improved efficiency and decarbonisation of heating and cooling systems are integral elements of the building renovation programme, as the most relevant measures for achieving both RES-related objectives and energy efficiency targets. The NECP also envisages ways to stimulate biomethane and hydrogen production with the aim of decarbonising the gas system, as well as further upgrading and development of district heating systems by enhancing the efficiency of generation facilities, integrating RES and reducing losses in the existing distribution network.

Part III of the Comprehensive Assessment, relating to the analysis of the economic potential for efficient heating and cooling, lays down the technical and economic potential and includes a cost-benefit analysis, conducted to identify the most cost-efficient solutions for meeting heating and cooling requirements in the three Croatian sectors observed. A sensitivity analysis, undertaken to determine how a variation of individual parameters or a combination of parameters affects final results of the calculation (economic potential and the most cost-effective solutions for meeting heating and cooling requirements), is included at the end of Part III. Alternative or SIM scenarios developed as part of the analysis of the economic potential for efficient heating and cooling were compared to baseline and BAU scenarios. Results show that proposed alternative scenarios lead to lower CO_2 emissions and lower costs than BAU scenarios. Total CO_2 emissions savings achieved by implementing the proposed measures for both periods observed (up to 2030 and 2031–2050) are as follows:

HOUSEHOLDS – individual systems → 1 160 975.65 tonnes of CO_2;

SERVICES – individual systems → 818 845.07 tonnes of CO_2;

HOUSEHOLDS – SERVICES – INDUSTRY – centralised systems or → DHS 365 013.51 tonnes of CO_2.

The cost-benefit analysis, performed separately for each measure and for each period in question (up to 2030 and 2031–2050), based on the calculation of the financial net present value (FNPV) and the economic NPV (ENPV), determined the cost-effectiveness of each proposed measure for individual systems in household and service sectors, as well as for district heating systems in the household, services and industrial sectors.

Given that the measures were observed over two periods (a shorter period up to 2030 and a longer one, between 2031 and 2050), some measures turned out not to be cost-effective (FNPV < 0 and ENPV < 0) due to the shorter observation period (measures up to 2030), whereas in the longer observation period the same measures (2031–2050 measures) proved cost-effective when supported (FNPV < 0 and ENPV > 0) or even without the necessary support (FNPV > 0 and ENPV > 0).

The replacement of traditional biomass in the case of individual systems in the household sector proved not to be cost-effective, whereas replacing fuel oil-fired boilers and LPG with all proposed technologies was cost-effective. Replacing natural gas with other technologies is generally cost-effective without necessary support, but some of the proposed technologies for the replacement of natural gas-fired boilers do require public support (installation of solar collectors for DHW preparation, replacement of natural gas boilers with modern biomass-fired boilers for space heating and DHW preparation). When it comes to individual systems in the service sector, the replacement of fuel oil and LPG-fired boilers with all the proposed technologies is a cost-effective measure. As in the household sector, replacing natural gas with other technologies is generally cost-effective without the necessary support; however, some of the proposed technologies for replacing natural gas boilers (installation of solar collectors for DHW preparation in service sector buildings where technically feasible and justified, replacement of natural gas boilers with modern biomass boilers for space heating and DHW preparation) do require public support.

DHS measures which are extremely important and cost-effective when supported relate to the exploitation of geothermal energy and utilisation of industrial waste heat. In addition, the sensitivity analysis showed which of the parameters can have a more significant impact on the outcome of a particular measure.

The final part, Part IV, provides the following potential new strategies and strategic policy measures, which would realise the economic potential for efficiency in heating and cooling, identified in the previous part of the Comprehensive Assessment (PART III):

- INDIVIDUAL SYSTEMS[1] – HOUSEHOLD SECTOR:
    - replacement of natural gas boilers with combined heat and power (micro-CHP) system, fuelled by natural gas (between 2030 and 2050);
    - installation of solar collectors for DHW preparation where natural gas central boilers are used for DHW preparation;
    - replacement of natural gas boilers with modern biomass boilers for space heating and DHW preparation, and installation of solar collectors for DHW preparation;
    - replacement of individual electric space heaters with heat pumps (by 2030);
- INDIVIDUAL SYSTEMS – SERVICE SECTOR:
    - installation of solar collectors for DHW preparation where natural gas central boilers are used for DHW preparation;
    - replacement of natural gas boilers with modern biomass boilers for space heating and DHW preparation, and installation of solar collectors for DHW preparation (where technically feasible and justified in service sector buildings);
- DISTRICT HEATING SYSTEMS[2] – increased efficiency and expansion of the distribution network of existing district heating systems in densely populated urban areas;
- DISTRICT HEATING SYSTEMS – modernisation of generation facilities of existing district heating systems:
    - replacement of natural gas boilers – industrial waste heat utilisation;
    - replacement of natural gas boilers – geothermal energy exploitation.

The comprehensive assessment of the potential for efficient heating and cooling in Croatia under Annex VIII to Directive 2012/27/EU shows notably the existence of great potential for an efficient district heating system in Croatia, based on the use of renewable energy sources (primarily geothermal energy) and high-efficiency cogeneration from natural gas and biomass, as well as considerable potential through the application of measures relating to individual systems in household and service sectors.

[1] Each consumer has their own separate source of heating and/or cooling energy.

[2] District heating systems used for heat distribution from the source (generation installation) to consumers.

METHODOLOGICAL APPROACH AND INPUT DATA USED IN PREPARING THE COMPREHENSIVE ANALYSIS

a) Methodological approach

The first set of comprehensive assessments was analysed by the **Joint Research Centre (JRC)**, which found that they could benefit from the collected new data, descriptions of new heating and cooling potentials, and a better interaction between national and local administrations.

In a letter of 8 April 2019, the European Commission asked all Member States to submit their most recent, updated comprehensive assessments of the potential for efficient heating and cooling by 31 December 2020 at the latest.

As part of the second comprehensive assessment, it is necessary to, among other things, ensure better alignment with the following Energy union regulations:

- **Regulation (EU) No 2018/1999** of the European Parliament and of the Council of 11 December 2018 **on the Governance of the Energy Union and Climate Action**,
- **Directive (EU) 2018/844** of the European Parliament and of the Council of 30 May 2018 **amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency**,
- **Directive (EU) 2018/2002** of the European Parliament and of the Council of 11 December 2018 **amending Directive 2012/27/EU on energy efficiency**,
- **Directive (EU) 2018/2001** of the European Parliament and of the Council of 11 December 2018 **on the promotion of the use of energy from renewable sources**.

The preparation of the analyses should be closely related to the planning and reporting set out in Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action, as well as based on previous assessments wherever possible.

The content of the comprehensive assessment is laid down in **Annex VIII** to Directive 2012/27/EU. Annexes VIII and IX to Directive 2012/27/EU were amended by Commission Delegated Regulation (EU) 2019/826 of 4 March 2019. With regard to the content of the comprehensive assessment, it is important to take note of the following Commission Recommendation and its Annexes:

- Commission Recommendation of 25 September 2019 on the content of the comprehensive assessment of the potential for efficient heating and cooling under Article 14 of Directive 2012/27/EU,
- Annexes to Commission Recommendation of 25 September 2019 on the content of the comprehensive assessment of the potential for efficient heating and cooling under Article 14 of Directive 2012/27/EU.

Commission Recommendation of 25 September 2019 contains the following Annexes:

Annex I: Contents of comprehensive assessments of the potential for efficient heating and cooling

Annex II: Additional sources of literature

Annex III: Waste heat accounting

Annex IV: Process for comprehensive assessments (Annex VIII EED)

Annex V: Financial and economic cost-benefit analysis

Annex VI: External costs of the cost-benefit analysis

Annex VII: Reporting template for reporting inputs and outputs

which explain the new requirements and facilitate the effective and coherent application of the provisions of Annex VIII EED.

Definitions of particular terms defined by Directive 2012/27/EU, which are relevant for this comprehensive assessment, are as follows:

- **high-efficiency cogeneration** – cogeneration meeting the criteria laid down in Annex II (Methodology for determining cogeneration process efficiency);
- **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 option 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 referred to in this Directive, taking into account the energy required for extraction, conversion, transport and distribution;
- **efficient individual heating and cooling** – an individual heating and cooling supply option 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 comprehensive assessment included a cost-benefit analysis, which identified the most cost-efficient solutions for meeting heating and cooling needs.

As a first step, the total annual energy delivered for heating/cooling purposes was defined, and the useful energy required for heating and cooling was determined for the following main sectors:

- household sector (residential sector),
- service sector,
- industry,
- agriculture,

and for the relevant sub-sectors:

- **household sector:**
  - family houses,
  - multi-apartment buildings,
- **service sector:**
  - public buildings,
  - educational buildings (kindergartens, primary schools, secondary schools, universities),
  - hotels,
  - hospitals,
  - shops,
  - office buildings,

  - other,

- **industry:**
  - breakdown by key activity, e.g. cement industry, cellulose and paper, metallurgy,

Given that data on service sector buildings (useful floor area of the heated part of the building A_k, energy products used for space heating and cooling or DHW preparation) was taken from the Energy Certification Information System (Cr. abbr. IEC) database, the rest of the study makes use of the following sub-sectors of the service sector, in accordance with the breakdown specified in the *Rules governing energy audits and energy performance certification of buildings* (*Narodne Novine* (NN; Official Gazette of the Republic of Croatia) No 88/2017):

  - office buildings,
  - educational buildings (kindergartens, primary schools, secondary schools, universities),
  - hospitals,
  - hotels and restaurants,
  - sports halls,
  - wholesale and retail trade buildings,
  - other non-residential buildings heated to a temperature of +18 °C (e.g. traffic and communication buildings, terminals, stations, post offices, telecommunications buildings, buildings for artistic and cultural activities and entertainment, museums, libraries).

After determining the currently required useful energy for heating and cooling, the annual useful energy required for heating and cooling was estimated. Defining the current and future useful energy requirements for heating/cooling is extremely important because the accuracy and relevance of the results of the comprehensive assessment depend precisely on the quality of data and the models used.

Also, data related to the distribution network of district heating systems was collected and shown on the map of Croatia.

The following two heating and cooling scenarios were defined for the purpose of cost-benefit analysis:

- **baseline scenario,** including a description of the current supply and its further trends over time, as well as information on how useful heating/cooling energy needs are currently being met and the assumptions on how they are to be met in the future, based on current knowledge, technological development and policy measures. This scenario is viewed as a reference scenario for identifying changes in the economic effects resulting from other scenarios;
- **alternative scenario,** based on previously determined technical potential. Alternative scenarios are proposed to be defined so that as much useful energy required for heating/cooling as possible (maximum scope) may be covered by each of the proposed solutions for efficient heating/cooling.

The main outcome of the cost-benefit analysis consists in **the most cost-efficient solutions for meeting heating and cooling needs**.

Definitions of the individual types of potential are provided below:

- TECHNICAL POTENTIAL – the amount of useful energy required, expressed in MWh/year, which could be covered by a technological solution or met from an estimated energy resource, taking into account its maximum achievable penetration over the time observed, considering technical and practical limitations (topographic limitations, environmental, and land-use constraints), without taking into account economic criteria. Technical potential may be expressed in MWh/year or MW.

- ECONOMIC POTENTIAL – a subset of technical potential that is economically cost-effective compared with conventional supply-side energy resources. Economic potential may be expressed in MWh/year or MW.
- COST-BENEFIT POTENTIAL

A diagram of the methodology used for comprehensive assessment is provided below.

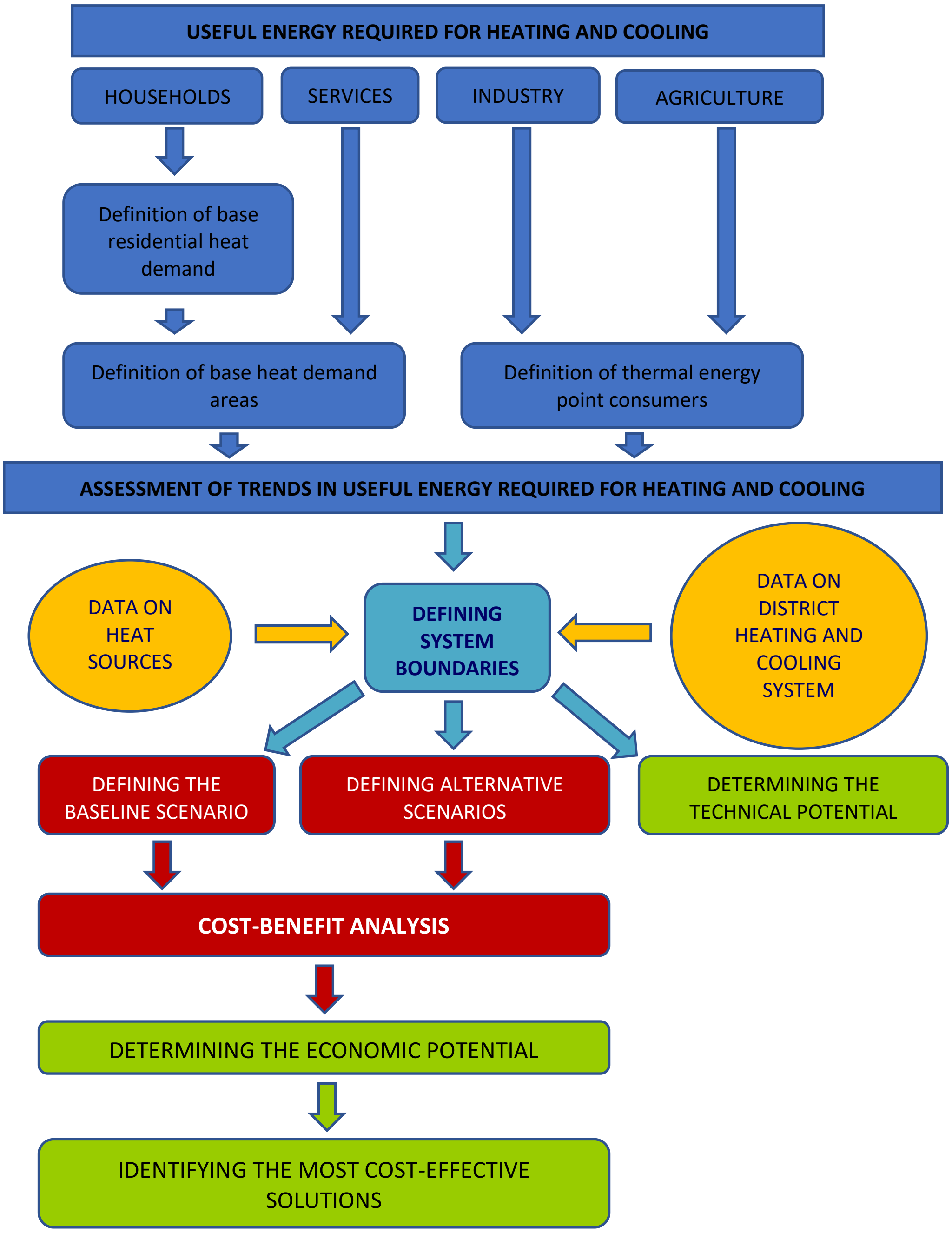


Figure 0.1: Diagram of the methodology for comprehensive assessment development

b) Input data

Given that trends in the building stock and, consequently, the energy consumption in those buildings, are predominantly affected by changes in the population size, Croatia's demographic profile in 2019 serving as the basis for all further analyses is presented first in this chapter. Next, an overview of the national building stock is provided with data on the useful heated floor area for the residential building stock (household sector) and the non-residential building stock (service sector). It is important to note that all input and output data within this chapter are specified at the level of municipalities, cities or towns, and City of Zagreb districts.

b.1) Croatia's projected population size in 2019

Given that the latest census in Croatia took place in 2011, population projections for 2019 were analysed in the Comprehensive Assessment. The projection of demographic trends in Croatia was taken from an analysis conducted by the Institute of Economics in Zagreb [17], which used the cohort component method according to Rowland's methodology to make population projections for an open population. The following variants were analysed:

- **Variant 1**
- includes constant fertility;
- foresees rising life expectancy for both sexes;
- foresees a slowdown in emigration.
- **Variant 2**
- includes an increase in the total fertility rate;
- foresees rising life expectancy for both sexes;
- foresees a slowdown in emigration.
- **Variant 3**
- includes a greater increase in the total fertility rate;
- foresees rising life expectancy for both sexes;
- foresees less emigration compared to previous variants.

The projection of population size was made at the level of municipalities, cities or towns, and City of Zagreb districts. However, for the sake of simplicity, the table below contains the projected number of inhabitants for 2019 at county level. All further analyses included in the Comprehensive Assessment were based on Variant 2.

Table 0.1: Croatia's projected population size for 2019 by county

	County name	Variant 1	Variant 2	Variant 3
1	Zagreb County	305 862	305 975	306 214
2	Krapina-Zagorje County	127 095	127 141	127 241
3	Sisak-Moslavina County	148 273	148 323	148 440
4	Karlovac County	115 683	115 720	115 799
5	Varaždin County	168 179	168 240	168 374
6	Koprivnica-Križevci County	109 587	109 630	109 710
7	Bjelovar-Bilogora County	109 222	109 264	109 358
8	Primorje-Gorski Kotar County	277 687	277 774	278 017
9	Lika-Senj County	44 299	44 315	44 350
10	Virovitica-Podravina County	76 712	76 741	76 813

	County name	Variant 1	Variant 2	Variant 3
11	Požega-Slavonia County	68 319	68 346	68 401
12	Slavonski Brod-Posavina County	141 906	141 963	142 076
13	Zadar County	163 013	163 078	163 230
14	Osijek-Baranja County	281 123	281 225	281 450
15	Šibenik-Knin County	96 427	96 461	96 528
16	Vukovar-Syrmia County	157 666	157 727	157 845
17	Split-Dalmatia County	438 355	438 530	438 893
18	Istria County	200 553	200 620	200 777
19	Dubrovnik-Neretva County	117 649	117 701	117 787
20	Međimurje County	110 417	110 467	110 546
21	City of Zagreb	781 762	782 068	782 825
	TOTAL	**4 039 789**	**4 041 309**	**4 044 674**

b.2) Overview of the national building stock

An overview of the total national building stock is provided in the table below, while a detailed breakdown of how data in the table were obtained is available in the subchapters below, separately for each sector.

Table 0.2: National building stock by county

Overview of the national building stock					
		Total useful floor area of the heated part of the building [m^2]			
	County name	Residential buildings	Non-residential buildings	Total	Share [%]
1	Zagreb County	9 261 485	2 424 273.00	10 490 100	6.29%
2	Krapina-Zagorje	3 684 540	952 821.00	6 023 845	3.61%
3	Sisak-Moslavina	5 229 179	858 898.00	4 203 951	2.52%
4	Karlovac	3 686 192	973 555.00	4 753 146	2.85%
5	Varaždin	4 968 459	1 720 080.00	6 389 353	3.83%
6	Koprivnica-Križevci	3 571 894	936 997.00	5 417 187	3.25%
7	Bjelovar-Bilogora	3 624 571	628 762.00	5 890 970	3.53%
8	Primorje-Gorski Kotar	9 585 069	3 145 783.00	9 547 308	5.73%
9	Lika-Senj	1 634 119	384 301.00	2 327 446	1.40%
10	Virovitica-Podravina	2 560 529	442 965.00	7 704 870	4.62%
11	Požega-Slavonia	2 320 386	651 126.00	2 036 609	1.22%
12	Slavonski Brod-Posavina	4 588 728	999 844.00	7 708 570	4.62%
13	Zadar	6 026 552	1 269 243.00	7 297 074	4.38%
14	Osijek-Baranja	9 466 070	2 244 601.00	15 441 288	9.26%
15	Šibenik-Knin	3 437 045	828 055.00	3 565 701	2.14%
16	Vukovar-Syrmia	5 242 420	764 623.00	4 150 532	2.49%
17	Split-Dalmatia	12 466 133	4 642 825.00	15 255 266	9.15%
18	Istria	7 664 291	3 107 615.00	7 985 361	4.79%
19	Dubrovnik-Neretva	3 702 961	1 195 171.00	4 968 716	2.98%
20	Međimurje	3 646 019	915 258.00	4 296 147	2.58%
21	City of Zagreb	22 564 317	8 724 268.00	31 288 585	18.76%
	TOTAL	**128 930 959**	**37 811 064**	**166 742 024**	**100%**

b.2.1) Overview of the national building stock – household sector

As part of the Comprehensive Assessment, the total useful floor area of the heated [building] part was determined separately for family houses and for multi-apartment buildings at the level of municipalities, cities or towns, and City of Zagreb districts. However, for the sake of simplicity, the data below is presented at county level.

The residential building stock calculation was based on data, as reported in the 2011 Croatian census of population, households and dwellings, concerning occupied dwellings according to the year of construction, building type and number of households, as well as on the 2010–2018 construction industry statistical reports. The residential building stock is divided into family houses and multi-apartment buildings, with family houses including buildings with one and two dwellings, while multi-apartment buildings include all buildings with three and more dwellings, as well as residences of communities and dwellings in non-residential buildings. A change in the 2011–2019 residential building stock was determined based on building permits issued between 2010 and 2018, minus the share of temporarily and permanently vacant dwellings in the total stock. Completed buildings follow the trend of issued building permits with a one-year delay, so the total floor area of the completed buildings is 7.75% smaller than the building area for which the building permits were issued. Dwellings excluded from fund statistics due to registered demolition or conversion, which on average account for less than 5% of the area of new constructions, are not excluded from the building stock, so a deviation is possible in the actual number and dwelling area. Further errors may also arise from incomplete sources of data regarding demolished dwellings, a lack of records on vacant dilapidated dwellings that are no longer fit for housing and changes in the use of the dwelling (e.g. if it is used for non-residential purposes). In addition, the large share of temporarily vacant dwellings in the total fund, which has doubled since the 2011 census and continues to increase, has individually the strongest impact on the number of permanently occupied dwellings, with the greatest deviations from the actual state of the stock occurring at the end of the census period.

The residential building stock by county presented in the table below show that family houses account for 64.75% of the total useful floor area of the heated part of buildings, while the remaining 35.25% refers to multi-apartment buildings.

Table 0.3: Residential building stock by county

HOUSEHOLDS – Overview of the national building stock					
	County name	FAMILY HOUSES – total number [–]	MULTI-APARTMENT BUILDINGS – total number [–]	FAMILY HOUSES – total useful floor area of the heated part of the building [m²]	MULTI-APARTMENT BUILDINGS – total useful floor area of the heated part of the building [m²]
1	Zagreb County	72 081	4 445	7 512 556	1 748 929
2	Krapina-Zagorje	36 359	846	3 367 853	316 687
3	Sisak-Moslavina	48 310	2 103	4 316 309	912 870
4	Karlovac	31 229	2 000	2 617 762	1 068 430
5	Varaždin	42 896	782	4 091 976	876 483
6	Koprivnica-Križevci	32 108	726	3 154 689	417 205
7	Bjelovar-Bilogora	34 345	1 427	3 141 986	482 585
8	Primorje-Gorski Kotar	42 466	14 872	4 506 092	5 078 976
9	Lika-Senj	14 609	1 328	1 226 590	407 528
10	Virovitica-Podravina	26 081	446	2 324 148	236 381
11	Požega-Slavonia	21 812	915	2 043 449	276 937
12	Slavonski Brod-Posavina	41 131	1 874	3 833 415	755 312
13	Zadar	35 873	6 242	3 879 533	2 147 019
14	Osijek-Baranja	77 877	4 170	7 189 259	2 276 811
15	Šibenik-Knin	24 170	3 264	2 336 090	1 100 955

HOUSEHOLDS – Overview of the national building stock						
	County name	FAMILY HOUSES – total number [–]	MULTI-APARTMENT BUILDINGS – total number [–]	FAMILY HOUSES – total useful floor area of the heated part of the building [m²]	MULTI-APARTMENT BUILDINGS – total useful floor area of the heated part of the building [m²]
16	Vukovar-Syrmia	48 533	1 970	4 402 879	839 541
17	Split-Dalmatia	56 294	14 021	5 856 807	6 609 326
18	Istria	42 077	7 621	4 666 767	2 997 524
19	Dubrovnik-Neretva	20 685	2 984	2 217 619	1 485 342
20	Međimurje	30 088	434	3 258 266	387 754
21	City of Zagreb	76 574	16 888	7 537 331	15 026 986
	TOTAL	**855 596**	**89 359**	**83 481 377**	**45 449 582**

B.2.2) Overview of the national building stock – service sector

The total useful floor area of the heated part of service sector buildings was taken from the IEC database. The database includes all energy performance certificates issued since 1 October 2017, while data on the certificates issued before that date were kept by the Ministry of Physical Planning, Construction and State Assets in an Excel file. All the available data were analysed to obtain the total useful floor area of the heated part of service sector buildings by type of non-residential building.

According to the *Rules governing energy audits and energy performance certification of buildings* (NN 88/17) [18], all public buildings exceeding 250 m^2 in total floor area must be energy certified. Hence, it was impossible to analyse service sector buildings with a floor area of less than 250 m^2. In addition, the analysis is based on the assumption that most other public buildings (> 250 m^2) have been energy certified.

The *Rules governing energy audits and energy performance certification of buildings* (NN 88/17) [18] define the following types of non-residential buildings in the service sector:

- office buildings,
- educational buildings,
- hospitals,
- hotels and restaurants,
- sports halls,
- wholesale and retail trade buildings,
- other non-residential buildings heated to a temperature of +18 °C or higher (e.g. traffic and communication buildings, terminals, stations, post offices, telecommunications buildings, buildings for artistic and cultural activities and entertainment, museums, libraries),

so this breakdown of non-residential buildings will be used in the rest of the Comprehensive Assessment.

As part of the Comprehensive Assessment, the total useful floor area of the heated part of all non-residential building types referred to above was determined at the level of municipalities, cities or towns, and City of Zagreb districts. However, for the sake of simplicity, the data below are presented at county level.

Table 0.4: Non-residential building stock by county

SERVICES – Overview of the national building stock									
	County name	Total useful floor area of the heated part of the building [m²]							
		Office buildings	Educational buildings	Hospitals	Hotels and restaurants	Sports halls	Trade buildings	Other non-residential buildings	**TOTAL**
1	Zagreb County	439 178.00	330 597.00	58 335.00	83 313.00	72 916.00	410 738.00	1 029 196.00	2 424 273.00
2	Krapina-Zagorje	139 913.00	193 817.00	128 938.00	78 498.00	47 453.00	82 179.00	282 023.00	952 821.00
3	Sisak-Moslavina	193 052.00	242 845.00	84 973.00	29 576.00	24 800.00	127 286.00	156 366.00	858 898.00
4	Karlovac	164 991.00	208 431.00	74 682.00	46 050.00	32 064.00	129 592.00	317 745.00	973 555.00
5	Varaždin	285 094.00	261 229.00	184 716.00	57 509.00	86 244.00	251 137.00	594 151.00	1 720 080.00
6	Koprivnica-Križevci	239 574.00	121 102.00	68 277.00	37 829.00	28 222.00	130 937.00	311 056.00	936 997.00
7	Bjelovar-Bilogora	125 226.00	151 453.00	81 822.00	28 214.00	59 490.00	78 897.00	103 660.00	628 762.00
8	Primorje-Gorski Kotar	575 784.00	451 912.00	156 662.00	908 012.00	101 885.00	566 027.00	385 501.00	3 145 783.00
9	Lika-Senj	68 406.00	66 745.00	44 510.00	78 610.00	13 424.00	50 726.00	61 880.00	384 301.00
10	Virovitica-Podravina	89 062.00	122 592.00	48 686.00	20 088.00	23 979.00	54 344.00	84 214.00	442 965.00
11	Požega-Slavonia	120 433.00	90 876.00	74 318.00	63 931.00	48 299.00	107 228.00	146 041.00	651 126.00
12	Slavonski Brod-Posavina	210 536.00	206 560.00	71 397.00	22 975.00	60 000.00	183 776.00	244 600.00	999 844.00
13	Zadar	184 313.00	203 445.00	81 901.00	319 706.00	27 072.00	330 065.00	122 741.00	1 269 243.00
14	Osijek-Baranja	456 968.00	521 663.00	117 446.00	82 585.00	114 116.00	457 405.00	494 418.00	2 244 601.00
15	Šibenik-Knin	122 987.00	142 215.00	123 598.00	155 934.00	24 024.00	140 752.00	118 545.00	828 055.00
16	Vukovar-Syrmia	170 532.00	133 363.00	60 999.00	55 056.00	51 969.00	153 545.00	139 159.00	764 623.00
17	Split-Dalmatia	567 512.00	441 916.00	216 826.00	882 296.00	146 744.00	1 813 562.00	573 969.00	4 642 825.00
18	Istria	494 671.00	269 361.00	133 074.00	1 140 597.00	76 337.00	480 889.00	512 686.00	3 107 615.00
19	Dubrovnik-Neretva	132 685.00	116 322.00	118 449.00	571 034.00	31 907.00	108 329.00	116 445.00	1 195 171.00
20	Međimurje	192 315.00	109 641.00	50 121.00	41 319.00	56 740.00	124 213.00	340 909.00	915 258.00
21	City of Zagreb	3 248 192.00	1 388 661.00	607 780.00	302 915.00	268 606.00	1 580 831.00	1 327 283.00	8 724 268.00
	TOTAL	**8 221 424.00**	**5 774 746.00**	**2 587 510.00**	**5 006 047.00**	**1 396 291.00**	**7 362 458.00**	**7 462 588.00**	**37 811 064.00**

Data presented in the table above show office buildings accounting for the largest, 21.74% share in the total useful floor area of the heated part of the non-residential building stock, followed by other non-residential buildings (19.74%), shops (19.47%), educational buildings (15.27%), hotels and restaurants (13.24%), and hospitals (6.84%), with sports halls accounting for the smallest share (3.69%).

Additionally, based on data in the IEC database, the useful floor area of the heated part of service sector buildings was determined according to the energy products used for heating, cooling and DHW preparation, as shown in the tables annexed to this document (Annexes – Part 1: Table 0.1:,

Table 0.2:, Table 0.3:). Floor area was determined according to the energy products used for each municipality, city or town, and City of Zagreb district. However, for the sake of simplicity, the tables include only county-level data.

DIO I. OVERVIEW OF HEATING AND COOLING

1 ANNUAL USEFUL ENERGY DELIVERED AND REQUIRED FOR HEATING/COOLING BY SECTOR

This chapter deals with an analysis of the 2019 energy delivered for heating, domestic hot water generation and cooling in Croatia for the following end-use consumption sectors or sub-sectors:

- **household sector:**
  - family houses,
  - multi-apartment buildings,
- **service sector:**
  - public buildings,
  - educational buildings (kindergartens, primary schools, secondary schools, universities),
  - hotels,
  - hospitals,
  - shops,
  - office buildings,
  - other,
- **industry:**
  - breakdown by key activity, e.g. cement industry, cellulose and paper, metallurgy.

It is important to note that, in the rest of the study, the terms delivered/useful **energy for heating** will include the energy for heating and domestic hot water generation!

In the household and service sectors, the terms heating/cooling refer exclusively to the heating/cooling of the building space and DHW preparation!

In the industrial sector, the terms heating/cooling refer to the heating/cooling of the building space, DHW preparation, as well as to heating / cooling / DHW preparation for industry processes.

1.1 Croatia's energy balance in 2019

The following is an overview of final energy consumption by individual sectors and by energy products, according to data provided in Energy in Croatia 2019.

1.1.1 Total final energy consumption by sector

According to the guidance provided by the **Joint Research Centre (JRC)** [1] in 2015, it is necessary to determine the useful energy required for heating and cooling in the following main sectors:

- households (residential buildings),
- services (non-residential buildings),
- industry,
- agriculture.

According to [2], the Comprehensive Assessment must include household, service and industrial sectors, as well as any other sector that individually accounts for more than 5% of the total national useful heating or cooling demand.

In accordance with Energy in Croatia 2019 [3], final energy consumption trends for the three main end-use sectors: industry, transport and general consumption between 2015 and 2019 are provided in tabular form. General consumption refers to energy consumption by households, services, agriculture and construction.

It can be observed that the share of agriculture and construction sectors in the total final energy consumption was less than 6% in 2019.

Table I.1: Final energy consumption in Croatia, 2019

FINAL ENERGY CONSUMPTION			**2015**	**2016**	**2017**	**2018**	**2019**	2019 – consumption share [%]
Industry		[GWh]	11 227.78	11 194.44	12 355.56	12 394.44	**12 427.78**	*15.49*
Transport		[GWh]	24 547.22	25 197.22	27 233.33	27 094.44	**28 288.89**	*35.26*
General consumption	Households	[GWh]	28 244.44	28 013.89	27 819.44	26 730.56	**26 030.56**	*32.44*
	Services	[GWh]	8 555.56	8 791.67	9 227.78	9 369.44	**9 458.33**	*11.79*
	Agriculture	[GWh]	2 677.78	2 716.67	2 680.56	2 733.33	**2 761.11**	*3.44*
	Construction	[GWh]	1 155.56	1 125.00	1 111.11	1 200.00	**1 266.67**	*1.58*
TOTAL			**76 408.33**	**77 038.89**	**80 427.78**	**79 522.22**	**80 233.33**	***100.00***

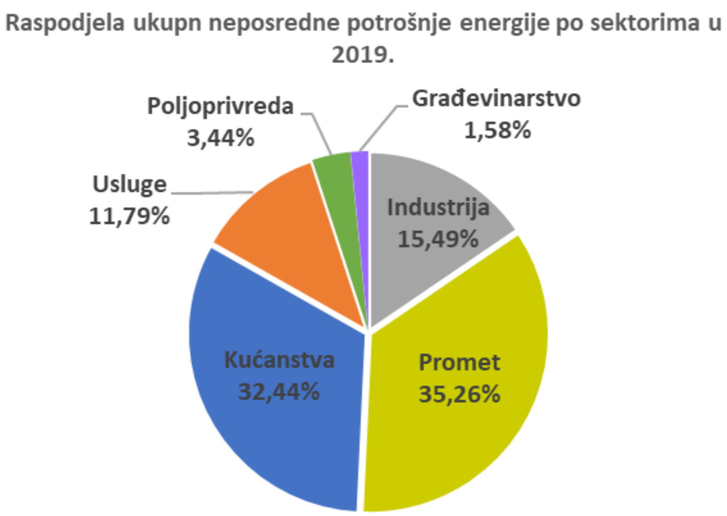


Figure I.1: Distribution of total final energy consumption by sector in 2019 (Source: Energy in Croatia 2019)

CROATIAN	ENGLISH
Raspodjela ukupn neposredne potrošnje energije po sektorima u 2019.	Distribution of total final energy consumption in 2019
Poljoprivreda	Agriculture
Građevinarstvo	Construction
Industrija	Industry
Promet	Transport
Kućanstva	Households
Usluge	Services

Accordingly, the following sectors are analysed in this Comprehensive Assessment:

- **households** (residential buildings),
- **services** (non-residential buildings),
- **industry**.

The total final energy consumption in household, service and industrial sectors amounted to **47 916.67 GWh in 2019.** The final energy consumption was the highest in the household sector (54.32%), followed by industry (25.94%) and services (19.74%).

Table I.2: Final energy consumption in Croatia, 2019

FINAL ENERGY CONSUMPTION		2015	2016	2017	2018	**2019**	2019 – consumption share [%]
Households	[GWh]	28 244.44	28 013.89	27 819.44	26 730.56	**26 030.56**	*54.32*
Services	[GWh]	8 555.56	8 791.67	9 227.78	9 369.44	**9 458.33**	*19.74*
Industry	[GWh]	11 227.78	11 194.44	12 355.56	12 394.44	**12 427.78**	*25.94*
TOTAL		48 027.78	48 000.00	49 402.78	48 494.44	**47 916.67**	***100.00***

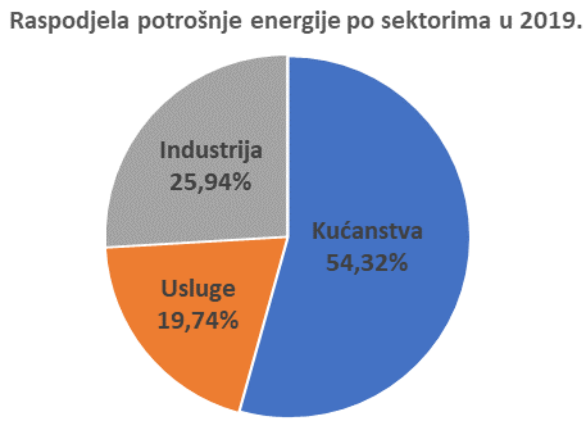


Figure I.2: Distribution of total final energy consumption by sector in 2019 (Source: Energy in Croatia 2019)

CROATIAN	ENGLISH
Raspodjela potrošnje energije po sektorima u 2019.	Distribution of energy consumption by sector in 2019
Industrija	Industry
Kućanstva	Households
Usluge	Services

In accordance with the guidance [1], **transport, agriculture and construction sectors are excluded from further analysis.**

In order to achieve greater accuracy, the three sectors (households, services and industry) are further divided into sub-sectors. For instance, a distinction is made between two sub-sectors, family houses and multi-apartment buildings, in the household sector. The energy consumption for heating purposes is typically lower in the case of a dwelling within a multi-apartment building than the energy consumption of a family house.

1.1.2 ENERGY BALANCE ACCORDING TO THE EUROSTAT METHOD – 2019

The following two balances for 2018 and 2019 are presented in Chapter 11, at the end of Energy in Croatia 2019 [3]:

- Energy balances according to the IAE method,
- Energy balances according to the Eurostat method,

specifying, among other things, the shares of individual energy products in the total final energy consumption of a particular sector (households, services, industry).

1.1.2.1 HOUSEHOLD SECTOR

In accordance with Energy in Croatia 2019 [3], total final energy consumption in the household sector amounted to **26 030.56 GWh** in 2019.

According to the Eurostat method, total final energy consumption in the household sector was **25 869.77 GWh** in 2019.

Table I.3: HOUSEHOLD SECTOR – Distribution of total final energy consumption by energy product according to the Eurostat method, 2019

HOUSEHOLD SECTOR									
Energy balance for 2019 – Eurostat	Electricity	DHS	Natural gas	Fuel oil	LPG	Woody biomass	Solar energy	Lignite	**TOTAL**
Total final energy consumption [1 000 toe[3]/a] *	533.6	109.6	459.1	51.8	48.7	1 007.9	10.8	2.9	**2 224.4**
Total final energy consumption [GWh/a]	6 205.77	1 274.65	5 339.33	602.43	566.38	11 721.88	125.60	33.73	**25 869.77**
Share [%]	*23.99*	*4.93*	*20.64*	*2.33*	*2.19*	*45.31*	*0.49*	*0.13*	***100.00***

* 1 000 toe = 11.63 GWh

It can be observed that woody biomass (45.31%) had the highest share in Croatia's 2019 consumption, followed by electricity (23.99%) and natural gas (20.64%). The share of energy delivered by district heating systems in the total final energy consumption stood at a mere 4.93%. Of the fossil fuels used in addition to natural gas, the household sector uses fuel oil (2.33%) and liquefied petroleum gas or LPG (2.19%).

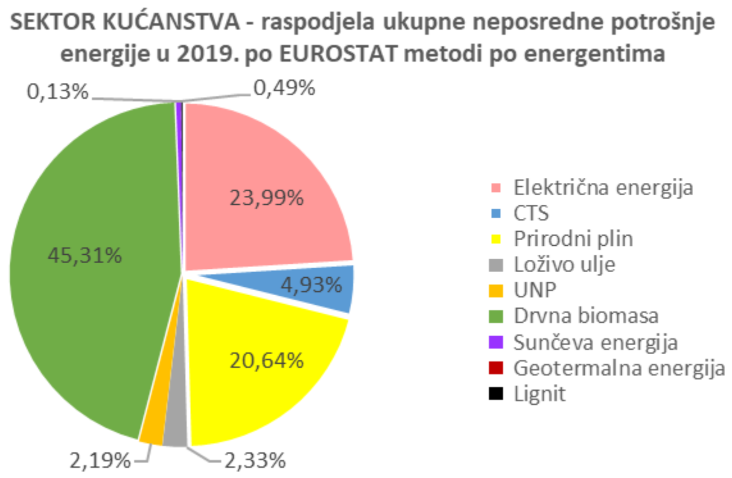


Figure I.3: HOUSEHOLD SECTOR – Distribution of the total final energy consumption by energy product according to the Eurostat method, 2019

CROATIAN	ENGLISH

[3] toe – 1 tonne of oil equivalent – 1 000 toe = 11.63 GWh.

SEKTOR KUĆANSTVA - raspodjela ukupne neposredne potrošnje energije u 2019. po EUROSTAT metodi po energentima	HOUSEHOLD SECTOR – Distribution of the total final energy consumption by energy product according to the Eurostat method, 2019
Električna energija	Electricity
CTS	DHS
Prirodni plin	Natural gas
Loživo ulje	Fuel oil
UNP	LPG
Drvna biomasa	Woody biomass
Sunčeva energija	Solar energy
Geotermalna energija	Geothermal energy
Lignit	Lignite

1.1.2.2 SERVICE SECTOR

According to Energy in Croatia 2019 [3], total final energy consumption in the service sector amounted to **9 458.33 GWh** in 2019.

Total 2019 final energy consumption in the service sector, according to the Eurostat method, was **9 579.63 GWh**.

Table I.4: SERVICE SECTOR – Distribution of the total final energy consumption by energy product according to the Eurostat method, 2019

SERVICE SECTOR									
Energy balance for 2019 – Eurostat	Electricity	DHS	Natural gas	Fuel oil	LPG	Woody biomass	Solar energy	Geothermal energy	**TOTAL**
Total final energy consumption [1 000 toe[4]/a] *	516.00	36.80	208.80	27.50	13.70	12.40	4.60	3.90	**823.70**
Total final energy consumption [GWh/a]	6 001.08	427.98	2 428.34	319.83	159.33	144.21	53.50	45.36	**9 579.63**
Share [%]	*62.64*	*4.47*	*25.35*	*3.34*	*1.66*	*1.51*	*0.56*	*0.47*	***100.00***

* 1 000 toe = 11.63 GWh

It can be observed that electricity (62.64%) had the highest share in Croatia's service sector consumption in 2019, followed by natural gas (25.35%). The share of energy delivered by district heating systems in the total final energy consumption stood at a mere 4.47%. Of the fossil fuels used in addition to natural gas, the service sector uses fuel oil (3.34%) and LPG (1.66%). The share of renewable energy delivered amounted to a total of 2.54%, with the share of woody biomass standing at 1.51%, solar energy at 0.56% and geothermal energy at 0.47%.

[4] toe – 1 tonne of oil equivalent – 1 000 toe = 11.63 GWh.

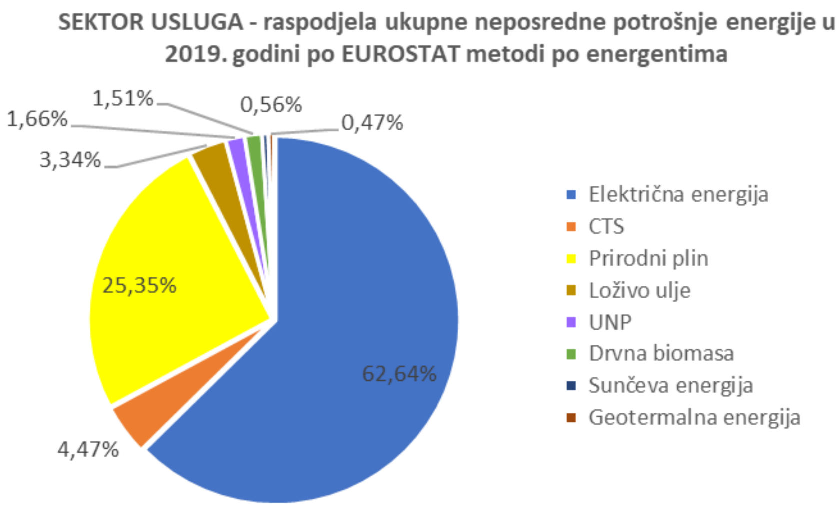


Figure I.4: SERVICE SECTOR – Distribution of the total final energy consumption by energy product according to the Eurostat method, 2019

CROATIAN	ENGLISH
SEKTOR USLUGA - raspodjela ukupne neposredne potrošnje energije u 2019. godini po EUROSTAT metodi po energentima	SERVICE SECTOR – Distribution of the total final energy consumption by energy product according to the Eurostat method, 2019
Električna energija	Electricity
CTS	DHS
Prirodni plin	Natural gas
Loživo ulje	Fuel oil
UNP	LPG
Drvna biomasa	Woody biomass
Sunčeva energija	Solar energy
Geotermalna energija	Geothermal energy

1.1.2.3 INDUSTRIAL SECTOR

According to Energy in Croatia 2019 [3], total final energy consumption in the industrial sector amounted to **12 427.78 GWh** in 2019.

Total 2019 final energy consumption in the household [sic – likely editing error, instead of: industrial] sector, according to the Eurostat method, was **13 908.32 GWh**.

Table I.5: INDUSTRIAL SECTOR – Distribution of the total final energy consumption by energy product according to the Eurostat method, 2019

Energy balance for 2019 – Eurostat	Total final energy consumption [1 000 toe/a] *	Total final energy consumption [GWh/a]	*Share [%]*
Hard coal	46.60	541.96	*3.90*
Coke	22.00	255.86	*1.84*
Lignite	7.70	89.55	*0.64*
LPG	11.10	129.09	*0.93*
Motor gasoline	3.90	45.36	*0.33*
Petroleum and jet fuel	1.70	19.77	*0.14*
Gas oil	125.00	1 453.75	*10.45*
Fuel oil	15.10	175.61	*1.26*
Other products	105.50	1 226.97	*8.82*
Natural gas	400.60	4 658.98	*33.50*
Biomass	32.20	374.49	*2.69*
Non-renewable waste	27.00	314.01	*2.26*
DHS	86.40	1 004.83	*7.22*
Electricity	311.10	3 618.09	*26.01*
TOTAL	**1 195.90**	**13 908.32**	***100.00***

* 1 000 toe = 11.63 GWh

It can be observed that natural gas (33.50%) had the highest share in Croatia's industrial sector consumption in 2019, followed by electricity (26.01%) and gas oil (10.45%). The share of energy delivered by district heating systems in the total final energy consumption stood at a mere 7.22%.

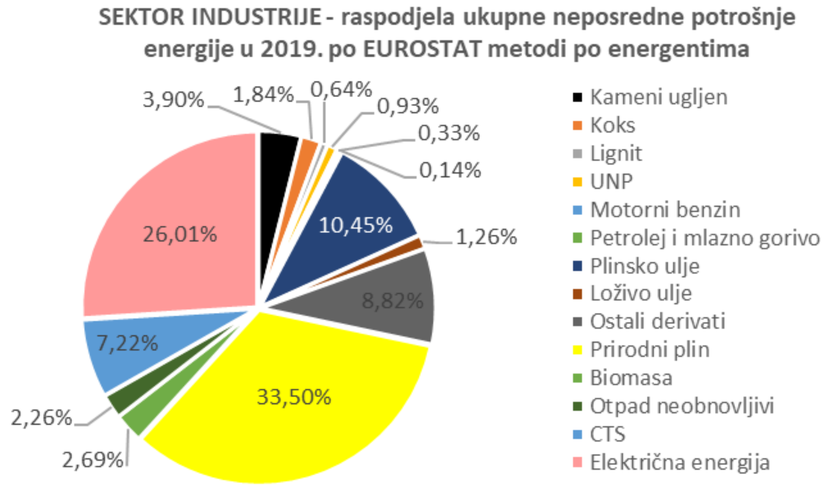


Figure I.5: INDUSTRIAL SECTOR – Distribution of the total final energy consumption by energy product according to the Eurostat method, 2019

CROATIAN	ENGLISH
SEKTOR INDUSTRIJE - raspodjela ukupne neposredne potrošnje energije u 2019. po EUROSTAT metodi po energentima	INDUSTRIAL SECTOR – Distribution of the total final energy consumption by energy product according to the Eurostat method, 2019
Kameni ugljen	Hard coal
Koks	Coke
Lignit	Lignite
UNP	LPG

Motorni benzin	Motor gasoline
Petrolej i mlazno gorivo	Petroleum and jet fuel
Plinsko ulje	Gas oil
Loživo ulje	Fuel oil
Ostali derivati	Other products
Prirodni plin	Natural gas
Biomasa	Biomass
Otpad neobnovljivi	Non-renewable waste
CTS	DHS
Električna energija	Electricity

1.2 ANNUAL ENERGY DELIVERED FOR HEATING/COOLING BY SECTOR

The sectoral distribution of the annual energy delivered for heating/cooling in Croatia in 2019 is provided in tabular form. It is evident that most energy for heating/cooling purposes was delivered to the household sector (62.46%), followed by the industrial sector (20.07%) and the service sector (17.55%).

Table I.6: Total annual energy delivered for heating/cooling in Croatia by sector, 2019

Sector name	Total annual energy delivered for heating/cooling [GWh/a]	*Share [%]*
HOUSEHOLDS	20 927.63	*62.46*
SERVICES	5 843.57	*17.44*
INDUSTRY	6 733.98	*20.10*
TOTAL	**33 505.18**	***100.00***

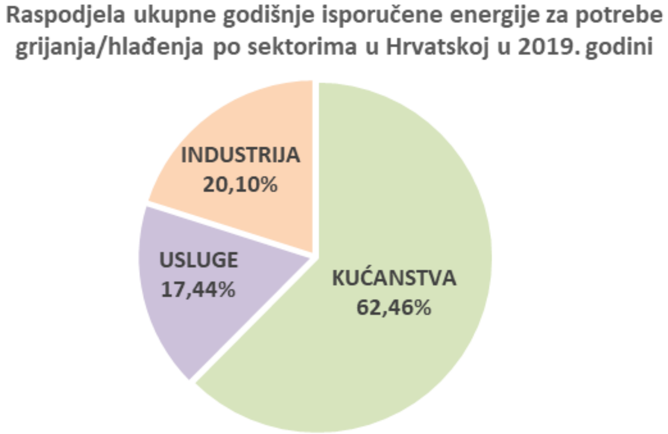


Figure I.6: Distribution of the total annual energy delivered for heating/cooling in Croatia by sector, 2019

CROATIAN	ENGLISH
Raspodjela ukupne godišnje isporučene energije za potrebe grijanja/hlađenja po sektorima u Hrvatskoj u 2019. godini	Distribution of the total annual energy delivered for heating/cooling in Croatia by sector, 2019
INDUSTRIJA	INDUSTRY
KUĆANSTVA	HOUSEHOLDS
USLUGE	SERVICES

1.2.1 HOUSEHOLD SECTOR

The household sector refers to residential buildings, comprising family houses and multi-apartment buildings.

NOTE: Heating refers to space heating and domestic hot water generation!

1.2.1.1 TOTAL ENERGY DELIVERED FOR HEATING/COOLING

The total energy delivered to Croatia's household sector was modelled down to the level of individual municipalities, cities or towns, and City of Zagreb districts (17 city districts), including the following energy products in the model:

- electricity,
- DHS (district heating system),
- natural gas,
- fuel oil,
- liquefied petroleum gas,
- firewood,
- wood pellets / wood chips / briquettes,
- solar energy (solar collectors),
- energy taken from the environment using heat pumps.

The annual consumption of lignite was excluded from the model because of the unknown distribution of lignite consumption at the level of individual municipalities, cities or towns, and City of Zagreb districts. Also, the model of delivered energy includes the energy taken from the environment using heat pumps, which is not included in the total 2019 final energy consumption of the household sector according to the Eurostat method.

The total 2019 final energy consumption in the household sector was modelled at **26 088.45 GWh**. This amount differs slightly from the total final consumption in the household sector according to the Eurostat method (25 869.77 GWh) precisely due to the exclusion of lignite and inclusion of energy taken from the environment using heat pumps.

Only the energy delivered to the household sector for space heating/cooling and DHW preparation was excluded from the total delivered energy in the next step.

<u>MODEL OF TOTAL ANNUAL ENERGY DELIVERED FOR SPACE HEATING WITHOUT RENEWABLE ENERGY TAKEN FROM THE ENVIRONMENT USING HEAT PUMPS</u>

The total 2019 final energy consumption in the household sector was modelled at **25 920.18 GWh** (excluding lignite consumption and energy taken from the environment using heat pumps).

The model put the total annual energy delivered for space heating/cooling and DHW preparation at **20 759.36 GWh**, which means that **80.09% of the total energy delivered to the household sector** in Croatia is consumed **for space heating/cooling and DHW preparation** (heating/cooling). The remaining energy delivered is used for other non-heating energy needs (cooking, lighting, operation of electric household appliances).

Table I.7: HOUSEHOLD SECTOR – Distribution of total energy delivered (without renewable energy for space heating taken from the environment using heat pumps)

HOUSEHOLD SECTOR	Family houses	Multi-apartment buildings	TOTAL	*Share [%]*
Annual energy delivered for space heating/cooling and DHW preparation [GWh/a]	14 400.06	6 359.30	**20 759.36**	**80.09**
Annual energy delivered for other energy needs (cooking, lighting, operation of el. appliances) [GWh/a]	3 464.88	1 695.94	**5 160.82**	**19.91**
Total annual energy delivered [GWh/a]	**17 864.94**	**8 055.24**	**25 920.18**	**100.00**
Share [%]	*68.92*	*31.08*	***100.00***	

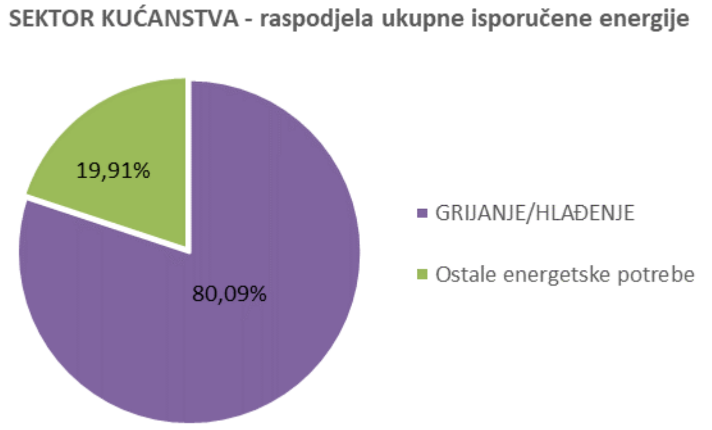


Figure I.7: HOUSEHOLD SECTOR – Distribution of total energy delivered

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela ukupne isporučene energije	HOUSEHOLD SECTOR – Distribution of total energy delivered
GRIJANJE/HLAĐENJE	HEATING/COOLING
Ostale energetske potrebe	Other energy needs

Family houses use 69.37% of the total energy delivered for space heating/cooling and DHW preparation, while the remaining 30.63% is used by multi-apartment buildings, as expected in view of the ratio of the total useful floor area of the heated part of family houses to that of multi-apartment buildings (see Table I.8:).

Table I.8: HOUSEHOLD SECTOR – Distribution of the total energy delivered for space heating/cooling and DHW preparation by building type

HOUSEHOLD SECTOR	Family houses	Multi-apartment buildings	TOTAL
Annual energy delivered for space heating/cooling and DHW preparation [GWh/a]	14 400.06	6 359.30	**20 759.36**
Share [%]	*69.37*	*30.63*	***100.00***

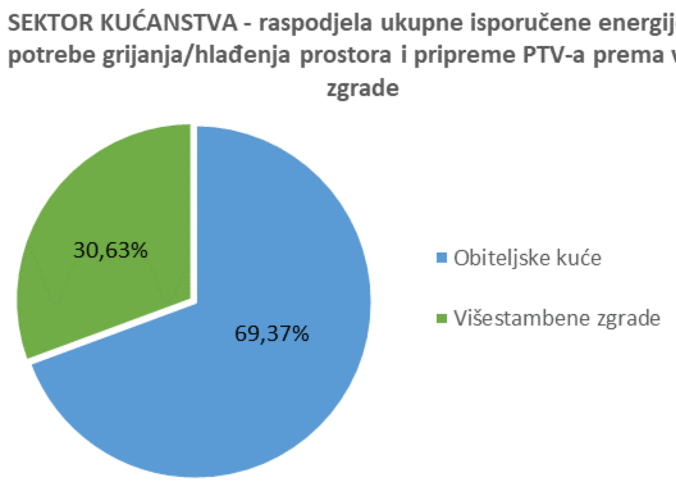


Figure I.8: HOUSEHOLD SECTOR – Distribution of the total energy delivered for space heating/cooling and DHW preparation by building type

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela ukupne isporučene energije za potrebe grijanja/hlađenja prostora i pripreme PTV-a prema vrsti zgrade	HOUSEHOLD SECTOR – Distribution of the total energy delivered for space heating/cooling and DHW preparation by building type
Obiteljske kuće	Family houses
Višestambene zgrade	Multi-apartment buildings

Given that delivered energy in the templates (in Excel file format) prepared by the European Commission includes:

- all energy entering the building through the system boundary (electricity, natural gas, LPG, fuel oil),
- renewable energy entering through the system boundary (e.g. biomass),
- energy from renewable energy sources generated on the site of the building (e.g. heat generated on-site using solar collectors, heat taken from the environment using heat pumps),

heat taken from the environment using heat pumps also needs to be included in the balance of delivered energy. When it comes to heat pumps, only the electricity used to drive compression heat pumps is currently included in the balance.

Where electricity is used for space heating in the household sector, it is important for the model to differentiate between direct electric resistance space heating (electric heaters, electric boilers) and space heating using compression heat pumps. Each municipality, city or town was assigned to the coastal or the continental part of Croatia to model electricity for space heating purposes. Percentage shares were obtained for the use of compression heat pumps and direct electric resistance space heating in the household sector based on the surveys conducted.

When it comes to electricity used for space heating, around 70% of the electricity consumed in the coastal part of Croatia is generated by compression heat pumps, while 30% is accounted for by the standard electric resistance heating system (electric heaters, electric boilers). In the continental part of Croatia, this ratio is somewhat less favourable. The distribution of electricity consumption for space heating by technology used is certainly important for determining the annual thermal energy needs for heating.

Table I.9: HOUSEHOLD SECTOR – Distribution of the electricity consumption for space heating

HOUSEHOLDS	Share of electricity consumption for space heating, [%]	
	Space heating – compression heat pump	Space heating – direct electric resistance heating
Continental Croatia	3.00	97.00
Coastal Croatia	18.83	81.17

Table I.10: HOUSEHOLD SECTOR – Distribution of the electricity consumption for space heating

HOUSEHOLD SECTOR	Total annual energy delivered for space heating [GWh/a]				
	Family houses		Multi-apartment buildings		**TOTAL**
	Space heating	Space heating – HP	Space heating	Space heating – HP	
Electricity	71.94	115.01	93.83	197.44	**478.23**

In the rest of the study, delivered energy will include all the forms of energy mentioned, also including the energy for space heating taken from the environment using heat pumps.

MODEL OF TOTAL ANNUAL DELIVERED ENERGY WITH RENEWABLE ENERGY FOR SPACE HEATING TAKEN FROM THE ENVIRONMENT USING HEAT PUMPS

The total 2019 final energy consumption in the household sector was modelled at **26 088.45 GWh** (excluding lignite consumption and including energy taken from the environment using heat pumps).

The total annual energy delivered for space heating/cooling and DHW preparation obtained by the model was **20 927.63 GWh**, which means that **80.22% of the total energy delivered to the household sector** in Croatia is consumed **for space heating/cooling and DHW preparation** (heating/cooling). The remaining energy delivered is used for other non-heating energy needs (cooking, lighting, operation of electric household appliances).

Table I.11: HOUSEHOLD SECTOR – Distribution of the total energy delivered (with renewable energy for space heating taken from the environment using heat pumps)

HOUSEHOLD SECTOR	Family houses	Multi-apartment buildings	**TOTAL**	*Share [%]*
Annual energy delivered for space heating/cooling and DHW preparation [GWh/a]	14 462.08	6 465.55	20 927.63	80.22
Annual energy delivered for other energy needs (cooking, lighting, operation of el. appliances) [GWh/a]	3 464.88	1 695.94	5 160.82	19.78
Total annual energy delivered [GWh/a]	17 926.96	8 161.49	26 088.45	100.00
Share [%]	68.72	31.28	100.00	

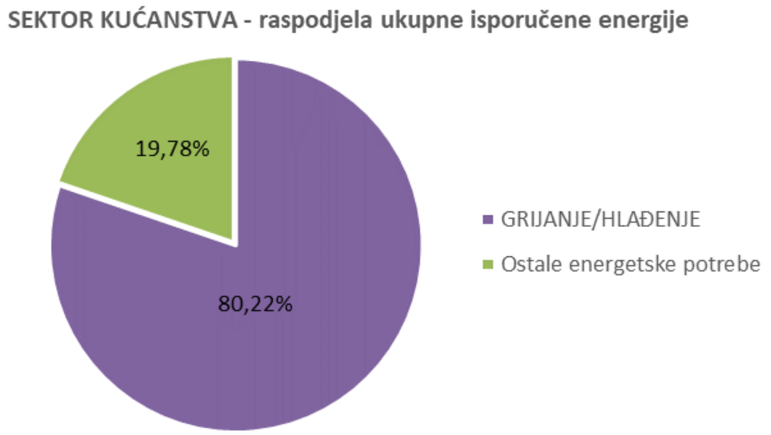


Figure I.9: HOUSEHOLD SECTOR – Distribution of the total energy delivered (with renewable energy for space heating taken from the environment using heat pumps)

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela ukupne isporučene energije	HOUSEHOLD SECTOR – Distribution of total energy delivered
GRIJANJE/HLAĐENJE	HEATING/COOLING
Ostale energetske potrebe	Other energy needs

Family houses use 69.11% of the total energy delivered for space heating/cooling and DHW preparation, while the remaining 30.89% is used by multi-apartment buildings, as expected given the total useful floor area of the heated part of family houses compared to that of multi-apartment buildings (see Table I.12:).

Table I.12: HOUSEHOLD SECTOR – Distribution of the total energy delivered for space heating/cooling and DHW preparation DHW preparation (with renewable energy for space heating taken from the environment using heat pumps)

HOUSEHOLD SECTOR	Family houses	Multi-apartment buildings	**TOTAL**
Annual energy delivered for space heating/cooling and DHW preparation [GWh/a]	14 462.08	6 465.55	**20 927.63**
Share [%]	*69.11*	*30.89*	***100.00***

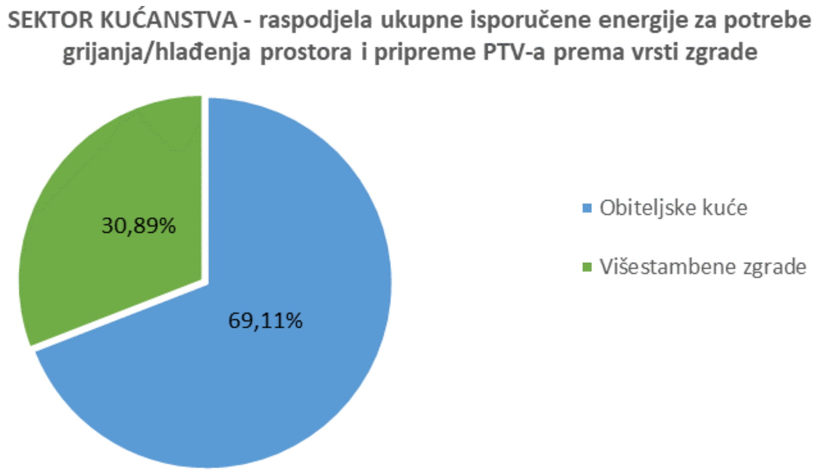


Figure I.10: HOUSEHOLD SECTOR – Distribution of the total energy delivered for space heating/cooling and DHW preparation DHW preparation (with renewable energy for space heating taken from the environment using heat pumps)

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela ukupne isporučene energije za potrebe grijanja/hlađenja prostora i pripreme PTV-a prema vrsti zgrade	HOUSEHOLD SECTOR – Distribution of the total energy delivered for space heating/cooling and DHW preparation by building type
Obiteljeske kuće	Family houses
Višestambene zgrade	Multi-apartment buildings

1.2.1.2 DISTRIBUTION OF TOTAL ENERGY DELIVERED FOR HEATING/COOLING BY PURPOSE AND SYSTEM TECHNOLOGY

DISTRIBUTION OF TOTAL ENERGY DELIVERED FOR HEATING/COOLING BY PURPOSE AND SYSTEM TECHNOLOGY, WITH RENEWABLE ENERGY FOR SPACE HEATING TAKEN FROM THE ENVIRONMENT USING HEAT PUMPS

An analysis of the total energy delivered by purpose (heating / cooling / DHW preparation) produces the following distribution of **20 927.63 GWh** in total annual energy delivered for space heating/cooling and DHW preparation in the household sector:

- **79.44% for space heating** (16 625.51 GWh/a),
- **1.48% for space cooling** (310.68 GWh/a),
- **19.07% for DHW preparation** (3 991.44 GWh/a).

Table I.13: HOUSEHOLD SECTOR – Distribution of total energy delivered by purpose (with renewable energy taken from the environment using heat pumps for space heating)

2019	**HOUSEHOLDS**			**TOTAL**	*Share [%]*
Annual energy delivered [GWh/a]	Space heating	Space cooling	DHW preparation		
Electricity	399.49	310.68	1 809.42	**2 519.58**	*12.04*
Electricity – heat pump	84.13	0.00	0.00	**84.13**	*0.40*
DHS	953.34	0.00	321.31	**1 274.65**	*6.09*
Natural gas	3 978.19	0.00	935.67	**4 913.86**	*23.48*
Fuel oil	583.54	0.00	18.89	**602.43**	*2.88*
LPG	35.50	0.00	20.38	**55.88**	*0.27*
Firewood	9 759.04	0.00	672.21	**10 431.25**	*49.84*
Wood pellets / wood chips / briquettes	646.95	0.00	105.01	**751.96**	*3.59*
Solar energy (solar collectors)	17.06	0.00	108.55	**125.60**	*0.60*
RES taken from the environment using heat pumps	168.27	0.00	0.00	**168.27**	*0.80*
TOTAL	**16 625.51**	**310.68**	**3 991.44**	**20 927.63**	***100.00***
Share [%]	*79.44*	*1.48*	*19.07*	***100.00***	

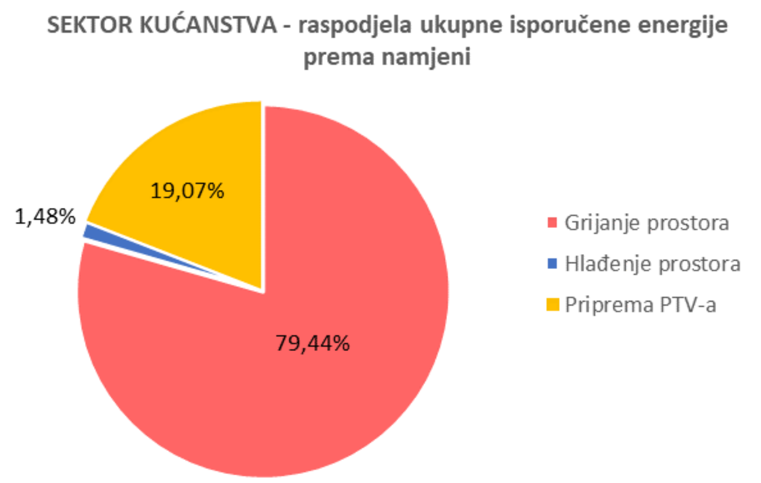


Figure I.11: HOUSEHOLD SECTOR – Distribution of total energy delivered by purpose (with renewable energy taken from the environment using heat pumps for space heating)

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela ukupne isporučene energije prema namjeni	HOUSEHOLD SECTOR – Distribution of total energy delivered by purpose
Grijanje prostora	Space heating
Hlađenje prostora	Space cooling
Priprema PTV-a	DHW preparation

Electricity, DHS, natural gas, fuel oil, LPG, woody biomass (log wood, pellets/chips/briquettes) are used for **space heating in buildings** in the household sector. Heating of building space in the household sector is decentralised (individual split air-conditioning, individual stoves) and centralised (boilers, heat pumps, DHS). The distribution of the total electricity delivered for space heating by type of building is provided in the table.

Furthermore, 56.50% of the total energy delivered for space heating in the household sector is consumed using a room-based, that is, a decentralised space heating system (individual stoves, split air conditioning). Merely 43.50% of the total energy delivered for space heating is consumed using district heating systems, so decentralised (room-based) space heating systems still account for a large share in Croatia.

Table I.14: HOUSEHOLD SECTOR – Distribution of total energy delivered for space heating by type of space heating system technology (with renewable energy taken from the environment using heat pumps for space heating)

HOUSEHOLD SECTOR	Total annual energy delivered for space heating [GWh/a]			*Share [%]*
	room-based	centralised	**TOTAL**	
Family houses	6 823.25	4 871.51	**11 694.76**	*70.34*
Multi-apartment buildings	2 570.96	2 359.79	**4 930.75**	*29.66*
TOTAL	9 394.21	7 231.30	**16 625.51**	*100.00*
Share [%]	*56.50*	*43.50*	*100.00*	

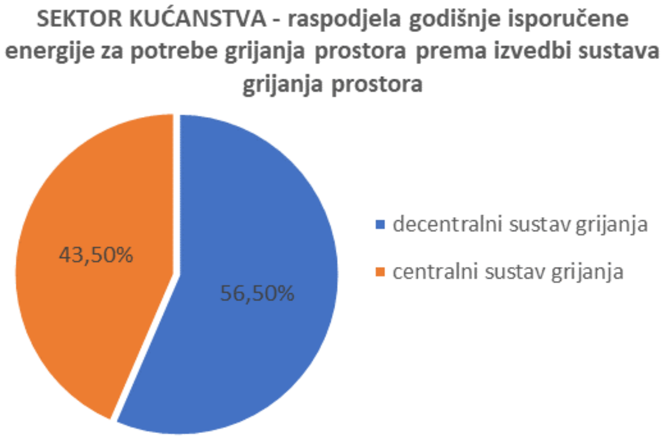


Figure I.12: HOUSEHOLD SECTOR – Distribution of total energy delivered for space heating by type of space heating system technology (with renewable energy taken from the environment using heat pumps for space heating)

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela godišnje isporučene energije za potrebe grijanja prostora prema izvedbi sustava grijanja prostora	HOUSEHOLD SECTOR – Distribution of total energy delivered for space heating by type of space heating system technology
decentralni sustav grijanja	decentralised heating system
centralni sustav grijanja	DHS

In the household sector, only electricity is used for **space cooling in buildings**, and space cooling is decentralised (individual split air conditioning) or centralised.

Approximately 85% of the total energy delivered for space cooling in the household sector is consumed using a room-based, that is, a decentralised space cooling (individual air conditioning), so decentralised (room-based) space cooling systems still account for a large share in Croatia.

Table I.15: HOUSEHOLD SECTOR – Distribution of total energy delivered for space cooling by type of space cooling system technology

HOUSEHOLD SECTOR	Total annual energy delivered for space cooling [GWh/a]			*Share [%]*
	room-based	centralised	**TOTAL**	

Family houses	157.68	27.83	**185.50**	*59.71*
Multi-apartment buildings	106.40	18.78	**125.17**	*40.29*
TOTAL	264.08	46.60	**310.68**	*100.00*
Share [%]	*85.00*	*15.00*	*100.00*	

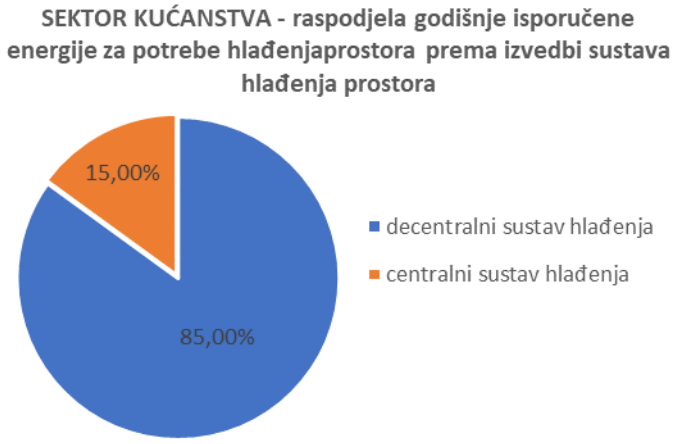


Figure I.13: HOUSEHOLD SECTOR – Distribution of total energy delivered for space cooling by type of space cooling system technology

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela godišnje isporučene energije za potrebe hlađenja prostora prema izvedbi sustava hlađenja prostora	HOUSEHOLD SECTOR – Distribution of annual energy delivered for space cooling by type of space cooling system technology
decentralni sustav grijanja	decentralised cooling system
centralni sustav grijanja	centralised cooling system

Domestic hot water in the household sector is generated using decentralised and centralised systems. The distribution of the total electricity delivered for DHW preparation by type of building is provided in the table.

Family houses use 64.68% of the total energy delivered for DHW preparation, while the remaining 35.32% is used by multi-apartment buildings.

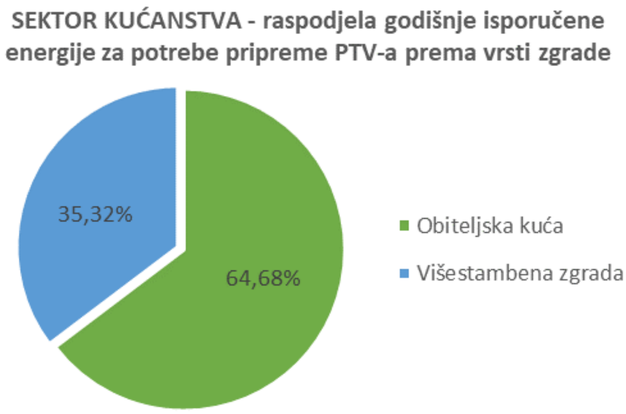


Figure I.14: HOUSEHOLD SECTOR – Distribution of total energy delivered for DHW preparation by building type

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela godišnje isporučene energije za potrebe pripreme PTV-a prema vrsti zgrade	HOUSEHOLD SECTOR – Distribution of annual energy delivered for DHW preparation by building type
Obiteljska kuća	Family houses
Višestambena zgrada	Multi-apartment buildings

In Croatia, decentralised DHW systems prevail, so 54.43% of the total annual energy delivered for DHW preparation is accounted for decentralised DHW systems and the remaining 45.57% by DHS-based DHW systems.

Table I.16: HOUSEHOLD SECTOR – Distribution of total energy delivered for DHW preparation by DHW system technology

HOUSEHOLD SECTOR	Total annual energy delivered for DHW preparation [GWh/a]			*Share [%]*
	room-based	centralised	**TOTAL**	
Family houses	1 494.00	1 087.81	**2 581.81**	*64.68*
Multi-apartment buildings	678.69	730.94	**1 409.63**	*35.32*
TOTAL	2 172.69	1 818.75	**3 991.44**	*100.00*
Share [%]	*54.43*	*45.57*	*100.00*	

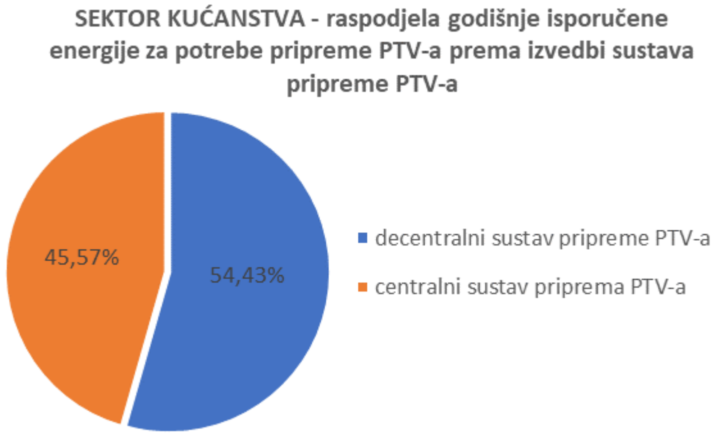


Figure I.15: HOUSEHOLD SECTOR – Distribution of total energy delivered for DHW preparation by DHW system technology

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela godišnje isporučene energije za potrebe pripreme PTV-a prema izvedbi sustava pripreme PTV-a	HOUSEHOLD SECTOR – Distribution of annual energy delivered for DHW preparation by DHW system technology
decentralni sustav pripreme PTV-a	decentralised DHW system
centralni sustav pripreme PTV-a	centralised DHW system

1.2.1.3 DISTRIBUTION OF TOTAL ENERGY DELIVERED FOR HEATING/COOLING BY ENERGY PRODUCT AND COUNTY

DISTRIBUTION OF TOTAL ENERGY DELIVERED FOR HEATING/COOLING BY ENERGY PRODUCT AND COUNTY, WITH RENEWABLE ENERGY TAKEN FROM THE ENVIRONMENT USING HEAT PUMPS

A distribution of total annual energy delivered for space heating/cooling and DHW preparation in the household sector by county and energy products analysed is provided in tabular form (Table I.18:).

The top six counties ranked by consumption of the total annual energy delivered for space heating/cooling and DHW preparation in the household sector, and separately of energy delivered for space heating, space cooling and DHW preparation (in the order of size from the top down) is shown in the table below.

Table I.17: HOUSEHOLD SECTOR – Ranking of counties (top six) by consumption of total annual energy delivered for space heating/cooling and DHW preparation (with renewable energy taken from the environment using heat pumps for space heating)

Ranking of counties (top six) by consumption of total annual energy delivered for space heating/cooling and DHW preparation in the household sector (in the order of size from the top down)				
	SPACE HEATING/COOLING AND DHW PREPARATION SYSTEM	**SPACE HEATING SYSTEM**	**SPACE COOLING SYSTEM**	**DHW SYSTEM**
1.	**City of Zagreb (15.74%)**	City of Zagreb (15.06%)	City of Zagreb (19.33%)	City of Zagreb (18.27%)
2.	**Zagreb County (8.11%)**	Zagreb County (8.27%)	Split-Dalmatia (8.76%)	Split-Dalmatia (9.95%)
3.	**Split-Dalmatia (7.57%)**	Osijek-Baranja (7.72%)	Zagreb County (7.48%)	Zagreb County (7.50%)
4.	**Osijek-Baranja (7.56%)**	Split-Dalmatia (6.98%)	Osijek-Baranja (7.36%)	Primorje-Gorski Kotar(6.93%)
5.	**Primorje-Gorski Kotar (6.79%)**	Primorje-Gorski Kotar (6.75%)	Primorje-Gorski Kotar (7.20%)	Osijek-Baranja (6.91%)
6.	**Sisak-Moslavina (5.07%)**	Sisak-Moslavina (5.27%)	Istria (5.34%)	Istria (4.86%)

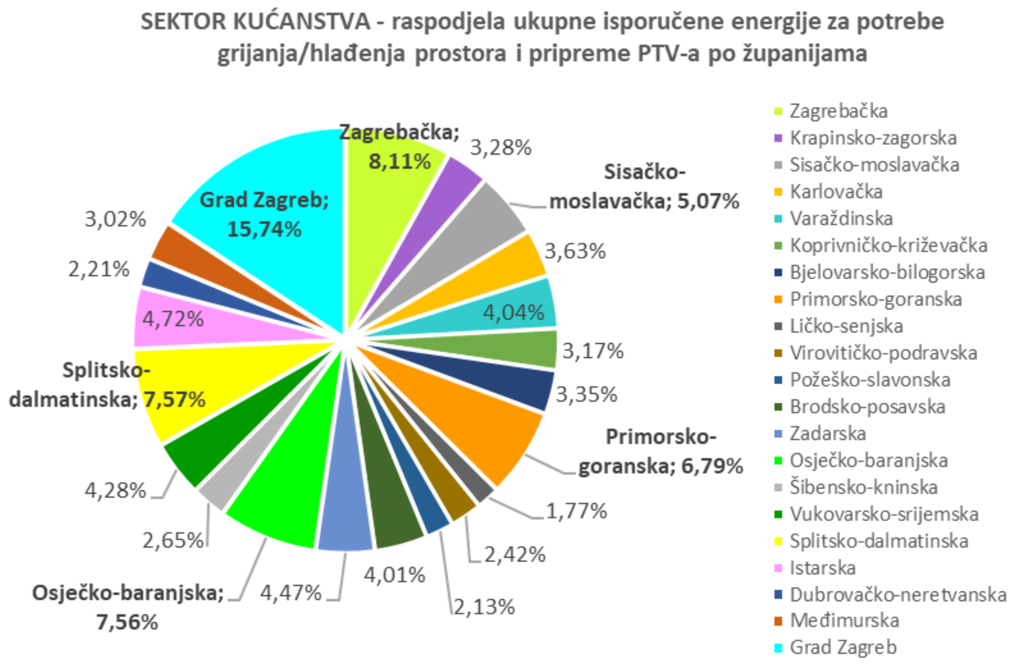


Figure I.16: HOUSEHOLD SECTOR – Distribution of total energy delivered for space heating/cooling and DHW preparation by county (with renewable energy taken from the environment using heat pumps for space heating)

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela ukupne isporučene energije za potrebe grijanja/hlađenja prostora i pripreme PTV-a po županijama	HOUSEHOLD SECTOR – Distribution of total energy delivered for space heating/cooling and DHW preparation by county
Zagrebačka	Zagreb County
Krapinsko-zagorska	Krapina-Zagorje
Sisačko-moslavačka	Sisak-Moslavina
Karlovačka	Karlovac
Varaždinska	Varaždin
Koprivničko-križevačka	Koprivnica-Križevci
Bjelovarsko-bilogorska	Bjelovar-Bilogora

Primorsko-goranska	Primorje-Gorski Kotar
Ličko-senjska	Lika-Senj
Virovitičko-podravska	Virovitica-Podravina
Požeško-slavonska	Požega-Slavonia
Brodsko-posavska	Slavonski Brod-Posavina
Zadarska	Zadar
Osječko-baranjska	Osijek-Baranja
Šibensko-kninska	Šibenik-Knin
Vukovarsko-srijemska	Vukovar-Syrmia
Splitsko-dalmatinska	Split-Dalmatia
Istarska	Istria
Dubrovačko-neretvanska	Dubrovnik-Neretva
Međimurska	Međimurje
Grad Zagreb	City of Zagreb

The use of firewood (49.84%) prevails in Croatia's household sector, followed by natural gas (23.48%) and electricity (12.44%). Just 6.09% of the total energy delivered to the household sector for space heating/cooling purposes and DHW preparation was delivered by district heating systems, with the energy going exclusively to multi-residential buildings. Thermal energy generated in solar collectors for DHW preparation or space heating is negligible in view of the potential of solar radiation in the territory of Croatia. Of renewable energy sources, wood pellets / wood chips / briquettes are used, but their share in the total energy delivered for space heating/cooling and DHW preparation stands at a modest 3.59%. The share of renewable energy taken from the environment using heat pumps is 0.80%.

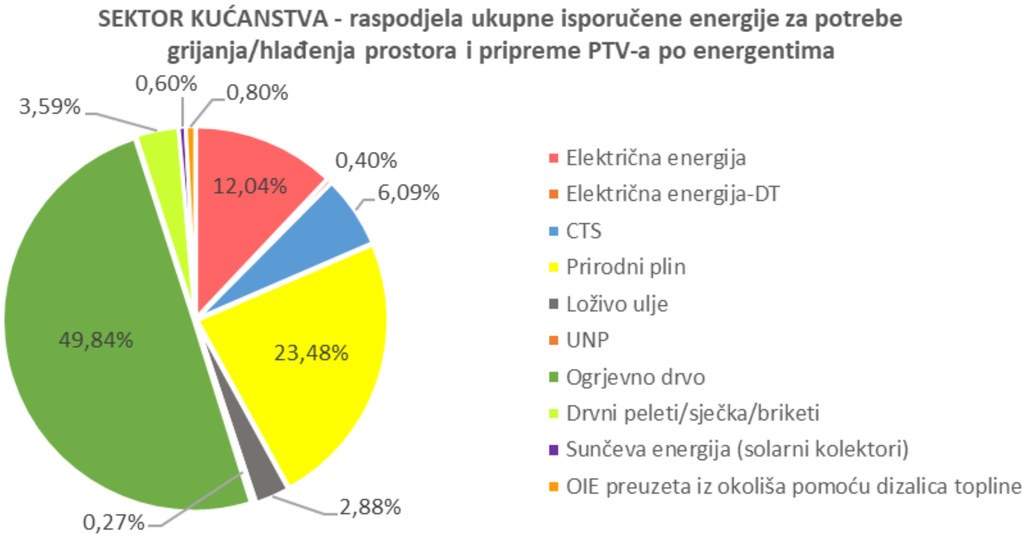


Figure I.17: HOUSEHOLD SECTOR – Distribution of total energy delivered for space heating/cooling and DHW preparation by energy product (with renewable energy taken from the environment using heat pumps for space heating)

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela ukupne isporučene energije za potrebe grijanja/hlađenja prostora i pripreme PTV-a po energentima	HOUSEHOLD SECTOR – Distribution of total energy delivered for space heating/cooling and DHW preparation by energy product
Električna energija	Electricity
Električna energija-DT	Electricity – heat pump
CTS	DHS
Prirodni plin	Natural gas
Loživo ulje	Fuel oil
UNP	LPG
Ogrjevno drvo	Firewood
Drvni peleti/sječka/briketi	Wood pellets / wood chips / briquettes
Sunčeva energija (solarni kolektori)	Solar energy (solar collectors)
OIE preuzeta iz okoliša pomoću dizalica topline	RES taken from the environment using heat pumps

Table I.18: HOUSEHOLD SECTOR – Distribution of total energy delivered for space heating/cooling and DHW preparation by county and energy product (with renewable energy taken from the environment using heat pumps for space heating)

SECTOR HOUSEHOLDS – Total annual energy delivered for space heating/cooling and DHW preparation [GWh/a]												
	County	Electricity	DHS	Natural gas	Fuel oil	LPG	Firewood	Wood pellets / wood chips / briquettes	Solar energy (solar collectors)	RES taken from the environment using heat pumps	**TOTAL**	*Share [%]*
1	Zagreb County	132.57	65.17	576.72	45.69	5.92	804.47	59.92	6.46	0.16	**1 697.08**	*8.11*
2	Krapina-Zagorje	61.76	0.00	186.85	1.57	1.39	400.14	32.02	3.43	0.03	**687.20**	*3.28*
3	Sisak-Moslavina	103.72	40.84	87.58	16.94	2.62	743.61	59.93	5.11	0.11	**1 060.47**	*5.07*
4	Karlovac	82.98	52.74	12.30	25.45	0.16	545.48	36.91	3.46	0.15	**759.63**	*3.63*
5	Varaždin	64.05	3.70	382.81	5.91	0.00	358.46	27.18	3.24	0.07	**845.42**	*4.04*
6	Koprivnica-Križevci	54.44	0.00	181.27	1.44	0.00	393.95	29.66	2.90	0.01	**663.67**	*3.17*
7	Bjelovar-Bilogora	60.45	0.00	153.78	2.10	2.43	436.89	41.75	3.57	0.01	**700.97**	*3.35*
8	Primorje-Gorski Kotar	273.07	45.72	62.91	114.19	11.57	829.70	45.23	11.37	27.46	**1 421.23**	*6.79*
9	Lika-Senj	38.66	0.00	0.00	10.05	0.00	301.11	19.06	1.73	0.78	**371.38**	*1.77*
10	Virovitica-Podravina	44.69	2.10	100.82	0.47	0.46	326.46	28.92	2.78	0.00	**506.71**	*2.42*
11	Požega-Slavonia	39.25	8.99	93.07	1.19	0.27	277.91	23.59	2.11	0.01	**446.39**	*2.13*
12	Slavonski Brod-Posavina	78.23	14.35	172.44	8.51	1.00	516.53	44.33	4.10	0.04	**839.54**	*4.01*
13	Zadar	165.12	0.00	6.93	50.38	2.76	650.71	36.34	8.92	15.12	**936.28**	*4.47*
14	Osijek-Baranja	126.15	131.93	520.89	6.94	1.01	722.47	63.99	8.14	0.39	**1 581.89**	*7.56*
15	Šibenik-Knin	107.98	0.00	0.31	29.84	1.01	379.74	21.10	5.18	10.06	**555.24**	*2.65*
16	Vukovar-Syrmia	82.54	35.06	219.17	4.86	2.47	498.90	46.71	4.87	0.19	**894.78**	*4.28*
17	Split-Dalmatia	520.78	0.00	5.76	78.71	4.02	835.63	47.01	20.79	71.46	**1 584.14**	*7.57*
18	Istria	197.47	0.00	90.01	102.87	12.64	529.31	26.88	9.38	20.09	**988.65**	*4.72*
19	Dubrovnik-Neretva	148.52	0.00	0.00	28.00	3.61	241.27	13.42	6.13	21.11	**462.07**	*2.21*
20	Međimurje	38.42	0.00	339.59	2.63	0.06	233.65	15.26	1.87	0.02	**631.50**	*3.02*
21	City of Zagreb	182.85	874.04	1 720.63	64.70	2.48	404.85	32.75	10.07	1.01	**3 293.40**	*15.74*
	TOTAL	**2 603.72**	**1 274.65**	**4 913.86**	**602.43**	**55.88**	**10 431.25**	**751.96**	**125.60**	**168.27**	**20 927.63**	***100.00***
	Share [%]	*12.44*	*6.09*	*23.48*	*2.88*	*0.27*	*49.84*	*3.59*	*0.60*	*0.80*	***100.00***	

The following counties are the top consumers of energy **for space heating in the household sector**:

1. City of Zagreb (15.06%),
2. Zagreb County (8.27%),
3. Osijek-Baranja (7.72%),
4. Split-Dalmatia (6.98%),
5. Primorje-Gorski Kotar (6.75%),
6. Sisak-Moslavina (5.27%).

Table I.19: HOUSEHOLD SECTOR – Distribution of total energy delivered for space heating by building type and county (with renewable energy taken from the environment using heat pumps for space heating)

HOUSEHOLD SECTOR		Total annual energy delivered for space heating [GWh/a]					
		Family houses		Multi-apartment buildings		**TOTAL**	*Share [%]*
	County	room-based	centralised	room-based	centralised		
1	Zagreb County	454.10	703.10	114.80	102.50	**1 374.51**	*8.27*
2	Krapina-Zagorje	282.61	228.67	30.17	13.40	**554.85**	*3.34*
3	Sisak-Moslavina	507.94	242.53	66.01	60.29	**876.76**	*5.27*
4	Karlovac	238.76	242.74	89.12	57.11	**627.73**	*3.78*
5	Varaždin	233.05	345.76	31.10	65.99	**675.90**	*4.07*
6	Koprivnica-Križevci	283.33	214.72	23.56	27.95	**549.56**	*3.31*
7	Bjelovar-Bilogora	352.17	164.86	25.40	32.70	**575.13**	*3.46*
8	Primorje-Gorski Kotar	287.71	292.52	480.90	61.25	**1 122.38**	*6.75*
9	Lika-Senj	166.95	75.08	69.01	3.75	**314.79**	*1.89*
10	Virovitica-Podravina	293.13	92.05	12.86	17.76	**415.80**	*2.50*
11	Požega-Slavonia	210.37	113.86	20.80	20.02	**365.04**	*2.20*
12	Slavonski Brod-Posavina	366.96	227.13	61.69	21.73	**677.50**	*4.08*
13	Zadar	411.35	79.94	254.78	5.35	**751.42**	*4.52*
14	Osijek-Baranja	642.32	339.52	94.69	206.77	**1 283.31**	*7.72*
15	Šibenik-Knin	258.91	46.87	129.55	2.17	**437.49**	*2.63*
16	Vukovar-Syrmia	455.60	172.01	30.27	61.03	**718.91**	*4.32*
17	Split-Dalmatia	547.44	137.65	468.39	6.43	**1 159.92**	*6.98*
18	Istria	240.45	243.06	275.32	19.22	**778.06**	*4.68*
19	Dubrovnik-Neretva	170.64	50.73	121.39	1.69	**344.44**	*2.07*
20	Međimurje	118.93	349.49	34.11	15.25	**517.77**	*3.11*
21	City of Zagreb	300.53	509.23	137.02	1 557.45	**2 504.24**	*15.06*
	TOTAL	6 823.25	4 871.51	2 570.96	2 359.79	**16 625.51**	*100.00*
			11 694.76		4 930.75	**16 625.51**	
	Share [%]		*70.34*		*29.66*	*100.00*	

The distribution of the total electricity delivered for space cooling by type of building is provided in tabular form.

The following counties are the top consumers of electricity **for cooling in the household sector**:

1. City of Zagreb (19.33%),
2. Split-Dalmatia (8.76%),
3. Zagreb County (7.48%),
4. Osijek-Baranja (7.36%),
5. Primorje-Gorski Kotar (7.20%),
6. Istria (5.34%).

Table I.20: HOUSEHOLD SECTOR – Distribution of total electricity delivered for space cooling by building type and county

HOUSEHOLD SECTOR		Total annual electricity delivered for space heating [GWh/a]			
County		Family houses	Multi-apartment buildings	**TOTAL**	*Share [%]*
1	Zagreb County	13.87	9.36	**23.24**	*7.48*
2	Krapina-Zagorje	5.86	3.96	**9.82**	*3.16*
3	Sisak-Moslavina	7.50	5.06	**12.56**	*4.04*
4	Karlovac	5.38	3.63	**9.01**	*2.90*
5	Varaždin	7.98	5.39	**13.37**	*4.30*
6	Koprivnica-Križevci	5.21	3.51	**8.72**	*2.81*
7	Bjelovar-Bilogora	5.48	3.70	**9.18**	*2.96*
8	Primorje-Gorski Kotar	13.35	9.01	**22.36**	*7.20*
9	Lika-Senj	2.41	1.62	**4.03**	*1.30*
10	Virovitica-Podravina	3.73	2.52	**6.24**	*2.01*
11	Požega-Slavonia	3.45	2.33	**5.77**	*1.86*
12	Slavonski Brod-Posavina	6.42	4.33	**10.75**	*3.46*
13	Zadar	6.96	4.70	**11.66**	*3.75*
14	Osijek-Baranja	13.65	9.21	**22.87**	*7.36*
15	Šibenik-Knin	4.71	3.18	**7.88**	*2.54*
16	Vukovar-Syrmia	7.42	5.01	**12.43**	*4.00*
17	Split-Dalmatia	16.24	10.96	**27.21**	*8.76*
18	Istria	9.90	6.68	**16.59**	*5.34*
19	Dubrovnik-Neretva	4.61	3.11	**7.72**	*2.48*
20	Međimurje	5.49	3.70	**9.19**	*2.96*
21	City of Zagreb	35.86	24.20	**60.06**	*19.33*
	TOTAL	185.50	125.17	**310.68**	*100.00*
	Share [%]	*59.71*	*40.29*	*100.00*	

The following counties are the top consumers of energy **for DHW preparation in the household sector**:

1. City of Zagreb (18.27%),
2. Split-Dalmatia (9.95%),
3. Zagreb County (7.50%),
4. Primorje-Gorski Kotar (6.93%),
5. Osijek-Baranja (6.91%),
6. Istria (4.86%),
7. Sisak-Moslavina (4.29%).

Table I.21: HOUSEHOLD SECTOR – Distribution of total energy delivered for DHW preparation by building type and county

HOUSEHOLD SECTOR		Total annual energy delivered for DHW preparation [GWh/a]					
		Family houses		Multi-apartment buildings		**TOTAL**	*Share [%]*
County		room-based	centralised	room-based	centralised		
1	Zagreb County	91.08	143.29	22.40	42.56	**299.33**	*7.50*
2	Krapina-Zagorje	61.60	51.56	6.18	3.19	**122.53**	*3.07*
3	Sisak-Moslavina	98.87	45.34	13.08	13.85	**171.14**	*4.29*
4	Karlovac	47.81	38.97	18.82	17.28	**122.89**	*3.08*
5	Varaždin	51.64	80.30	6.60	17.61	**156.15**	*3.91*
6	Koprivnica-Križevci	55.50	39.81	4.02	6.06	**105.39**	*2.64*
7	Bjelovar-Bilogora	70.22	34.48	4.68	7.28	**116.66**	*2.92*
8	Primorje-Gorski Kotar	63.98	60.54	121.91	30.06	**276.49**	*6.93*
9	Lika-Senj	28.14	11.58	11.79	1.05	**52.57**	*1.32*
10	Virovitica-Podravina	59.09	19.72	2.42	3.45	**84.67**	*2.12*

	HOUSEHOLD SECTOR	Total annual energy delivered for DHW preparation [GWh/a]					
		Family houses		Multi-apartment buildings		TOTAL	Share [%]
	County	room-based	centralised	room-based	centralised		
11	Požega-Slavonia	43.45	23.51	4.08	4.54	**75.58**	*1.89*
12	Slavonski Brod-Posavina	77.80	50.35	13.76	9.38	**151.29**	*3.79*
13	Zadar	86.94	23.55	58.73	3.97	**173.20**	*4.34*
14	Osijek-Baranja	133.67	76.44	19.03	46.57	**275.71**	*6.91*
15	Šibenik-Knin	59.95	15.89	32.03	1.98	**109.86**	*2.75*
16	Vukovar-Syrmia	97.10	43.46	6.31	16.57	**163.44**	*4.09*
17	Split-Dalmatia	153.90	50.93	181.14	11.05	**397.02**	*9.95*
18	Istria	58.95	55.84	72.63	6.58	**194.00**	*4.86*
19	Dubrovnik-Neretva	50.12	15.83	40.54	3.41	**109.91**	*2.75*
20	Međimurje	24.50	70.03	6.71	3.29	**104.53**	*2.62*
21	City of Zagreb	79.68	136.38	31.80	481.23	**729.10**	*18.27*
	TOTAL	1 494.00	1 087.81	678.69	730.94	**3 991.44**	*100.00*
			2 581.81		1 409.63	**3 991.44**	
	Share [%]		*64.68*		*17.00*		

The use of firewood (58.70%) and natural gas (23.93%) for space heating prevails in Croatia's household sector. These energy products are followed by much smaller shares of DHS (5.73%), wood pellets / wood chips / briquettes (3.89%), fuel oil (3.51%) and electricity (2.91%). The share of renewable energy taken from the environment using heat pumps is just 1.01%.

Table I.22: HOUSEHOLD SECTOR – Distribution of total energy delivered for space heating by building type and energy product (with renewable energy taken from the environment using heat pumps for space heating)

HOUSEHOLD SECTOR	Total annual energy delivered for space heating [GWh/a]			
	Family houses	Multi-apartment buildings	TOTAL	Share [%]
Electricity	189.09	294.53	**483.62**	*2.91*
DHS	0.00	953.34	**953.34**	*5.73*
Natural gas	2 514.74	1 463.44	**3 978.19**	*23.93*
Fuel oil	527.57	55.97	**583.54**	*3.51*
LPG	35.50	0.00	**35.50**	*0.21*
Firewood	7 701.83	2 057.21	**9 759.04**	*58.70*
Wood pellets / wood chips / briquettes	646.95	0.00	**646.95**	*3.89*
Solar energy (solar collectors)	17.06	0.00	**17.06**	*0.10*
RES taken from the environment using heat pumps	62.02	106.25	**168.27**	*1.01*
TOTAL	11 694.76	4 930.75	**16 625.51**	**100.00**
Share [%]	*70.34*	*29.66*	*100.00*	

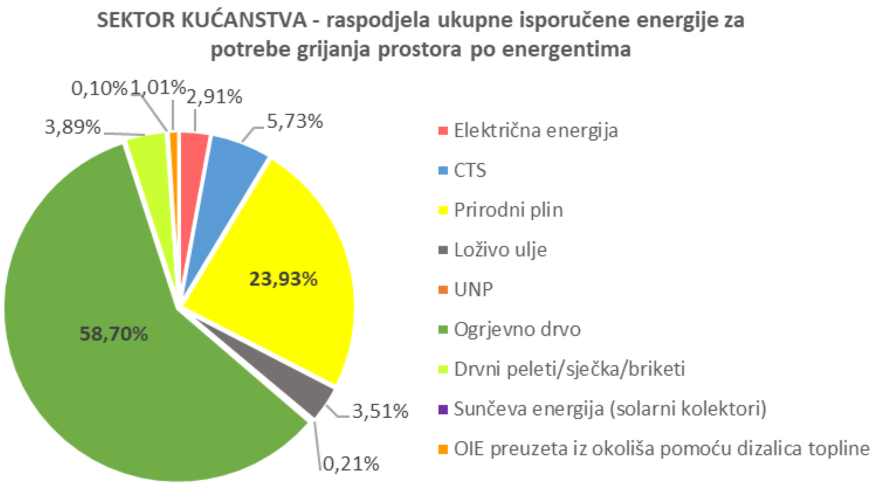


Figure I.18: HOUSEHOLD SECTOR – Distribution of total energy delivered for space heating ,by energy product (with renewable energy taken from the environment using heat pumps for space heating)

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela ukupne isporučene energije za potrebe grijanja prostora po energentima	HOUSEHOLD SECTOR – Distribution of total energy delivered for space heating by energy product
Električna energija	Electricity
CTS	DHS
Prirodni plin	Natural gas
Loživo ulje	Fuel oil
UNP	LPG
Ogrjevno drvo	Firewood
Drvni peleti/sječka/briketi	Wood pellets / wood chips / briquettes
Sunčeva energija (solarni kolektori)	Solar energy (solar collectors)
OIE preuzeta iz okoliša pomoću dizalica topline	RES taken from the environment using heat pumps

In the household sector, only electricity is used for **space cooling in buildings** in Croatia, and space cooling is decentralised (individual split air conditioning) or centralised.

The use of electricity (45.33%) and natural gas (23.44%) for DHW preparation prevails in Croatia's household sector. Firewood (16.84%) and DHS (8.05%) follow. Other energy products (solar energy, wood pellets / wood chips / briquettes, LPG, fuel oil) have negligible shares in DHW preparation. Merely 2.72% of the total annual energy delivered for DHW preparation is derived from solar collectors.

Table I.23: HOUSEHOLD SECTOR – Distribution of total energy delivered for DHW preparation by building type and energy product

HOUSEHOLD SECTOR	Total annual energy delivered for DHW preparation [GWh/a]			
	Family houses	Multi-apartment buildings	TOTAL	*Share [%]*
Electricity	1 234.91	574.50	**1 809.42**	*45.33*
DHS	0.00	321.31	**321.31**	*8.05*
Natural gas	583.92	351.75	**935.67**	*23.44*
Fuel oil	17.95	0.94	**18.89**	*0.47*
LPG	20.38	0.00	**20.38**	*0.51*
Firewood	511.09	161.12	**672.21**	*16.84*
Wood pellets / wood chips / briquettes	105.01	0.00	**105.01**	*2.63*
Solar energy (solar collectors)	108.55	0.00	**108.55**	*2.72*
TOTAL	2 581.81	1 409.63	**3 991.44**	**100.00**
Share [%]	*64.68*	*35.32*	*100.00*	

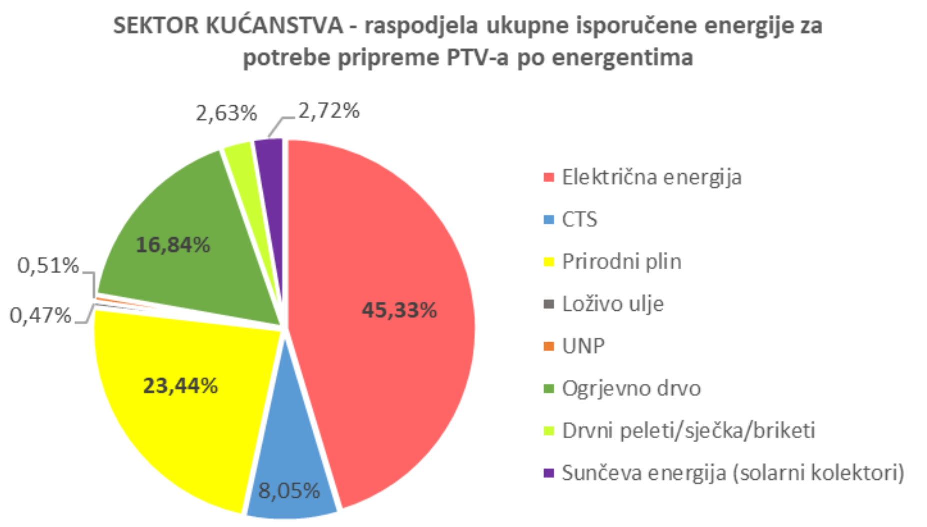


Figure I.19: HOUSEHOLD SECTOR – Distribution of total energy delivered for DHW preparation by energy product

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela ukupne isporučene energije za potrebe pripreme PTV-a po energentima	HOUSEHOLD SECTOR – Distribution of total energy delivered for DHW preparation by energy product
Električna energija	Electricity
CTS	DHS
Prirodni plin	Natural gas
Loživo ulje	Fuel oil
UNP	LPG
Ogrjevno drvo	Firewood
Drvni peleti/sječka/briketi	Wood pellets / wood chips / briquettes
Sunčeva energija (solarni kolektori)	Solar energy (solar collectors)

1.2.2 SERVICE SECTOR

The energy delivered for heating, DHW preparation and cooling in the service sector is derived from:

- data on the heated area, location and building type available and determined from the IEC database;

data on the specific energy needed for heating, DHW preparation and cooling for different types of buildings and two climate zones (continental and coastal) taken from the study entitled *Determining minimum requirements for energy performance of buildings*, prepared by the EIHP for the Ministry of Physical Planning, Construction and State Assets, 2020 [19] - (Annexes:

- Table 0.4:, Table 0.5:, Table 0.6:);
- assumptions on the efficiency of the technology used, derived from the energy product used for heating, DHW preparation and cooling specified in the IEC database (Annexes: Table 0.7:); and
- available data obtained from distributors.

Based on such data, the energy delivered for heating, DHW preparation and cooling in Croatia's service sector has been calculated at **5 843.57 GWh/a**. A comparison of that consumption with the total service sector consumption provided in Energy in Croatia leads to a conclusion that the energy delivered for heating, cooling and DHW preparation accounts for 61.00% of the total energy delivered, while the remaining energy is consumed for other non-heating energy needs (cooking, lighting, operation of electrical appliances). A detailed presentation and distribution of the energy delivered are provided in the table and chart below.

Table I.24. SERVICE SECTOR – Energy delivered for heating, DHW preparation and cooling by energy product

Energy product	Heating [GWh/a]	DHW preparation [GWh/a]	Cooling [GWh/a]	Total [GWh/a]
LPG	121.38	18.70	–	**139.80**
Fuel oil	257.07	43.50	–	**300.29**
Natural gas	1 951.21	170.49	–	**2 121.42**
Total renewable energy sources*	142.73	56.15	–	**223.53**
DHS	374.19	34.54	–	**408.45**
Electricity	695.30	347.15	1 490.70	**2 503.24**
Other	97.17	13.65	29.64	**120.95**
TOTAL	**3 639.05**	**684.18**	**1 520.34**	**5 843.57**
SHARE	*62.27%*	*11.71%*	*26.02%*	***100.00%***

*Traditional biomass (firewood), modern biomass (pellet and briquettes) and solar energy included.
**Geothermal energy and other energy products which could not be analysed based on the IEC database included.

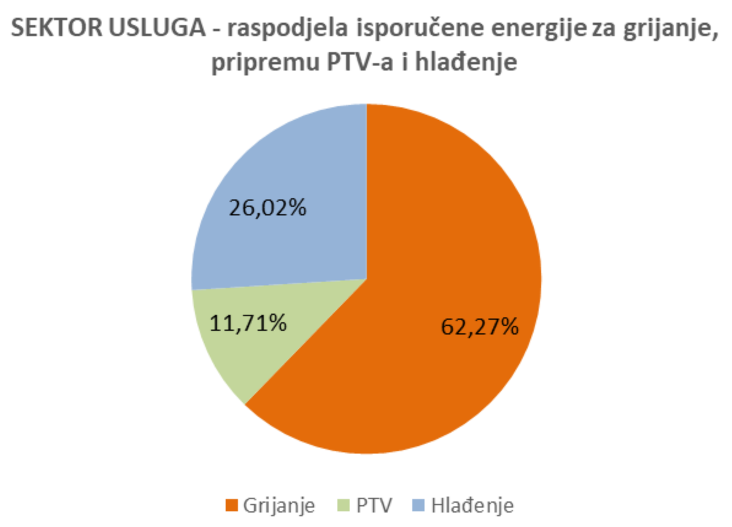


Figure I.20: SERVICE SECTOR – Share of the energy delivered for heating, DHW preparation and cooling

CROATIAN	ENGLISH

SEKTOR USLUGA – Raspodjela isporučene energije za grijanje, pripremu PTV-a i hlađenje	SERVICE SECTOR – Distribution of the energy delivered for heating, DHW preparation and cooling
Grijanje	Heating
PTV	DHW
Hlađenje	Cooling

In addition, the energy delivered for heating, DHW preparation and cooling was analysed for each municipality, city or town, and City of Zagreb district. However, for the sake of simplicity, the tables include only county-level data. The overall energy delivered for heating, DHW preparation and cooling by energy product and building type is presented below, while the energy delivered separately for each purpose (heating, DHW preparation and cooling) is provided in an annex to this document (Table 0.8: – Table 0.13:).

The following counties are the top consumers of total energy delivered for space heating, DHW preparation and cooling in the service sector:

1. City of Zagreb (23.80%),
2. Split-Dalmatia (11.12%),
3. Istria (7.76%),
4. Primorje-Gorski Kotar (7.67%),
5. Zagreb County (6.88%),
6. Osijek-Baranja (6.31%).

In addition, most of the total energy delivered to the service sector is accounted for by non-residential buildings (20.33%), followed by office buildings (18.83%), trade buildings (18.74%), hotels and restaurants (15.56%), educational buildings (12.59%), hospitals (9.65%) and sports halls (4.54%).

An analysis of the total energy consumption by energy product reveals the consumption of electricity (43.35%) and natural gas (36.31%) to have the biggest share in the total energy consumption for space heating, DHW preparation and cooling, while the remaining energy products together (LPG, fuel oil, RES, DHS sources and other) account for just 20.34% of the total consumption.

Table I.25: SERVICE SECTOR – Energy delivered for heating, DHW preparation and cooling by building type at county level

SERVICE SECTOR										
		Total energy delivered for heating, DHW preparation and cooling [GWh/a]								
	County name	Office buildings	Educational buildings	Hotels and restaurants	Hospitals	Sports halls	Trade buildings	Other non-residential buildings	**TOTAL**	**SHARE**
1	Zagreb County	62.945	45.592	18.070	14.389	16.170	68.009	177.085	**402.259**	6.88%
2	Krapina-Zagorje	20.213	27.488	17.798	29.570	8.039	12.496	47.648	**163.252**	2.79%
3	Sisak-Moslavina	24.807	30.462	6.324	16.721	4.319	19.876	24.285	**126.795**	2.17%
4	Karlovac	19.495	24.806	9.758	12.170	4.893	16.832	43.555	**131.508**	2.25%
5	Varaždin	41.903	36.970	13.093	44.535	18.319	38.577	100.563	**293.960**	5.03%
6	Koprivnica-Križevci	27.795	17.735	6.446	16.760	6.129	21.406	53.495	**149.766**	2.56%
7	Bjelovar-Bilogora	18.605	21.728	6.370	20.711	13.031	11.794	18.541	**110.779**	1.90%
8	Primorje-Gorski Kotar	66.312	52.025	153.089	28.821	18.439	75.293	54.125	**448.104**	7.67%
9	Lika-Senj	6.872	5.466	18.356	7.122	2.257	6.491	11.683	**58.245**	1.00%
10	Virovitica-Podravina	13.145	18.802	4.479	11.795	5.122	7.945	14.432	**75.719**	1.30%
11	Požega-Slavonia	17.475	13.087	13.210	18.258	10.364	15.839	25.357	**113.590**	1.94%
12	Slavonski Brod-Posavina	28.408	27.258	5.487	15.377	12.027	30.393	37.861	**156.811**	2.68%
13	Zadar	19.204	17.826	53.934	13.571	3.554	41.061	15.207	**164.356**	2.81%
14	Osijek-Baranja	62.639	74.754	17.742	27.927	23.386	77.042	85.421	**368.911**	6.31%
15	Šibenik-Knin	13.275	14.228	29.128	22.390	2.628	19.332	16.848	**117.829**	2.02%
16	Vukovar-Syrmia	23.928	17.671	10.932	15.057	10.186	24.402	22.176	**124.352**	2.13%
17	Split-Dalmatia	61.335	46.137	160.017	41.369	21.360	241.514	78.188	**649.922**	11.12%
18	Istria	57.668	28.036	185.556	26.787	11.969	70.733	72.927	**453.676**	7.76%
19	Dubrovnik-Neretva	14.171	11.439	103.360	20.148	5.592	14.245	14.103	**183.057**	3.13%
20	Međimurje	29.102	16.431	9.682	12.862	12.187	20.023	59.857	**160.145**	2.74%
21	City of Zagreb	465.755	187.686	66.370	147.316	55.084	253.683	214.644	**1 390.538**	23.80%
	TOTAL	**1 095.051**	**735.627**	**909.200**	**563.655**	**265.055**	**1 086.986**	**1 188.001**	**5 843.575**	100.00%
	SHARE	18.74%	12.59%	15.56%	9.65%	4.54%	18.60%	20.33%	100.00%	

Table I.26: SERVICE SECTOR – Energy delivered for heating, DHW preparation and cooling by energy product at county level

SERVICE SECTOR										
		Total energy delivered for heating, DHW preparation and cooling [GWh/a]								
	County name	LPG	Fuel oil	Natural gas	Total RES	DHS	Electricity	Other	**TOTAL**	**SHARE**
1	Zagreb County	7.190	5.882	227.214	11.932	13.119	114.507	22.416	**402.259**	6.88%
2	Krapina-Zagorje	0.603	2.861	104.526	3.814	0.448	46.329	4.670	**163.252**	2.79%
3	Sisak-Moslavina	2.380	8.705	54.272	11.131	8.785	39.555	1.967	**126.795**	2.17%
4	Karlovac	2.020	15.490	28.580	13.855	17.892	51.053	2.618	**131.508**	2.25%
5	Varaždin	2.906	0.866	198.039	6.355	1.647	77.631	6.515	**293.960**	5.03%
6	Koprivnica-Križevci	0.173	5.625	100.268	2.788	0.423	39.689	0.801	**149.766**	2.56%
7	Bjelovar-Bilogora	0.225	0.249	73.202	8.725	0.360	27.291	0.727	**110.779**	1.90%
8	Primorje-Gorski Kotar	35.208	57.084	69.965	19.284	4.928	254.518	7.116	**448.104**	7.67%
9	Lika-Senj	8.778	7.640	2.452	12.058	0.075	26.459	0.782	**58.245**	1.00%
10	Virovitica-Podravina	0.639	0.460	47.269	3.373	0.861	18.963	4.155	**75.719**	1.30%
11	Požega-Slavonia	1.659	0.849	62.600	8.667	1.206	36.867	1.743	**113.590**	1.94%
12	Slavonski Brod-Posavina	2.041	6.682	85.658	7.498	5.559	45.602	3.770	**156.811**	2.68%
13	Zadar	2.944	24.640	4.820	3.010	2.175	122.773	3.994	**164.356**	2.81%
14	Osijek-Baranja	2.577	4.764	160.213	19.190	56.843	113.748	11.576	**368.911**	6.31%
15	Šibenik-Knin	13.679	17.056	3.953	5.149	0.008	77.031	0.953	**117.829**	2.02%
16	Vukovar-Syrmia	0.629	3.446	70.656	5.188	1.449	38.616	4.369	**124.352**	2.13%
17	Split-Dalmatia	21.013	45.799	10.727	20.370	0.391	546.015	5.607	**649.922**	11.12%
18	Istria	16.965	52.029	85.688	7.217	3.570	279.338	8.869	**453.676**	7.76%
19	Dubrovnik-Neretva	13.519	24.700	3.829	9.553	0.000	126.588	4.868	**183.057**	3.13%
20	Međimurje	2.648	0.577	105.685	13.471	0.390	36.112	1.263	**160.145**	2.74%
21	City of Zagreb	2.278	15.163	622.085	6.255	288.597	414.471	41.689	**1 390.538**	23.80%
	TOTAL	**140.074**	**300.568**	**2 121.698**	**198.885**	**408.727**	**2 533.156**	**140.469**	**5 843.575**	100.00%
	SHARE	2.40%	5.14%	36.31%	3.40%	6.99%	43.35%	2.40%	100.00%	

1.2.3 INDUSTRIAL SECTOR

The exact 2019 annual consumption of the energy delivered to the industrial sector separately for each company was obtained from the Croatian Bureau of Statistics.

1.2.3.1 DEFINING THE INDUSTRIAL SECTOR AS PART OF THE COMPREHENSIVE ASSESSMENT

The annual consumption of all energy products in 2019 for every company, as well as their National Classification of Activities (NCA) code, is stated separately in the Excel file provided by the Croatian Bureau of Statistics. Each company has been assigned an actual address, used subsequently to determine the geographical coordinates (latitude and longitude) of the biggest consumers.

In addition to the industry, the Croatian Bureau of Statistics also monitors other activities which are not part of the industry, so they have been dropped from further analysis.

All Croatian economic activities are classified into defined divisions from 01 to 99. Each division belongs to one of a total of 14 main sections of activities, marked with codes A to N.

The NCA code used for determining the type of activity consists of 4 digits in total. The first two digits define the main section or division of activity, while the last two digits define the group within a particular division.

For instance, a company with the code NCA 10.81 belongs to the main section C – Manufacturing, the Manufacture of food products division (10 as the two initial digits), the Manufacture of sugar group (the remaining two digits 81).

An overview of the main sections of activities with related divisions is provided in tabular form (Table I.27:). The Comprehensive Assessment takes into account the following two main sections in the industrial sector:

A – Mining and quarrying

B – Manufacturing

with a few exceptions, which do not belong in the industrial sector (Table I.28:):

- 05 – Mining of coal and lignite → belongs in the ENERGY sector;
- 06 – Extraction of crude petroleum and natural gas → belongs in the ENERGY sector;
- 19 – Manufacture of coke and refined petroleum products → belongs in the ENERGY SECTOR;
- 33 – Repair and installation of machinery and equipment → belongs in the SERVICE sector.

Table I.27: Overview of the main sections of activities with divisions

Section code	Section name	Division number	Taken into account
A	Agriculture, forestry and fisheries	01-03	NO
B	**Mining and quarrying**	**05-09**	**YES**
C	**Manufacturing**	**10-33**	**YES**
D	Electricity, gas, steam and air conditioning supply	35	NO
E	Water supply, sewerage, waste management and remediation activities	36-39	NO
F	Construction	41-43	NO
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	45-47	NO
H	Transportation and storage	49-53	NO
I	Accommodation and food service activities	55-56	NO
J	Information and communication	59-63	NO
K	Financial and insurance activities	64-66	NO
L	Real estate activities	68	NO
M	Professional, scientific and technical activities	69-75	NO
N	Administrative and support service activities	77-82	NO

Section code	Section name	Division number	Taken into account
O	Public administration and defence; compulsory social security	84	NO
P	Education	85	NO
Q	Human health services and social work activities	86-88	NO
R	Arts, entertainment and recreation	90-93	NO
S	Other service activities	94-96	NO
T	Activities of households as employers; undifferentiated goods and services producing activities of households for own use	97-98	NO
U	Activities of extraterritorial organisations and bodies	99	NO

Table I.28: Overview of industrial sector divisions

Section code	Section name	Division number	Division name	Sector	Taken into account
B	**MINING AND QUARRYING**	**05**	**Mining of coal and lignite**	**ENERGY**	**NO**
		06	**Extraction of crude petroleum and natural gas**	**ENERGY**	**NO**
		07	Mining of metal ores	INDUSTRY	YES
		08	Other mining and quarrying	INDUSTRY	YES
		09	Mining support service activities	INDUSTRY	YES
C	**MANUFACTURING**	10	Manufacture of food products	INDUSTRY	YES
		11	Manufacture of beverages	INDUSTRY	YES
		12	Manufacture of tobacco products	INDUSTRY	YES
		13	Manufacture of textiles	INDUSTRY	YES
		14	Manufacture of wearing apparel	INDUSTRY	YES
		15	Manufacture of leather and related products	INDUSTRY	YES
		16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	INDUSTRY	YES
		17	Manufacture of paper and paper products	INDUSTRY	YES
		18	Printing and reproduction of recorded media	INDUSTRY	YES
		19	**Manufacture of coke and refined petroleum products**	**ENERGY**	**NO**
		20	Manufacture of chemicals and chemical products	INDUSTRY	YES
		21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	INDUSTRY	YES
		22	Manufacture of rubber and plastic products	INDUSTRY	YES
		23	Manufacture of other non-metallic mineral products	INDUSTRY	YES
		24	Metal production	INDUSTRY	YES
		25	Manufacture of fabricated metal products, except machinery and equipment	INDUSTRY	YES
		26	Manufacture of computer, electronic and optical products	INDUSTRY	YES
		27	Manufacture of electrical equipment	INDUSTRY	YES
		28	Manufacture of machinery and equipment n.e.c.	INDUSTRY	YES
		29	Manufacture of motor vehicles, trailers and semi-trailers	INDUSTRY	YES
		30	Manufacture of other transport equipment	INDUSTRY	YES
		31	Manufacture of furniture	INDUSTRY	YES
		32	Other manufacturing	INDUSTRY	YES
		33	**Repair and installation of machinery and equipment**	**SERVICES**	**NO**

While section B is mining, all parts of mining which are not so-called energy mining (e.g. mining of coal and lignite, extraction of crude petroleum and natural gas) are also observed as a single branch of the industry (mining) in energy balances.

While manufacturing includes divisions from number 10 up to and including 32, division 19 – Manufacture of coke and refined petroleum products does not belong in the industrial sector but in the energy sector in energy balances.

Construction is also observed as a single branch of the industry but it has been dropped from further analysis, considering that the share of energy delivered in the total energy delivered used for heating and cooling is negligible and is of no interest for the comprehensive assessment.

1.2.3.2 Overview of energy products taken into account in the industrial sector

The annual consumption of all energy products in 2019 is stated separately for every company in the Excel file provided by the Croatian Bureau of Statistics. Upon the determination of the companies that belong in the industrial sector with regard to their activity, energy products used for heating/cooling were defined, and all energy products not used for heating/cooling have been dropped from further analysis. E.g. all energy products used in transport (petrol, diesel fuels) have been dropped from further analysis.

An overview of all energy products that companies use has been provided in tabular form, together with the energy product codes, units and the lower heating value of energy products, and also the indication of which energy products are taken into account for further analysis, that is, for determining the annual thermal energy needs for heating and cooling. In addition, the average degree of efficiency for combustion plants has been defined for energy products burned in combustion plants, to be used for the subsequent determination of useful thermal energy needs for heating.

Table I.29: INDUSTRIAL SECTOR – List of energy products taken into account

Energy product code	Energy product name	Unit	Lower heating value [kWh/unit]	Energy product taken into account for heating/cooling (YES/NO)	Degree of efficiency
11	**Electricity**	–	–	**YES**	–
15	**Steam and water at temperatures lower than or equal to 200 °C**	–	–	**YES**	–
16	**Steam and water at temperatures higher than 200 °C**	–	–	**YES**	–
21	Technical gases	–	–	NO	–
22	**Hard coal and its briquettes**	kg	7.443056	**YES**	0.80
23	**Brown coal and its briquettes**	kg	5.001389	**YES**	0.80
25	**Coke (metallurgical and foundry)**	kg	7.734722	**YES**	0.85
29	Biodiesel fuels	–	–	NO	–
31	Petrol for means of transport (fossil)	–	–	NO	–
32	Petrol other than for means of transport (fossil)	–	–	NO	–
34	Diesel fuels for means of transport (fossil)	–	–	NO	–
35	Diesel fuels other than for means of transport (fossil)	–	–	NO	–
37	**Extra light and special fuel oil**	kg	11.666666	**YES**	0.83
38	**Low-sulphur fuel oil** (up to 1% S)	kg	11.111111	**YES**	0.83
39	**High-sulphur fuel oil** (1% S and higher; heavy oil)	kg	10.833333	**YES**	0.83
40	**Petroleum coke**	kg	8.611111	**YES**	0.85
51	**Natural gas, network-distributed**	m^3	9.480000[5]	**YES**	–
61	Other gas, network-distributed	–	–	NO	–

[5] Average value calculated from the distributor's data.

Energy product code	Energy product name	Unit	Lower heating value [kWh/unit]	Energy product taken into account for heating/cooling (YES/NO)	Degree of efficiency
62	**Liquefied gas**	kg	12.780000	**YES**	0.87
63	Refinery gas[6]	kg	13.491667	NO	0.83
71	**Firewood**	spatial m^3	2 500.00	**YES**	0.70
72	**Wood pellets**	kg	5.000000	**YES**	0.80
73	**Wood chips**	kg	3.000000	**YES**	0.80
74	**Wood, straw and similar briquettes**	kg	4.730000	**YES**	0.75
75	**Wood and plant waste**	kg	2.860000	**YES**	0.70
81	**Old tyres**	kg	8.333333	**YES**	0.75
82	**Waste oils and emulsions**		10.222222	**YES**	0.75
83	**Meat and bone meal**	kg	3.068056	**YES**	0.75
84	**Dried sludge – DSS**	kg	2.303611	**YES**	0.75
85	RDF – fuel derived from different waste	–	–	NO	–

In the industrial sector, electricity is used for the following needs, related to heating/cooling:

- heating in the production process;
- cooling in the production process using compression cooling unit;
- space cooling in office buildings using split air conditioning; and
- DHW preparation in office buildings using individual electric boilers.

In the industrial sector, network-distributed natural gas is used for the following heating/cooling-related needs:

- heating in the production process;
- heating of building space; and
- cooling in the production process (using gas absorption cooling unit).

The average values of the degree of efficiency of the sources of heating and cooling energy needed for determining useful thermal energy for heating/cooling in the case of electricity and natural gas are provided in tabular form.

Table I.30: INDUSTRIAL SECTOR – Use of electricity and natural gas as energy product for covering heating/cooling needs

Code	Energy product name	Needs	HEATING – degree of efficiency [–]	COOLING – energy efficiency ratio [–]
11	**Electricity**	Heating in the production process	0.99	–
		Cooling in the production process using compression cooling unit	–	3.00
		Space cooling in office buildings using split air conditioning	–	2.80
		DHW preparation in office buildings using individual electric boilers	0.99	–
51	**Natural gas, network-distributed**	Heating in the production process	0.87	–
		Heating of building space	0.91	–
		Cooling in the production process (gas absorption cooling unit)	–	1.10[7]

[6] Used in the energy sector.

[7] EER of gas absorption cooling unit – ratio between the efficiency of the evaporator and the generator.

Naturally, in the industrial sector, electricity is used for motor drives, electrochemical purposes, powering of appliances (including IT equipment), lighting and other energy purposes, but the Comprehensive Assessment only takes into account that part of a certain energy product which is used for heating, DHW preparation and cooling.

1.2.3.3 TOTAL ENERGY DELIVERED TO THE INDUSTRIAL SECTOR

Within this study, it is important to distinguish between:

- **total energy delivered to the industrial sector** for the defined energy products, covering other needs in addition to heating/cooling; and
- **energy delivered for heating[8]/cooling**.

Based on the data provided by the Croatian Bureau of Statistics, **total energy delivered** and registered in Croatia in 2019 amounts to **8 981.44 GWh** for a total of **2 478 companies** that fall in the **industrial sector** according to their NCA code. Only the energy products defined in Chapter 1.2.3.2 have been taken into account.

It should be noted that the following two energy products:

- steam and water at temperatures lower than or equal to 200 °C, and
- steam and water at temperatures higher than 200 °C

are obtained through the following:

- supply directly from district heating systems (DHS);
- generation from industrial boiler rooms; and
- generation from industrial cogeneration installations.

When it comes to industrial boiler rooms and cogeneration installations, different types of energy products are used to generate steam and water (natural gas, fuel oil, waste, brown coal and lignite).

Total number of industrial boiler rooms in Croatia in 2019: **57**

Total number of industrial cogeneration installations in Croatia in 2019: **5**

More data on industrial boiler rooms and industrial cogeneration installations is available in the following chapters.

Total energy delivered in the industrial sector by county, with consumption referring to steam and water and not the energy product used to generate steam and water, is stated in Table I.31:. Of the specified amount of steam and water, the portion of energy needed for heating/cooling has been excluded to determine the useful energy for heating and cooling.

Electricity (38,60%) had for the highest share in industrial sector consumption, followed by network-distributed natural gas (23.93%) and petroleum coke (13.66%).

While consumption at the level of each company is known, due to data confidentiality and extensiveness it is not stated in this study at individual company level, but an overview at county level is provided.

[8] Heating refers to space heating and domestic hot water preparation.

Table I.31: INDUSTRIAL SECTOR – Total energy delivered from the energy products taken into account

INDUSTRIAL SECTOR	TOTAL ENERGY DELIVERED BY ENERGY PRODUCTS [GWh/a], 2019																Share [%]
County	Electricity	Natural gas	DHS	Hard/brown coal and their briquettes	Coke (metallurgical and foundry)	Fuel oil	Petroleum coke	LPG	Firewood	Wood pellets / wood chips	Wood, straw and similar briquettes	Wood waste	Old tyres	Waste oils and emulsions	Meat and bone meal	Dried sludge – DSS	**TOTAL**	
Zagreb County	244.97	133.59	0.01	0.00	0.62	14.43	0.00	1.06	2.87	0.65	0.10	0.26	0.00	0.00	0.00	0.00	**398.56**	*4.44*
Krapina-Zagorje	215.41	453.66	0.00	0.00	0.00	0.54	0.00	2.12	0.00	2.73	0.05	0.00	0.00	0.00	0.00	0.00	**674.50**	*7.51*
Sisak-Moslavina	353.91	73.32	150.26	0.00	0.00	5.77	0.00	0.43	17.63	6.70	0.00	1.48	0.00	0.00	0.00	0.00	**609.50**	*6.79*
Karlovac	107.45	37.31	0.00	0.00	0.00	32.49	0.00	0.92	1.18	0.87	0.00	0.00	0.00	0.00	0.00	0.00	**180.23**	*2.01*
Varaždin	262.26	261.34	0.46	0.00	61.13	5.51	0.00	0.52	37.52	1.92	0.00	0.00	0.00	0.07	0.00	0.00	**630.73**	*7.02*
Koprivnica-Križevci	103.37	132.08	0.00	0.00	0.00	1.71	0.00	1.62	0.00	7.44	0.00	1.72	0.00	0.00	0.00	0.00	**247.94**	*2.76*
Bjelovar-Bilogora	101.05	54.56	0.00	0.00	0.00	0.00	0.00	0.04	0.69	2.85	0.00	14.07	0.00	0.00	0.00	0.00	**173.25**	*1.93*
Primorje-Gorski Kotar	146.83	4.49	0.00	0.00	0.00	15.42	0.00	4.79	0.10	3.87	0.00	42.66	0.00	0.00	0.00	0.00	**218.17**	*2.43*
Lika-Senj	91.85	0.66	24.02	0.00	0.00	2.04	0.00	15.19	0.44	0.20	0.00	0.63	0.00	0.00	0.00	0.00	**135.03**	*1.50*
Virovitica-Podravina	60.89	43.79	0.00	0.00	9.34	0.00	0.00	0.31	14.45	19.99	0.04	22.73	0.00	0.00	0.00	0.00	**171.54**	*1.91*
Požega-Slavonia	68.54	13.99	18.72	0.00	0.00	1.05	0.00	0.60	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**103.04**	*1.15*
Slavonski Brod-Posavina	81.37	83.96	52.81	0.00	1.93	2.09	0.00	3.50	0.23	0.04	0.00	0.38	0.00	0.00	0.00	0.00	**226.31**	*2.52*
Zadar	46.27	21.16	0.00	0.00	0.00	12.21	0.00	0.90	0.00	21.67	0.00	0.00	0.00	0.00	0.00	0.00	**102.20**	*1.14*
Osijek-Baranja	354.97	182.30	140.12	240.41	0.00	4.91	280.17	1.81	2.22	5.58	0.00	0.92	0.00	69.10	0.00	2.52	**1 285.03**	*14.31*
Šibenik-Knin	108.08	152.12	0.00	0.00	0.00	11.19	0.00	10.19	11.12	2.12	0.00	0.00	0.00	16.26	0.00	0.00	**311.07**	*3.46*
Vukovar-Syrmia	98.45	110.33	0.00	5.28	17.41	15.27	0.00	0.33	0.99	0.00	0.22	3.03	0.00	0.00	0.00	0.00	**251.31**	*2.80*
Split-Dalmatia	232.20	1.33	0.00	13.90	0.00	66.18	721.52	18.93	0.79	5.73	0.07	0.00	0.00	9.07	0.00	0.00	**1 069.69**	*11.91*
Istria	248.63	77.12	1.14	318.03	152.11	54.49	225.19	27.69	0.20	0.18	0.00	0.00	28.95	4.64	3.84	0.56	**1 142.76**	*12.72*
Dubrovnik-Neretva	7.36	0.00	0.00	0.00	0.00	3.13	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**11.17**	*0.12*
Međimurje	154.91	76.62	0.00	0.08	0.00	4.37	0.00	1.60	7.68	0.71	0.00	0.44	0.00	0.00	0.00	0.00	**246.40**	*2.74*
City of Zagreb	377.64	235.68	107.26	0.00	0.00	48.90	0.00	4.60	1.15	0.33	0.06	14.30	0.00	3.07	0.00	0.00	**792.99**	*8.83*
TOTAL	**3 466.41**	**2 149.41**	**494.80**	**577.70**	**242.54**	**301.71**	**1 226.88**	**97.82**	**99.38**	**83.56**	**0.55**	**102.60**	**28.95**	**102.21**	**3.84**	**3.08**	**8 981.44**	***100.00***
Share [%]	*38.60*	*23.93*	*5.51*	*6.43*	*2.70*	*3.36*	*13.66*	*1.09*	*1.11*	*0.93*	*0.01*	*1.14*	*0.32*	*1.14*	*0.04*	*0.03*	***100.00***	

1.2.3.4 Total energy delivered to the industrial sector for heating/cooling

Total energy delivered for heating/cooling purposes to the industrial sector in Croatia amounted to **6 733.98 GWh** in 2019.

Most energy in the industrial sector is used for the purposes of heating in the production process (85.72%), while 8.61% of the total annual energy delivered for heating/cooling is used for space heating and DHW preparation. Space cooling and cooling for production process purposes account for only 5.67% of the total annual energy delivered for heating/cooling purposes.

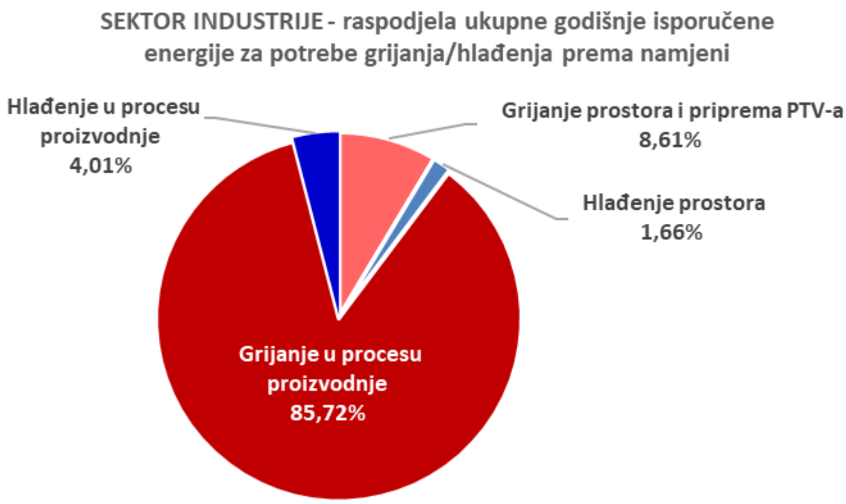


Figure I.21: INDUSTRIAL SECTOR – Distribution of total annual energy delivered for heating/cooling by purpose

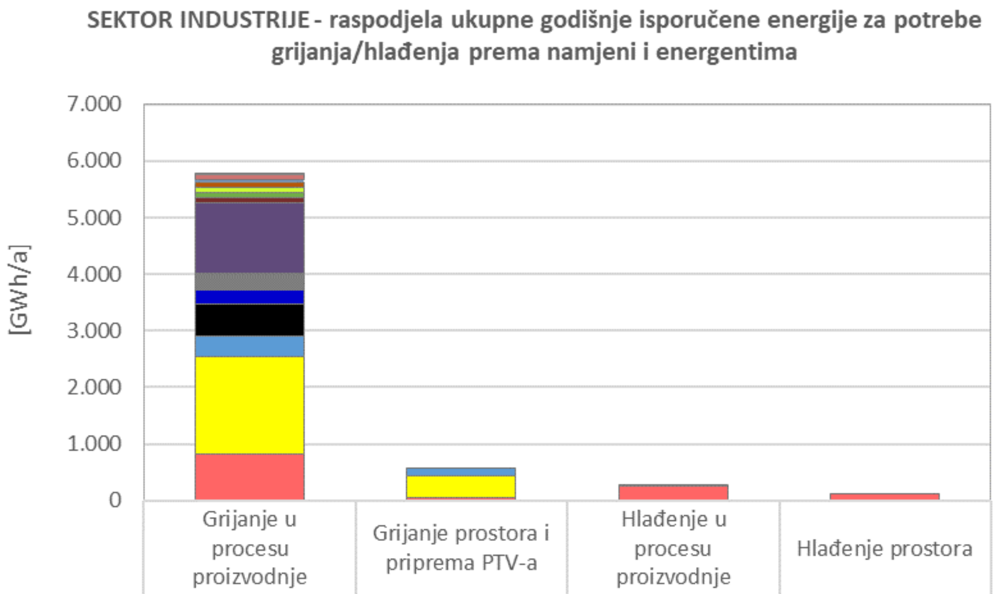
CROATIAN	ENGLISH
SEKTOR INDUSTRIJE - raspodjela ukupne godišnje isporučene energije za potrebe grijanja/hlađenja prema namjeni	INDUSTRIAL SECTOR – Distribution of total annual energy delivered for heating/cooling by purpose
Hlađenje u procesu proizvodnje	Cooling in the production process
Grijanje prostora i priprema PTV-a	Space heating and DHW preparation
Hlađenje prostora	Space cooling
Grijanje u procesu proizvodnje	Heating in the production process

Figure I.22: shows the distribution of total annual energy delivered for heating/cooling to the industrial sector by purpose and energy products.

The most widely used energy products for heating in the production process are:

- natural gas (1 724.45 GWh/a; 29.88%),
- petroleum coke (1 226.88 GWh/a; 21.25%),
- electricity (821.78 GWh/a; 14.24%),
- hard/brown coal and their briquettes (577.70 GWh/a; 10.01%),
- DHS (355.14 GWh/a; 6.15%).

Electricity is the main energy product used for cooling in the production process, with natural gas used to a certain extent.



	Grijanje u procesu proizvodnje	Grijanje prostora i priprema PTV-a	Hlađenje u procesu proizvodnje	Hlađenje prostora
DSS - osušeni mulj	3,08	0,00	0,00	0,00
Mesno i koštano brašno	3,84	0,00	0,00	0,00
Otpadna ulja i emulzije	102,21	0,00	0,00	0,00
Stare gume	28,95	0,00	0,00	0,00
Drvni otpaci	102,60	0,00	0,00	0,00
Briketi od drva, slame i sl.	0,55	0,00	0,00	0,00
Drvni peleti/sječka	83,56	0,00	0,00	0,00
Ogrjevno drvo	99,38	0,00	0,00	0,00
UNP	97,82	0,00	0,00	0,00
Naftni koks	1.226,88	0,00	0,00	0,00
Loživo ulje	301,71	0,00	0,00	0,00
Koks (metalurški i ljevaonički)	242,54	0,00	0,00	0,00
Kameni/mrki ugljen i njihovi briketi	577,70	0,00	0,00	0,00
CTS	355,14	139,66	0,00	0,00
Prirodni plin	1.724,45	397,90	24,66	0,00
Električna energija	821,78	42,19	245,65	111,72

Figure I.22: INDUSTRIAL SECTOR – Distribution of total annual energy delivered for heating/cooling by purpose and energy product

CROATIAN	ENGLISH
SEKTOR INDUSTRIJE - raspodjela ukupne godišnje isporučene energije za potrebe grijanja/hlađenja prema namjeni i energentima	INDUSTRIAL SECTOR – Distribution of total annual energy delivered for heating/cooling by purpose and energy product
Grijanje u procesu proizvodnje	Heating in the production process
Grijanje prostora i priprema PTV-a	Space heating and DHW preparation
Hlađenje u procesu proizvodnje	Cooling in the production process
Hlađenje prostora	Space cooling
DSS - osušeni mulj	Dried sludge – DSS
Mesno i koštano brašno	Meat and bone meal
Otpadna ulja i emulzije	Waste oils and emulsions
Stare gume	Old tyres
Drvni otpaci	Wood waste
Briketi od drva, slame i si.	Wood, straw and similar briquettes
Drvni peleti/sječka	Wood pellets / wood chips
Ogrjevno drvo	Firewood
UNP	LPG
Naftni koks	Petroleum coke
Loživo ulje	Fuel oil
Koks (metalurški i ljevaonički)	Coke (metallurgical and foundry)

Kameni/mrki ugljen i njihovi briketi	Hard/brown coal and their briquettes
CTS	DHS
Prirodni plin	Natural gas
Električna energija	Electricity

Table I.32: INDUSTRIAL SECTOR – Total annual energy delivered for heating/cooling by county and energy product

INDUSTRIAL SECTOR	TOTAL ANNUAL ENERGY DELIVERED FOR HEATING/COOLING IN 2019 BY ENERGY PRODUCT [GWh/a]																Share [%]
County	Electricity	Natural gas	DHS	Hard/brown coal and their briquettes	Coke (metallurgical and foundry)	Fuel oil	Petroleum coke	LPG	Firewood	Wood pellets / wood chips	Wood, straw and similar briquettes	Wood waste	Old tyres	Waste oils and emulsions	Meat and bone meal	Dried sludge – DSS	TOTAL	
Zagreb County	97.55	133.59	0.01	0.00	0.62	14.43	0.00	1.06	2.87	0.65	0.10	0.26	0.00	0.00	0.00	0.00	**251.14**	*3.73*
Krapina-Zagorje	53.93	451.49	0.00	0.00	0.00	0.54	0.00	2.12	0.00	2.73	0.05	0.00	0.00	0.00	0.00	0.00	**510.86**	*7.59*
Sisak-Moslavina	147.93	73.32	150.26	0.00	0.00	5.77	0.00	0.43	17.63	6.70	0.00	1.48	0.00	0.00	0.00	0.00	**403.53**	*5.99*
Karlovac	39.71	37.31	0.00	0.00	0.00	32.49	0.00	0.92	1.18	0.87	0.00	0.00	0.00	0.00	0.00	0.00	**112.50**	*1.67*
Varaždin	104.09	261.10	0.46	0.00	61.13	5.51	0.00	0.52	37.52	1.92	0.00	0.00	0.00	0.07	0.00	0.00	**472.32**	*7.01*
Koprivnica-Križevci	32.93	132.08	0.00	0.00	0.00	1.71	0.00	1.62	0.00	7.44	0.00	1.72	0.00	0.00	0.00	0.00	**177.50**	*2.64*
Bjelovar-Bilogora	27.70	54.56	0.00	0.00	0.00	0.00	0.00	0.04	0.69	2.85	0.00	14.07	0.00	0.00	0.00	0.00	**99.91**	*1.48*
Primorje-Gorski Kotar	20.03	4.49	0.00	0.00	0.00	15.42	0.00	4.79	0.10	3.87	0.00	42.66	0.00	0.00	0.00	0.00	**91.36**	*1.36*
Lika-Senj	20.35	0.66	24.02	0.00	0.00	2.04	0.00	15.19	0.44	0.20	0.00	0.63	0.00	0.00	0.00	0.00	**63.53**	*0.94*
Virovitica-Podravina	10.31	43.79	0.00	0.00	9.34	0.00	0.00	0.31	14.45	19.99	0.04	22.73	0.00	0.00	0.00	0.00	**120.96**	*1.80*
Požega-Slavonia	29.25	13.99	18.72	0.00	0.00	1.05	0.00	0.60	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**63.76**	*0.95*
Slavonski Brod-Posavina	28.24	83.96	52.81	0.00	1.93	2.09	0.00	3.50	0.23	0.04	0.00	0.38	0.00	0.00	0.00	0.00	**173.18**	*2.57*
Zadar	14.34	21.16	0.00	0.00	0.00	12.21	0.00	0.90	0.00	21.67	0.00	0.00	0.00	0.00	0.00	0.00	**70.28**	*1.04*
Osijek-Baranja	121.64	182.30	140.12	240.41	0.00	4.91	280.17	1.81	2.22	5.58	0.00	0.92	0.00	69.10	0.00	2.52	**1 051.71**	*15.62*
Šibenik-Knin	26.21	152.12	0.00	0.00	0.00	11.19	0.00	10.19	11.12	2.12	0.00	0.00	0.00	16.26	0.00	0.00	**229.19**	*3.40*
Vukovar-Syrmia	30.67	110.33	0.00	5.28	17.41	15.27	0.00	0.33	0.99	0.00	0.22	3.03	0.00	0.00	0.00	0.00	**183.53**	*2.73*
Split-Dalmatia	114.04	1.33	0.00	13.90	0.00	66.18	721.52	18.93	0.79	5.73	0.07	0.00	0.00	9.07	0.00	0.00	**951.53**	*14.13*
Istria	103.38	77.12	1.14	318.03	152.11	54.49	225.19	27.69	0.20	0.18	0.00	0.00	28.95	4.64	3.84	0.56	**997.51**	*14.81*
Dubrovnik-Neretva	2.99	0.00	0.00	0.00	0.00	3.13	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**6.79**	*0.10*
Međimurje	45.52	76.62	0.00	0.08	0.00	4.37	0.00	1.60	7.68	0.71	0.00	0.44	0.00	0.00	0.00	0.00	**137.01**	*2.03*
City of Zagreb	150.54	235.68	107.26	0.00	0.00	48.90	0.00	4.60	1.15	0.33	0.06	14.30	0.00	3.07	0.00	0.00	**565.89**	*8.40*
TOTAL	**1 221.34**	**2 147.01**	**494.80**	**577.70**	**242.54**	**301.71**	**1 226.88**	**97.82**	**99.38**	**83.56**	**0.55**	**102.60**	**28.95**	**102.21**	**3.84**	**3.08**	**6 733.98**	***100.00***
Share [%]	*18.14*	*31.88*	*7.35*	*8.58*	*3.60*	*4.48*	*18.22*	*1.45*	*1.48*	*1.24*	*0.01*	*1.52*	*0.43*	*1.52*	*0.06*	*0.05*	***100.00***	

Table I.33: INDUSTRIAL SECTOR – Total annual energy delivered for heating/cooling by purpose and energy product

INDUSTRIAL SECTOR	TOTAL ANNUAL ENERGY DELIVERED FOR HEATING/COOLING IN 2019 BY ENERGY PRODUCT [GWh/a]																Share [%]
County	Electricity	Natural gas	DHS	Hard/brown coal and their briquettes	Coke (metallurgical and foundry)	Fuel oil	Petroleum coke	LPG	Firewood	Wood pellets / wood chips	Wood, straw and similar briquettes	Wood waste	Old tyres	Waste oils and emulsions	Meat and bone meal	Dried sludge – DSS	TOTAL	
Heating in the production process	821.78	1 724.45	355.14	577.70	242.54	301.71	1 226.88	97.82	99.38	83.56	0.55	102.60	28.95	102.21	3.84	3.08	**5 772.19**	85.72
Space heating and DHW preparation	42.19	397.90	139.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**579.75**	8.61
Cooling in the production process	245.65	24.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**270.31**	4.01
Space cooling	111.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**111.72**	1.66
TOTAL	**1 221.34**	**2 147.01**	**494.80**	**577.70**	**242.54**	**301.71**	**1 226.88**	**97.82**	**99.38**	**83.56**	**0.55**	**102.60**	**28.95**	**102.21**	**3.84**	**3.08**	**6 733.98**	***100.00***
Share [%]	*18.14*	*31.88*	*7.35*	*8.58*	*3.60*	*4.48*	*18.22*	*1.45*	*1.48*	*1.24*	*0.01*	*1.52*	*0.43*	*1.52*	*0.06*	*0.05*	***100.00***	

For the following energy products:

- electricity,
- steam and water at temperatures lower than or equal to 200 °C,
- steam and water at temperatures higher than 200 °C, and
- network-distributed natural gas,

the Croatian Bureau of Statistics has provided data on the distribution of the total energy delivered by individual energy products, according to their purpose for each type of activity defined by its NCA code.

Due to the complexity and size of the table, this study does not include it in its entirety. The distribution of the total electricity delivered, using mill products and beer as examples, is provided in the table below.

Table I.34: Distribution of total electricity delivered according to needs, using manufacture of mill products and beer as examples

NCA code	Name	**Electricity – share in the total energy delivered [–]**							
		Heat in the production process	Space and water heating/cooling in office buildings	Cooling in the production process	Electric motor	Electrochemical use	Appliances (including IT equipment) and lighting	Other energy purposes	**TOTAL**
1061	Manufacture of mill products	**0.0745**	**0.0005**	**0.0195**	0.8303	0.0000	0.0752	0.0000	**1.00**
1105	Manufacture of beer	**0.4546**	**0.0385**	**0.1444**	0.3424	0.0016	0.0185	0.0000	**1.00**

The total energy delivered from individual energy products (electricity, steam and water at temperatures lower than or equal to 200 °C, steam and water at temperature higher than 200 °C, and network-distributed natural gas) has been distributed by needs, depending on their NCA code. For the purpose of further analysis, only the portion of energy delivered from individual energy products used for heating (heating for production process purposes or building space heating), DHW preparation and cooling (cooling for production process purposes or building space cooling) in the industrial sector has been taken into account.

Of the following total energy delivered to the industrial sector:

- electricity,
- steam and water at temperatures lower than or equal to 200 °C,
- steam and water at temperatures higher than 200 °C, and
- network-distributed natural gas,

only the energy delivered for heating/cooling purposes is shown below.

Electricity and natural gas are used for (see Table I.35:. Table I.36:):

- heating in the production process;
- space and water heating/cooling in related office buildings; and
- cooling in the production process (using absorption cooling unit).

It is evident that 35.23% of the total electricity delivered to the industrial sector is consumed for heating/cooling, while 64.77% is used for other purposes (motor drives, electrochemical purposes, powering of appliances including IT equipment, lighting and other energy purposes).

In the case of network-distributed natural gas, 99.89% of natural gas is used for heating/cooling.

Table I.35: INDUSTRIAL SECTOR – Distribution of electricity delivered by counties

INDUSTRIAL SECTOR		ELECTRICITY DISTRIBUTION [GWh/a]				
	County	TOTAL	Heat in the production process	Space and water heating/cooling in office buildings	Cooling in the production process	Other
1	Zagreb County	**245.08**	49.48	27.30	20.77	147.52
2	Krapina-Zagorje	**215.41**	46.12	3.79	4.02	161.48
3	Sisak-Moslavina	**353.91**	96.24	5.05	46.64	205.97
4	Karlovac	**107.45**	28.74	3.76	7.22	67.74
5	Varaždin	**262.26**	76.97	6.14	20.97	158.18
6	Koprivnica-Križevci	**103.37**	8.87	9.74	14.32	70.44
7	Bjelovar-Bilogora	**101.05**	18.68	2.46	6.56	73.35
8	Primorje-Gorski Kotar	**146.83**	10.76	5.33	3.93	126.81
9	Lika-Senj	**91.85**	5.16	1.32	13.87	71.50
10	Virovitica-Podravina	**60.89**	6.28	2.43	1.60	50.58
11	Požega-Slavonia	**68.54**	25.25	2.29	1.71	39.28
12	Slavonski Brod-Posavina	**81.37**	15.26	4.86	8.12	53.13
13	Zadar	**46.27**	8.58	2.63	3.13	31.93
14	Osijek-Baranja	**354.97**	94.55	11.12	15.97	233.32
15	Šibenik-Knin	**108.08**	24.20	0.97	1.04	81.87
16	Vukovar-Syrmia	**98.45**	20.70	3.14	6.84	67.78
17	Split-Dalmatia	**232.20**	95.18	9.73	9.12	118.16
18	Istria	**248.63**	80.18	11.27	11.93	145.25
19	Dubrovnik-Neretva	**7.36**	1.77	0.59	0.62	4.38
20	Međimurje	**155.28**	34.10	4.78	6.78	109.62
21	City of Zagreb	**377.17**	74.69	35.21	40.48	226.78
	TOTAL	**3 466.41**	**821.78**	**153.91**	**245.65**	**2 245.06**
	Share [%]	*100.00*	*23.71*	*4.44*	*7.09*	*64.77*

Table I.36: INDUSTRIAL SECTOR – Distribution of network-distributed natural gas delivered by counties

INDUSTRIAL SECTOR		DISTRIBUTION OF NETWORK-DISTRIBUTED NATURAL GAS [GWh/a]				
	County	TOTAL	Heat in the production process	Space and water heating/cooling in office buildings	Cooling in the production process	Other
1	Zagreb County	**133.59**	89.04	44.26	0.30	0.00
2	Krapina-Zagorje	**453.66**	421.32	29.88	0.29	2.16
3	Sisak-Moslavina	**73.32**	59.63	13.34	0.34	0.00
4	Karlovac	**37.31**	36.14	1.17	0.01	0.00
5	Varaždin	**261.34**	180.88	79.90	0.31	0.24
6	Koprivnica-Križevci	**132.08**	93.20	38.81	0.07	0.00
7	Bjelovar-Bilogora	**54.56**	42.18	12.35	0.03	0.00
8	Primorje-Gorski Kotar	**4.49**	3.22	1.01	0.27	0.00
9	Lika-Senj	**0.66**	0.35	0.32	0.00	0.00
10	Virovitica-Podravina	**43.79**	31.48	12.20	0.11	0.00
11	Požega-Slavonia	**13.99**	8.45	5.54	0.00	0.00
12	Slavonski Brod-Posavina	**83.96**	65.16	18.47	0.33	0.00
13	Zadar	**21.16**	18.78	2.37	0.01	0.00
14	Osijek-Baranja	**182.30**	153.61	21.64	7.05	0.00
15	Šibenik-Knin	**152.12**	149.91	2.21	0.00	0.00
16	Vukovar-Syrmia	**110.33**	99.30	10.97	0.06	0.00
17	Split-Dalmatia	**1.33**	0.53	0.79	0.01	0.00
18	Istria	**77.12**	63.73	8.87	4.52	0.00
19	Dubrovnik-Neretva	**0.00**	0.00	0.00	0.00	0.00
20	Međimurje	**76.88**	44.02	29.04	3.83	0.00
21	City of Zagreb	**235.42**	163.53	64.76	7.12	0.00
	TOTAL	**2 149.41**	**1 724.45**	**397.90**	**24.66**	**2.40**
	Share [%]	*100.00*	*80.23*	*18.51*	*1.15*	*0.11*

Steam and water at temperatures lower than or equal to 200 °C and steam and water at temperatures higher than 200 °C are used for (Table I.37:, Table I.38:):

- heating in the production process; and
- space and water heating/cooling in related office buildings.

The delivered steam and water energy is mainly used for heating/cooling. In the Zadar County, there is a company using steam and water at temperatures lower than or equal to 200 °C, with the NCA code 0893. However, according to the Croatian Bureau of Statistics distribution of steam and water consumption, no delivered steam or water energy is used for heating/cooling, so the stated amount of steam and water has been categorised under other energy purposes.

Table I.37: INDUSTRIAL SECTOR – Distribution of energy delivered from steam and water at temperatures lower than or equal to 200 °C by counties

INDUSTRIAL SECTOR		Distribution of steam and water at temperatures lower than or equal to 200 °C [GWh/a]			
	County	**TOTAL**	**Heat in the production process**	**Space and water heating/cooling in office buildings**	**Other**
1	Zagreb County	**88.23**	57.24	30.99	0.00
2	Krapina-Zagorje	**3.35**	2.82	0.53	0.00
3	Sisak-Moslavina	**1 324.14**	1 319.24	4.90	0.00
4	Karlovac	**9.96**	9.32	0.63	0.00
5	Varaždin	**72.96**	63.01	9.95	0.00
6	Koprivnica-Križevci	**54.32**	35.49	18.83	0.00
7	Bjelovar-Bilogora	**22.72**	21.28	1.44	0.00
8	Primorje-Gorski Kotar	**0.00**	0.00	0.00	0.00
9	Lika-Senj	**24.02**	22.40	1.63	0.00
10	Virovitica-Podravina	**21.81**	13.15	8.66	0.00
11	Požega-Slavonia	**18.72**	11.79	6.93	0.00
12	Slavonski Brod-Posavina	**64.17**	63.53	0.64	0.00
13	Zadar	**21.67**	0.00	0.00	21.67
14	Osijek-Baranja	**62.29**	51.37	10.92	0.00
15	Šibenik-Knin	**0.00**	0.00	0.00	0.00
16	Vukovar-Syrmia	**4.51**	2.72	1.79	0.00
17	Split-Dalmatia	**3.90**	3.61	0.29	0.00
18	Istria	**23.31**	20.93	2.38	0.00
19	Dubrovnik-Neretva	**0.00**	0.00	0.00	0.00
20	Međimurje	**0.00**	0.00	0.00	0.00
21	City of Zagreb	**113.93**	71.46	42.47	0.00
	TOTAL	**1 933.99**	**1 769.35**	**142.98**	**21.67**
	Share [%]	*100.00*	*91.49*	*7.39*	*1.12*

Table I.38: INDUSTRIAL SECTOR – Distribution of energy delivered from steam and water at temperatures higher than 200 °C by counties

INDUSTRIAL SECTOR		Distribution of steam and water at temperatures higher than 200 °C [GWh/a]			
	County	**TOTAL**	**Heat in the production process**	**Space and water heating/cooling in office buildings**	**Other**
1	Zagreb County	**7.50**	0.00	0.00	7.50
2	Krapina-Zagorje	**0.00**	0.00	0.00	0.00
3	Sisak-Moslavina	**0.00**	0.00	0.00	0.00
4	Karlovac	**37.50**	23.31	14.19	0.00
5	Varaždin	**1.39**	1.26	0.13	0.00
6	Koprivnica-Križevci	**10.29**	3.88	5.02	1.39
7	Bjelovar-Bilogora	**3.67**	1.60	2.07	0.00
8	Primorje-Gorski Kotar	**13.89**	9.00	4.89	0.00

INDUSTRIAL SECTOR		Distribution of steam and water at temperatures higher than 200 °C [GWh/a]			
County		**TOTAL**	**Heat in the production process**	**Space and water heating/cooling in office buildings**	**Other**
9	Lika-Senj	**0.00**	0.00	0.00	0.00
10	Virovitica-Podravina	**115.00**	107.71	7.28	0.00
11	Požega-Slavonia	**4.28**	3.43	0.84	0.00
12	Slavonski Brod-Posavina	**0.00**	0.00	0.00	0.00
13	Zadar	**51.39**	51.39	0.00	0.00
14	Osijek-Baranja	**855.84**	809.16	46.68	0.00
15	Šibenik-Knin	**3.33**	2.78	0.56	0.00
16	Vukovar-Syrmia	**62.60**	60.52	2.07	0.00
17	Split-Dalmatia	**2.78**	2.78	0.00	0.00
18	Istria	**22.70**	11.65	11.05	0.00
19	Dubrovnik-Neretva	**0.00**	0.00	0.00	0.00
20	Međimurje	**13.25**	12.54	0.71	0.00
21	City of Zagreb	**51.48**	39.26	12.22	0.00
	TOTAL	**1 256.87**	**1 140.28**	**107.70**	**8.89**
	Share [%]	*100.00*	*90.72*	*8.57*	*0.71*

Furthermore, in the case of all energy products (electricity, natural gas, steam and water at temperatures lower than or equal to 200 °C, and steam and water temperature higher than 200 °C), the already excluded amount of energy products for heating/cooling and DHW in the related office buildings needs to be divided further as follows:

- energy delivered for space heating in office buildings,
- energy delivered for space cooling in office buildings, and
- energy delivered for DHW preparation in office buildings

to determine separately the annual thermal energy needed for heating and cooling.

ELECTRICITY DISTRIBUTION – Space and water heating/cooling in office buildings

A portion of the total electricity delivered is used for space heating/cooling in office buildings, or for DHW preparation. In office buildings, DHW is mostly generated from individual electric boilers, space cooling is performed by compression cooling units (mostly split air conditioning), while electricity in the heating system is mostly used for powering circulation pumps in initial heating circuits. The distribution of consumption of electricity delivered to office buildings in the continental and the coastal part of Croatia is provided in tabular form. The figures have been defined based on the experience acquired in the process of conducting energy audits of office buildings and electricity consumption modelling, which forms a mandatory part of the *Report on a completed energy audit of the building* for the purpose of energy certification of buildings. As expected, in the coastal part of Croatia, more electricity is used for space cooling and less for space heating.

Table I.39: INDUSTRIAL SECTOR – Distribution of a portion of the total electricity delivered for space heating/cooling of offices and DHW preparation

INDUSTRY – related office buildings	**Share of distribution of the consumption of electricity for space heating/cooling and DHW preparation [–]**			
	Space heating	**DHW**	**Space cooling**	**TOTAL**
K – continental Croatia	0.1083	0.2052	0.6864	**1.0000**
P – coastal Croatia	0.0541	0.0560	0.8899	**1.0000**

Municipalities, cities or towns belong in continental Croatia when the average monthly external air temperature in the coldest month, according to meteorological data for the nearest competent weather station, $\theta_{mm} \leq 3$ °C.

Municipalities, cities or towns belong in coastal Croatia when the average monthly external air temperature in the coldest month, according to meteorological data for the nearest competent weather station, θ_{mm} > 3 °C.

Table I.40: INDUSTRIAL SECTOR – Distribution of electricity delivered by counties

INDUSTRIAL SECTOR		ELECTRICITY DISTRIBUTION [GWh/a]			
	County	Space and water heating/cooling in office buildings	Space heating	DHW	Space cooling
1	Zagreb County	**27.30**	2.96	5.60	18.74
2	Krapina-Zagorje	**3.79**	0.41	0.78	2.60
3	Sisak-Moslavina	**5.05**	0.55	1.04	3.47
4	Karlovac	**3.76**	0.41	0.77	2.58
5	Varaždin	**6.14**	0.67	1.26	4.22
6	Koprivnica-Križevci	**9.74**	1.06	2.00	6.69
7	Bjelovar-Bilogora	**2.46**	0.27	0.50	1.69
8	Primorje-Gorski Kotar	**5.33**	0.33	0.41	4.59
9	Lika-Senj	**1.32**	0.14	0.25	0.92
10	Virovitica-Podravina	**2.43**	0.26	0.50	1.67
11	Požega-Slavonia	**2.29**	0.25	0.47	1.57
12	Slavonski Brod-Posavina	**4.86**	0.53	1.00	3.34
13	Zadar	**2.63**	0.14	0.15	2.34
14	Osijek-Baranja	**11.12**	1.21	2.28	7.63
15	Šibenik-Knin	**0.97**	0.05	0.05	0.86
16	Vukovar-Syrmia	**3.14**	0.34	0.64	2.15
17	Split-Dalmatia	**9.73**	0.53	0.54	8.66
18	Istria	**11.27**	0.61	0.63	10.03
19	Dubrovnik-Neretva	**0.59**	0.03	0.03	0.53
20	Međimurje	**4.78**	0.52	0.98	3.28
21	City of Zagreb	**35.21**	3.82	7.23	24.17
	TOTAL	**153.91**	**15.06**	**27.13**	**111.72**
	Share [%]	*100.00*	*9.78*	*17.63*	*72.59*

NATURAL GAS DISTRIBUTION – Space and water heating/cooling in office buildings

Where natural gas is used in related office buildings, the already excluded amount of natural gas for heating/cooling of space and water in office buildings is taken to be used exclusively for space heating of office buildings. Due to low DHW consumption in office buildings, DHW preparation is predominantly decentralised using individual electric boilers. Space cooling using natural gas combustion in office buildings is rare in Croatia.

STEAM AND WATER DISTRIBUTION – Space and water heating/cooling in office buildings

Where steam and water are used for heating/cooling and DHW preparation in office buildings, the entire amount of already excluded steam/water energy for heating/cooling and DHW preparation in office buildings is taken to be consumed exclusively for space heating of related office buildings.

Total energy delivered to the industrial sector in Croatia in 2019 amounted to **8 981.44 GWh** for a total of 2 4798 [sic – likely editing error, instead of 2 478] companies which, according to their NCA code, belong to the industrial sector.

Total energy delivered for heating/cooling purposes to the industrial sector in Croatia amounted to **6 733.98 GWh** in 2019.

Of the total 2019 energy delivered to the industrial sector, 74.98% was used for heating/cooling.

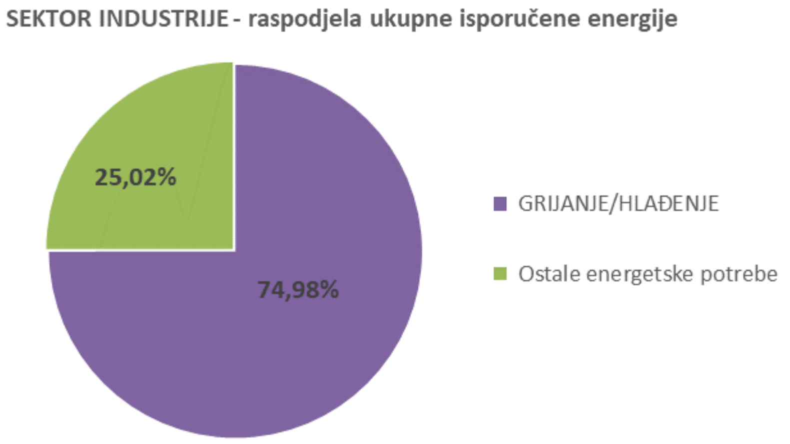


Figure I.23: INDUSTRIAL SECTOR – Distribution of total energy delivered

CROATIAN	ENGLISH
SEKTOR INDUSTRIJE - raspodjela ukupne isporučene energije	INDUSTRIAL SECTOR – Distribution of total energy delivered
GRIJANJE/HLAĐENJE	HEATING/COOLING
Ostale energetske potrebe	Other energy needs

An overview of energy delivered for heating/cooling is provided in tabular form (Table I.41:). It is evident that 94.33% of the total energy delivered to the industrial sector for heating/cooling is used for heating, with a mere 5.67% used for cooling.

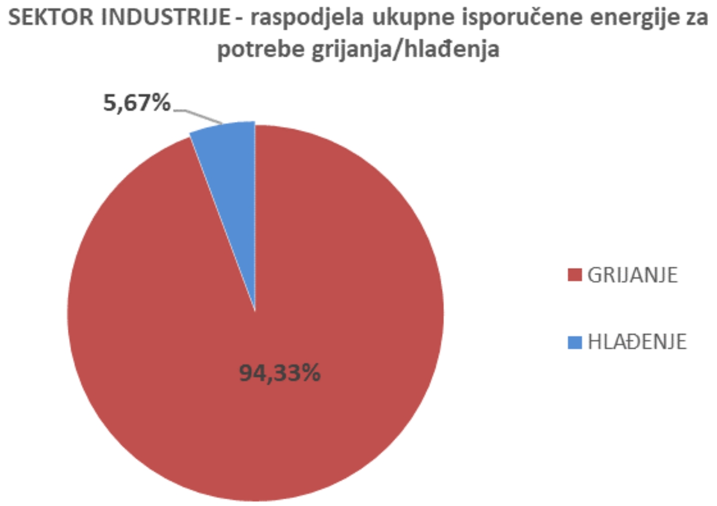


Figure I.24: INDUSTRIAL SECTOR – Distribution of total annual energy delivered for heating/cooling

CROATIAN	ENGLISH
SEKTOR INDUSTRIJE - raspodjela ukupne isporučene energije za potrebe grijanja/hlađenja	INDUSTRIAL SECTOR – Distribution of total annual energy delivered for heating/cooling
GRIJANJE	HEATING
HLAĐENJE	COOLING

The amount of energy delivered for heating/cooling was the highest in the Osijek-Baranja County (15.62%), followed by the Istria County (14.81%) and the Split-Dalmatia County (14.13%).

The following counties are large consumers of the energy delivered for heating/cooling:

- **Osijek-Baranja County**: manufacture of paper, cement industry, processing of wood and wood products, manufacture of sugar, manufacture of oil, and manufacture of other non-metallic mineral products;
- **Istria County**: manufacture of other non-metallic mineral products, manufacture of motor vehicles, trailers and semi-trailers, and manufacture of tobacco products; and
- **Split-Dalmatia County**: manufacture of other non-metallic mineral products, printing and reproduction of recorded media, manufacture of rubber and plastic products, and manufacture of other transport equipment.

Table I.41: INDUSTRIAL SECTOR – Total annual energy delivered for heating/cooling by county

INDUSTRIAL SECTOR		**ENERGY DELIVERED FOR HEATING/COOLING**			
County		**Energy delivered for heating [GWh/a]**	**Energy delivered for cooling [GWh/a]**	**Total energy delivered for heating/cooling [GWh/a]**	**Share [%]**
1	Zagreb County	211.33	39.81	251.14	3.73
2	Krapina-Zagorje	503.95	6.91	510.86	7.59
3	Sisak-Moslavina	353.08	50.45	403.53	5.99
4	Karlovac	102.69	9.80	112.50	1.67
5	Varaždin	446.81	25.50	472.32	7.01
6	Koprivnica-Križevci	156.42	21.08	177.50	2.64
7	Bjelovar-Bilogora	91.62	8.28	99.91	1.48
8	Primorje-Gorski Kotar	82.57	8.79	91.36	1.36
9	Lika-Senj	48.74	14.80	63.53	0.94
10	Virovitica-Podravina	117.59	3.37	120.96	1.80
11	Požega-Slavonia	60.47	3.29	63.76	0.95
12	Slavonski Brod-Posavina	161.39	11.79	173.18	2.57
13	Zadar	64.79	5.48	70.28	1.04
14	**Osijek-Baranja**	**1 021.05**	**30.65**	**1 051.71**	**15.62**
15	Šibenik-Knin	227.29	1.90	229.19	3.40
16	Vukovar-Syrmia	174.49	9.04	183.53	2.73
17	Split-Dalmatia	933.74	17.79	951.53	14.13
18	Istria	971.03	26.48	997.51	14.81
19	Dubrovnik-Neretva	5.64	1.15	6.79	0.10
20	Međimurje	123.53	13.89	137.42	2.04
21	City of Zagreb	493.70	71.78	565.48	8.40
	TOTAL	**6 351.94**	**382.04**	**6 733.98**	**100.00**
	Share [%]	*94.33*	*5.67*	*100.00*	

Table I.42: provides an overview of the number of industrial companies and the total energy delivered for heating/cooling in a total of five intervals of energy delivered for heating/cooling.

Croatia has a total of 54 industrial companies with the total individual energy delivered for heating/cooling ≥ 20 GWh.

For 2 317 out of the total of 2 478 industrial companies, the total individual energy delivered for heating/cooling is below 5 GWh.

Table I.42: INDUSTRIAL SECTOR - Total energy delivered for heating/cooling

Total individual energy delivered for heating/cooling **X** [GWh/a]	Number of industrial enterprises	Total energy delivered for heating/cooling [GWh/a]	Share of total energy delivered for heating/cooling [%]
***X* ≥ 100**	7	2 895.85	*42.70*
50 ≥ X < 100	12	886.09	*13.07*
20 ≥ X < 50	35	1 076.87	*15.88*
10 ≥ X < 20	45	635.61	*9.37*

5 ≥ X < 10	62	431.75	*6.37*

1.2.3.5 DISTRIBUTION OF TOTAL ENERGY DELIVERED TO THE INDUSTRIAL SECTOR BY ACTIVITY

The distribution of:

- total energy delivered to the industrial sector,
- energy delivered to the industrial sector for heating,
- energy delivered to the industrial sector for cooling, and
- total energy delivered to the industrial sector for heating/cooling,

is provided in tabular form, according to the type of activity, i.e. the NCA code.

74.98% of the total energy delivered to the industrial sector for heating/cooling is used for the following activities:

1. **Manufacture of other non-metallic mineral products** (50.79%),
2. manufacture of food products (12.39%),
3. manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials (7.53%), and
4. metal production (4.50%).

Less than 3.06% of the total energy delivered for heating/cooling is consumed individually for other individual activities, stated in the table.

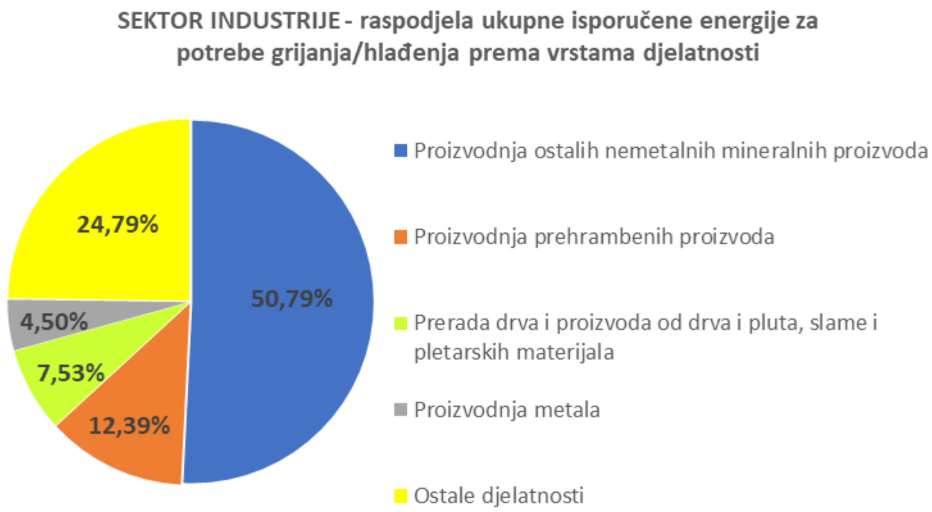


Figure I.25: INDUSTRIAL SECTOR – Distribution of total energy delivered for heating/cooling by type of activity

CROATIAN	ENGLISH
SEKTOR INDUSTRIJE - raspodjela ukupne isporučene energije za potrebe grijanja/hlađenja prema vrstama djelatnosti	INDUSTRIAL SECTOR – Distribution of total energy delivered for heating/cooling by type of activity
Proizvodnja ostalih nemetalnih mineralnih proizvoda	Manufacture of other non-metallic mineral products
Proizvodnja prehrambenih proizvoda	Manufacture of food products
Prerada drva i proizvoda od drva i pluta, slame i pletarskih materijala	Manufacture of wood and of products of wood and cork, straw and plaiting materials
Proizvodnja metala	Metal production
Ostale djelatnosti	Other activities

Manufacture of other non-metallic mineral products (sand, gravel, stone, clay) includes: manufacture of glass and glass products, manufacture of refractory products (plaster, concrete, brick, roofing-tile), manufacture of clay products (ceramic tiles, brick, roofing-tile), manufacture of other porcelain and clay products, manufacture of cement, lime and plaster, manufacture of cement, lime and plaster products, cutting, shaping and finishing of stone, and manufacture of stone working products and non-metallic mineral products.

Table I.43: INDUSTRIAL SECTOR – Total energy delivered by type of activity

NCA code	TYPE OF ACTIVITY	Total energy delivered to the industry [GWh/a]	Energy delivered for heating [GWh/a]	Energy delivered for cooling [GWh/a]	Total energy delivered for heating/cooling [GWh/a]	Share [%]
0811	Other mining and quarrying	137.85	46.51	15.20	**61.71**	*0.92*
0910	Mining support service activities	8.30	2.88	0.08	**2.97**	*0.04*
1083	Manufacture of food products	1 072.55	695.97	138.19	**834.16**	*12.39*
1101	Manufacture of beverages	217.67	159.99	8.47	**168.46**	*2.50*
1 200	Manufacture of tobacco products	35.23	16.42	2.14	**18.56**	*0.28*
1396	Manufacture of textiles	79.48	9.96	0.40	**10.36**	*0.15*
1439	Manufacture of wearing apparel	123.61	72.59	3.53	**76.12**	*1.13*
1520	Manufacture of leather and related products	43.58	10.78	1.78	**12.56**	*0.19*
1629	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	822.15	503.51	3.80	**507.32**	*7.53*
1721	Manufacture of paper and paper products	291.59	107.46	3.65	**111.11**	*1.65*
1812	Printing and reproduction of recorded media	167.76	82.59	11.37	**93.97**	*1.40*
2059	Manufacture of chemicals and chemical products	256.75	104.29	50.59	**154.88**	*2.30*
2120	Manufacture of basic pharmaceutical products and pharmaceutical preparations	231.28	128.89	41.77	**170.66**	*2.53*
2229	Manufacture of rubber and plastic products	302.34	184.70	21.69	**206.39**	*3.06*
2363	**Manufacture of other non-metallic mineral products**	3 764.49	3 402.35	17.60	**3 419.95**	*50.79*
2410	Metal production	445.37	301.17	2.10	**303.27**	*4.50*
2511	Manufacture of fabricated metal products, except machinery and equipment	270.37	145.97	8.12	**154.09**	*2.29*
2620	Manufacture of computer, electronic and optical products	20.38	9.13	1.08	**10.20**	*0.15*
2790	Manufacture of electrical equipment	177.45	78.01	25.68	**103.68**	*1.54*
2829	Manufacture of machinery and equipment n.e.c.	130.76	73.60	4.62	**78.22**	*1.16*
2920	Manufacture of motor vehicles, trailers and semi-trailers	105.02	63.51	12.69	**76.20**	*1.13*
3012	Manufacture of other transport equipment	44.83	24.80	4.23	**29.03**	*0.43*
3101	Manufacture of furniture	198.26	105.15	2.57	**107.72**	*1.60*
3220	Other manufacturing	34.38	21.72	0.68	**22.40**	*0.33*
	TOTAL	**8 981.44**	**6 351.94**	**382.04**	**6 733.98**	**100.00**
	Share [%]		94.33	5.67	**100.00**	

1.2.3.6 INDUSTRIAL BOILER ROOMS

Total number of industrial boiler rooms in Croatia in 2019: **57**

The combustion of fuel (natural gas, fuel oil, wood waste) in the industrial boiler rooms generates the following:

- steam and water at temperatures lower than or equal to 200 °C,
- steam and water temperature higher than 200 °C.

The total consumption of energy products for the generation of steam and water at temperatures lower than or equal to 200 °C, and steam and water at temperature higher than 200 °C in industrial boiler rooms in 2019 stood at **770.58 GWh** .

Data on the consumption of individual energy source for each industrial boiler room, as well as the data on the consumption of the generated steam/water are known. The values of actually generated steam were corrected in order to obtain the average boiler room efficiency. It is evident that natural gas (78.95%) was most frequently used for steam and water generation, followed by fuel oil (11.51%) and waste (9.53%). Seven industrial boiler rooms use exclusively waste as energy source (wood industry, manufacture of furniture).

Table I.44: shows summed up data on the consumption of individual energy sources for industrial boiler room purposes.

Table I.44: INDUSTRIAL SECTOR – Industrial boiler rooms – Total annual consumption of energy sources for steam and water generation, 2019

INDUSTRIAL SECTOR – industrial boiler rooms	**Annual consumption of energy sources for steam and water generation [GWh]**				**Steam consumption (CBS) [GWh]**	**Steam generation** – corrected value **[GWh]**	**Average boiler room efficiency [–]**
	natural gas	**fuel oil**	**wood waste**	**TOTAL**			
Steam and water at temperatures lower than or equal to 200 °C	391.32	34.31	64.81	**490.44**	**409.34**	**403.32**	0.822
Steam and water at temperatures higher than 200 °C	217.06	54.42	8.66	**280.14**	**231.06**	**237.11**	0.846
TOTAL	**608.38**	**88.73**	**73.47**	**770.58**	**640.40**	**640.43**	**0.831**
Share [%]	*78.95*	*11.51*	*9.53*	***100.00***			

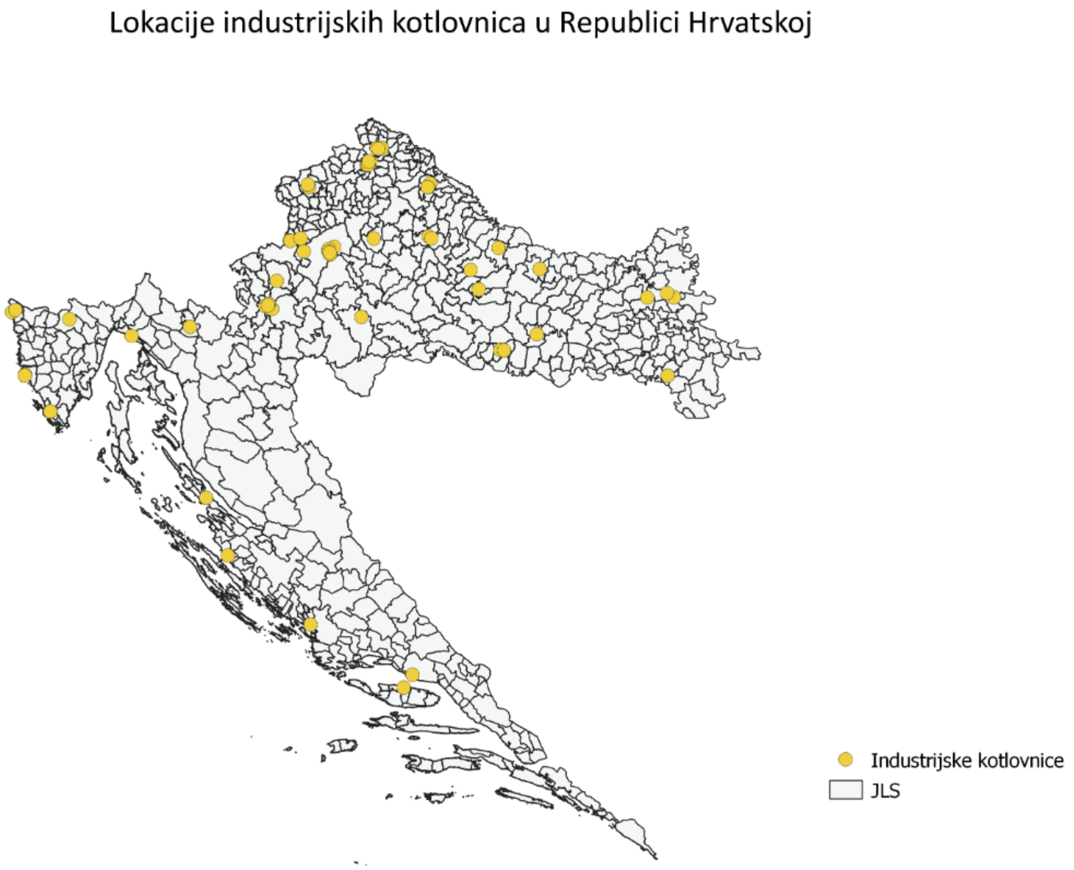


Figure I.26: INDUSTRIAL SECTOR – industrial boiler rooms

CROATIAN	ENGLISH
Lokacije industrijskih kotlovnica u Republici Hrvatskoj	Location of industrial boiler rooms in Croatia
Industrijske kotlovnice	Industrial boiler rooms
JLS	LSGU

The consumption of individual energy sources at the level of individual counties is shown in the table below, separately for:

- steam and water at temperatures less than or equal to 200 °C;
- steam and water at temperatures higher than 200 °C; and
- steam and water at temperatures lower than or equal to or higher than 200 °C (together).

Table I.45: INDUSTRIAL SECTOR – Industrial boiler rooms – Total annual consumption of energy products to generate steam and water at temperatures lower than or equal to 200 °C, 2019

	INDUSTRIAL SECTOR – industrial boiler rooms	**Steam and water at temperatures lower than or equal to 200 °C – energy source consumption [GWh]**				**Steam consumption (CBS) [GWh]**	**Steam generation – corrected value [GWh]**	**Average boiler room efficiency [–]**	Delivered steam and water energy generated from RES [GWh]	Delivered steam and water energy generated from fossil fuels [GWh]
	County	**Natural gas**	**Fuel oil**	**Wood waste**	**TOTAL**					
1	Zagreb County	91.39	1.82	0.00	**93.21**	**88.22**	**79.19**	0.850	0.00	88.22
2	Krapina-Zagorje	3.61	0.00	0.00	**3.61**	**3.35**	**3.07**	0.850	0.00	3.35
3	Sisak-Moslavina	26.16	0.00	0.00	**26.16**	**18.87**	**18.87**	0.721	0.00	18.87
4	Karlovac	0.00	11.98	0.00	**11.98**	**9.96**	**9.96**	0.831	0.00	9.96
5	Varaždin	91.00	0.00	0.00	**91.00**	**72.50**	**72.41**	0.796	0.00	72.50
6	Koprivnica-Križevci	61.63	0.00	1.89	**63.52**	**54.32**	**54.32**	0.855	1.56	52.76
7	Bjelovar-Bilogora	25.70	0.00	1.51	**27.20**	**22.72**	**22.89**	0.841	0.99	21.73
8	Primorje-Gorski Kotar	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
9	Lika-Senj	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
10	Virovitica-Podravina	0.00	0.00	28.32	**28.32**	**21.81**	**21.81**	0.770	21.81	0.00
11	Požega-Slavonia	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
12	Slavonski Brod-Posavina	4.53	0.00	1.05	**5.58**	**11.36**	**4.66**	0.835	0.81	10.56
13	Zadar	0.00	0.00	27.03	**27.03**	**21.67**	**21.67**	0.802	21.67	0.00
14	Osijek-Baranja	57.26	0.26	0.00	**57.51**	**47.17**	**49.19**	0.855	0.00	47.17
15	Šibenik-Knin	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
16	Vukovar-Syrmia	0.00	0.00	5.03	**5.03**	**4.51**	**3.89**	0.774	4.51	0.00
17	Split-Dalmatia	0.00	5.15	0.00	**5.15**	**3.90**	**3.90**	0.758	0.00	3.90
18	Istria	27.18	7.59	0.00	**34.77**	**22.32**	**28.93**	0.832	0.00	22.32
19	Dubrovnik-Neretva	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
20	Međimurje	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
21	City of Zagreb	2.86	7.51	0.00	**10.38**	**6.66**	**8.56**	0.825	0.00	6.66
	TOTAL	**391.32**	**34.31**	**64.81**	**490.44**	**409.34**	**403.32**	**0.822**	**51.34**	**358.00**
	Share [%]	*79.79*	*7.00*	*13.22*	***100.00***					

Table I.46: INDUSTRIAL SECTOR – Industrial boiler rooms – Total annual consumption of energy sources to generate steam and water temperature higher than 200 °C, 2019

INDUSTRIAL SECTOR – industrial boiler rooms		**Steam and water at temperatures higher than 200 °C – energy source consumption [GWh]**				**Steam consumption (CBS) [GWh]**	**Steam generation** – corrected value **[GWh]**	**Average boiler room efficiency [–]**	Delivered steam and water energy generated from RES [GWh]	Delivered steam and water energy generated from fossil fuels [GWh]
	County	**Natural gas**	**Fuel oil**	**Wood waste**	**TOTAL**					
1	Zagreb County	5.93	0.00	0.00	**5.93**	**7.50**	**5.04**	0.850	0.00	7.50
2	Krapina-Zagorje	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
3	Sisak-Moslavina	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
4	Karlovac	21.76	20.85	0.00	**42.62**	**37.50**	**37.50**	0.880	0.00	37.50
5	Varaždin	2.00	0.00	0.00	**2.00**	**1.39**	**1.39**	0.696	0.00	1.39
6	Koprivnica-Križevci	16.33	0.00	0.00	**16.33**	**10.29**	**13.54**	0.829	0.00	10.29
7	Bjelovar-Bilogora	4.67	0.00	0.00	**4.67**	**3.67**	**3.67**	0.787	0.00	3.67
8	Primorje-Gorski Kotar	9.88	0.25	8.66	**18.78**	**13.89**	**13.89**	0.739	6.67	7.22
9	Lika-Senj	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
10	Virovitica-Podravina	8.97	0.00	0.00	**8.97**	**7.78**	**7.78**	0.867	0.00	7.78
11	Požega-Slavonia	5.99	0.00	0.00	**5.99**	**4.28**	**5.09**	0.850	0.00	4.28
12	Slavonski Brod-Posavina	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
13	Zadar	53.25	0.00	0.00	**53.25**	**51.39**	**45.27**	0.850	0.00	51.39
14	Osijek-Baranja	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
15	Šibenik-Knin	0.00	4.11	0.00	**4.11**	**3.33**	**3.33**	0.811	0.00	3.33
16	Vukovar-Syrmia	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
17	Split-Dalmatia	0.00	2.69	0.00	**2.69**	**2.78**	**2.23**	0.830	0.00	2.78
18	Istria	0.17	26.53	0.00	**26.70**	**22.55**	**22.55**	0.845	0.00	22.55
19	Dubrovnik-Neretva	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
20	Međimurje	18.88	0.00	0.00	**18.88**	**13.25**	**16.05**	0.850	0.00	13.25
21	City of Zagreb	69.23	0.00	0.00	**69.23**	**51.48**	**59.78**	0.864	0.00	51.48
	TOTAL	**217.06**	**54.42**	**8.66**	**280.14**	**231.06**	**237.11**	**0.846**	**6.67**	**224.40**
	Share [%]	*77.48*	*19.43*	*3.09*	***100.00***					

Table I.47. INDUSTRIAL SECTOR – Industrial boiler rooms – Total annual consumption of energy sources for steam and water generation, 2019

INDUSTRIAL SECTOR – industrial boiler rooms		**Steam and water – energy source consumption [GWh]**				**Steam consumption (CBS) [GWh]**	**Steam generation** – corrected value **[GWh]**	**Average boiler room efficiency [–]**	Delivered steam and water energy generated from RES [GWh]	Delivered steam and water energy generated from fossil fuels [GWh]
	County	**Natural gas**	**Fuel oil**	**Wood waste**	**TOTAL**					
1	Zagreb County	97.31	1.82	0.00	**99.13**	**95.72**	**84.23**	0.850	0.00	95.72
2	Krapina-Zagorje	3.61	0.00	0.00	**3.61**	**3.35**	**3.07**	0.850	0.00	3.35
3	Sisak-Moslavina	26.16	0.00	0.00	**26.16**	**18.87**	**18.87**	0.721	0.00	18.87
4	Karlovac	21.76	32.83	0.00	**54.60**	**47.46**	**47.46**	0.869	0.00	47.46
5	Varaždin	93.00	0.00	0.00	**93.00**	**73.89**	**73.80**	0.794	0.00	73.89
6	Koprivnica-Križevci	77.96	0.00	1.89	**79.84**	**64.60**	**67.86**	0.850	1.56	63.05
7	Bjelovar-Bilogora	30.36	0.00	1.51	**31.87**	**26.39**	**26.56**	0.833	0.99	25.40
8	Primorje-Gorski Kotar	9.88	0.25	8.66	**18.78**	**13.89**	**13.89**	0.739	6.67	7.22
9	Lika-Senj	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
10	Virovitica-Podravina	8.97	0.00	28.32	**37.29**	**29.58**	**29.58**	0.793	21.81	7.78
11	Požega-Slavonia	5.99	0.00	0.00	**5.99**	**4.28**	**5.09**	0.850	0.00	4.28
12	Slavonski Brod-Posavina	4.53	0.00	1.05	**5.58**	**11.36**	**4.66**	0.835	0.81	10.56
13	Zadar	53.25	0.00	27.03	**80.28**	**73.06**	**66.93**	0.834	21.67	51.39
14	Osijek-Baranja	57.26	0.26	0.00	**57.51**	**47.17**	**49.19**	0.855	0.00	47.17
15	Šibenik-Knin	0.00	4.11	0.00	**4.11**	**3.33**	**3.33**	0.811	0.00	3.33
16	Vukovar-Syrmia	0.00	0.00	5.03	**5.03**	**4.51**	**3.89**	0.774	4.51	0.00
17	Split-Dalmatia	0.00	7.84	0.00	**7.84**	**6.68**	**6.13**	0.783	0.00	6.68
18	Istria	27.36	34.12	0.00	**61.47**	**44.87**	**51.48**	0.838	0.00	44.87
19	Dubrovnik-Neretva	0.00	0.00	0.00	**0.00**	**0.00**	**0.00**	0.000	0.00	0.00
20	Međimurje	18.88	0.00	0.00	**18.88**	**13.25**	**16.05**	0.850	0.00	13.25
21	City of Zagreb	72.09	7.51	0.00	**79.60**	**58.14**	**68.34**	0.859	0.00	58.14
	TOTAL	**608.38**	**88.73**	**73.47**	**770.58**	**640.40**	**640.43**	**0.831**	**58.00**	**582.40**
	Share [%]	*78.95*	*11.51*	*9.53*	***100.00***					

The delivered steam and water energy is generated by fossil fuel combustion (90.47%) and, to a lesser extent, by combustion of renewable energy sources – wood waste (9.53%).

Table I.48: INDUSTRIAL SECTOR – Industrial boiler rooms – Total annual consumption of energy sources for steam generation from fossil fuels and RES, 2019

INDUSTRY – industrial boiler rooms	Annual consumption of energy sources for steam and water generation [GWh/a]	Steam and water energy delivered [GWh/a]	Energy source share [%]
Steam and water generated by fossil fuel combustion	697.11	573.51	*90.47*
Steam and water generated by RES combustion	73.47	36.34	*9.53*
TOTAL	**770.58**	**609.84**	*100.00*

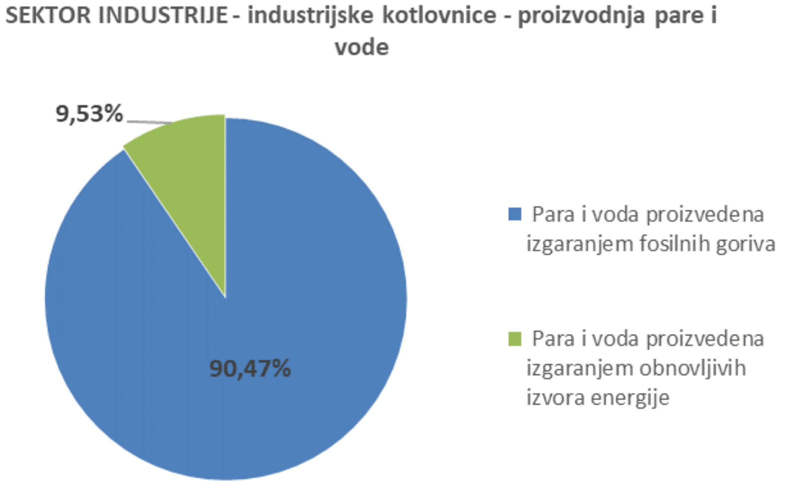


Figure I.27: INDUSTRIAL SECTOR – Industrial boiler rooms – Drive energy products for steam and water generation

CROATIAN	ENGLISH
SEKTOR INDUSTRIJE – Industrijske kotlovnice - proizvodnja pare i vode	INDUSTRIAL SECTOR – Industrial boiler rooms – Steam and water generation
Para i voda proizvedena izgaranjem fosilnih goriva	Steam and water generated by fossil fuel combustion
Para i voda proizvedena izgaranjem obnovljivih izvora energije	Steam and water generated by RES combustion

1.2.3.7 INDUSTRIAL COGENERATION INSTALLATIONS

Total number of industrial cogeneration installations in Croatia in 2019: **5**

The industrial cogeneration installations burning exclusively fossil fuels as energy sources (natural gas, brown coal and lignite) generate:

- steam and water at temperatures lower than or equal to 200 °C; (one industrial cogeneration installation); and
- steam and water at temperatures higher than 200 °C (four industrial cogeneration installations).

Croatia's industrial companies having cogeneration installations are engaged in the following:

- manufacture of sugar (three companies, with one company using brown coal and lignite as energy sources);
- manufacture of paper and paper products (one company); and
- manufacture of chemicals and chemical products (one company).

Total consumption of energy sources used to generate steam and water at temperatures lower than or equal to 200 °C, and steam and water at temperatures higher than 200 °C in the industrial cogeneration installations in 2019 stood at **2,013.01 GWh** .

It is evident that natural gas (94.33%) is the most frequently used energy source for the simultaneous generation of electricity and thermal energy in industrial cogeneration installations.

A summary of data on the consumption of individual drive energy products for industrial cogeneration installation purposes is presented in Table I.49:. Data on electricity and thermal energy generated at industrial cogeneration installations, as well as the average efficiency of cogeneration installations, have also been summarised.

Table I.49: INDUSTRIAL SECTOR – Industrial cogeneration installations – Total annual consumption of drive energy products for electricity and thermal energy generation, 2019

INDUSTRIAL SECTOR – industrial cogeneration installations	**Annual consumption of drive energy products for electricity and thermal energy generation [GWh]**			Electricity generated [GWh]	Thermal energy generated [GWh]	Average cogeneration installation efficiency [–]
	Natural gas	**Brown coal and lignite**	**TOTAL**			
Steam and water at temperatures lower than or equal to 200 °C	1 224.18	0.00	**1 224.18**	40.14	1 013.89	0.861
Steam and water at temperatures higher than 200 °C	674.72	114.12	**788.84**	80.98	557.60	0.810
TOTAL	**1 898.90**	**114.12**	**2 013.01**	**121.12**	**1 571.48**	**0.841**
Share [%]	*94.33*	*5.67*	***100.00***			

A list of industrial cogeneration installations in Croatia in 2019, stating the drive energy product consumption and generated electricity and thermal energy, is provided in tabular form.

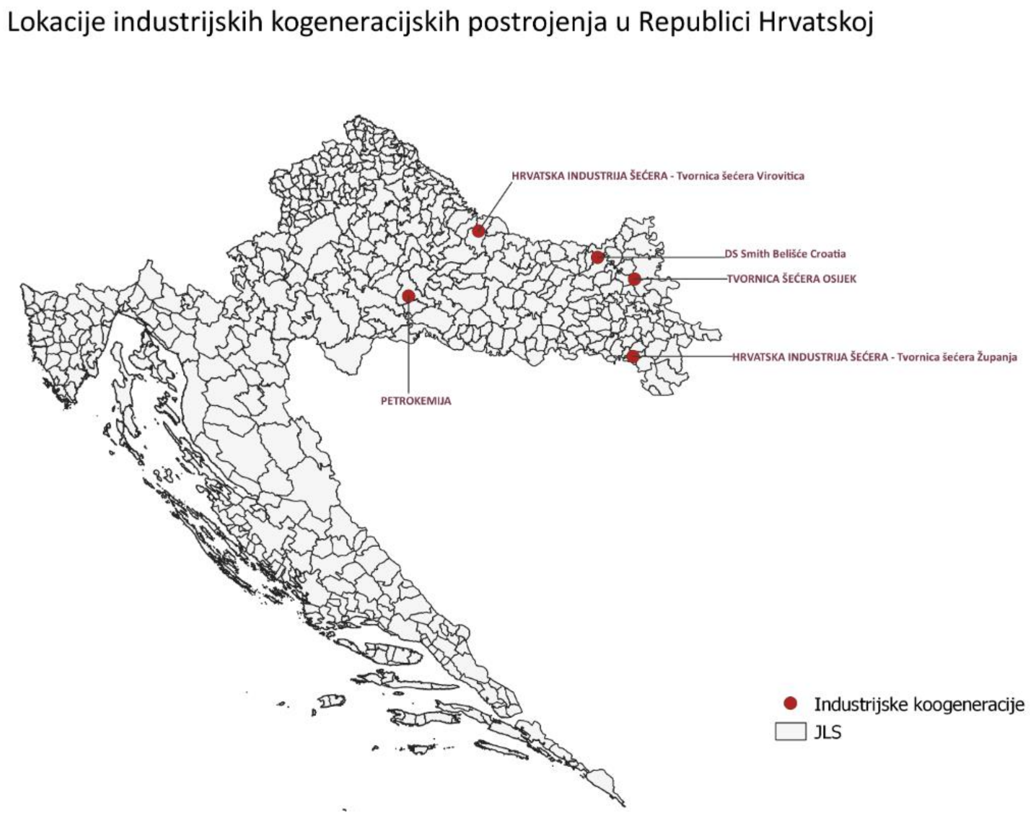


Figure I.28: INDUSTRIAL SECTOR – Industrial cogeneration installations

CROATIAN	ENGLISH

Lokacije industrijskih kogeneracijskih postrojenja u Republici Hrvatskoj	Location of industrial cogeneration installations in Croatia
Industrijske koogeneracije	Industrial cogeneration installation
JLS	LSGU
HRVATSKA INDUSTRIJA ŠEĆERA - Tvornica šećera Virovitica	CROATIAN SUGAR INDUSTRY – Virovitica Sugar Factory
DS Smith Belišće Croatia	[Paper products manufacturer] DS Smith Belišće, Croatia
TVORNICA ŠEĆERA OSIJEK	CROATIAN SUGAR INDUSTRY – Osijek Sugar Factory
HRVATSKA INDUSTRIJA ŠEĆERA - Tvornica šećera Županja	CROATIAN SUGAR INDUSTRY – Županja Sugar Factory
Lokacije industrijskih kogeneracijskih postrojenja u Republici Hrvatskoj	[Chemical company] PETROKEMIJA

Table I.50: INDUSTRIAL SECTOR – Overview of industrial cogeneration installations (2019)

	INDUSTRIAL COGENERATION INSTALLATIONS – 2019	County	Energy product name	Drive energy product	Annual consumption of drive energy products [GWh]	Electricity generated [GWh]	Thermal energy generated [GWh]	Cogeneration installation efficiency [–]
1	DS Smith Belišće Croatia	Osijek-Baranja	Steam and water at temperatures higher than 200 °C	Natural gas	**450.53**	**48.86**	**319.17**	0.817
2	CROATIAN SUGAR INDUSTRY – Županja Sugar Factory	Vukovar-Syrmia	Steam and water at temperatures higher than 200 °C	Natural gas	**84.75**	**6.46**	**62.60**	0.815
3	PETROKEMIJA	Sisak-Moslavina	Steam and water at temperatures lower than or equal to 200 °C	natural gas	**1 224.18**	**40.14**	**1 013.89**	0.861
4	CROATIAN SUGAR INDUSTRY – Osijek Sugar Factory	Osijek-Baranja	Steam and water at temperatures higher than 200 °C	brown coal and lignite	**114.12**	**12.71**	**74.44**	0.764
5	CROATIAN SUGAR INDUSTRY – Virovitica Sugar Factory	Virovitica-Podravina	Steam and water at temperatures higher than 200 °C	natural gas	**139.45**	**12.94**	**101.39**	0.820
	TOTAL				**2 013.01**	**121.12**	**1 571.48**	**0.841**

1.2.3.8 Distribution of total energy delivered to the industrial sector by technology

The following energy products were delivered to the industrial sector in 2019:

- steam and water,
  - supply directly from district heating systems (DHS),
  - generation from industrial boiler rooms,
  - generation at industrial cogeneration installations,
- electricity,
- natural gas, network-distributed,
- hard and brown coal and their briquettes,
- coke,
- fuel oil (extra light and special fuel oil, low-sulphur fuel oil (up to 1% S), high-sulphur fuel oil (1% S and higher; heavy oil)),
- petroleum coke,
- liquefied gas,
- biomass (firewood, wood pellets and chips, wood and straw briquettes, wood and plant waste),
- old tyres,
- waste oils and emulsions,
- meat and bone meal, and
- dried sludge – DSS.

The energy delivered to the industrial sector uses the following technologies:

- **industrial boiler rooms** for steam and water generation;
- **industrial cogeneration installations** for steam and water generation;
- **district heating system – DHS** for steam and water supply; and
- **other technologies,** which are powered by electricity, natural gas, hard and brown coal and their briquettes, coke, fuel oil, petroleum coke, liquefied gas, biomass, old tyres, waste oils and emulsions, meat and bone meal, and dried sludge – DSS.

A total of 57 industrial boiler rooms use predominantly fossil fuels and, to a lesser extent, renewable energy sources – wood waste, as energy products for steam and water generation. Consequently, a portion of steam and water generated at the industrial boiler rooms can be considered renewable energy sources.

All five industrial cogeneration installations in Croatia are powered by fossil fuels (natural gas, brown coal and lignite).

Considering that other technologies in the industrial sector depend on individual type of activity in the industrial sector, and they are unknown from the existing database, they were categorised among other technologies. There are surely industrial stoves among them, but also boilers. To be precise, natural gas, hard and brown coal and their briquettes, coke, fuel oil, petroleum coke, liquefied gas, biomass, old tyres, waste oils and emulsions, meat and bone meal, and dried sludge – DSS are unquestionably energy products that generate thermal energy by their combustion in industrial stoves and boilers. It should be noted that biomass, meat and bone meal, and dried sludge are considered to be renewable energy sources. Thus, we can differentiate between the category of other technologies powered by fossil fuels and the category of other technologies powered by renewable energy sources.

A total of 3 466.41 GWh of electricity was delivered to the industrial sector in 2019, amounting to 29.92% of the total energy delivered.

In 2019, 40.09% of consumed electricity in Croatia was generated from renewable energy sources, while 59.91% was generated from non-renewable energy sources (fossil and nuclear fuels).

Taking into consideration the shares of electricity generated from renewable and non-renewable energy sources, it follows that, for heating/cooling purposes in the industrial sector:

- 731.67 GWh of electricity was generated from non-renewable energy sources (fossil and nuclear fuels); and
- 489.67 GWh of electricity was generated from renewable energy sources (hydroelectric power plants, wind farms, solar cells, geothermal power plants).

Since technologies are unknown, electricity has also been categorised among other technologies, separating the electricity generated from non-renewable energy sources from the electricity generated from renewable energy sources.

Steam or water generated in district heating systems for the purposes of the industrial sector is generated by the following technologies:

- fossil fuel boilers (Vartop – Varaždin, Komunalac – Požega, GTG Vinkovci, Tehnostan Vukovar, Energo Rijeka, Brod Plin SB, Gradska toplana Karlovac) (75.96%);
- fossil fuel cogeneration (thermal power and heating plant Termoelektrana Toplana (TE-TO) Osijek, thermal power plant (TE) Sisak) (15.92%);
- fossil fuel high-efficiency cogeneration (electricity and heating plant Elektrana Toplana (EL-TO) Zagreb, TE-TO Zagreb) (7.33%);
- RES high-efficiency cogeneration (Sisak, Osijek) (0.76%); and
- solar collectors (Vukovar, Slavonski Brod) (0.03%).

Table I.51: INDUSTRIAL SECTOR – DHS – Distribution of DHS thermal energy delivered by generation technology

INDUSTRY – DHS	**Distribution of DHS thermal energy delivered by generation technology [GWh/a]**	**Share [%]**
DHS – fossil fuel boilers	375.85	*75.96*
DHS – solar collectors	0.16	*0.03*
DHS – high-efficiency fossil fuel cogeneration	36.25	*7.33*
DHS – fossil fuel cogeneration	78.79	*15.92*
DHS – high-efficiency RES cogeneration	3.75	*0.76*
TOTAL	**494.80**	**100.00**

Of the total steam or water energy delivered to the industrial sector from DHS, 75.96% was generated in fossil fuel boilers, 15.29% in fossil fuel cogeneration installations, and 7.33% in high-efficiency cogeneration installations.

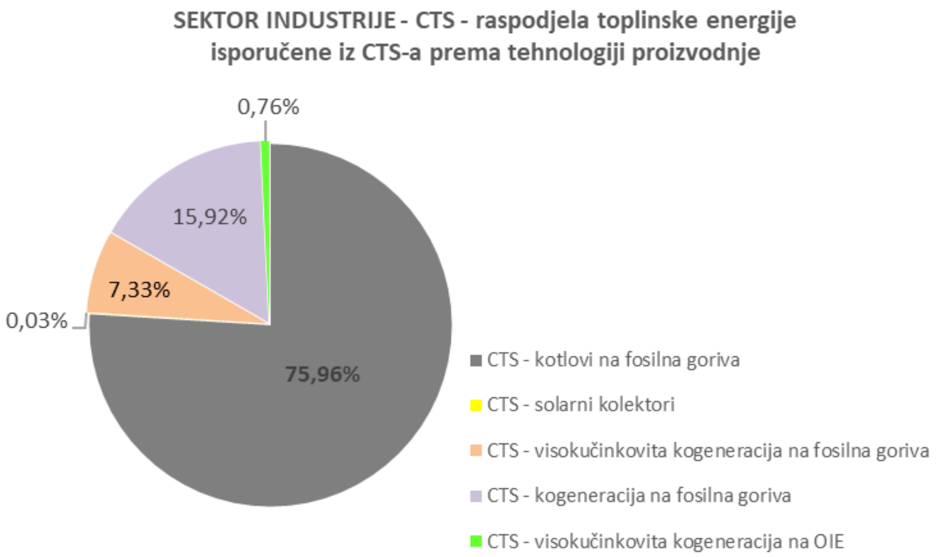


Figure I.29: INDUSTRIAL SECTOR – DHS – Distribution of DHS thermal energy delivered by generation technology

CROATIAN	ENGLISH
SEKTOR INDUSTRIJE - CTS - raspodjela toplinske energije isporučene iz CTS-a prema tehnologiji proizvodnje	INDUSTRIAL SECTOR – DHS – Distribution of the thermal energy delivered from DHS by generation technology
CTS - kotlovi na fosilna goriva	DHS – fossil fuel boilers
CTS - solarni kolektori	DHS – solar collectors
CTS-visokučinkovita kogeneracija na fosilna goriva	DHS – high-efficiency fossil fuel cogeneration
CTS - kogeneracija na fosilna goriva	DHS – fossil fuel cogeneration
CTS-visokučinkovita kogeneracija na OIE	DHS – high-efficiency RES cogeneration

The European Commission has prepared templates in Excel file form recommended for use, among other things, **for the printout of the energy delivered for heating/cooling purposes by analysed sectors** (households, services, industry, other sectors if undergoing comprehensive assessment). There is a distinction between:

- energy delivered on-site, and
- energy delivered off-site (DHS).

Within each analysed sector (households, services, industry, other sectors), there is also a distinction between:

- delivered energy derived from fossil fuels, and
- delivered energy derived from renewable energy sources.

A further division refers to the type of technology generating delivered energy (boilers, cogeneration, heat pumps, other technologies).

An overview of the energy delivered in the industrial sector in 2019, according to the template prepared by the European Commission, is provided in Table I.52:.

Table I.52: Overview of the energy delivered for heating/cooling purposes to the industrial sector in 2019, according to the template prepared by the European Commission

DELIVERED ENERGY PROVIDED ON-SITE			Unit	Value
INDUSTRY	Sources of fossil fuels	Boilers used for heating only	GWh/a	2 711.81[9]
		Other technologies	GWh/a	731.67
		High-efficiency cogeneration	GWh/a	2 013.01[10]
	RES energy	Boilers used for heating only	GWh/a	293.01[11]
		High-efficiency cogeneration	GWh/a	0.00
		Heat pumps	GWh/a	0.00
		Other technologies	GWh/a	489.67
DELIVERED ENERGY PROVIDED OFF-SITE				
INDUSTRY	Sources of fossil fuels	Waste heat	GWh/a	0.00
		High-efficiency cogeneration	GWh/a	36.25[12]
		Other technologies	GWh/a	454.64[13]
	RES energy	Waste heat	GWh/a	0.00
		High-efficiency cogeneration	GWh/a	3.75
		Other technologies	GWh/a	0.16
TOTAL				**6 733.98**

1.2.3.9 DISTRIBUTION OF TOTAL ENERGY DELIVERED TO THE INDUSTRIAL SECTOR BY PURPOSE

Total annual energy delivered to the industrial sector for heating/cooling purposes includes the energy delivered for:

- space heating and DHW preparation,
- space cooling,
- heating in the production process, and
- cooling in the production process.

The distribution of total annual energy delivered for heating/cooling by purpose is provided in tabular form and figures. It is evident that 85.72% of the total annual energy delivered for heating/cooling is used for the purposes of heating in the production process, while 8.61% of the total annual energy delivered for heating/cooling is used for space heating and DHW preparation. Space cooling and cooling for production process purposes account for only 5.67% of the total annual energy delivered for heating/cooling.

[9] The figure refers to industrial boiler rooms, registered by the Croatian Bureau of Statistics and powered by fossil fuels.

[10] Five existing industrial cogeneration installations in Croatia powered exclusively by fossil fuels.

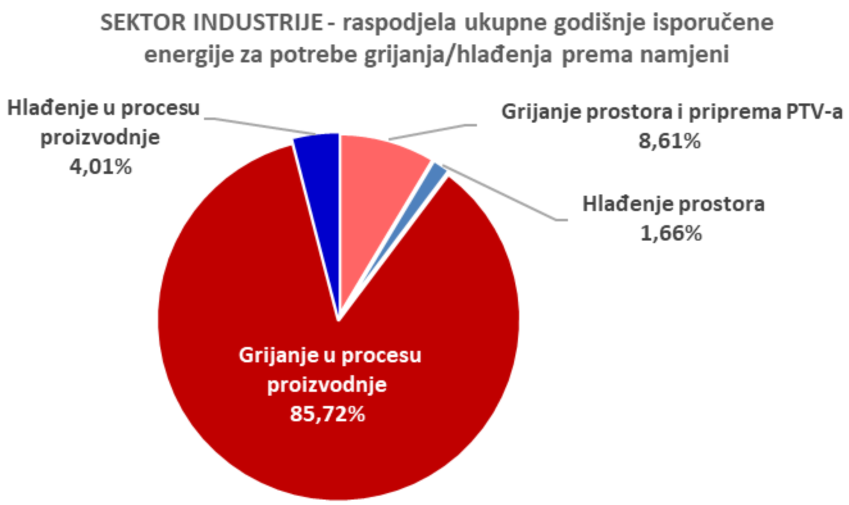
[11] The figure refers to industrial boiler rooms, registered by the Croatian Bureau of Statistics and powered by renewable energy sources.

[12] EL-TO Zagreb, TETO Zagreb.

[13] Fossil fuel boilers and non-high-efficiency fossil fuel cogeneration.

Table I.53: INDUSTRIAL SECTOR – Distribution of total annual energy delivered for heating/cooling by purpose

Sector name	Total annual energy delivered for heating/cooling [GWh/a]				
	Space heating and DHW preparation	Space cooling	Heating in the production process	Cooling in the production process	TOTAL
INDUSTRY	579.75[14]	111.72	5 772.19	270.31	**6 733.98**
Share [%]	*8.61*	*1.66*	*85.72*	*4.01*	*100.00*



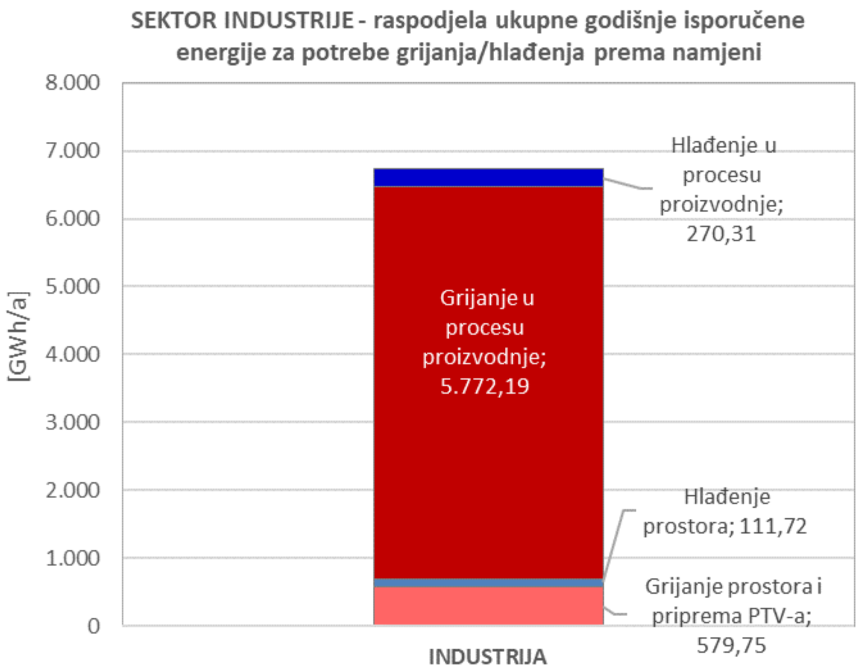


Figure I.30: INDUSTRIAL SECTOR – Distribution of total annual energy delivered for heating/cooling by purpose

CROATIAN	ENGLISH
SEKTOR INDUSTRIJE – raspodjela ukupne godišnje isporučene energije za potrebe grijanja/hlađenja prema namjeni	INDUSTRIAL SECTOR – Distribution of total annual energy delivered for heating/cooling by purpose
Hlađenje u procesu proizvodnje	Cooling in the production process
Grijanje prostora i priprema PTV-a	Space heating and DHW preparation
Hlađenje prostora	Space cooling
Grijanje u procesu proizvodnje	Heating in the production process

[14] The amount of annual energy delivered includes the energy delivered for space heating and DHW preparation.

SEKTOR INDUSTRIJE – raspodjela ukupne godišnje isporučene energije za potrebe grijanja/hlađenja prema namjeni	INDUSTRY

1.3 ANNUAL USEFUL ENERGY NEEDS FOR HEATING/COOLING BY SECTOR

This chapter provides the annual useful energy needed for heating/cooling in the household, service and industrial sectors, expressed in GWh.

In addition, in order to simplify reporting for the comprehensive assessment of the potential for efficient heating and cooling under Annex VIII to Directive 2012/27/EU, the European Commission has prepared and recommends the use of Excel file templates. Among other things, a **template is provided for the printout of delivered and useful energy for heating/cooling purposes by analysed sectors** (households, services, industry, other sectors if they are the subject to the comprehensive assessment).

An overview of energy delivered and useful energy needed by sectors (household, services, industry) in 2019 is provided below in tabular form (Table I.54:), following the template prepared by the European Commission.

Total annual energy delivered for heating/cooling purposes to household, service and industrial sectors in Croatia amounted to **33 505.18 GWh** in 2019.

Total annual useful energy needed for heating/cooling purposes to household, service and industrial sectors in Croatia amounted to **32 366.55 GWh** in 2019.

Table I.54: Overview of energy delivered and useful energy needed by sectors in 2019, according to the template prepared by the European Commission

	Sector	Unit	2019	TOTAL	
Heating demand[15], **end-use** energy	HOUSEHOLDS	GWh/a	20 616.95	31 292.12	**33 505.18**
	SERVICES	GWh/a	4 323.24		
	INDUSTRY	GWh/a	6 351.94		
	OTHER SECTORS	GWh/a	0.00		
Cooling demand, **end-use** energy	HOUSEHOLDS	GWh/a	310.68	2 213.05	
	SERVICES	GWh/a	1 520.34		
	INDUSTRY	GWh/a	382.04		
	OTHER SECTORS	GWh/a	0.00		
Heating demand[15], **useful** energy	HOUSEHOLDS	GWh/a	15 777.57	25 915.04	**32 366.55**
	SERVICES	GWh/a	4 590.75		
	INDUSTRY	GWh/a	5 546.73		
	OTHER SECTORS	GWh/a	0.00		
Cooling demand, **useful** energy	HOUSEHOLDS	GWh/a	869.89	6 451.51	
	SERVICES	GWh/a	4 504.70		
	INDUSTRY	GWh/a	1 076.91		
	OTHER SECTORS	GWh/a	0.00		

[15] The term heating encompasses heating (space heating and heating for industrial process purposes) and DHW preparation.

Table I.55: Total annual energy delivered and useful energy needed for heating/cooling in Croatia by sector, 2019

Sector name	Total annual energy delivered for heating/cooling [GWh/a]	Total annual useful energy needed for heating/cooling [GWh/a]
HOUSEHOLDS	20 927.63	16 647.46
SERVICES	5 843.57	9 095.45
INDUSTRY	6 733.98	6 623.64
TOTAL	**33 505.18**	**32 366.55**

It is evident that most energy for heating/cooling purposes was delivered to the household sector (62.46%), followed by the industrial sector (20.10%) and the service sector (17.44%).

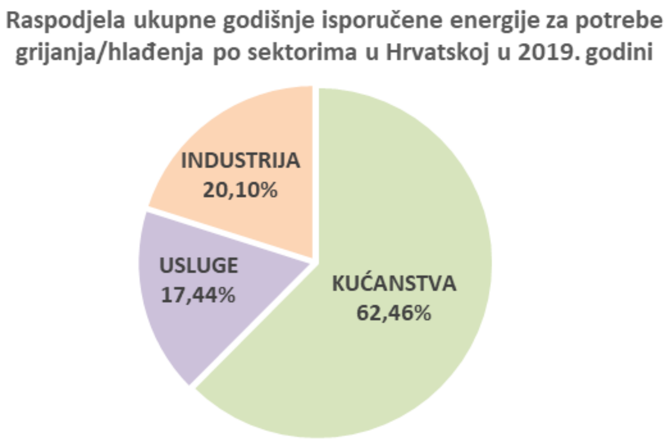


Figure I.31: Distribution of the total annual energy delivered for heating/cooling in Croatia by sector, 2019

CROATIAN	ENGLISH
Raspodjela ukupne godišnje isporučene energije za potrebe grijanja/hlađenja po sektorima u Hrvatskoj u 2019. godini	Distribution of the total annual energy delivered for heating/cooling in Croatia by sector, 2019
KUĆANSTVA	HOUSEHOLDS
USLUGE	SERVICES
INDUSTRIJA	INDUSTRY

Furthermore, the household sector needs 51.43% of the total annual useful energy, followed by the service sector (28.10%) and the industrial sector (20.46%).

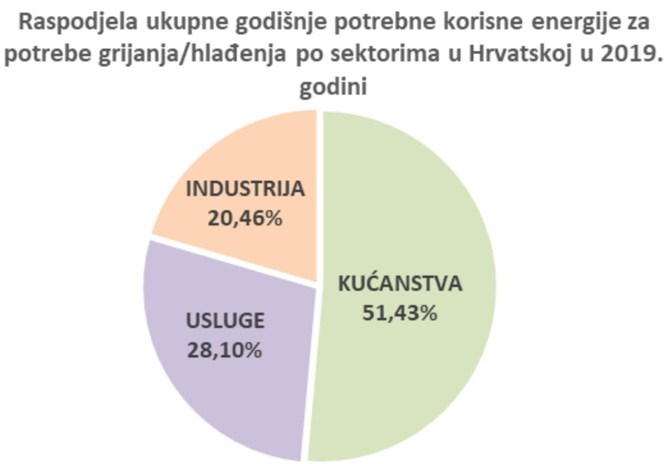


Figure I.32: Distribution of total annual useful energy needed for heating/cooling in Croatia by sector, 2019

CROATIAN	ENGLISH
Raspodjela ukupne godišnje potrebne korisne energije za potrebe grijanja/hlađenja po sektorima u Hrvatskoj u 2019. godini	Distribution of total annual useful energy needed for heating/cooling in Croatia by sector, 2019

KUĆANSTVA	HOUSEHOLDS
USLUGE	SERVICES
INDUSTRIJA	INDUSTRY

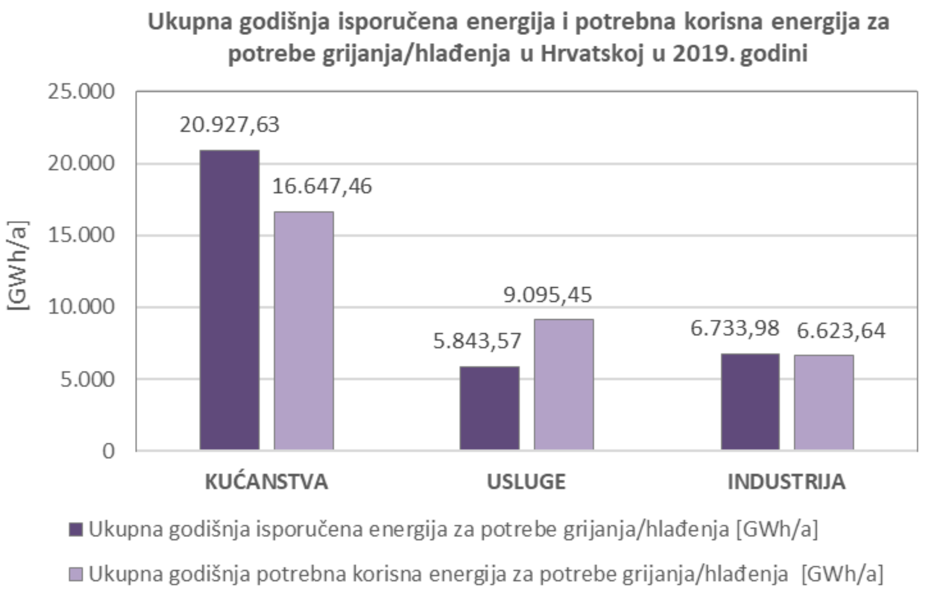


Figure I.33: Total annual energy delivered and useful energy needed for heating/cooling in Croatia, 2019

CROATIAN	ENGLISH
Ukupna godišnja isporučena energija i potrebna korisna energija za potrebe grijanja/hlađenja u Hrvatskoj u 2019. godini	Total annual energy delivered and useful energy needed for heating/cooling in Croatia, 2019
KUĆANSTVA	HOUSEHOLDS
USLUGE	SERVICES
INDUSTRIJA	INDUSTRY
Ukupna godišnja isporučena energija za potrebe grijanja/hlađenja [GWh/a]	Total annual energy delivered for heating/cooling [GWh/a]
Ukupna godišnja potrebna korisna energija za potrebe grijanja/hlađenja [GWh/a]	Total annual useful energy needed for heating/cooling [GWh/a]

Total annual energy delivered for heating purposes to household, service and industrial sectors in Croatia amounted to **31 292.12 GWh** in 2019.

Total annual useful energy needed for heating purposes to household, service and industrial sectors in Croatia amounted to **25 915.04 GWh** in 2019.

Table I:56: Total annual energy delivered and useful energy needed for heating in Croatia by sector, 2019

Sector name	Total annual energy delivered for heating [GWh/a]	Total annual useful energy needed for heating [GWh/a]
HOUSEHOLDS	20 616.95	15 777.57
SERVICES	4 323.24	4 590.75
INDUSTRY	6 351.94	5 546.73
TOTAL	**31 292.12**	**25 915.04**

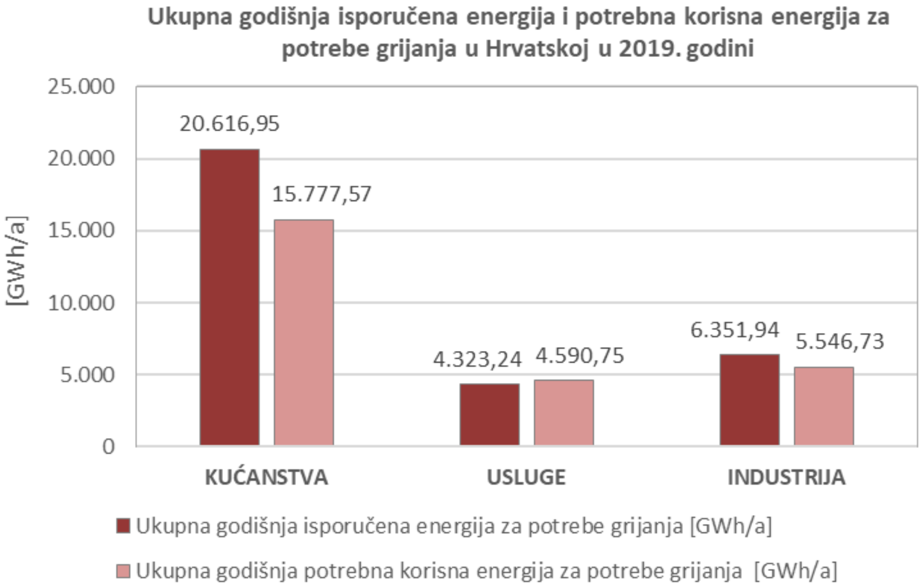


Figure I.34: Total annual energy delivered and useful energy needed for heating in Croatia, 2019

CROATIAN	ENGLISH
Ukupna godišnja isporučena energija i potrebna korisna energija za potrebe grijanja u Hrvatskoj u 2019. godini	Total annual energy delivered and useful energy needed for heating in Croatia, 2019
KUĆANSTVA	HOUSEHOLDS
USLUGE	SERVICES
INDUSTRIJA	INDUSTRY
Ukupna godišnja isporučena energija za potrebe grijanja [GWh/a]	Total annual energy delivered for heating [GWh/a]
Ukupna godišnja potrebna korisna energija za potrebe grijanja [GWh/a]	Total annual useful energy needed for heating [GWh/a]

Total annual energy delivered for cooling purposes to household, service and industrial sectors in Croatia amounted to **2 213.05 GWh** in 2019.

Total annual useful energy needed for cooling purposes to household, service and industrial sectors in Croatia amounted to **6 451.51 GWh** in 2019.

Table I.57; Total annual energy delivered and useful energy needed for cooling in Croatia by sector, 2019

Sector name	Total annual energy delivered for cooling [GWh/a]	Total annual useful energy needed for cooling [GWh/a]
HOUSEHOLDS	310.68	869.89
SERVICES	1 520.34	4 504.70
INDUSTRY	382.04	1 076.91
TOTAL	**2 213.05**	**6 451.51**

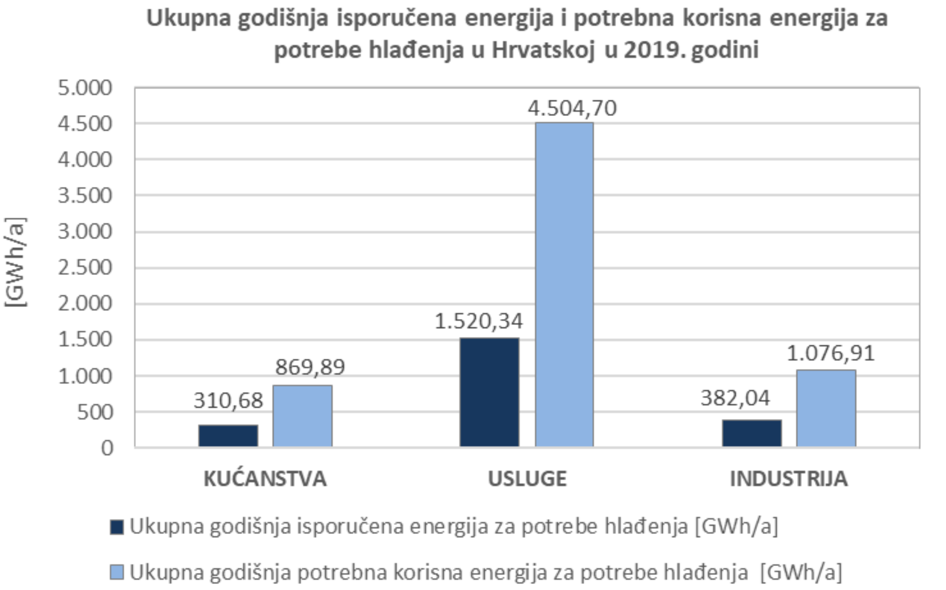


Figure I.35: Total annual energy delivered and useful energy needed for cooling in Croatia, 2019

CROATIAN	ENGLISH
Ukupna godišnja isporučena energija i potrebna korisna energija za potrebe hlađenja u Hrvatskoj u 2019. godini	Total annual energy delivered and useful energy needed for cooling in Croatia, 2019
KUĆANSTVA	HOUSEHOLDS
USLUGE	SERVICES
INDUSTRIJA	INDUSTRY
Ukupna godišnja isporučena energija za potrebe hlađenja [GWh/a]	Total annual energy delivered for cooling [GWh/a]
Ukupna godišnja potrebna korisna energija za potrebe hlađenja [GWh/a]	Total annual useful energy needed for cooling [GWh/a]

Useful energy needed for heating and cooling was derived from the energy delivered by applying specific conversion end-use factors (e.g. degrees of efficiency in heating systems and cooling factors in cooling systems).

1.3.1 HOUSEHOLD SECTOR

1.3.1.1 TOTAL USEFUL ENERGY NEEDS FOR HEATING/COOLING

The total energy delivered to the household sector in Croatia in 2019 amounted to **26 088.45 GWh** (excluding lignite consumption and including energy taken from the environment using heat pumps).

The total energy delivered for space heating/cooling and DHW preparation to the industrial sector in Croatia in 2019 amounted to **20 927.63 GWh**. Space heating/cooling and DHW preparation (heating/cooling) accounts for 80.22% of the consumption of total energy delivered to the household sector.

Using the degrees of efficiency, that is, the coefficients of performance for heating and energy efficiency ratios for cooling provided in tabular form (Table I.58:), and depending on the energy product and technology, the **total annual useful energy needed for space heating/cooling and DHW preparation in the household sector** has been calculated at **16 647.46 GWh**.

Table I.58: HOUSEHOLD SECTOR – Degree of efficiency, i.e. coefficient of performance for heating and cooling factor

Energy product	Building type	Purpose	Degree of efficiency [–] Cooling factor [–]	
			room-based	centralised
DHS	Multi-apartment buildings	Space heating	–	0.980
		DHW preparation	–	0.980
Natural gas	Family houses	Space heating	0.700	0.850
		DHW preparation	0.750	0.800
	Multi-apartment buildings	Space heating	0.700	0.850
		DHW preparation	0.750	0.800
Fuel oil	Family houses	Space heating	0.680	0.800
		DHW preparation	–	0.750
	Multi-apartment buildings	Space heating	0.680	0.800
		DHW preparation	–	0.750
LPG	Family houses	Space heating	–	0.850
		DHW preparation	–	0.800
Firewood	Family houses	Space heating	0.650	0.800
		DHW preparation	0.500	0.750
	Multi-apartment buildings	Space heating	0.650	0.800
		DHW preparation	0.500	0.750
Wood pellets / wood chips / briquettes	Family houses	Space heating	0.700	0.850
		DHW preparation	0.600	0.800
Solar energy (solar collectors)	Family houses	Space heating	–	0.990
		DHW preparation	–	0.990
Electricity	Family houses	Space heating	0.980	0.980
		Space heating – HP	3.000	3.000
		DHW preparation	0.920	0.920
		space cooling	2.800	2.800
	Multi-apartment buildings	Space heating	0.980	0.980
		Space heating – HP	3.000	3.000
		DHW preparation	0.920	0.920
		space cooling	2.800	2.800

1.3.1.2 DISTRIBUTION OF TOTAL USEFUL ENERGY NEEDS FOR HEATING/COOLING BY PURPOSE

Total annual useful energy needed for space heating/cooling and DHW preparation **in the household sector** in Croatia amounted to **16 647.46 GWh**.

By comparing the annual energy delivered with the useful energy needed for each purpose, the following average annual degrees of efficiency of individual systems are derived:

- **heating system → 0.752,**
- **DHW preparation system → 0.820,**
- **space cooling system → 2.800.**

Table I.59. HOUSEHOLD SECTOR – Overview of the annual energy delivered and useful energy needed for heating/cooling

HOUSEHOLD SECTOR	Total annual energy delivered [GWh/a]	Total annual useful energy needs [GWh/a]	Degree of efficiency [–]
Space heating	16 625.51	12 503.19	0.752
DHW preparation	3 991.44	3 274.38	0.820
Space cooling	310.68	869.89	2.800
TOTAL	**20 927.63**	**16 647.46**	**0.795**

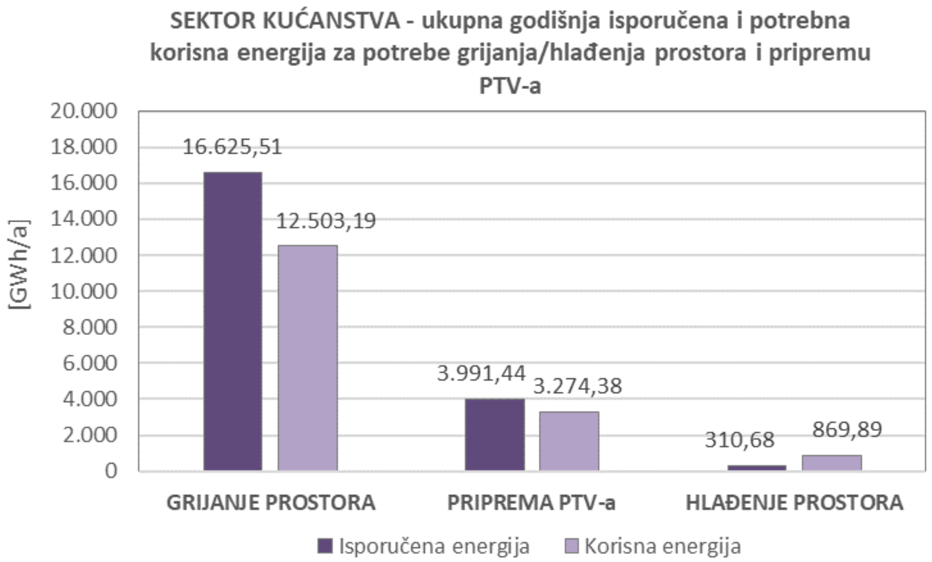


Figure I.36: HOUSEHOLD SECTOR – Total annual energy delivered and useful energy needed for space heating/cooling and DHW preparation

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - ukupna godišnja isporučena i potrebna korisna energija za potrebe grijanja/hlađenja prostora i pripremu PTV-a	HOUSEHOLD SECTOR – Total annual energy delivered and useful energy needed for space heating/cooling and DHW preparation
GRIJANJE PROSTORA	SPACE HEATING
PRIPREMA PTV-a	DHW PREPARATION
HLAĐENJE PROSTORA	SPACE COOLING
Isporučena energija	Delivered energy
Korisna energija	Useful energy

An analysis of the annual useful energy needs by purpose (space heating/cooling, DHW preparation) produces the following distribution of **16 647.46 GWh** in the total annual useful energy needed for space heating/cooling and DHW preparation in the household sector:

- **75.11% for space heating** (12 503.19 GWh/a),
- **19.67% for DHW preparation** (3 274.38 GWh/a),

- **5.23% for space cooling** (869.89 GWh/a).

Table I.60. HOUSEHOLD SECTOR – Total annual useful energy needs

HOUSEHOLD SECTOR	**Total annual useful energy needs [GWh/a]**			
	Family houses	Multi-apartment buildings	**TOTAL**	*Share [%]*
Space heating	8 563.17	3 940.02	**12 503.19**	*75.11*
DHW preparation	2 068.79	1 205.59	**3 274.38**	*19.67*
Space cooling	519.41	350.48	**869.89**	*5.23*
TOTAL	**11 151.37**	**5 496.09**	**16 647.46**	***100.00***
Share [%]	*66.99*	*33.01*	***100.00***	

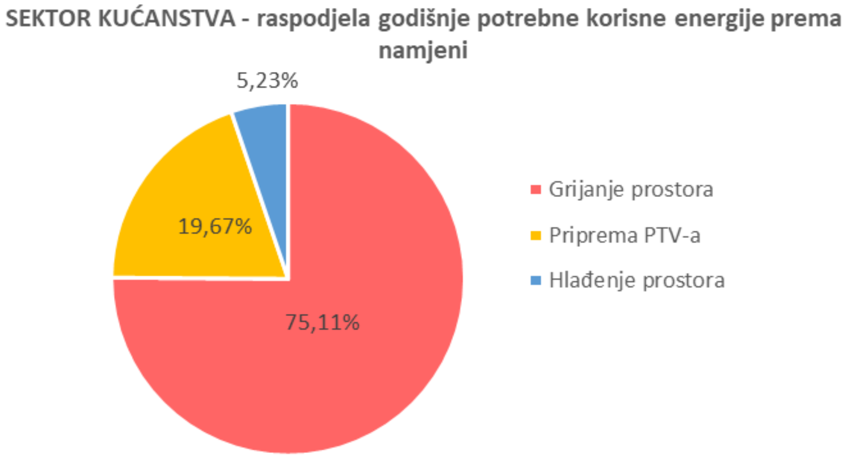


Figure I.37: HOUSEHOLD SECTOR – Distribution of total useful energy needs by purpose

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela godišnje potrebne korisne energije prema namjeni	HOUSEHOLD SECTOR – Distribution of annual useful energy needs by purpose
Grijanje prostora	Space heating
Priprema PTV-a	DHW preparation
Hlađenje prostora	Space cooling

Also, it is evident that 66.99% of the total annual useful energy needed for heating/cooling is accounted for by family houses, and the remaining 33.01% by multi-apartment buildings.

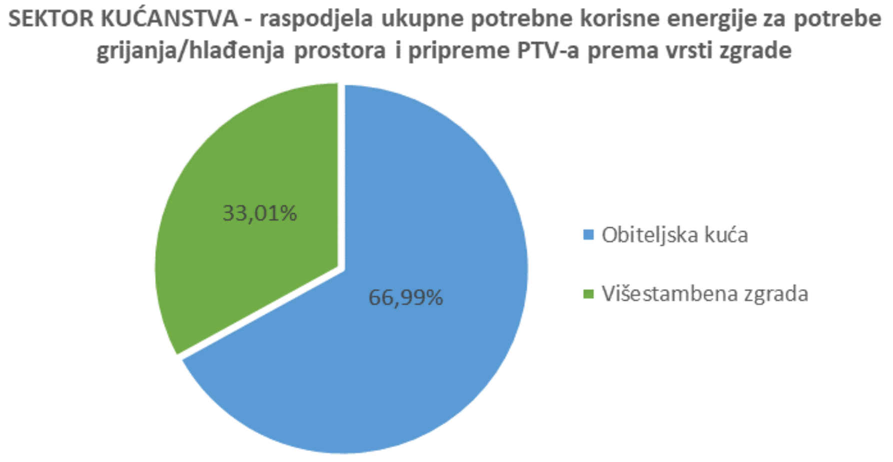


Figure I.38: HOUSEHOLD SECTOR – Distribution of total useful energy needed for space heating/cooling by building type

CROATIAN	ENGLISH

SEKTOR KUĆANSTVA - raspodjela ukupne potrebne korisne energije za potrebe grijanja/hlađenja prostora i pripreme PTV-a prema vrsti zgrade	HOUSEHOLD SECTOR – Distribution of total useful energy needed for space heating/cooling and DHW preparation by building type
Obiteljska kuća	Family houses
Višestambena zgrada	Multi-apartment buildings

1.3.1.3 DISTRIBUTION OF TOTAL USEFUL ENERGY NEEDS FOR HEATING/COOLING BY COUNTY

A distribution of total annual useful energy needed for space heating/cooling and DHW preparation in the household sector by county is provided in tabular form (Table I.61:).

Table I.61: HOUSEHOLD SECTOR – Distribution of total useful energy needed for space heating/cooling and DHW preparation by county

	HOUSEHOLD SECTOR	Total annual useful energy needs [GWh/a]				
	County	Space heating	DHW preparation	Space cooling	**TOTAL**	*Share [%]*
1	Zagreb County	1 048.84	244.00	65.06	**1 357.89**	*8.16*
2	Krapina-Zagorje	406.14	96.60	27.50	**530.24**	*3.19*
3	Sisak-Moslavina	628.27	136.06	35.17	**799.50**	*4.80*
4	Karlovac	463.29	101.26	25.24	**589.79**	*3.54*
5	Varaždin	518.53	124.69	37.44	**680.66**	*4.09*
6	Koprivnica-Križevci	402.50	83.32	24.41	**510.24**	*3.06*
7	Bjelovar-Bilogora	411.75	91.14	25.71	**528.60**	*3.18*
8	Primorje-Gorski Kotar	824.89	231.42	62.62	**1 118.93**	*6.72*
9	Lika-Senj	217.98	41.32	11.28	**270.59**	*1.63*
10	Virovitica-Podravina	292.61	65.51	17.49	**375.60**	*2.26*
11	Požega-Slavonia	263.59	59.30	16.17	**339.06**	*2.04*
12	Slavonski Brod-Posavina	488.54	119.52	30.11	**638.16**	*3.83*
13	Zadar	520.36	138.89	32.66	**691.91**	*4.16*
14	Osijek-Baranja	962.49	220.79	64.03	**1 247.31**	*7.49*
15	Šibenik-Knin	304.45	88.79	22.08	**415.32**	*2.49*
16	Vukovar-Syrmia	519.38	128.78	34.81	**682.97**	*4.10*
17	Split-Dalmatia	862.09	336.51	76.18	**1 274.78**	*7.66*
18	Istria	574.36	161.01	46.44	**781.81**	*4.70*
19	Dubrovnik-Neretva	256.97	93.35	21.62	**371.94**	*2.23*
20	Međimurje	406.09	83.82	25.74	**515.65**	*3.10*
21	City of Zagreb	2 130.06	628.29	168.16	**2 926.51**	*17.58*
	TOTAL	**12 503.19**	**3 274.38**	**869.89**	**16 647.46**	***100.00***
	Share [%]	*75.11*	*19.67*	*5.23*	***100.00***	

The county ranking (top six) by consumption of the total annual useful energy needed for space heating/cooling and DHW preparation in the household sector, as well as useful energy needs for space heating, space cooling and DHW preparation (in the order of size from the top down) are presented in tabular form.

As expected, the City of Zagreb had the largest annual useful energy needs for space heating/cooling and DHW preparation (17.58%), followed by the Zagreb County (8.16%), the Split-Dalmatia County (7.66%), the Osijek-Baranja County (7.49%) and the Primorje-Gorski Kotar County (6.72%). The Istria County ranked 6th (4.70%).

Table I.62: HOUSEHOLD SECTOR – Ranking of counties (top six) by total annual useful energy needed for space heating/cooling and DHW preparation

Ranking of counties (top six) by total annual useful energy needed for space heating/cooling and DHW preparation in the household sector (in the order of size from the top down)				
	SPACE HEATING/COOLING AND DHW PREPARATION SYSTEM	**SPACE HEATING SYSTEM**	**DHW SYSTEM**	**SPACE COOLING SYSTEM**
1.	**City of Zagreb (17.58%)**	City of Zagreb (17.04%)	City of Zagreb (19.19%)	City of Zagreb (19.33%)
2.	**Zagreb County (8.16%)**	Zagreb County (8.39%)	Split-Dalmatia (10.28%)	Split-Dalmatia (8.76%)
3.	**Split-Dalmatia (7.66%)**	Osijek-Baranja (7.70%)	Zagreb County (7.45%)	Zagreb County (7.48%)
4.	**Osijek-Baranja (7.49%)**	Split-Dalmatia (6.89%)	Primorje-Gorski Kotar (7.07%)	Osijek-Baranja (7.36%)
5.	**Primorje-Gorski Kotar (6.72%)**	Primorje-Gorski Kotar (6.60%)	Osijek-Baranja (6.74%)	Primorje-Gorski Kotar (7.20%)
6.	**Istria (4.70%)**	Istria (4.59%)	Istria (4.92%)	Istria (5.34%)

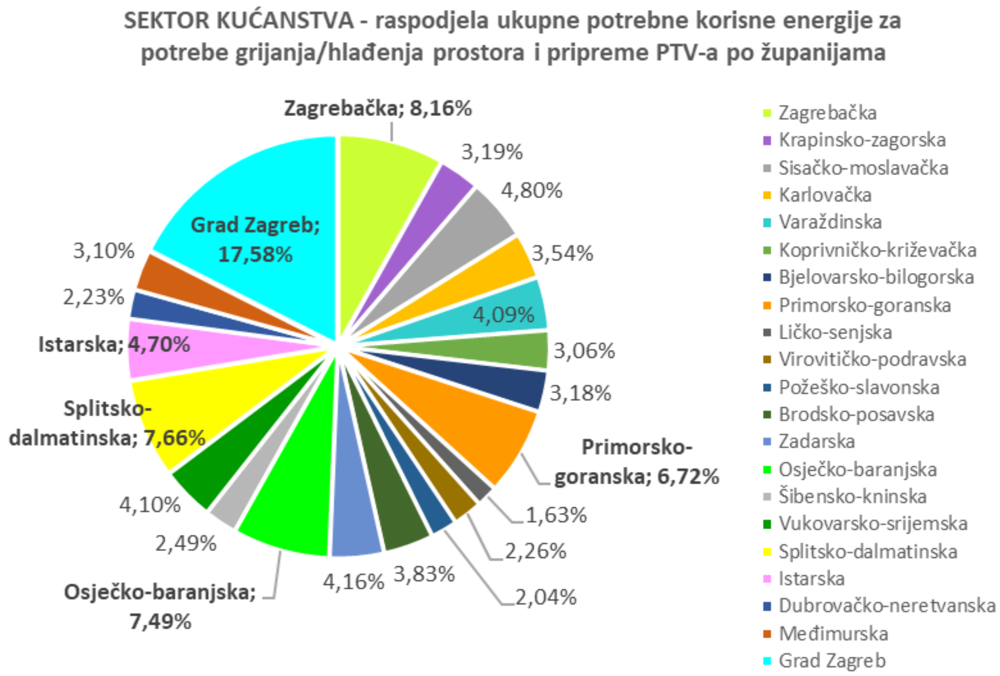


Figure I.39: HOUSEHOLD SECTOR – Distribution of total useful energy needed for space heating/cooling and DHW preparation by county

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela ukupne potrebne korisne energije za potrebe grijanja/hlađenja prostora i pripreme PTV-a po županijama	HOUSEHOLD SECTOR – Distribution of total useful energy needed for space heating/cooling and DHW preparation by county
Zagrebačka	Zagreb County
Krapinsko-zagorska	Krapina-Zagorje
Sisačko-moslavačka	Sisak-Moslavina
Karlovačka	Karlovac
Varaždinska	Varaždin
Koprivničko-križevačka	Koprivnica-Križevci
Bjelovarsko-bilogorska	Bjelovar-Bilogora
Primorsko-goranska	Primorje-Gorski Kotar
Ličko-senjska	Lika-Senj
Virovitičko-podravska	Virovitica-Podravina
Požeško-slavonska	Požega-Slavonia
Brodsko-posavska	Slavonski Brod-Posavina
Zadarska	Zadar
Osječko-baranjska	Osijek-Baranja
Šibensko-kninska	Šibenik-Knin
Vukovarsko-srijemska	Vukovar-Syrmia
Splitsko-dalmatinska	Split-Dalmatia
Istarska	Istria
Dubrovačko-neretvanska	Dubrovnik-Neretva
Međimurska	Međimurje
Grad Zagreb	City of Zagreb

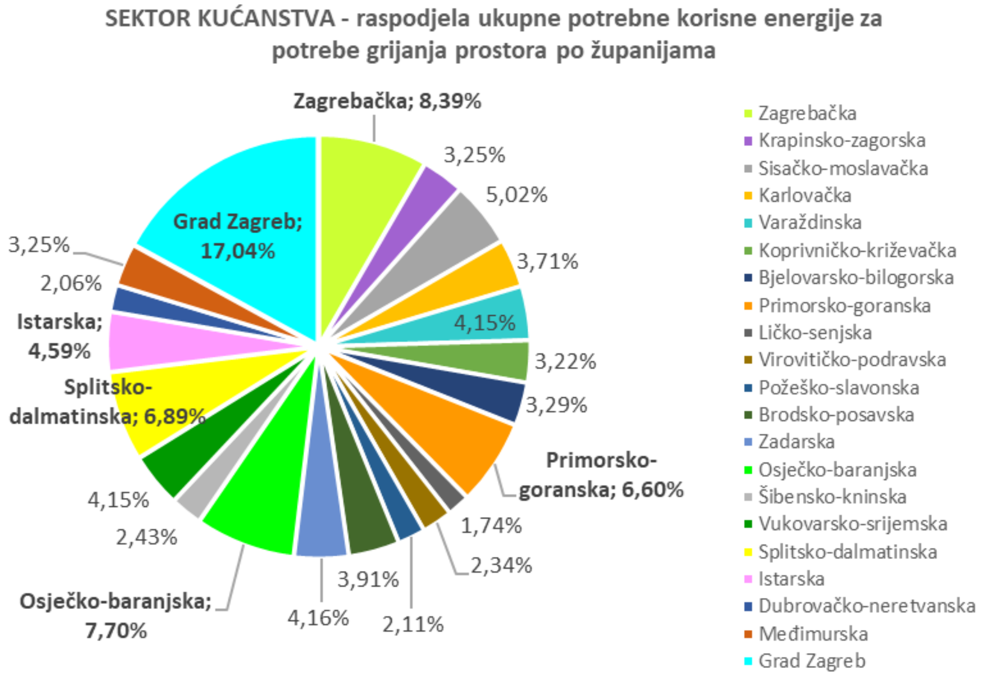


Figure I.40: HOUSEHOLD SECTOR – Distribution of total useful energy needed for space heating by county

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela ukupne potrebne korisne energije za potrebe grijanja prostora po županijama	HOUSEHOLD SECTOR – Distribution of total useful energy needed for space heating by county
Zagrebačka	Zagreb County
Krapinsko-zagorska	Krapina-Zagorje
Sisačko-moslavačka	Sisak-Moslavina
Karlovačka	Karlovac
Varaždinska	Varaždin
Koprivničko-križevačka	Koprivnica-Križevci
Bjelovarsko-bilogorska	Bjelovar-Bilogora
Primorsko-goranska	Primorje-Gorski Kotar
Ličko-senjska	Lika-Senj
Virovitičko-podravska	Virovitica-Podravina
Požeško-slavonska	Požega-Slavonia
Brodsko-posavska	Slavonski Brod-Posavina
Zadarska	Zadar
Osječko-baranjska	Osijek-Baranja
Šibensko-kninska	Šibenik-Knin
Vukovarsko-srijemska	Vukovar-Syrmia
Splitsko-dalmatinska	Split-Dalmatia
Istarska	Istria
Dubrovačko-neretvanska	Dubrovnik-Neretva
Međimurska	Međimurje
Grad Zagreb	City of Zagreb

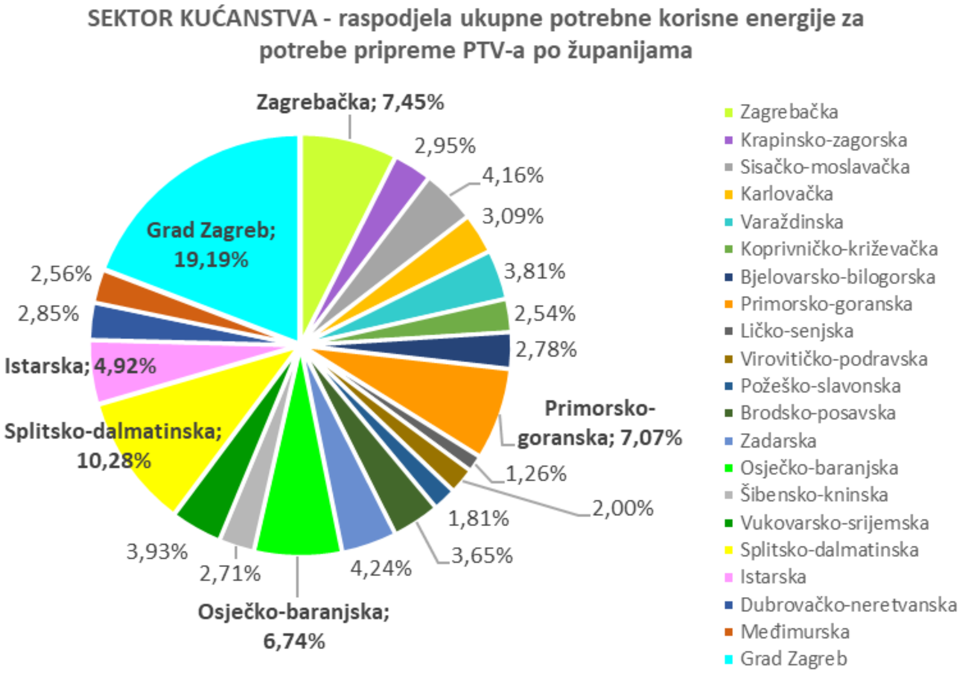


Figure I.41: HOUSEHOLD SECTOR – Distribution of total useful energy needed for DHW preparation by county

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela ukupne potrebne korisne energije za potrebe pripreme PTV-a po županijama	HOUSEHOLD SECTOR – Distribution of total useful energy needed for DHW preparation by county
Zagrebačka	Zagreb County
Krapinsko-zagorska	Krapina-Zagorje
Sisačko-moslavačka	Sisak-Moslavina
Karlovačka	Karlovac
Varaždinska	Varaždin
Koprivničko-križevačka	Koprivnica-Križevci
Bjelovarsko-bilogorska	Bjelovar-Bilogora
Primorsko-goranska	Primorje-Gorski Kotar
Ličko-senjska	Lika-Senj
Virovitičko-podravska	Virovitica-Podravina
Požeško-slavonska	Požega-Slavonia
Brodsko-posavska	Slavonski Brod-Posavina
Zadarska	Zadar
Osječko-baranjska	Osijek-Baranja
Šibensko-kninska	Šibenik-Knin
Vukovarsko-srijemska	Vukovar-Syrmia
Splitsko-dalmatinska	Split-Dalmatia
Istarska	Istria
Dubrovačko-neretvanska	Dubrovnik-Neretva
Međimurska	Međimurje
Grad Zagreb	City of Zagreb

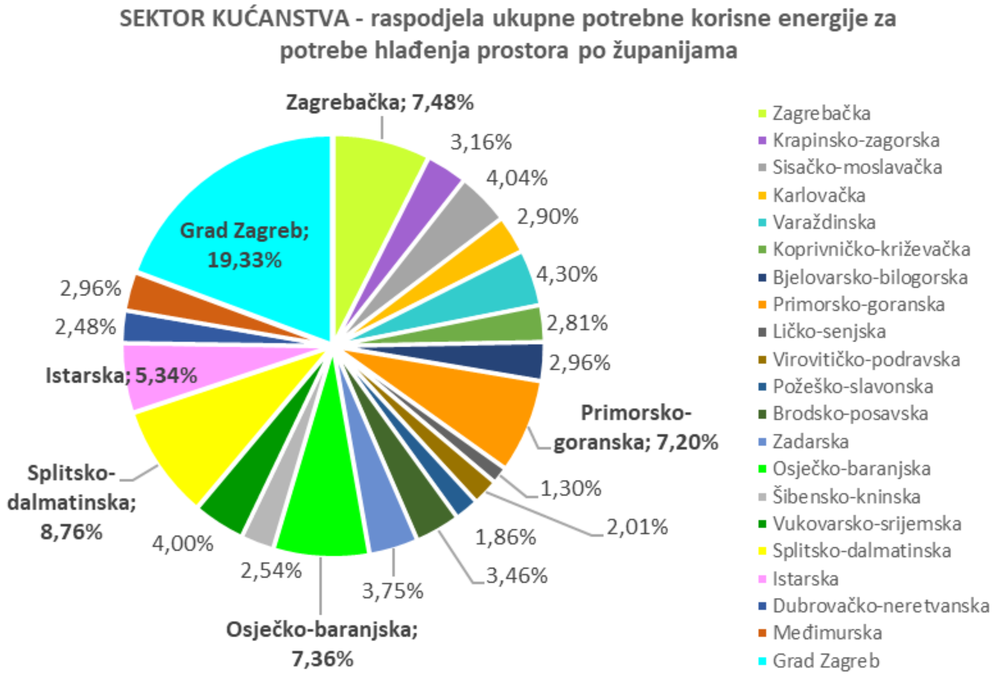


Figure I.42: HOUSEHOLD SECTOR – Distribution of total useful energy needed for space cooling by county

CROATIAN	ENGLISH
SEKTOR KUĆANSTVA - raspodjela ukupne potrebne korisne energije za potrebe hlađenja prostora po županijama	HOUSEHOLD SECTOR – Distribution of total useful energy needed for space cooling by county
Zagrebačka	Zagreb County
Krapinsko-zagorska	Krapina-Zagorje
Sisačko-moslavačka	Sisak-Moslavina
Karlovačka	Karlovac
Varaždinska	Varaždin
Koprivničko-križevačka	Koprivnica-Križevci
Bjelovarsko-bilogorska	Bjelovar-Bilogora
Primorsko-goranska	Primorje-Gorski Kotar
Ličko-senjska	Lika-Senj
Virovitičko-podravska	Virovitica-Podravina
Požeško-slavonska	Požega-Slavonia
Brodsko-posavska	Slavonski Brod-Posavina
Zadarska	Zadar
Osječko-baranjska	Osijek-Baranja
Šibensko-kninska	Šibenik-Knin
Vukovarsko-srijemska	Vukovar-Syrmia
Splitsko-dalmatinska	Split-Dalmatia
Istarska	Istria
Dubrovačko-neretvanska	Dubrovnik-Neretva
Međimurska	Međimurje
Grad Zagreb	City of Zagreb

1.3.1.4 SPECIFIC ANNUAL USEFUL ENERGY NEEDS FOR HEATING/COOLING BY COUNTY

Specific values of useful energy needs are provided below, according to the following purposes:

- space heating,
- DHW preparation,
- space cooling,

by counties for family houses and multi-apartment buildings separately.

SPECIFIC ANNUAL USEFUL ENERGY NEEDED FOR SPACE HEATING BY COUNTY

As expected, Lika-Senj County holds the highest value of specific annual useful energy needed for space heating. The lowest values are found in Dubrovnik-Neretva, Istria, Split-Dalmatia and Zadar counties.

Table I.63: HOUSEHOLD SECTOR – Family houses – Trends in specific useful energy needed for space heating by county

HOUSEHOLD SECTOR – family houses		**SPACE HEATING**		
	County	Useful floor area of the heated part of the building A_K [m²]	Annual useful energy needed for space heating [GWh/a]	Specific annual useful energy needed for space heating [kWh/(m²a)]
1	Zagreb County	7 622 454.36	881.52	*115.65*
2	Krapina-Zagorje	3 367 853.28	375.07	*111.37*
3	**Sisak-Moslavina**	4 316 309.43	529.93	***122.77***
4	**Karlovac**	2 617 762.42	351.75	***134.37***
5	Varaždin	4 091 976.04	441.51	*107.90*
6	Koprivnica-Križevci	3 154 688.85	363.19	*115.13*
7	Bjelovar-Bilogora	3 141 985.67	367.40	*116.93*
8	Primorje-Gorski Kotar	4 506 092.20	431.19	*95.69*
9	**Lika-Senj**	1 226 590.26	169.97	***138.57***
10	Virovitica-Podravina	2 324 147.64	268.85	*115.68*
11	Požega-Slavonia	2 043 448.64	232.09	*113.58*
12	Slavonski Brod-Posavina	3 833 415.40	428.73	*111.84*
13	Zadar	3 794 473.01	340.71	*89.79*
14	Osijek-Baranja	7 189 259.47	708.91	*98.61*
15	Šibenik-Knin	2 336 089.95	212.99	*91.17*
16	Vukovar-Syrmia	4 487 939.70	443.98	*98.93*
17	Split-Dalmatia	5 856 806.84	490.25	*83.71*
18	Istria	4 556 868.51	362.29	*79.50*
19	Dubrovnik-Neretva	2 217 619.32	163.95	*73.93*
20	Međimurje	3 258 265.61	370.37	*113.67*
21	City of Zagreb	7 537 330.84	628.51	*83.39*
	TOTAL	**83 481 377.45**	**8 563.17**	***102.58***

Table I.64: HOUSEHOLD SECTOR – Multi-apartment buildings – Trends in specific useful energy needed for space heating by county

HOUSEHOLD SECTOR – multi-apartment buildings		**SPACE HEATING**		
	County	Useful floor area of the heated part of the building A_K [m²]	Annual useful energy needed for space heating [GWh/a]	Specific annual useful energy needed for space heating [kWh/(m²a)]
1	Zagreb County	1 766 491.60	167.31	*94.72*
2	Krapina-Zagorje	316 686.64	31.07	*98.11*
3	Sisak-Moslavina	912 869.57	98.33	*107.72*
4	Karlovac	1 068 430.02	111.55	*104.40*
5	Varaždin	876 483.00	77.02	*87.88*
6	Koprivnica-Križevci	417 204.71	39.31	*94.22*
7	Bjelovar-Bilogora	482 585.05	44.34	*91.89*
8	Primorje-Gorski Kotar	5 078 976.36	393.70	*77.52*
9	**Lika-Senj**	407 528.42	48.02	***117.83***
10	Virovitica-Podravina	236 381.32	23.76	*100.50*
11	**Požega-Slavonia**	276 937.08	31.50	***113.74***
12	Slavonski Brod-Posavina	755 312.28	59.81	*79.18*
13	Zadar	2 110 050.94	179.65	*85.14*
14	**Osijek-Baranja**	2 276 810.89	253.58	***111.38***
15	Šibenik-Knin	1 100 955.38	91.46	*83.07*
16	Vukovar-Syrmia	876 508.72	75.40	*86.02*
17	Split-Dalmatia	6 609 326.32	371.84	*56.26*
18	Istria	2 979 961.85	212.07	*71.17*
19	Dubrovnik-Neretva	1 485 341.84	93.03	*62.63*
20	Međimurje	387 753.71	35.72	*92.11*
21	City of Zagreb	15 026 986.35	1 501.55	*99.92*
	TOTAL	**45 449 582.03**	**3 940.02**	***86.69***

Table I.65: HOUSEHOLD SECTOR – Trends in specific useful energy needed for space heating

HOUSEHOLD SECTOR – DHW preparation	Useful floor area of the heated part of the building A_K [m²]	Annual useful energy needed for space heating [GWh/a]	Specific annual useful energy needed for space heating [kWh/(m²a)]
Family houses	83 481 377.45	8 563.17	*102.58*
Multi-apartment buildings	45 449 582.03	3 940.02	*86.69*
TOTAL	**128 930 959.49**	**12 503.19**	*96.98*

SPECIFIC ANNUAL USEFUL ENERGY NEEDED FOR DHW PREPARATION BY COUNTY

Average specific useful energy needs for DHW preparation, reduced to the useful floor area of the heated part of the building are as follows:

- family houses – 24.78 kWh/(m²a),
- multi-apartment buildings – 26.53 kWh/(m²a).

Table I.66: HOUSEHOLD SECTOR – Trends in specific useful energy needed for DHW preparation

HOUSEHOLD SECTOR – DHW preparation	Useful floor area of the heated part of the building A_K [m²]	Annual useful energy needed for DHW preparation [GWh/a]	Specific annual useful energy needed for DHW preparation [kWh/(m²a)]
Family houses	83 481 377.45	2 068.79	*24.78*
Multi-apartment buildings	45 449 582.03	1 205.59	*26.53*
TOTAL	**128 930 959.49**	**3 274.38**	*25.40*

Actual values of specific annual useful energy needed for DHW preparation, derived by modelling, are significantly larger than the values presented in the *Technical regulation on energy economy and heat retention in buildings* (NN Nos 128/15, 70/18, 73/18, 86/18, and 102/20):

- 12.5 kWh/(m²a) for residential buildings with three of fewer apartments (family houses), and
- 16.0 kWh/(m²a) for residential buildings with more than three apartments (multi-apartment buildings).

SPECIFIC ANNUAL USEFUL ENERGY NEEDS FOR SPACE COOLING BY COUNTY

Average specific useful energy needs for space cooling, reduced to the useful floor area of the heated part of the building (cooled part unknown) are as follows:

- family houses – 6.22 kWh/(m²a),
- multi-apartment buildings – 7.71 kWh/(m²a).

Table I.67: HOUSEHOLD SECTOR – Trends in specific useful energy needed for space cooling

HOUSEHOLD SECTOR – space cooling	Useful floor area of the heated part of the building A_K [m²]	Annual useful energy needed for space cooling [GWh/a]	Specific annual useful energy needed for space cooling [kWh/(m²a)]
Family houses	83 481 377.45	519.41	*6.22*
Multi-apartment buildings	45 449 582.03	350.48	*7.71*
TOTAL	**128 930 959.49**	**869.89**	*6.75*

The said values of the specific annual useful energy needed for space cooling in the household sector were derived by modelling of the total annual electricity for space cooling, using top-down approach, and are low due to relatively small number of space cooling appliances installed in the household sector, and not due to small cooling needs,

1.3.2 SERVICE SECTOR

The useful energy needs for heating, DHW preparation and cooling in the service sector have been modelled on the following:

- data on the heated area, location and building type available and determined from the IEC database; and

data on the specific energy needed for heating, DHW preparation and cooling for different types of buildings and two climate zones (continental and coastal) taken from the study entitled *Determining minimum requirements for energy performance of buildings*, prepared by the EIHP for the Ministry of Physical Planning, Construction and State Assets, 2020 [19] – (Annexes:

- Table 0.4:, Table 0.5:, Table 0.6:).

Based on such data, the energy needed for heating, DHW preparation and cooling in Croatia's service sector has been calculated at **9 095.45 GWh/a**. A more detailed presentation and distribution of energy needs are presented in the table below.

Table I.68: SERVICE SECTOR – Energy needed for heating, DHW preparation and cooling by building type

Building type	Heating [GWh/a]	DHW preparation [GWh/a]	Cooling [GWh/a]	Total [GWh/a]
Offices	823.59	61.96	728.36	1613.91
Education	459.07	74.90	519.18	1053.15
Hotels and restaurants	531.25	275.62	665.13	1472.00
Hospitals	281.47	105.33	474.72	861.52
Sports halls	206.16	31.86	54.26	292.28
Trade	738.95	9.46	1 481.29	2229.70
Other non-residential buildings	918.397	72.75	581.76	1572.91
TOTAL	**3 958.89**	**631.86**	**4 504.70**	**9 095.45**
SHARE	*43.53%*	*6.95%*	*49.53%*	***100.00%***

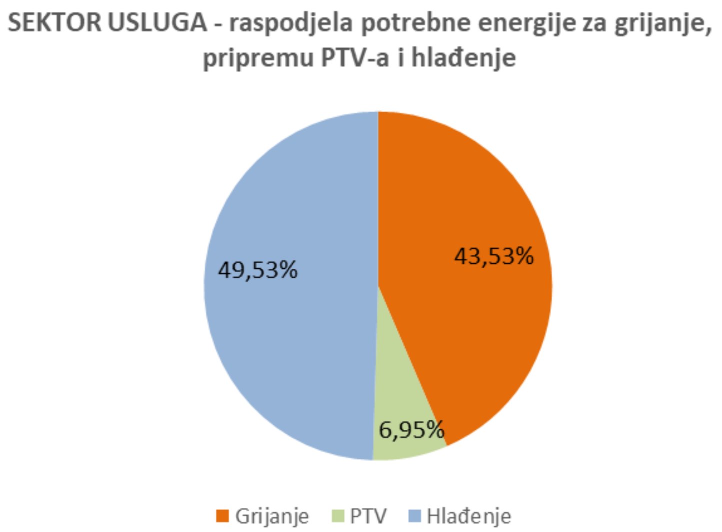


Figure I.43: SERVICE SECTOR – Share of energy needed for heating, DHW preparation and cooling

CROATIAN	ENGLISH
SEKTOR USLUGA – raspodjela potrebne energije za grijanje, pripremu PTV-a i hlađenje	SERVICE SECTOR – Distribution of energy needed for heating, DHW preparation and cooling
Grijanje	Heating
PTV	DHW
Hlađenje	Cooling

By comparing the annual energy delivered with the useful energy needed for each purpose, the following average annual degrees of efficiency of individual systems are derived:

- **space heating system → 1.088,**
- **DHW preparation system → 0.924,**
- **space cooling system → 2.963.**

A detailed presentation of the annual energy delivered and useful energy needed is provided in the table below. It has also been shown in a graph, where the energy for heating represents the sum of energy for space heating and DHW preparation.

Table I.69: SERVICE SECTOR – Overview of the annual energy delivered and useful energy needed for heating/cooling

SERVICE SECTOR	Total annual energy delivered [GWh/a]	Total annual useful energy needs [GWh/a]	Degree of efficiency [–]
Space heating	3 639.05	3 958.89	1.088
DHW preparation	684.18	631.86	0.924
Space cooling	1 520.34	4 504.70	2.963
TOTAL	**5 843.57**	**9 095.45**	**1.556**

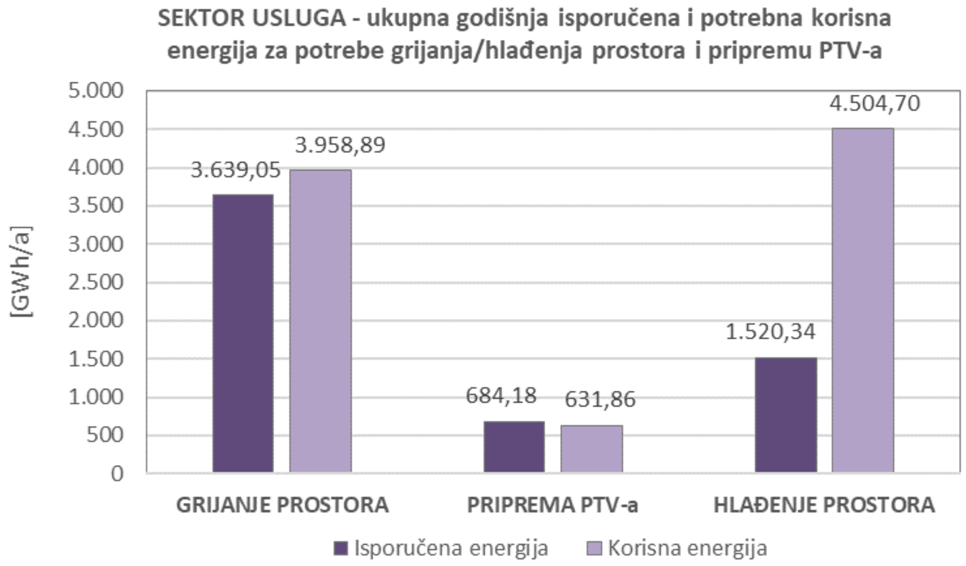


Figure I.44: SERVICE SECTOR – Total annual energy delivered and useful energy needed for space heating/cooling and DHW preparation

CROATIAN	ENGLISH
SEKTOR USLUGA- ukupna godišnja isporučena i potrebna korisna energija za potrebe grijanja/hlađenja prostora i pripremu PTV-a	SERVICE SECTOR – Total annual energy delivered and useful energy needed for space heating/cooling and DHW preparation
GRIJANJE PROSTORA	SPACE HEATING
PRIPREMA PTV-a	DHW PREPARATION
HLAĐENJE PROSTORA	SPACE COOLING
Isporučena energija	Delivered energy
Korisna energija	Useful energy

As already stated above, electricity amounts for the largest share of total energy delivered in the service sector. Since this includes direct electric resistance heating, heating using individual split / multi-split air-conditioning, heat pumps, as well as space cooling using compression cooling units, individual split/multisplit air-conditioning and VRV systems, the obtained degree of efficiency for space heating and cooling is above 1.

In addition, the energy needed for heating, DHW preparation and cooling has been analysed for each municipality, city or town, and City of Zagreb district. However, for the sake of simplicity, only county-level data are included in the tables. The overall energy needed for heating, DHW preparation and cooling by energy product and building type is presented below, while the energy needed for each purpose (heating, DHW preparation and cooling) is provided separately in an annex to this document (Table 0.14: – Table 0.16:).

Table I.70: SERVICE SECTOR – Energy needed for heating, DHW preparation and cooling by building type at county level

SERVICE SECTOR										
		Total energy needed for heating, DHW preparation and cooling [GWh/a]								
	County name	Office buildings	Educational buildings	Hotels and restaurants	Hospitals	Sports halls	Trade buildings	Other non-residential buildings	**TOTAL**	**SHARE**
1	Zagreb County	86.249	58.501	25.769	20.285	16.935	123.406	217.792	**548.939**	*6.04%*
2	Krapina-Zagorje	26.702	32.447	23.525	44.786	8.207	24.825	56.138	**216.630**	*2.38%*
3	Sisak-Moslavina	33.736	39.576	7.833	23.938	4.295	36.247	29.792	**175.417**	*1.93%*
4	Karlovac	28.398	32.647	12.344	19.685	5.264	32.196	63.468	**194.003**	*2.13%*
5	Varaždin	54.970	45.579	15.851	67.383	18.388	65.809	119.638	**387.619**	*4.26%*
6	Koprivnica-Križevci	39.464	22.567	8.106	23.206	5.924	37.948	64.736	**201.951**	*2.22%*
7	Bjelovar-Bilogora	24.236	25.117	8.239	29.138	12.122	22.248	19.809	**140.908**	*1.55%*
8	Primorje-Gorski Kotar	115.973	80.067	248.265	49.976	23.441	162.046	84.656	**764.424**	*8.40%*
9	Lika-Senj	10.422	7.777	25.468	12.089	2.313	13.247	14.120	**85.436**	*0.94%*
10	Virovitica-Podravina	17.515	23.651	5.509	16.366	4.824	13.473	15.713	**97.052**	*1.07%*
11	Požega-Slavonia	23.439	17.027	21.033	25.095	10.750	30.019	29.030	**156.393**	*1.72%*
12	Slavonski Brod-Posavina	38.241	37.087	6.776	21.505	12.120	53.896	45.122	**214.747**	*2.36%*
13	Zadar	37.591	30.619	97.066	22.722	5.670	99.211	30.041	**322.920**	*3.55%*
14	Osijek-Baranja	83.391	101.750	22.362	40.184	22.792	136.002	106.875	**513.356**	*5.64%*
15	Šibenik-Knin	25.762	25.068	51.046	37.112	3.282	46.966	25.188	**214.423**	*2.36%*
16	Vukovar-Syrmia	31.622	23.646	13.806	20.669	10.280	42.054	27.920	**169.997**	*1.87%*
17	Split-Dalmatia	126.138	86.667	281.893	77.517	33.881	611.720	152.051	**1 369.866**	*15.06%*
18	Istria	96.802	46.455	320.751	47.921	16.465	149.632	106.134	**784.159**	*8.62%*
19	Dubrovnik-Neretva	30.185	20.587	172.951	37.578	6.384	35.120	27.019	**329.822**	*3.63%*
20	Međimurje	37.252	20.463	12.584	17.489	11.177	36.671	66.589	**202.225**	*2.22%*
21	City of Zagreb	645.817	275.849	90.816	206.872	57.764	456.967	271.074	**2 005.159**	*22.05%*
	TOTAL	**1 613.905**	**1 053.147**	**1 471.994**	**861.515**	**292.277**	**2 229.703**	**1 572.904**	**9 095.447**	*100.00%*
	SHARE	*17.74%*	*11.58%*	*16.18%*	*9.47%*	*3.21%*	*24.51%*	*17.29%*	*100.00%*	

1.3.3 INDUSTRIAL SECTOR

Total energy delivered to the industrial sector in Croatia amounted to **8 981.44 GWh** for a total of 2 478 companies that belong in the industrial sector according to their NCA code in 2019.

Total energy for heating/cooling delivered to the industrial sector in Croatia in 2019 amounted to **6 733.98 GWh**. Using the degrees of efficiency for heating and energy efficiency ratios for cooling, as defined in the tables below,

- Table I.29: INDUSTRIAL SECTOR – List of energy products taken into account
- Table I.30: INDUSTRIAL SECTOR – Use of electricity and natural gas as energy product for covering heating/cooling needs

the total annual useful energy for heating and cooling has been calculated at **6 623.64 GWh**.

An overview of energy delivered and useful energy needed for heating and cooling by counties in the industrial sector in 2019 is provided in Table I.72:.

It should be noted that the energy delivered and useful energy needed for heating purposes in the industrial sector include the energy for:

- heating (heating of the building space, heating for the purposes of the production process), and
- DHW preparation.

Energy delivered and useful energy needed for cooling purposes in the industrial sector, include energy for:

- cooling of the building space, and
- cooling for the purposes of the production process.

If total useful energy for heating is divided by the total energy delivered for heating at the level of entire Croatia, the average degree of efficiency of the heating and DHW preparation system is calculated at 87.32%:

$$\frac{5.546,73}{6.351,94} = 0,8732$$

If the total useful energy for cooling is divided by the total energy delivered for cooling at the level of entire Croatia, the average cooling system energy efficiency ratio is 2.82%:

$$\frac{1.076,91}{382,04} = 2,82$$

A comparison of the annual delivered and useful energy by purpose is provided in tabular form. In the case of energy use for heating purposes in the production process, the ratio between useful and delivered energy equals 86.98%. That ratio is somewhat higher when it comes to energy use for space heating and DHW preparation.

Table I.71: SERVICE SECTOR – Overview of the annual useful energy delivered and needed for heating/cooling by purpose

INDUSTRIAL SECTOR	Total annual energy delivered for heating/cooling [GWh]	Total annual energy needed for heating/cooling [GWh]	Ratio of useful energy needed and energy delivered [–]
Heating in the production process	5 772.19	5 020.91	0.8698
Space heating and DHW preparation	579.75	525.81	0.9070
Cooling in the production process	270.31	764.09	2.83
Space cooling	111.72	312.83	2.80
TOTAL	**6 733.98**	**6 623.64**	**0.98**

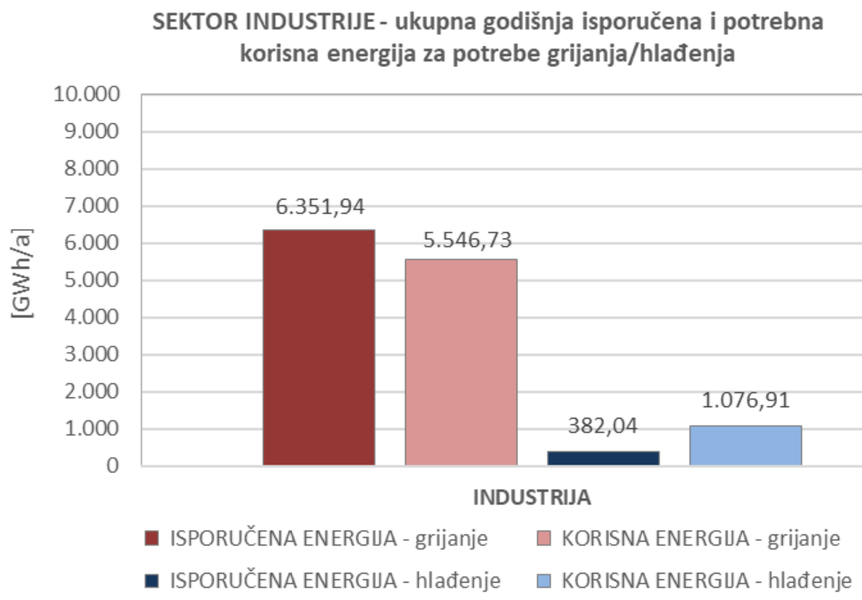


Figure I.45: INDUSTRIAL SECTOR – Total annual energy delivered and useful energy needed for space heating/cooling

CROATIAN	ENGLISH
SEKTOR INDUSTRIJE - ukupna godišnja isporučena i potrebna korisna energija za potrebe grijanja/hlađenja	INDUSTRIAL SECTOR – Total annual energy delivered and useful energy needed for space heating/cooling
INDUSTRIJA	INDUSTRY
ISPORUČENA ENERGIJA - grijanje	DELIVERED ENERGY – heating
ISPORUČENA ENERGIJA - hlađenje	DELIVERED ENERGY – cooling
KORISNA ENERGIJA - grijanje	USEFUL ENERGY – heating
KORISNA ENERGIJA - hlađenje	USEFUL ENERGY – cooling

Table I.72: INDUSTRIAL SECTOR – Overview of the annual energy delivered and useful energy needed for heating/cooling

	INDUSTRIAL SECTOR	**DELIVERED ENERGY [GWh/a]**			**USEFUL ENERGY [kWh/a]**		
	County	**HEATING**	**COOLING**	**TOTAL**	**HEATING**	**COOLING**	**TOTAL**
1	Zagreb County	211.33	39.81	**251.14**	187.38	115.11	**302.49**
2	Krapina-Zagorje	503.95	6.91	**510.86**	444.69	19.66	**464.35**
3	Sisak-Moslavina	353.08	50.45	**403.53**	331.49	150.01	**481.50**
4	Karlovac	102.69	9.80	**112.50**	91.35	28.88	**120.24**
5	Varaždin	446.81	25.50	**472.32**	392.82	75.07	**467.89**
6	Koprivnica-Križevci	156.42	21.08	**177.50**	137.36	61.76	**199.12**
7	Bjelovar-Bilogora	91.62	8.28	**99.91**	79.56	24.45	**104.01**
8	Primorje-Gorski Kotar	82.57	8.79	**91.36**	65.32	24.95	**90.27**
9	Lika-Senj	48.74	14.80	**63.53**	45.31	44.20	**89.51**
10	Virovitica-Podravina	117.59	3.37	**120.96**	96.66	9.58	**106.23**
11	Požega-Slavonia	60.47	3.29	**63.76**	57.70	9.54	**67.23**
12	Slavonski Brod-Posavina	161.39	11.79	**173.18**	148.25	34.07	**182.32**
13	Zadar	64.79	5.48	**70.28**	55.38	15.96	**71.34**
14	Osijek-Baranja	1 021.05	30.65	**1 051.71**	883.04	77.04	**960.08**
15	Šibenik-Knin	227.29	1.90	**229.19**	196.20	5.53	**201.72**
16	Vukovar-Syrmia	174.49	9.04	**183.53**	153.07	26.60	**179.66**
17	Split-Dalmatia	933.74	17.79	**951.53**	803.94	51.63	**855.56**
18	Istria	971.03	26.48	**997.51**	817.15	68.84	**885.99**
19	Dubrovnik-Neretva	5.64	1.15	**6.79**	4.97	3.35	**8.32**
20	Međimurje	123.53	13.89	**137.42**	110.78	33.73	**144.52**
21	City of Zagreb	493.70	71.78	**565.48**	444.31	196.97	**641.28**
	TOTAL	**6 351.94**	**382.04**	**6 733.98**	**5 546.73**	**1 076.91**	**6 623.64**
	Share [%]	*94.33*	*5.67*	***100.00***	*83.74*	*16.26*	***100.00***

2 ANNUAL ENERGY DELIVERED FOR HEATING/COOLING PURPOSES BY SECTOR AND TECHNOLOGY

2.1 ANNUAL ENERGY DELIVERED FOR HEATING/COOLING PURPOSES BY SECTOR AND TECHNOLOGY

In order to simplify reporting for the comprehensive assessment of the potential for efficient heating and cooling under Annex VIII to Directive 2012/27/EU, the European Commission has prepared and recommends the use of Excel file templates. Among other things, a **template is provided for the printout of the energy delivered for heating/cooling purposes by analysed sectors** (households, services, industry, other sectors if they are the subject to the comprehensive assessment). There is a distinction between:

- energy delivered on-site, and
- energy delivered off-site (referring to district heating systems).

Within each analysed sector (households, services, industry, other sectors), there is also a distinction between:

- delivered energy derived from fossil fuels, and
- delivered energy derived from renewable energy sources (RES).

A further division refers to the type of technology used for generating delivered energy (boilers, high-efficiency cogeneration, heat pumps, other technologies).

An overview of delivered energy by sectors in 2019, according to the template prepared by the European Commission, is provided in tabular form (Table I.74:) below.

Delivered energy provided on-site means the energy generated at the very site [at which it is used]. There is a distinction between:

- delivered energy derived from fossil fuels:
    - → *boilers used for heating only* – fossil fuel boilers (natural gas, fuel oil, LPG) as sources of thermal energy in district heating systems and DHW preparation;
    - → *other technologies* – individual fossil fuel furnaces as decentralised sources of thermal energy, electricity as a drive energy product generated from fossil fuels, and waste heat for DHW preparation;
    - → *high-efficiency cogeneration* – not existent in the household or service sector in Croatia;
- Delivered energy derived from renewable energy sources (RES):
    - → *boilers used for heating only* – biomass boilers (firewood, pellets / wood chips / briquettes) as sources of thermal energy in district heating systems and DHW preparation;
    - → *RES high-efficiency cogeneration* – not existent in the household and service sector in Croatia;
    - → *heat pumps* – heat taken from the environment (air, soil, water) and considered a renewable energy source has been mentioned;
    - → *other technologies* – solar collectors, individual biomass furnaces (firewood, pellets / wood chips / briquettes) as decentralised sources of thermal energy, electricity as a drive energy product generated from renewable energy sources.

Compression heat pumps are categorised as renewable energy sources according to the seasonal performance factor (SPF), which is a ratio of total thermal energy delivered to the heating / DHW preparation system, Q_{dov}, and total drive electricity, E_{pog}:

$$SPF = \frac{Q_{\text{dov}}}{E_{\text{pog}}}$$

The heat pump takes heat from the environment, Q_{OIE}, (considered a renewable energy source) and, using the consumer drive electricity, E_{pog}, raises it to a higher temperature level and delivers it to the heating / DHW preparation system, Q_{dov}:

$$Q_{\text{OIE}} + E_{\text{pog}} = Q_{\text{dov}}$$

The equation for *SPF*

$$SPF = \frac{Q_{\text{dov}}}{E_{\text{pog}}} = \frac{Q_{\text{OIE}} + E_{\text{pog}}}{E_{\text{pog}}}$$

calculates the amount of renewable energy taken from the environment, Q_{RES}:

$$Q_{\text{OIE}} = E_{\text{pog}} \cdot (SPF - 1)$$

$$Q_{\text{OIE}} = Q_{\text{dov}} \cdot \left(1 - \frac{1}{SPF}\right)$$

Renewable energy taken from the environment, Q_{OIE}, is stated under the category:

- Delivered energy derived from renewable energy sources (RES):
    - → *heat pumps* – heat taken from the environment (air, soil, water) and considered a renewable energy source, Q_{OIE} [i.e. Q_{RES}] is stated.

It is important to note that electricity is used as a drive energy product for:

- → direct electric resistance space heating (individual electric heaters, electric boilers);
- → space heating using compression heat pumps (individual split / multi-split A/C, VRV systems, heat pumps);
- → DHW preparation (individual electric boilers);
- → space cooling (individual split / multi-split A/C, VRV systems, compression coolers).

Considering that **40.09% of consumed electricity** in Croatia in 2019 **was generated from renewable energy sources** and 59.91% from non-renewable energy sources (fossil and nuclear fuels), the overall electricity delivered falls into the following two categories:

- delivered energy derived from fossil fuels:
    - → *other technologies* – electricity as a drive energy product generated from fossil fuels;
- delivered energy derived from renewable energy sources (RES):
    - → *other technologies* – electricity as a drive energy product generated from renewable energy sources.

Thus, the electricity delivered for space cooling using compression cooling units (decentralised or centralised) is also categorised under other technologies!

Delivered energy provided off-site means the energy delivered from heating systems. There is a distinction between:

- delivered energy derived from fossil fuels:
    - → *waste heat* – no heating system in Croatia exploits waste heat for now;

→ *high-efficiency cogeneration* – the example of DHS in Zagreb;

→ *other technologies* – fossil fuel boilers, fossil fuel cogeneration;

- delivered energy derived from renewable energy sources (RES):

→ *waste heat* – no heating system in Croatia exploits waste heat for now;

→ *RES high-efficiency cogeneration* – the example of biomass BETO DHSs in Osijek and Sisak;

→ *other technologies* – RES boilers (DHS in Vukovar), solar collectors (DHS in Vukovar and Slavonski Brod), geothermal energy (DHS in Topusko).

The delivered annual energy provided off-site is allocated to its respective categories according to the shares in delivered energy provided in Table I.82:, separately for each DHS.

Technical regulation amending the Technical regulation on energy economy and heat retention in buildings (NN No 102/2020) provides the following definition of energy delivered to a building:

→ Delivered energy means the energy, expressed per energy carrier, which is conducted to the building's technical system through a system boundary in order to meet the observed needs for heating, cooling, ventilation, and air conditioning, domestic hot water and lighting according to Table 8.a.

According to the definition, energy from renewable energy sources (e.g. heat generated at the building site using solar collectors, heat taken from the environment using heat pumps) is not included in the total energy delivered to a building.

However, according to Excel file templates prepared by the European Commission, delivered energy includes all energy entering the building through a system boundary, energy from renewable sources entering through a system boundary (e.g. biomass), as well as energy from renewable energy sources generated at the building site (e.g. heat generated on-site using solar collectors, heat taken from the environment using heat pumps). Delivered energy in this study will include all the aforementioned forms of energy.

The total annual energy delivered to household, service and industrial sectors in Croatia for heating/cooling purposes in 2019 amounted to **33 505.18 GWh**.

The sectoral distribution of the annual energy delivered for heating/cooling in Croatia in 2019 is provided in tabular form. It is evident that most energy for heating/cooling purposes was delivered to the household sector (62.46%), followed by the industrial sector (20.07%) and the service sector (17.55%).

Table I.73: Total annual energy delivered for heating/cooling purposes in Croatia by sector, 2019

Sector name	Total annual energy delivered for heating/cooling [GWh/a]	*Share [%]*
HOUSEHOLDS	20 927.63	*62.46*
SERVICES	5 843.57	*17.44*
INDUSTRY	6 733.98	*20.10*
TOTAL	**33 505.18**	***100.00***

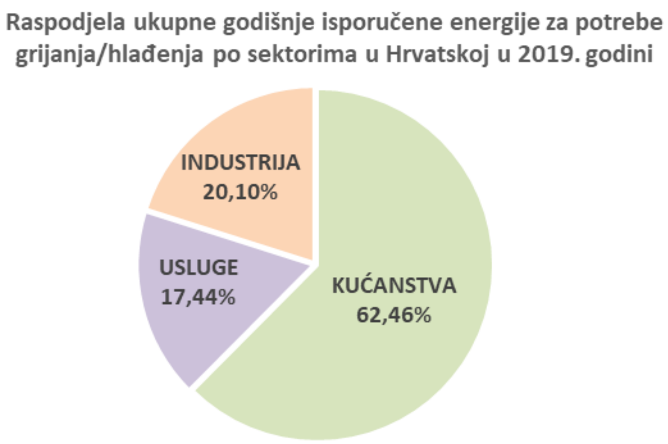


Figure I.46: Distribution of the total annual energy delivered for heating/cooling in Croatia by sector, 2019

CROATIAN	ENGLISH
Raspodjela ukupne godišnje isporučene energije za potrebe grijanja/hlađenja po sektorima u Hrvatskoj u 2019. godini	Distribution of the total annual energy delivered for heating/cooling in Croatia by sector, 2019
KUĆANSTVA	HOUSEHOLDS
USLUGE	SERVICES
INDUSTRIJA	INDUSTRY

Table I.74: Overview of the energy delivered for heating/cooling by sector in 2019, according to the template prepared by the European Commission

DELIVERED ENERGY PROVIDED ON-SITE			Unit	Value
HOUSEHOLDS	Sources of fossil fuels	Boilers used for heating only	GWh/a	4 942.74
		Other technologies	GWh/a	1 673.26
		High-efficiency cogeneration	GWh/a	0.00
	RES energy	Boilers used for heating only	GWh/a	2 146.76
		High-efficiency cogeneration	GWh/a	0.00
		Heat pumps	GWh/a	168.27
		Other technologies	GWh/a	10 721.94
SERVICES	Sources of fossil fuels	Boilers used for heating only	GWh/a	2 567.01
		Other technologies	GWh/a	1 458.18
		High-efficiency cogeneration	GWh/a	0.00
	RES energy	Boilers used for heating only	GWh/a	144.20
		High-efficiency cogeneration	GWh/a	0.00
		Heat pumps	GWh/a	327.89
		Other technologies	GWh/a	937.57
INDUSTRY	Sources of fossil fuels	Boilers used for heating only	GWh/a	2 711.81
		Other technologies	GWh/a	731.67
		High-efficiency cogeneration	GWh/a	2 013.01
	RES energy	Boilers used for heating only	GWh/a	293.01
		High-efficiency cogeneration	GWh/a	0.00
		Heat pumps	GWh/a	0.00
		Other technologies	GWh/a	489.67
DELIVERED ENERGY PROVIDED OFF-SITE				
HOUSEHOLDS	Sources of fossil fuels	Waste heat	GWh/a	0.00
		High-efficiency cogeneration	GWh/a	295.43
		Other technologies	GWh/a	910.49
	RES energy	Waste heat	GWh/a	0.00
		High-efficiency cogeneration	GWh/a	66.52
		Other technologies	GWh/a	2.21
SERVICES	Sources of fossil fuels	Waste heat	GWh/a	0.00
		High-efficiency cogeneration	GWh/a	97.55
		Other technologies	GWh/a	282.76
	RES energy	Waste heat	GWh/a	0.00
		High-efficiency cogeneration	GWh/a	20.00
		Other technologies	GWh/a	8.42
INDUSTRY	Sources of fossil fuels	Waste heat	GWh/a	0.00
		High-efficiency cogeneration	GWh/a	36.25
		Other technologies	GWh/a	454.64
	RES energy	Waste heat	GWh/a	0.00
		High-efficiency cogeneration	GWh/a	3.75
		Other technologies	GWh/a	0.16
TOTAL				**33 505.18**

It is important to point out that in Croatia, in 2019, only 6.50% of the total annual delivered energy for heating/cooling purposes is provided off-site (from district heating systems). Of the total annual delivered energy for heating/cooling purposes, 93.50% is provided on-site.

Table I.75: Total annual energy delivered for heating/cooling purposes in Croatia by sector, 2019

Sector name	Total annual energy delivered for heating/cooling [GWh/a]			
	Delivered energy provided on-site	Delivered energy provided off-site	TOTAL	*Share [%]*
HOUSEHOLDS	19 652.98	1 274.65	20 927.63	*62.46*
SERVICES	5 434.84	408.73	5 843.57	*17.44*
INDUSTRY	6 239.17	494.80	6 733.98	*20.10*
TOTAL	31 327.05	2 178.18	**33 505.23**	*100.00*
Share [%]	*93.50*	*6.50*	*100.00*	

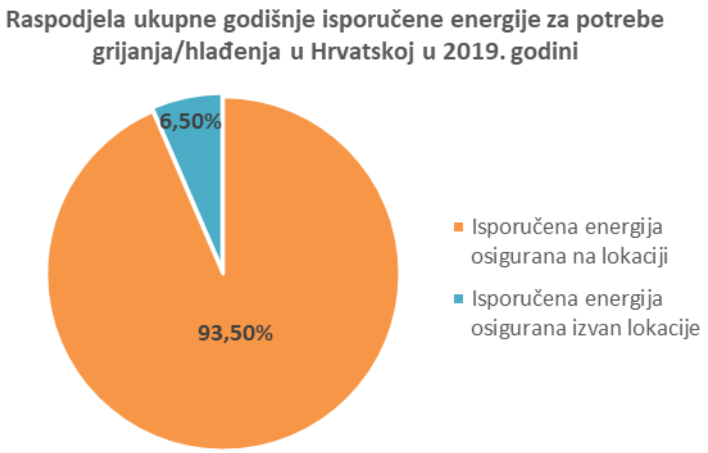


Figure I.47: Distribution of total annual energy delivered for heating/cooling purposes in Croatia, 2019

CROATIAN	ENGLISH
Raspodjela ukupne godišnje isporučene energije za potrebe grijanja/hlađenja u Hrvatskoj u 2019. godini	Distribution of total annual energy delivered for heating/cooling purposes in Croatia, 2019
Isporučena energija osigurana na lokaciji	Delivered energy provided on-site
Isporučena energija osigurana izvan lokacije	Delivered energy provided off-site

The distribution of total annual energy delivered for heating/cooling by sector (household, service, industry) and purpose is provided in tabular form and figure below. **Of the total annual energy delivered for heating/cooling** in the observed sectors, **76.55% is used for space heating and DHW preparation** and 17.03% for heating in the production process. Space cooling and cooling for the purposes of the production process account for only 6.43% of the total annual energy delivered for heating/cooling.

Table I.76: Total annual energy delivered for heating/cooling by sector and purpose in Croatia, 2019

Sector name	Total annual energy delivered for heating/cooling [GWh/a]						
	Space heating	DHW preparation	Space cooling	Heating in the production process	Cooling in the production process	TOTAL	*Share [%]*
HOUSEHOLDS	16 625.51	3 991.44	310.68	0.00	0.00	20 927.63	*62.46*
SERVICES	3 639.05	684.18	1 520.34	0.00	0.00	5 843.57	*17.44*
INDUSTRY	579.75[16]		111.72	5 772.19	270.31	6 733.98	*20.10*
TOTAL	20 844.30	4 675.62	1 942.74	5 772.19	270.31	**33 505.17**	*100.00*
Share [%]	*62.21*	*13.95*	*5.80*	*17.23*	*0.81*	*100.00*	
		76.17	*5.80*	*17.23*	*0.81*	*100.00*	

[16] The amount of annual energy delivered includes the energy delivered for space heating and DHW preparation.

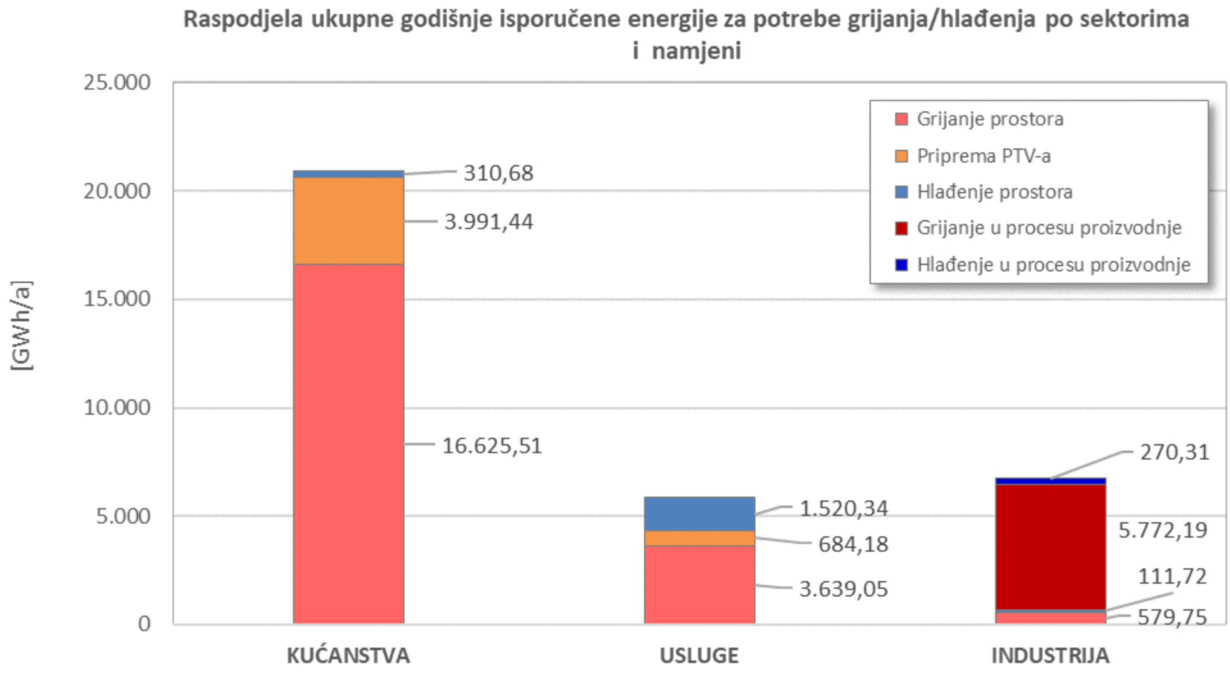


Figure I.48: Distribution of total annual energy delivered for heating/cooling, by sector and purpose

CROATIAN	ENGLISH
Raspodjela ukupne godišnje isporučene energije za potrebe grijanja/hlađenja po sektorima i namjeni	Distribution of total annual energy delivered for heating/cooling, by sector and purpose
Grijanje prostora	Space heating
Priprema PTV-a	DHW preparation
Hlađenje prostora	Space cooling
Grijanje u procesu proizvodnje	Heating in the production process
Hlađenje u procesu proizvodnje	Cooling in the production process
KUĆANSTVA	HOUSEHOLDS
USLUGE	SERVICES
INDUSTRIJA	INDUSTRY

2.2 Identification of the installations generating waste heat or cold and their potential for heating or cooling supply

Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources defines waste heat/cold as follows:

> 'WASTE HEAT AND COLD' means unavoidable heat or cold generated as by-product in industrial or power generation installations, or in the tertiary sector, which would be dissipated unused in air or water without access to a district heating or cooling system, where a cogeneration process has been used or will be used or where cogeneration is not feasible.

Therefore, heat or cold are considered waste only in the cases when they are by-products of another process, and would otherwise be dissipated into the environment (air, water). Waste heat is the excess heat that remains after an industrial process and heat dissipation.

Examples of waste heat:

- **computer centres or shopping centres** whose space needs to be cooled (typically, the heat dissipated for the purpose of space cooling is dissipated into the environment through a cooling unit condenser, but it would be more expedient to redirect it);
- **direct use of a cooling current on power plant condensers** (e.g. heat can be delivered for greenhouse heating).

The following categories are not considered waste heat:

- heat produced for the main purpose of being used directly on-site or off-site, which it is not a by-product of another process;
- heat from a cogeneration installation;
- heat that is used or could be used on the same site.

As part of the comprehensive assessment, it is necessary to identify the installations that are potential sources of waste heat and cold and indicate their annual potential in GWh. The following types of installations must be included as a minimum:

1. **thermal power generation installations** that can supply or can be retrofitted to supply waste heat with a total thermal capacity exceeding 50 MW;
2. **heat and power cogeneration installations** using technologies referred to in Part II of Annex I with a total thermal capacity exceeding 20 MW;
3. **waste incineration plants**;
4. **renewable energy installations** with a total thermal capacity exceeding 20 MW other than the installations, generating heating or cooling using the energy from renewable source;
5. **industrial installations** with a total thermal capacity exceeding 20 MW which can provide waste heat.

Cogeneration technologies covered by Directive 2012/27/EU on energy efficiency (EED) (Annex I, Part II):

a) combined cycle gas turbine with heat recovery,

b) steam back pressure turbine,

c) steam condensing extraction turbine,

d) gas turbine with heat recovery,

e) internal combustion engine,

f) microturbines,

g) Stirling engines,

h) fuel cells
i) steam engines,
j) organic Rankine cycles,
k) any other type of technology or combination thereof falling under the definition laid down in Article 2(30) ((30) ‘cogeneration’ means the simultaneous generation in one process of thermal energy and electrical or mechanical energy).

2.2.1 THERMAL POWER GENERATION INSTALLATIONS WITH A TOTAL THERMAL CAPACITY EXCEEDING 50 MW

As part of [state-owned joint-stock power company] *Hrvatska elektroprivreda* – HEP d.d., there are three thermal power generation installations with a thermal capacity exceeding 50 MW_t:

1. TE Plomin,
2. TE Rijeka and
3. KTE Jertovec.

The **Plomin Thermal Power Generation Installation (TE Plomin)** was built in the Plomin Bay and is the only active coal-fired thermal power generation installation in Croatia. The location was chosen because of a former coal mine, topographically and geologically suitable terrain, fresh and sea water supply, and a well-developed sea and land transport infrastructure. The TE Plomin is a condensing thermal power generation installation, consisting of two production units, Block A and Block B, having its own boiler and one steam turbine each. Hard coal is procured on the global market and transported by ships to the special purpose port at Plomin, where it is unloaded and delivered to an open repository by a conveyor system. Demineralised raw water from a nearby spring (Bubić Jama) is used for the production of steam, while sea water is used for cooling at both production units. The 125 MW Block A production unit was completed and put into operation in 1970. The Decision on integrated environmental protection conditions (Environmental Permit) ceased to be valid as of 1 January 2018, so Block A is a production unit unavailable until further notice. Block B production unit (TE Plomin 2) with an input of 210 MW was built and put into commercial operation in 2000. The installation was built by TE Plomin d.o.o., a joint venture 50% owned by HEP d.d. and 50% owned by RWE, Germany. As of 1 August 2017, the TE Plomin d.o.o. company was merged with HEP d.d., and operations have continued within [its generation arm] *HEP – Proizvodnja d.o.o.* Block B has been equipped with a flue gas desulphurisation installation since 2000. The device for removing nitrogen oxide from flue gases was completed and put into operation in 2017. By modernising the low-pressure part of the turbine and carrying out capital overhaul activities on other parts of the system in 2017, the internal efficiency of the turbine was improved, increasing the turbogenerator’s rated power to 217 MW. Block B is connected to the electric power system by a 220/110 kV switchyard.

TE Plomin has implemented an Environmental, Quality and Energy Management System, certified in accordance with ISO 14001:2015, 9001:2015 and 50001:2018, and a Safety Management System compliant with the Decree on the prevention of major accidents involving hazardous substances.

The **Rijeka Thermal Power Generation Installation** (TE Rijeka) is located at Urinj, southeast of the city of Rijeka, on the coast, enabling the use of sea water for cooling, while the proximity of a refinery significantly facilitates energy supply. The construction of the thermal power plant began in 1974, the trial operation was during 1978, and since 1979 TPP Rijeka has been in regular production. A 320 MW condensing block was installed at the TE Rijeka, as one of the largest production facilities of *Hrvatska Elektroprivreda* at the time it was commissioned. Its advantage over standard thermal power plant blocks is the possibility of fast load regulation ranging between 25% and 100%, which makes it extremely adaptable to changes in the electric power system. TE Rijeka is connected to two 220 kV voltage transmission lines with a transmission power of 612 MW per transmission line, connected to the 380/220/110 kV Melina transformer substation. In its service life, TE Rijeka was in operation for 143 047 hours and generated 25.72 TWh of electricity or an average of 695 MWh per year with an average power of 180 MW. This means that TE Rijeka was in the so-called rotational reserve with 120 MW of power on average, that is, it was connected to the network with the possibility of rapid power increase in the EE system if additional power was necessary due to any disruptions and, at gradients of more than 10 MW/min.

TE Rijeka has implemented an Environmental, Quality and Energy Management System, certified in accordance with ISO 14001:2015, 9001:2015 and 50001:2018, and a Safety Management System compliant with the Decree on the prevention of major accidents involving hazardous substances.

The **Jertovec Combined Cycle Power Generation Installation** (KTE Jertovec) is located in the village of Jertovec in the Konjščina municipality. Electricity generation at the power plant began in 1954, when the first (14.8 MW BBC) turbogenerator was put into operation. The second and the third (2X12.5 MW Jugoturbina-Končar) generator entered into operation in 1957. Lignite from local coal mines was used as the energy product. As the exploitation of coal mines in the Zagorje region ceased in the early 1970s due to depletion of resources, the use of coal was replaced by heavy fuel oil in reconstructed boilers. The crude oil crisis and rising prices of heavy fuel oil have made production unprofitable since 1974. At the same time, activities began on the installation of two 2x31.5 MW gas turbine generators, provided by Westighouse as part of the construction of the Krško Nuclear Power Plant for the purpose of safety power supply. Gas turbine generators (GTG), using extra light fuel oil (ELFO) as fuel, were put into operation in 1976 and became the first gas turbine generators to be put into operation in this region. The use of natural gas as the basic fuel began by connecting the power plant to the newly built gas network in 1980. Recovery boilers were put into operation in 1980 and using the heat of the exhaust flue gases of gas turbines, they produced superheated steam, which generates an additional 10 MW of power on steam turbine generators (STG), as the first combined gas-steam blocks used for electricity generation in Croatia. **KTE Jertovec is used as a back-up electrical power plant** in Croatia’s electrical power system thanks to its available power of 2x28 MW (gas turbine generators) and 2x10 MW (steam turbine generators), with the possibility of commissioning within 15 minutes of the order to do so.

KTE Jertovec has implemented an Environmental, Quality and Energy Management System, certified in accordance with ISO 14001:2015, 9001:2015 and 50001:2018, and a Safety Management System compliant with the Decree on the prevention of major accidents involving hazardous substances.

Given the specifics of each of the three existing thermal power plants described above, it is estimated that it is unlikely that they will be used to produce waste heat or retrofitted so that they can produce waste heat.

In particular, TE Plomin is located far from larger urban centres, so the exploitation of waste heat is technically and economically questionable. The location of TE Rijeka has already been considered several times in the context of building new production units (cogeneration, heat pumps, solar hot water collectors) in order to produce thermal energy to meet heating requirements of the city of Rijeka. In view of the distance between the city of Rijeka and the TE Rijeka site (approx. 5.5 km), the cost-effectiveness of that option has proven questionable and, taking into account the fact that the heating system in Rijeka is not integral, it can be concluded that the option is not realistic. Another option consists in building a new cogeneration installation and thermal energy marketing to the INA oil refinery. Both of these options exclude the use of the existing cogeneration block, so exploitation of waste heat of the existing TE Rijeka may be said to be unrealistic.

The KTE Jertovec site is intended for the future construction and use of modern technologies, such as battery electrolyser systems for hydrogen production. Both technologies will serve primarily for electricity system balancing and gas system decarbonisation, so the use of existing cogenerations to produce and exploit waste heat is unlikely.

2.2.2 COGENERATION INSTALLATIONS WITH A TOTAL THERMAL CAPACITY EXCEEDING 20 MW FOR THERMAL ENERGY AND ELECTRICITY GENERATION – HIGH-EFFICIENCY THERMAL ENERGY AND ELECTRICITY COGENERATION

An analysis of the existing cogeneration thermal energy installations, presuming the use of high-efficiency cogeneration, has been performed.

Under the provisions of applicable statutory regulations and other relevant directives, high-efficiency cogeneration is that which through simultaneous production of electricity and thermal energy from a cogeneration installation ensures primary energy savings (PES) of at least 10% compared with the reference values for separate production of thermal energy and electricity.

The methodology for calculating the value of primary energy savings is defined 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), which also defines both technical and operational conditions for such generation installations.

In order for a generation installation to be granted the status of eligible electricity producer, it must meet the following requirements for obtaining a status decision:

- be connected to the electricity transmission or distribution grid and supply electricity to the electricity network, in accordance with the conditions of grid use;
- meet the technical and operational requirements laid down in Article 4 of the Rules governing the grant of eligible electricity producer status; and
- simultaneously produce electricity and thermal energy in a highly efficient manner and/or use waste or renewable energy sources to produce electricity in an economically appropriate manner, in accordance with environmental legislation, irrespective of the generation installation input.

The following existing thermal and electricity cogeneration installations, as part of *HEP Proizvodnja d.o.o.*, were covered by the analysis:

- [electricity and heating plant] EL-TO Zagreb;
- [thermal power and heating plant] TE-TO Zagreb;
- TE-TO Sisak,
- TE-TO Osijek.

The analysis took into account the 2019 data for these installations, based on the collected data on the annual electricity and thermal energy production, fuel consumption (types and quantities), comparing it with the reference for separate electricity and thermal energy production. Primary energy savings (PES) were calculated using the methodology defined by the Rules, and the results obtained are presented in the table below.

An extended scope of results of the high-efficiency cogeneration analysis is provided in an annex to this study (Table 0.17).

Table I.77: Results of the high-efficiency cogeneration analysis at HEP Proizvodnja d.o.o. production plants

Installation	Block name	Cogeneration unit type	Year built	Fuel 1	Fuel 2	h_u	PES
						%	%
EL-TO Zagreb	**Block B**	Steam back pressure turbine	1996 and earlier	Natural gas	Gas oil, fuel oil, LPG	94.85	0.00
	Block H	Waste heat recovery gas turbine	1996 and earlier	Natural gas	–	85.32	13.62
	Block J	Waste heat recovery gas turbine	1996 and earlier	Natural gas	–	86.55	15.41
TETO Zagreb	**Block C**	Extraction condensing turbine	1996 and earlier	Natural gas	Gas oil, fuel oil, LPG	0.00	0.00
	Block K	Combined cycle gas and steam turbine	2001	Natural gas	Gas oil, fuel oil, LPG	61.50	0.00
	Block L	Combined cycle gas and steam turbine	2006 and later	Natural gas	–	82.93	20.52
TETO Osijek	**Block 45 MW**	Extraction condensing turbine	1996 and earlier	Natural gas	Gas oil, fuel oil, LPG	65.99	0.00
	Block PTA 1	Waste heat recovery gas turbine	1996 and earlier	Natural gas	Gas oil, fuel oil, LPG	0.00	0.00
	Block PTA 2	Waste heat recovery gas turbine	1996 and earlier	Natural gas	Gas oil, fuel oil, LPG	0.00	0.00
	Block A	Extraction condensing turbine	1996 and earlier	Natural gas	Gas oil, fuel oil, LPG	0.00	0.00

Installation	Block name	Cogeneration unit type	Year built	Fuel 1	Fuel 2	h_u	PES
						%	%
[Thermal power plant] TE Sisak	**Block B**	Extraction condensing turbine	1996 and earlier	Natural gas	Gas oil, fuel oil, LPG	0.00	0.00
	Block C	Combined cycle gas and steam turbine	2006 and later	Natural gas	–	51.26	0.00

At the time of the analysis, only Block L at TE-TO Zagreb had been granted the eligible electricity producer status. For this block, *HEP-Proizvodnja d.o.o.* signed an Addendum to the Power Purchase Agreement with the Croatian Energy Market Operator, with 27 July 2016 being defined as the first day of the eligible electricity producer status for Block L at TE-TO Zagreb. The agreement was signed for a fixed period of eight years, ten months and nine days from the date of payment of the incentive purchase price set out in the original agreement, until 5 June 2025.

Blocks H and J at EL-TO Zagreb use identical technologies. Having been implemented more recently in EL TO Zagreb, they could meet the requirements of high-efficiency cogeneration under an appropriate operating regime. Over the past calendar year, both blocks have achieved high levels of efficiency, and on the assumption of an appropriate operating regime which prevailed in 2020, they could meet the requirements of high-efficiency cogeneration. However, since neither of these blocks comply with permitted [limits for] IED emissions into air, it is realistic to expect their being turned into cold reserve and further commissioning only in the event of emergency.

On account of their electricity and heat generation performance, fuel consumption, associated technology, and non-compliance with the permitted [limits for] IED emissions into the environment, all other blocks do not realistically constitute the potential for qualifying high-efficiency cogeneration.

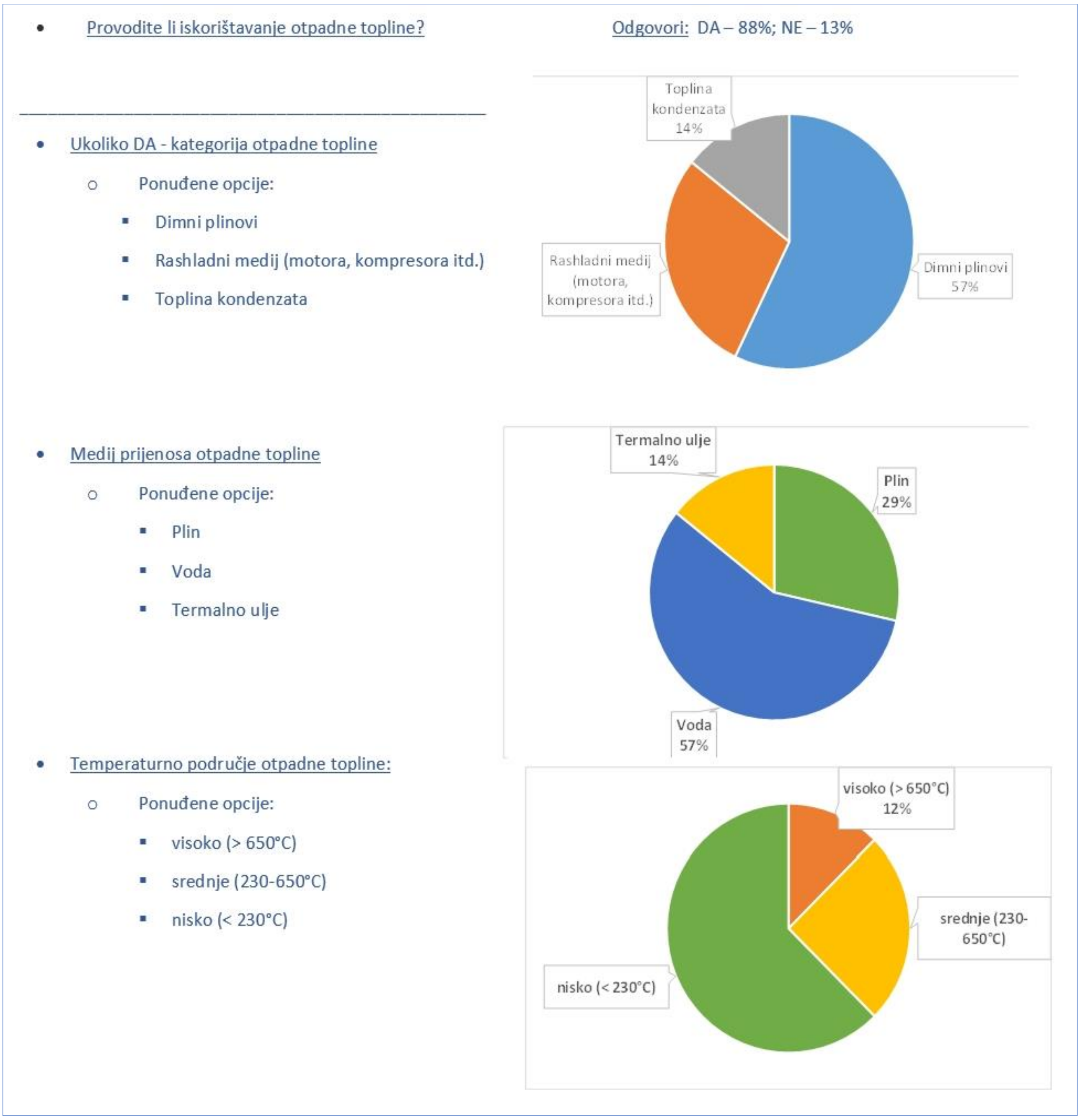
2.2.3 WASTE INCINERATION INSTALLATIONS

There are currently no waste incineration installations in Croatia.

2.2.4 INDUSTRIAL INSTALLATIONS THAT CAN PROVIDE WASTE HEAT

The main difficulty in estimating the sources of industrial waste heat and their real potential consists in the fact that data on waste or excess heat are not systematically recorded, either in international or national statistics. Furthermore, the potential of waste heat recovery depends significantly on the characteristics of the industrial sectors under observation, and even with the same product, it depends on fuels, conversions and process characteristics. One way of collecting data on sector characteristics and sites is to use relevant publications and contact relevant entities directly. The distribution of specified questionnaires is a useful method, but it is demanding in terms of organisation and time and the response is questionable, and so is the representativeness of the sample of industrial entities responding to the survey.

For example, industrial enterprises in different sectors were sent a request asking for characteristic data, with an overview of the processed answers provided below:



CROATIAN	ENGLISH
Provodite li iskorištavanje otpadne topline?	Do you carry out waste heat recovery?
Odgovori: DA-88%; NE-13%	Answers: YES – 88%; NO – 13%
Ukoliko DA - kategorija otpadne topline	If YES – waste heat category

Ponuđene opcije:	Offered options:
Dimni plinovi	flue gases
Rashladni medij (motora, kompresora itd.)	cooling medium (engine, compressor, etc.)
Toplina kondenzata	heat of condensate
Medij prijenosa otpadne topline	waste heat transfer medium
Ponuđene opcije:	Offered options:
Plin	gas
Voda	water
Termalno ulje	thermal oil
Temperaturne područje otpadne topline:	waste heat temperature range:
visoko (> 650°C)	high (>650 °C)
srednje (230-650°C)	medium (230–650 °C)
nisko (< 230°C)	low (<230 °C)

But as the sample of responses was too small, these results could not be considered representative for developing a model covering the wider industry.

In developed practice, there are methodologies seeking to overcome data gaps and complexity due to heterogeneous industrial sub-sectors. This is based on the knowledge of production capacities of individual entities and product groups, in conjunction with specific energy consumption. Respective potential is derived from the known load factor in the process of energy use and heat loads. An example estimating the potential according to different sources/methodologies is provided in the table below:

Table I.78: Potential of waste heat recovery in various industries

ind. sector	*source/potential of waste heat recovery (%)*		
	UK (McKenna et al.)	*Sweden (Fjärnvärme AB)*	*STRATEGO (2015)*
Chemical industry	7	24	25
Aluminium	20	n.a.	50
Cement industry	25	n.a.	25
Ceramics	20	n.a.	25
Manufacture of food products and beverages	7	9	25
Manufacture of glass	20	n.a.	10
Iron and steel industry	15	20	25
Base metals	n.a.	11	25
Paper and paperboard industry	7	6	n.a.
Wood industry	n.a.	18	25

Data for other sectors is also available. However, initial analyses show that the direct application of such indicators to the Croatian industry does not produce reliable results. Therefore, it is necessary to develop a more appropriate methodology based on available data on the domestic industry.

Basically, there are two axes for structuring an overview of energy use in the industry – through differentiation of the industrial sectors or production processes, and differentiation by the energy products used.

Similarly to examining the level of rational use of energy in the industry, the analysis using the energy products used first sorts electricity and energy products for heat generation. Although electricity is also used in certain processes for heat generation, waste heat generated in the process typically has no usable potential, so this energy product is omitted.

Thus, the observed heat generation energy products are the following:

- conventional fossil fuels: natural gas, extra light and special fuel oil, high-sulphur fuel oil, low-sulphur fuel oil, diesel fuels other than for transport, petrol other than for transport, liquefied gas, hard coal and its briquettes, brown coal and its briquettes, coke (metallurgical, foundry, and petroleum);
- energy transformation media (DHS, boiler rooms): steam and water at temperatures lower than or equal to 200 °C; steam and water at temperatures higher than 200 °C;

– biomass: firewood, wood pellets and chips, wood and plant waste;

– fuels from residues: waste oils and emulsions, old tyres, DSS, RDF and others.

The lower heating value of the fuel and the average degree of energy transformation were defined for each of the energy products.

In a general simplified division, space heating and cooling, DHW preparation, and heat in the production process were considered as heat utilisation methods. Space heating and cooling, as a process, was not taken into account as a relevant source of waste heat, but its potential was considered in the transformation for the medium preparation (boiler rooms etc.).

At the stated level of analysis of relevant factors and taking into account the most common energy utilisation methods, major sources of waste heat recovery in industry and their potential were considered separately in:

- transformed forms of energy – steam and hot water, separately for temperatures lower than or equal to 200 °C and higher than 200 °C;
- natural gas;
- all other fuels.

Only in the case of steam and hot water at temperatures higher than 200 °C was the waste heat generated during space heating and cooling and DHW preparation taken into account, while being considered only in the process heat generation using all other energy products. Temperature levels are such that the potential for waste heat in heating, cooling and DHW, using these other energy products, is not interesting for practical analysis.

This is presented on one axis, while industrial enterprises are grouped by sections and subsections of activities on the other axis. The following sections of the groups are of interest to the observation:

- Fabricated metal products
- Manufacture of rubber and plastic
- Chemicals and chemical products
- Motor vehicles, trailers
- Basic pharmaceutical products
- Other non-metallic minerals
- Other mining and quarrying
- Paper and paper products
- Manufacture of wood and of products of wood and cork
- Manufacture of electrical equipment
- Metal production
- Manufacture of furniture
- Manufacture of wearing apparel
- Manufacture of beverages
- Manufacture of food products
- Printing and reproduction.

According to these groups of production or energy processes, the waste heat recovery factor presumed for each group but varied again according to the energy products mentioned above. Thus, companies were processed collectively by groups but, in the second iteration, an individual factor was determined for each individual company and process where deviations pointed to the assumption being unrealistic. These presumed factors depend on the efficiency of energy transformation (boiler rooms), the efficiency of a separate thermal process, the characteristics of the process in a group, according to the energy product in each case. This indicates the total available residual heat, so its realistically recoverable share is determined according to the temperature level. The estimates made are relatively conservative. The primary energy consumed was multiplied by these factors to obtain the quantities of waste heat for each observed entity. The analysis was performed for industrial entities with the highest heat consumption, and the results of the analysis are provided at county level for easier overview in the table below.

Table I.79: Annual available waste heat and power from the industrial sector at county level

	County	Available industrial waste heat [MWh/a]	Available power of industrial waste heat [MW]
1	Zagreb County	833.92	0.39
2	Krapina-Zagorje	500.33	0.10
3	Sisak-Moslavina	35 639.89	3.97
4	Karlovac	1 983.44	0.38
5	Varaždin	5 796.30	2.03
6	Koprivnica-Križevci	4 217.49	0.81
7	Bjelovar-Bilogora	1 236.05	0.33
8	Primorje-Gorski Kotar	748.00	0.14
9	Lika-Senj	1 510.07	0.39
10	Virovitica-Podravina	3 180.79	0.64
11	Požega-Slavonia	420.79	0.08
12	Slavonski Brod-Posavina	3 092.98	0.78
13	Zadar	1 733.03	0.40
14	Osijek-Baranja	65 143.05	13.48
15	Šibenik-Knin	3 601.93	0.90
16	Vukovar-Syrmia	6 212.50	1.19
17	Split-Dalmatia	13 504.10	2.80
18	Istria	15 816.80	3.07
19	Dubrovnik-Neretva	–	–
20	Međimurje	1 645.05	0.41
21	City of Zagreb	8 243.54	1.59
	TOTAL	**175 060.04**	**33.88**

2.3 SOURCES OF GEOTHERMAL ENERGY – EXISTING AND POTENTIAL

The geothermal potential of Croatia is manifested in the form of numerous natural geothermal phenomena, mostly in the territory of the Pannonian Basin. Since baths, spas or health resorts have most often developed in these places, they have a centuries-old tradition of using geothermal water from natural springs for balneological purposes, for recreation and rehabilitation. Even though the phenomenon of spas is predominantly related to the Pannonian area (Varaždinske Toplice, Krapinske Toplice, Tuheljske Toplice, Daruvarske Toplice, Bizovačke Toplice, etc.), a few are also present in the Dinarides (Livade-Istarske Toplice, Split, Sinj, Omiš, and Mokošica near Dubrovnik).

Today, Croatia has some twenty active sites at which geothermal energy is used directly to heat water in swimming pools and for space heating, and two sites at which geothermal energy is used in agricultural greenhouse production (Table I.80:). The total capacity for direct use of geothermal energy is 83.5 MW_t, of which 45.1 MW_t is accounted for by space heating[17].

The first geothermal power generation installation Velika 1, built in Velika Ciglena near Bjelovar, with a nominal capacity of 17.5 Mwe_e has been in operation since 2018.

Calculations of the capacity and recovery of energy from geothermal water on an annual basis depend on a number of factors, such as flow-through, inlet water temperature, outlet temperature and the number of days of use during the year. Therefore, the calculations of recovered or estimated capacities may differ, depending on the circumstances of use, as well as on possible changes in the hydrodynamic characteristics of the reservoir. Given the relatively low capacity factor of the installations in use today, technical potential is several times greater than the one currently in use.

Table I.80: Geothermal energy use in Croatia

[17] Energy Institute Hrvoje Požar, Energy in Croatia, 2019. Annual Energy Report, Ministry of Economy and Sustainable Development of the Republic of Croatia, 2020.

Site	Use*	Temperature [C°]	Flow-through [l/s]	Maximum capacity [MWt]	Remaining capacity [MWt]
Bizovačke Toplice	H, B	80-86	6.4	1.4	0.95
Daruvar	B	48	21	4.2	3.7
Naftalan (Ivanić Grad)	B	60	2.8	0.3	0.3
Terme Jezerčica	B	37.8	34.2	1.5	1.4
Krapinske Toplice	H, B	39.1-40.7	76	6.3	6.1
Toplice Lešće	B	32	6.2	0.4	0.3
Toplice Lipik	H, B	60	6.8	0.9	0.7
Istarske Toplice	B	28	2	0.1	0.09
Stubičke Toplice	H, B	56	17	1.7	1.4
Topusko	H, B	64	136	23.7	20.6
Terme Tuhelj	B	31	85	3.9	3.8
Varaždinske Toplice	H, B	57.6	95	9.8	8.8
Terme Sv. Martin	B	37.5	10	0.3	0.2
Zagreb geothermal field	H, B	55-82	78	14.7	13.7
Bošnjaci Sjever (North)	G	65	20	2.9	2.19
Sv. Nedelja	G	63	25	3.5	2.66
Velika-1 (Velika Ciglena)	E	170	208	10	–
TOTAL			**829.40**	**85.60**	**66.89**

*H – heating; B – bathing; G – greenhouses; E – electricity.

Source: EIHP

Given the increased interest in geothermal energy, a number of activities at existing sources have recently been launched to increase the use of geothermal energy. Thus, additional exploration was initiated at the Zagreb geothermal field in 2016 with the aim of maximizing the use of the existing capacities of the reservoir itself. For the time being, in addition to long-term users of the ŠRC Mladost [sports complex] and space heating of the Novi Zagreb Clinical Hospital facilities, the Faculty of Kinesiology in Zagreb has also been connected to geothermal heating, and preparations for the addition of new users are under way.

Late in 2020, the *Topusko – pametni termalni grad* (Topusko – smart thermal city) project was launched in Topusko with the aim to build new hot water network infrastructure throughout the city, connect new users, centralise management from the district heating station, connect four thermal wells into a single network, return all thermal water to the district heating station and use it for therapeutic purposes after it has been exploited for energy.

During the construction of an outdoor pool, a new high-capacity (58 °C, 10 l/s) thermal spring was discovered in Stubičke Toplice, and the possibility of its energy use is yet to be considered.

In Bošnjaci and Sv. Nedjelja, where there is greenhouse production of tomatoes, the capacities of the geothermal wells used for plant heating provide the potential of expansion to exploit the remaining capacity of the spring.

A new hotel in Varaždinske Toplice was granted a concession to use geothermal water in 2019 and is expected to reopen soon. A project for the Energy renovation of a set of buildings – *Terme, Konstantinov Dom, Hidroterapija Terme and Konstantinova Kupelj* – at Trg slobode 1B and 1C in Varaždinske Toplice is also under way. It was approved under the Operational Programme “Competitiveness and Cohesion 2014–2020”, Priority Axes 4 “Promoting Energy Efficiency and Renewable Energy”, Investment Priority 4c “Supporting energy efficiency, smart energy management and renewable energy use in public infrastructure, including in public buildings and in the housing sector” and Specific Objective 4c1 “Reduction of energy consumption in public sector buildings”. The implementation of energy renovation measures for the buildings of the Special Hospital for Medical Rehabilitation (*Terme, Konstantinov dom, Hidroterapija Terme and Konstantinova Kupelj*) in Varaždinske Toplice will reduce the annual primary energy consumption by 49.79%, annual heat consumption by 51.44%, with new measures for RES use from local sources to be introduced and providing for CO_2 emissions to be reduced by 50.20%. Promotion and visibility activities will raise the awareness of users of the buildings of the Varaždinske Toplice Special Hospital for Medical Rehabilitation while also informing the general public about the more efficient use of energy and daily benefits of increasing energy efficiency.

The Lipik Special Hospital for Medical Rehabilitation has a concession for geothermal water well and plans to build a replacement well, for which water rights have been granted by [the water authority] *Hrvatske Vode*, to be followed by renovation of the geothermal water installation so that it can be exploited more efficiently using its entire capacity.

2.3.1 EXISTING GEOTHERMAL SPRING EXPLOITATION FIELDS

Currently, there are six active geothermal projects in Croatia.

Projects in the exploitation phase:

1. Velika Ciglena – electricity generation,
2. Draškovec – electricity generation,
3. Bizovac – thermal energy generation,
4. GT Ivanić– thermal energy generation,
5. Zagreb geothermal field – thermal energy generation,
6. Bošnjaci Sjever – thermal energy generation for agricultural purposes (greenhouse production of tomatoes).

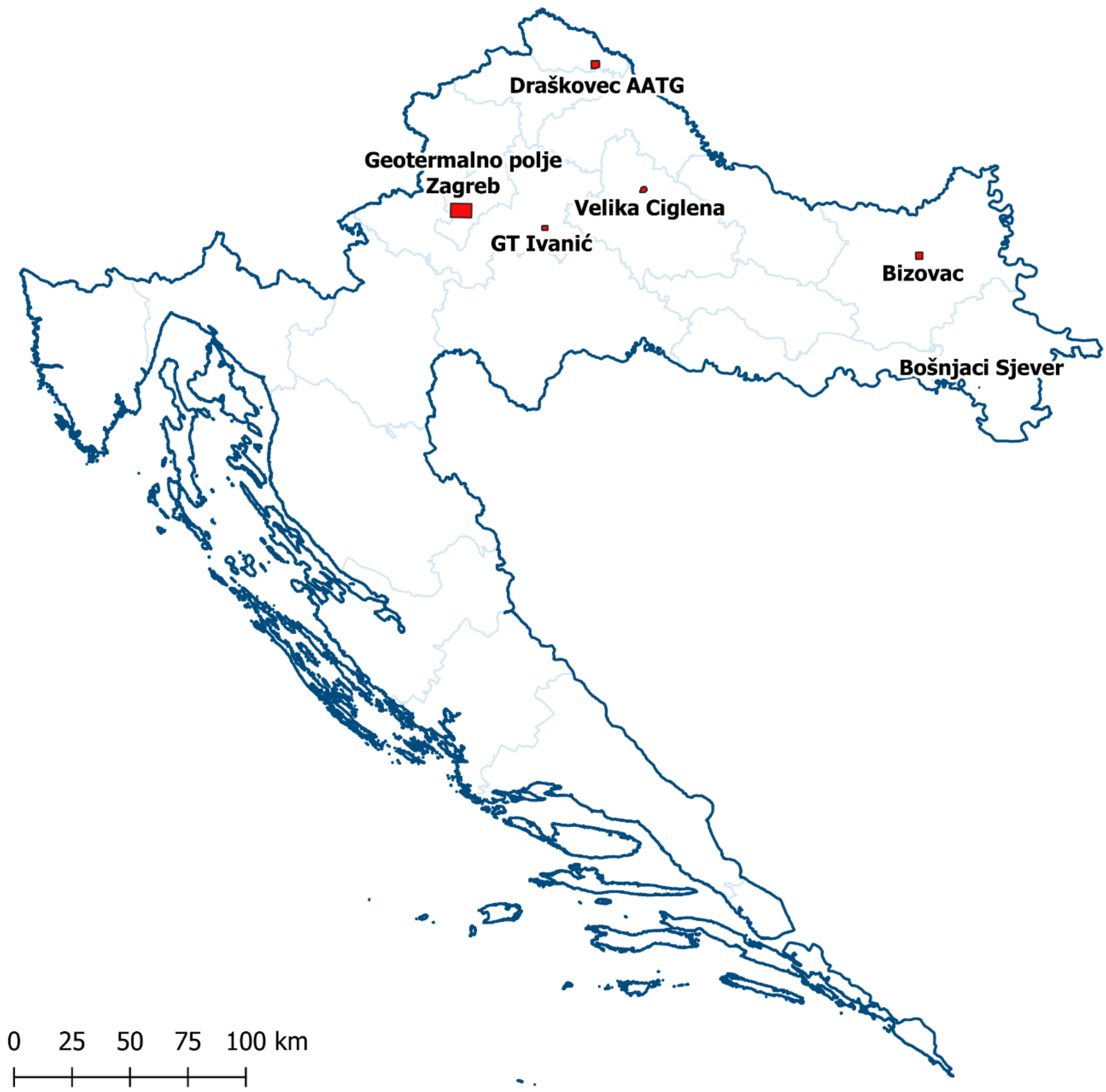


Figure I.49: Geothermal water exploitation fields

CROATIAN	ENGLISH
Geotermalno polje Zagreb	Zagreb geothermal field
Bošnjaci Sjever	Bošnjaci Sjever (North)

The first geothermal power generation installation in Croatia, Velika 1, began operating in Velika Ciglena late in 2018. The power plant operates on the principle of the Organic Rankine Cycle (ORC). Its nominal capacity is 17.5 MW, of which 10 MW is distributed to the electricity network.

A project is under way in Draškovac in the Međimurje County to build a pilot installation for an innovative advanced geothermal power generation installation with internalisation of carbon compounds. The project received a grant from the NER300 programme, the world's largest programme for financing innovative low-carbon energy demonstration projects. The unique closed technological process, which is being implemented in Draškovac for the first time in the world, includes extraction, a separation of liquid and gaseous stages, and utilisation of the geothermal resource in its liquid stage of in a binary system with real matter (e.g. ORC, Kalina), as well as the utilisation of the gaseous stage in cogeneration systems during which flue gases are collected and purified, and CO_2 is isolated in its entirety. The collected CO_2 is dissolved in the energetically recovered liquid stage of the geothermal resource; they are injected back together into the same geological layer from which they were obtained and where they are regenerated in a sustainable way.

The Bizovac geothermal field includes the Terme reservoir and the A3 + A4 reservoir. The water from this reservoir is the warmest iodine hyperthermal water in Europe[18], with almost three times more salt than in sea water and with large amounts of iron, iodine and other minerals, its composition making it unique in the world. It has very favourable balneological properties, based on which Bizovačke Toplice developed into what has become a well-established spa. In addition to balneological applications, the water is also used for energy purposes by exploiting the water temperature to heat hotels and swimming pools. Water is transported by an overhead pipeline to the facilities, in which so-called plate heat exchangers are used to heat the district heating system of the Termia Hotel and sanitary water. Apart from the water, natural gas at this site – used as fuel in the hotel kitchen – is also found at the site.

Thermal mineral water was found in Ivanić Grad, and a Naftalan Special Hospital for Medical Rehabilitation was opened at the site in 1989. Water is obtained from a depth of 1 300 m, and its temperature at the wellhead is 60 °C. It has a characteristic crude oil smell and is classified as oily water. Nowadays, it is used only for special cosmetics to treat skin diseases.

Greenhouses are an example of successful commercialisation of the use of geothermal waters. For now in Croatia, geothermal water is used in greenhouse production at two locations – in Sv. Nedelja near Zagreb and in Bošnjaci near Županja. The greenhouse capacities are extensive – 3.5 ha in Bošnjaci, with the potential for expansion, and 5 ha in Sv. Nedelja – the two sites at which geothermal water is used for greenhouse heating in tomato production (Figure I.50).

[18] https://www.bizovacke-toplice.hr/bizovacka-termalna-voda.aspx

Figure I.50: Greenhouse production of tomatoes in Sv. Nedelja

Source: Rajska d.o.o.[19]

2.3.2 GEOTHERMAL SPRING EXPLORATION AREAS

In the last few years, the Hydrocarbon Agency (AZU) has embarked on intensive preparations of the existing geological and oil-mining documentation as a basis for a tender to be called for the allocation of geothermal water exploration areas in Croatia. There are 13 currently active exploration areas in Croatia, in which new geothermal projects are expected to be developed over the next 3–5 years. In the exploration areas, the focus is on exploration activities aimed at obtaining electricity, and to a lesser extent, thermal energy generation relating mostly to local communities with plans to use thermal energy for heating the settlements.

[19] https://rajskarajcica.com/about/

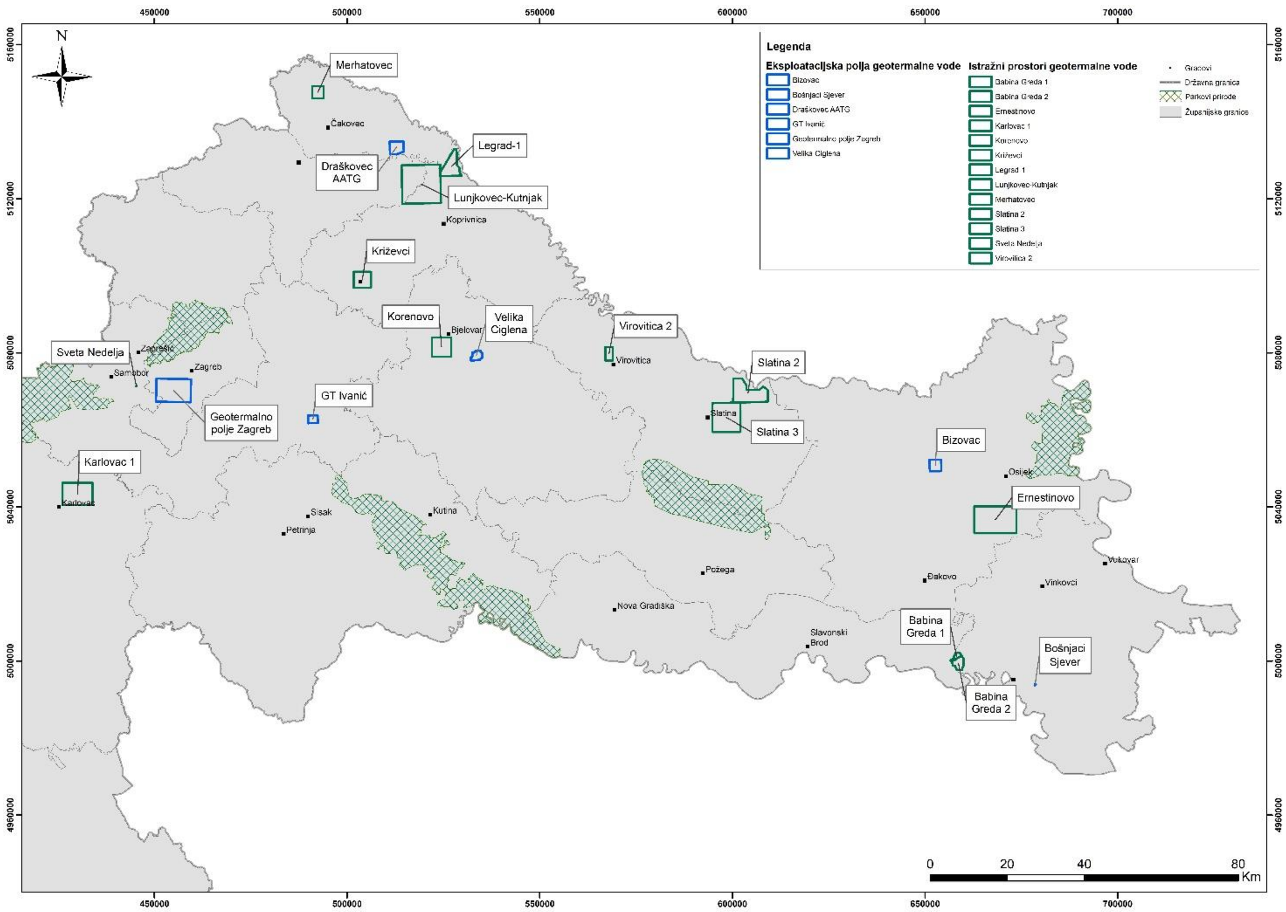


Figure I.51: Exploration areas and exploitation fields of geothermal energy in Croatia

Source: Hydrocarbon Agency, May 2021.

CROATIAN	ENGLISH
Legenda	Key
Eksploatacijska polja geotermalne vode	Geothermal water exploitation fields
Bošnjaci Sjever	Bošnjaci Sjever (North)
Geotermalno polje Zagreb	Zagreb geothermal field
Istražni prostori geotermalne vode	Exploration areas for geothermal water
Gradovi	Cities or towns
Državna granica	State border
Parkovi prirode	Nature parks
Županijske granice	County borders

Active exploration areas:

1. Babina Greda 1– electricity,
2. Babina Greda 2 – electricity,
3. Karlovac 1 – electricity / thermal energy,
4. Korenovo – thermal energy,
5. Križevci – thermal energy,
6. Slatina-2 – electricity,
7. Slatina-3 – electricity,
8. Virovitica 2 – thermal energy,
9. Lunjkovec-Kutnjak – electricity,

10. Legrad-1 – electricity,
11. Ernestinovo – electricity,
12. Merhatovec – electricity,
13. Sveta Nedjelja – thermal energy.

The projects, which are currently undergoing exploration, have the potential to produce 59 MW_e of electricity and can be fully implemented between 2022 and 2025.

2.3.3 POTENTIAL SOURCES OF GEOTHERMAL ENERGY

In addition to the previously mentioned natural sources of thermal water indicating the geothermal potential of Croatia, geothermal water was also found in many wells as part of oil and gas exploration in the second half of the 20th century. Some wells were tested during or after drilling, with a consequent confirmation of geothermal potential, but in a number of them geothermal water was only observed, with no additional testing performed to confirm there is a reservoir. It is in these numerous wells that the **huge potential for the use of geothermal resources lies**.

The total estimated potential power at 52 sites is **546 MW_e** and **almost 2 000 MW_t**, of which 180 MW_e and 762 MW_t may be expected to be exploited by 2030 and another 94 MW_e and 525 MW_t by 2040, with the remaining potential by 2050 (Hydrocarbon Agency, 2021). However, the final potential can be determined only after research activities have been completed.

Table I.81: Potential sources of geothermal energy

County	Name of city or town / municipality / city district	Site	T [°C]	Pex [MWe]	P_{top} [MW]
Bjelovar-Bilogora	Bjelovar	Velika Ciglena	180	16.032	81.841
Međimurje	Prelog	Draškovec	105	5.855	200.110
Osijek-Baranja	Bizovac	Bizovac	90		1.103
Zagreb County	Ivanić Grad	Ivanić	58		0.349
City of Zagreb	ZG – Novi Zagreb-zapad (west)	GT Zagreb – Blato	80		1.259
Vukovar-Syrmia	Bošnjaci	Bošnjaci Sjever (north)	65		1.441
Zagreb County	**Sveta Nedelja**	Sveta Nedjelja	65		3.097
Vukovar-Syrmia	Babina Greda	Babina Greda 1	170	11.147	30.600
Karlovac	Karlovac	Karlovac 1	137	5.560	34.000
Vukovar-Syrmia	Babina Greda	Babina Greda 2	170	11.147	30.600
Koprivnica-Križevci	Križevci	Križevci	68		7.010
Virovitica-Podravina	Slatina	Slatina-2	186	20.587	53.000
Virovitica-Podravina	Slatina	Slatina-3	190	10.701	20.000
Virovitica-Podravina	Virovitica	Virovitica 2	76		8.610
Osijek-Baranja	Ernestinovo	Ernestinovo (Ern-2,3)	132	2.396	17.000
Međimurje	Selnica	Merhatovec (Mer-1,2)	140	9.103	51.000
Virovitica-Podravina	Suhopolje	Pčelić (Pče-1A)	205	22.572	34.000
Koprivnica-Križevci	Legrad	Legrad-1	190	26.752	51.000
Koprivnica-Križevci	Ferdinandovac	Ferdinandovac-1	162	15.724	51.000
Međimurje	Kotoriba	Kotoriba	165	16.767	51.000
Koprivnica-Križevci	Legrad	Lunjkovec-Kutnjak	140	6.069	34.000
Međimurje	Sveta Marija	Međimurje-2	108	0.894	17.000
Međimurje	Donji Kraljevec	Međimurje-3	130	4.459	34.000
Međimurje	Čakovec	Međimurje-4	85		10.630
Međimurje	Sveti Juraj na Bregu	Međimurje-5 (Međ-5;Lop-1al)	139	5.897	34.000
Međimurje	Nedelišće	Međimurje-6	68		7.010
Međimurje	Prelog	Prelog-1	129	2.156	17.000
Koprivnica-Križevci	Ferdinandovac	Ferdinanovac-1DU	162	10.483	34.000

County	Name of city or town / municipality / city district	Site	T [°C]	Pex [MWe]	P_{top} [MW]
Koprivnica-Križevci	Molve	Dravka-1 (+ Fer-8)	138	5.727	34.000
Virovitica-Podravina	Suhopolje	Pepelana -2A	107	0.424	8.500
Koprivnica-Križevci	Kalinovac	Leščan-1,2	199	20.610	34.000
Osijek-Baranja	Bizovac	Madarinci-1	125	3.747	34.000
Osijek-Baranja	Marijanci	Marijanci-1,3,4	149	3.845	17.000
Osijek-Baranja	Petrijevci	Petrijevci-1	135	5.233	34.000
Osijek-Baranja	Marijanci	Sječe 1,2,3	155	8.843	34.000
Zagreb County	Križ	Okešinec-1al	121	3.221	34.000
Karlovac	Karlovac	Rečica	140	6.069	34.000
Varaždin	Mali Bukovec	Mali Bukovec (L-4, Pdk-1)	120	1.548	17.000
Sisak-Moslavina	Sisak	Sisak	54		4.040
Vukovar-Syrmia	Vukovar	Vukovar	54		4.040
Bjelovar-Bilogora	Rovišće	Rovišće	105	0.759	17.000
Osijek-Baranja	Viljevo	Stjepanik	150	3.963	17.000
Zagreb County	Dugo Selo	Kopčevec-1	142	6.421	34.000
Koprivnica-Križevci	Molve	Molve – carbonates	180	112.396	255.000
Koprivnica-Križevci	Gola	Gola	160	15.048	51.000
Virovitica-Podravina	Pitomača	Stari Gradac	195	9.676	17.000
Osijek-Baranja	Magadenovac	Beničanci	123	17.395	170.000
Koprivnica-Križevci	Kalinovac	Kalinovac	176	52.185	127.500
Međimurje	Donji Kraljevec	Hodošan-2	180	44.630	17.000
Zagreb County	Križ	Žutica	123	20.400	17.000
Vukovar-Syrmia	Vinkovci	Vinkovci	75		14.880
Požega-Slavonia	Lipik	Lipik – ergela (stud farm)	60		0.430
TOTAL				**546.44**	**1 942.05**

Source: AZU, EIHP

2.4 Reported share of energy from renewable sources and waste heat or cold in the consumption of delivered energy in the sector of district heating systems in the past 5 years under Directive (EU) 2018/2001

There are district heating systems in a total of 16 cities in Croatia (Karlovac, Ogulin, Osijek, Požega, Rijeka, Samobor, Sisak, Slavonski Brod, Topusko, Varaždin, Velika Gorica, Vinkovci, Virovitica, Vukovar, Zagreb, Zaprešić).

In district heating systems in a total of 10 cities (Karlovac, Ogulin, Požega, Rijeka, Samobor, Varaždin, Velika Gorica, Vinkovci, Virovitica, and Zaprešić), heat is produced exclusively through fossil fuel combustion in boilers. Heating systems in Slavonski Brod and Vukovar use fossil fuel boilers to produce heat, and a smaller part of heat is derived from solar energy using built-in solar collectors.

The largest district heating system in Croatia, the one in Zagreb, produces heat through fossil fuel cogeneration and high-efficiency fossil fuel cogeneration.

District heating systems in Osijek and Sisak produce heat through fossil fuel cogeneration and high-efficiency RES cogeneration.

The Topusko heating system uses exclusively geothermal energy as a source of heat.

In order to determine the origin of thermal energy delivered from district heating systems to the household and service sectors, it is important to know the shares of individual technologies for each district heating system (see Table I.82:).

Table I.82: District heating systems in Croatia – origin of produced thermal energy delivered to household and service sectors

DISTRICT HEATING SYSTEMS – share of produced heat delivered to household and service sectors									
City		Fossil fuel boilers, [–]	RES boilers, [–]	Solar collectors, [–]	Geothermal energy, [–]	High-efficiency fossil fuel cogeneration, [–]	Fossil fuel cogeneration, [–]	High-efficiency RES cogeneration, [–]	Sum of shares [–]
1.	Karlovac	1.000	–	–	–	–	–	–	**1.0**
2.	Ogulin	1.000	–	–	–	–	–	–	**1.0**
3.	Osijek	–	–	–	–		0.675	0.325	**1.0**
4.	Požega	1.000	–	–	–	–	–	–	**1.0**
5.	Rijeka	1.000	–	–	–	–	–	–	**1.0**
6.	Samobor	1.000	–	–	–	–	–	–	**1.0**
7.	Sisak	–	–	–	–	–	0.399	0.601	**1.0**
8.	Slavonski Brod	0.997	–	0.003	–	–	–	–	**1.0**
9.	Topusko	–	–	–	1.000	–	–	–	**1.0**
10.	Varaždin	1.000	–	–	–	–	–	–	**1.0**
11.	Velika Gorica	1.000	–	–	–	–	–	–	**1.0**
12.	Vinkovci	1.000	–	–	–	–	–	–	**1.0**
13.	Virovitica	1.000	–	–	–	–	–	–	**1.0**
14.	Vukovar	0.952	0.033	0.015	–	–	–	–	**1.0**
15.	Zagreb	–	–	–	–	0.338	0.662	–	**1.0**
16.	Zaprešić	1.000	–	–	–	–	–	–	**1.0**

A total of 1 949.65 GWh of thermal energy was delivered in the district heating sector in Croatia in 2019. Of this, **4.9%** is accounted for by delivered energy from renewable energy sources. An overview of the share of renewable energy sources in the total delivered energy from district heating systems in the last 5 years is provided in tabular form.

Table I.83: Share of RES in the district heating sector, 2015–2019

	THERMAL ENERGY DELIVERED

City	RES	Technology	2019	2018	2017	2016	2015
Osijek	Biomass	BE-TO	62 200	46 416	–	–	–
Sisak	Biomass	BE-TO	28 558	27 926	–	–	–
Topusko	geothermal energy	directly through a heat exchanger	3 833	4 316	4 230	4 486	4 486
Vukovar	pellets	pellet boiler	532	530	578	519	92
Vukovar	solar energy	thermal collectors	241	–	–	–	–
Slavonski Brod	solar energy	thermal collectors	99	105	111	114	117
Total energy delivered from RES, [MWh]			**95 463**	**79 294**	**4 918**	**5 119**	**4 696**
Total thermal energy delivered, [MWh]			**1 949 675**	**1 999 970**	**2 093 081**	**2 126 142**	**2 120 527**
Share of RES			**4.90%**	**3.96%**	**0.23%**	**0.24%**	**0.22%**

Table I.84: Shares of RES in the district heating sector – 2019 data

	THERMAL ENERGY DELIVERED FROM RES IN 2019	
Source	[MWh]	[%]
Biomass	90 758	95.1
Geothermal energy	3 833	4.0
Woody biomass	532	0.6
Solar energy	340	0.4
TOTAL	**95 463**	100.0

3 MAPS OF CROATIA

Based on the analyses conducted in the two preceding chapters, this chapter includes only maps showing the following:

- distribution of annual delivered and required useful energy for heating/cooling purposes at the level of municipalities / cities or towns in the base year 2019 separately for the household sector and service sector (in the case of the City of Zagreb, the distribution is provided at the level of 17 City of Zagreb districts);
- positions of large industrial sector companies in Croatia in the base year 2019 with a total delivered energy for heating/cooling purposes exceeding 5 GWh/a (also providing an overview of the maximum heating and cooling load);
- positions of heat production facilities of the existing district heating systems in the base year 2019;
- distribution network of existing district heating systems;
- supply points of industrial installations producing waste heat;
- geothermal springs (existing and potential sources of geothermal energy).

Data presented on the maps was used to identify consumers who could be connected to a district heating system and to available sources of waste heat and renewable energy sources.

3.1 MAP OF CROATIA – ANNUAL DELIVERED AND REQUIRED USEFUL ENERGY FOR HEATING/COOLING

As part of this chapter, a spatial representation of delivered and required useful energy for heating (space heating and DHW preparation) and cooling at the level of municipalities, cities or towns, and City of Zagreb districts, is provided separately for the household sector (Chapter 3.1.1) and the service sector (Chapter 3.1.2). It is based on the data already provided on delivered and required energy for those sectors. In addition, the annual energy delivered for heating/cooling purposes, as well as the maximum load for heating and cooling at industrial enterprises with a consumption exceeding 5 GWh per year, is provided in Chapter 3.1.3. As already mentioned, due to data confidentiality, no names of industrial enterprises are listed.

3.1.1 HOUSEHOLD SECTOR

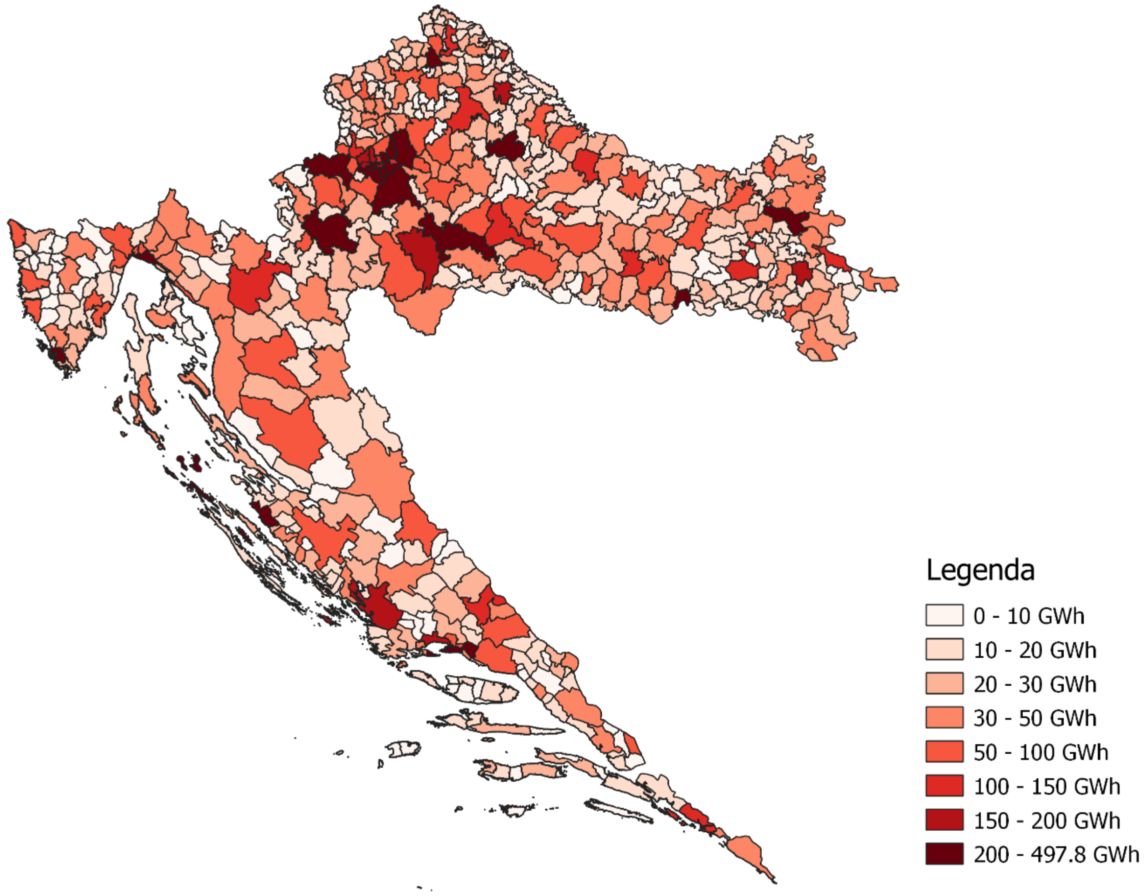


Figure I.52: HOUSEHOLD SECTOR – Spatial representation of energy delivered for heating and DHW preparation [GWh/a]

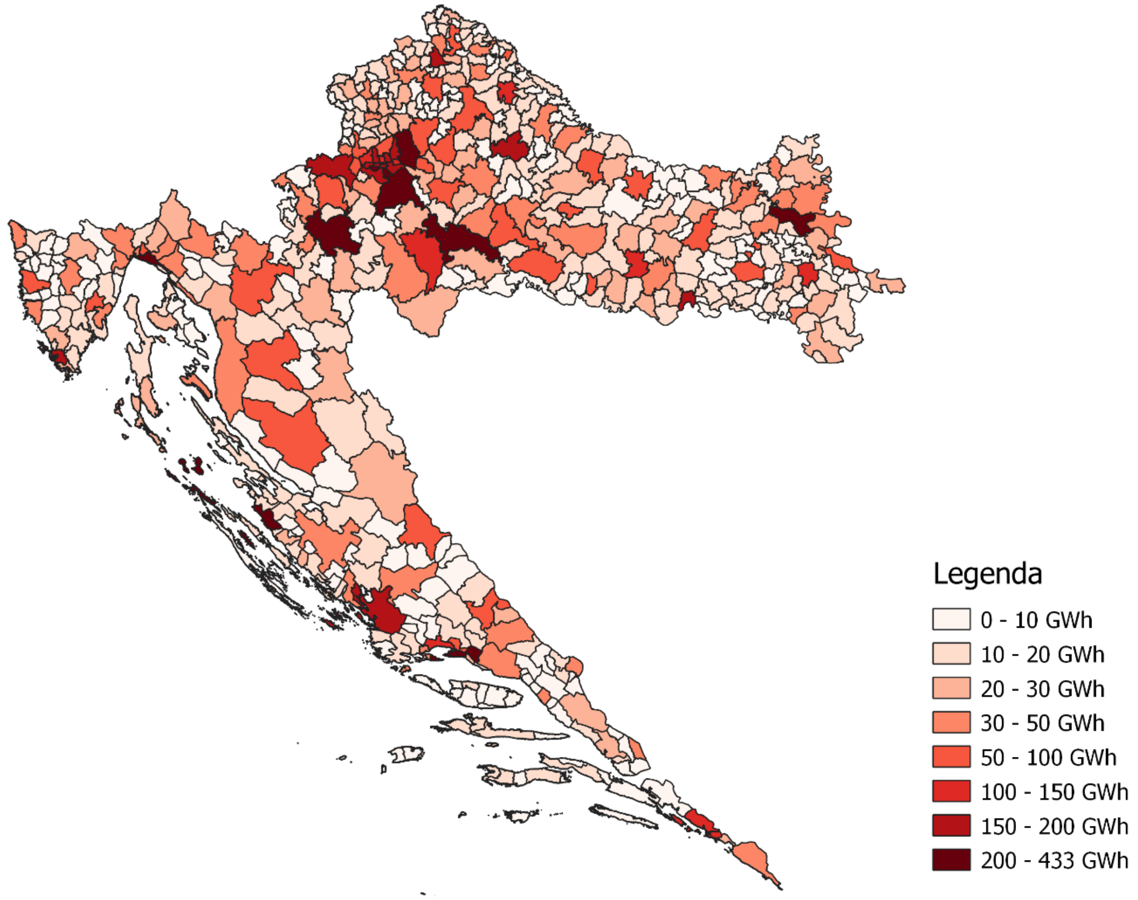


Figure I.53: HOUSEHOLD SECTOR – Spatial representation of energy needed for heating and DHW preparation [GWh/a]

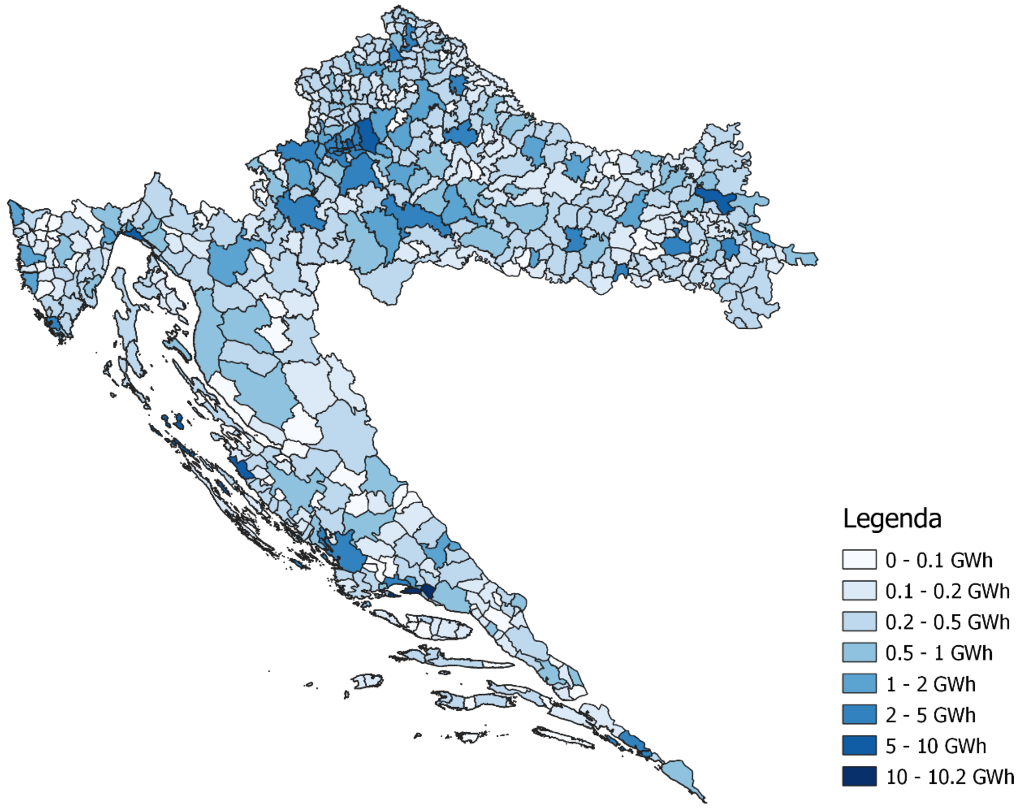


Figure I.54: HOUSEHOLD SECTOR – Spatial representation of energy delivered for cooling [GWh/a]

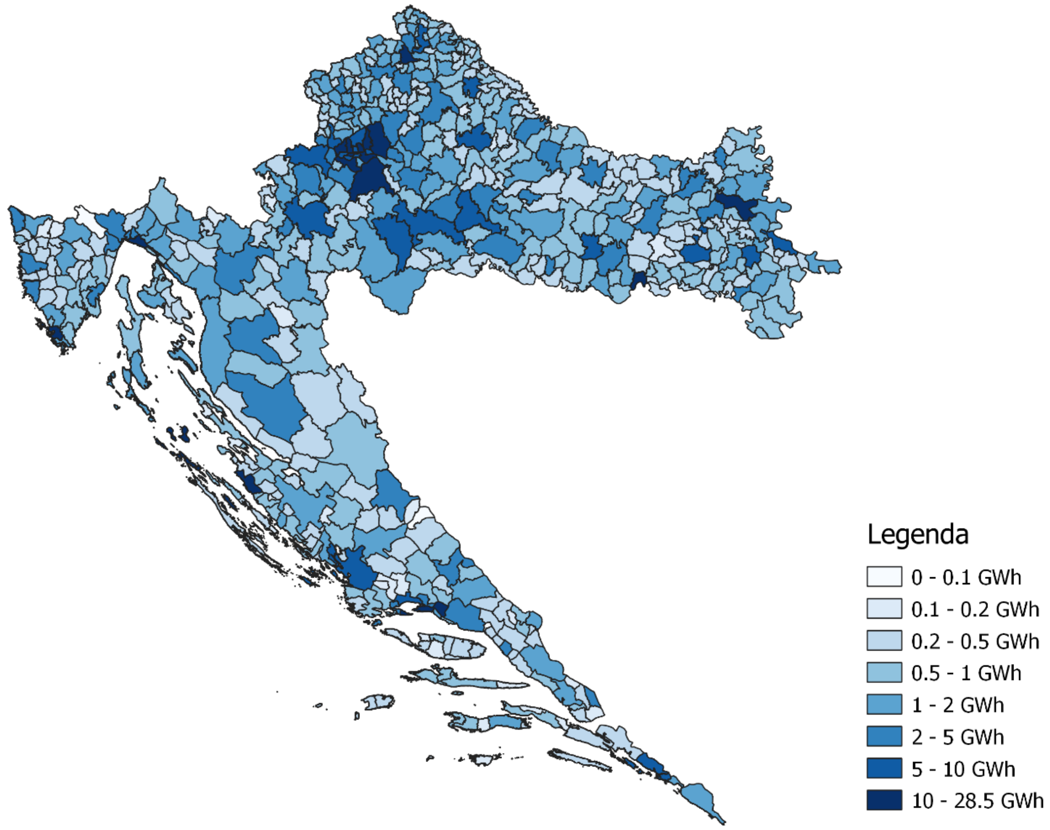


Figure I.55: HOUSEHOLD SECTOR – Spatial representation of energy needed for cooling [GWh/a]

3.1.2 SERVICE SECTOR

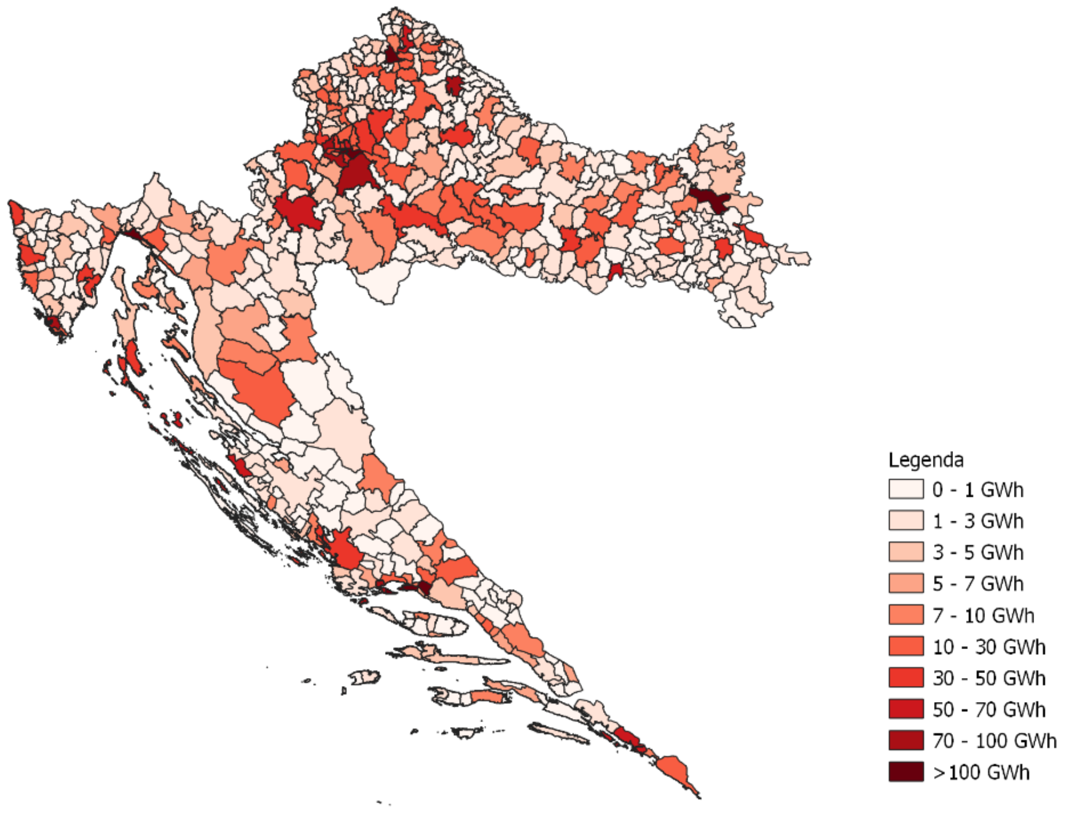


Figure I.56: SERVICE SECTOR – Spatial representation of energy delivered for heating and DHW preparation [GWh/a]

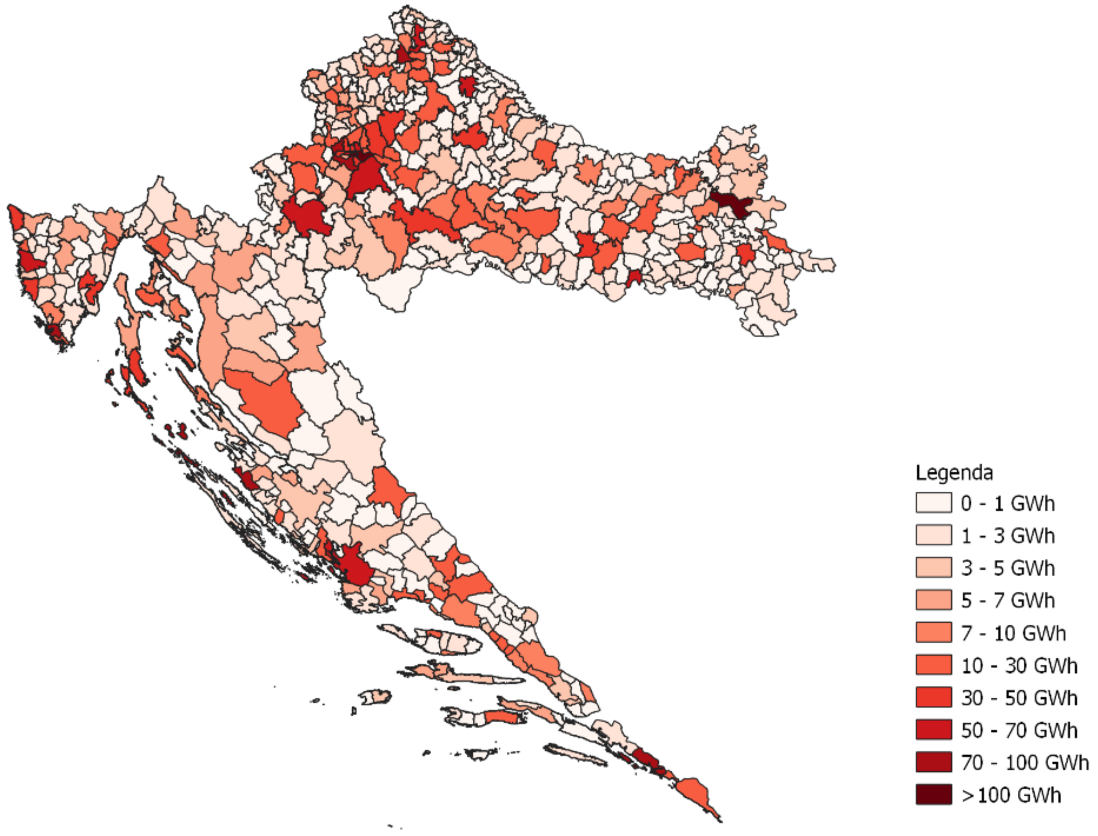


Figure I.57: SERVICE SECTOR – Spatial representation of energy needed for heating and DHW preparation [GWh/a]

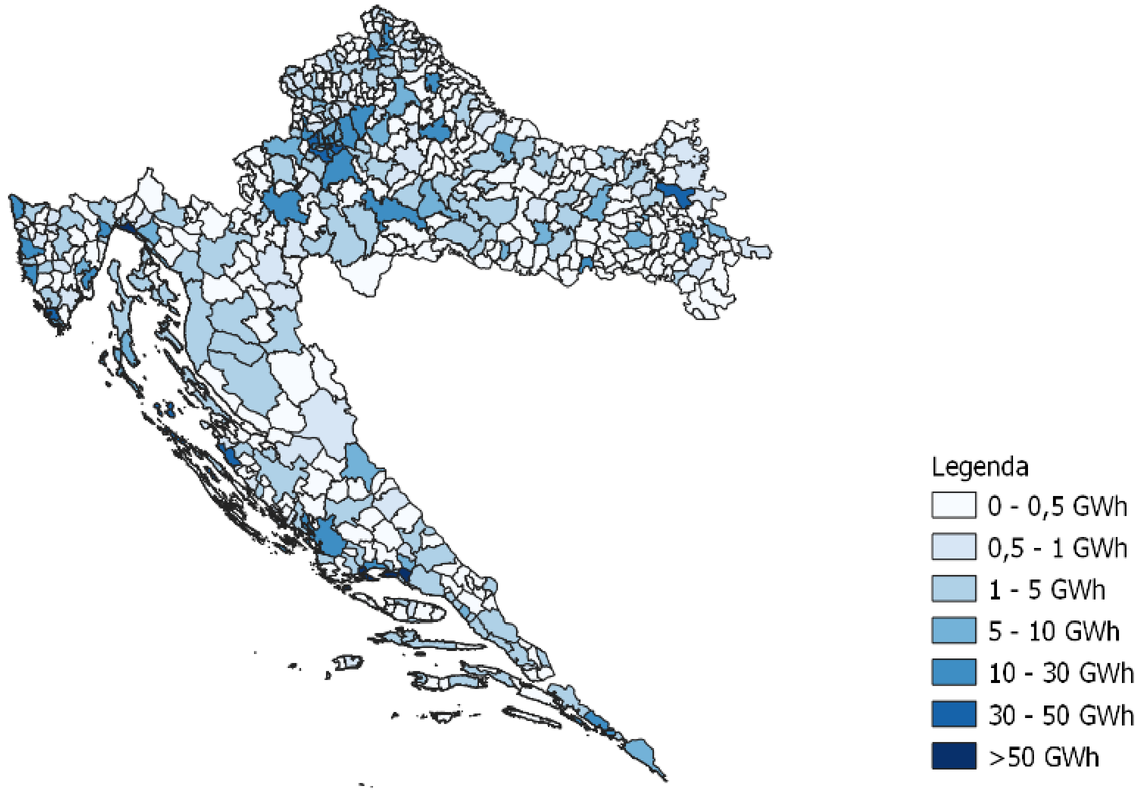


Figure I.58: SERVICE SECTOR – Spatial representation of energy delivered for cooling [GWh/a]

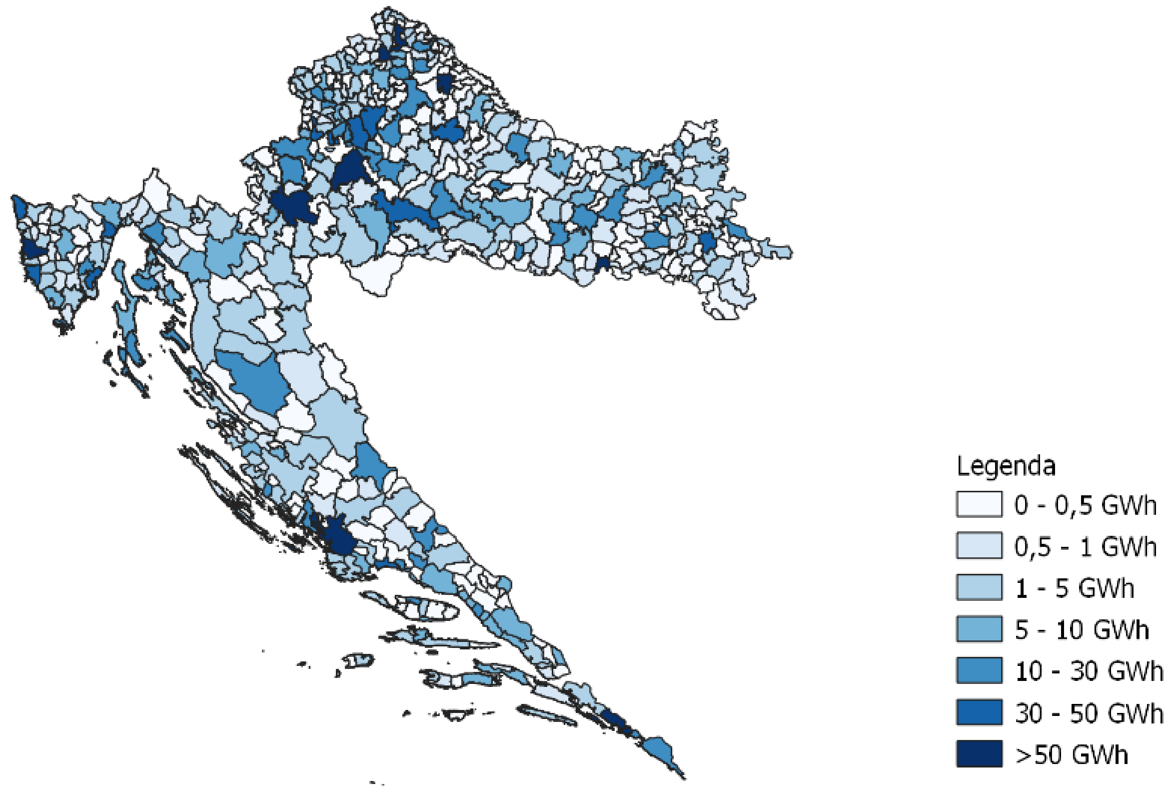


Figure I.59: SERVICE SECTOR – Spatial representation of energy needed for cooling [GWh/a]

3.1.3 INDUSTRIAL SECTOR

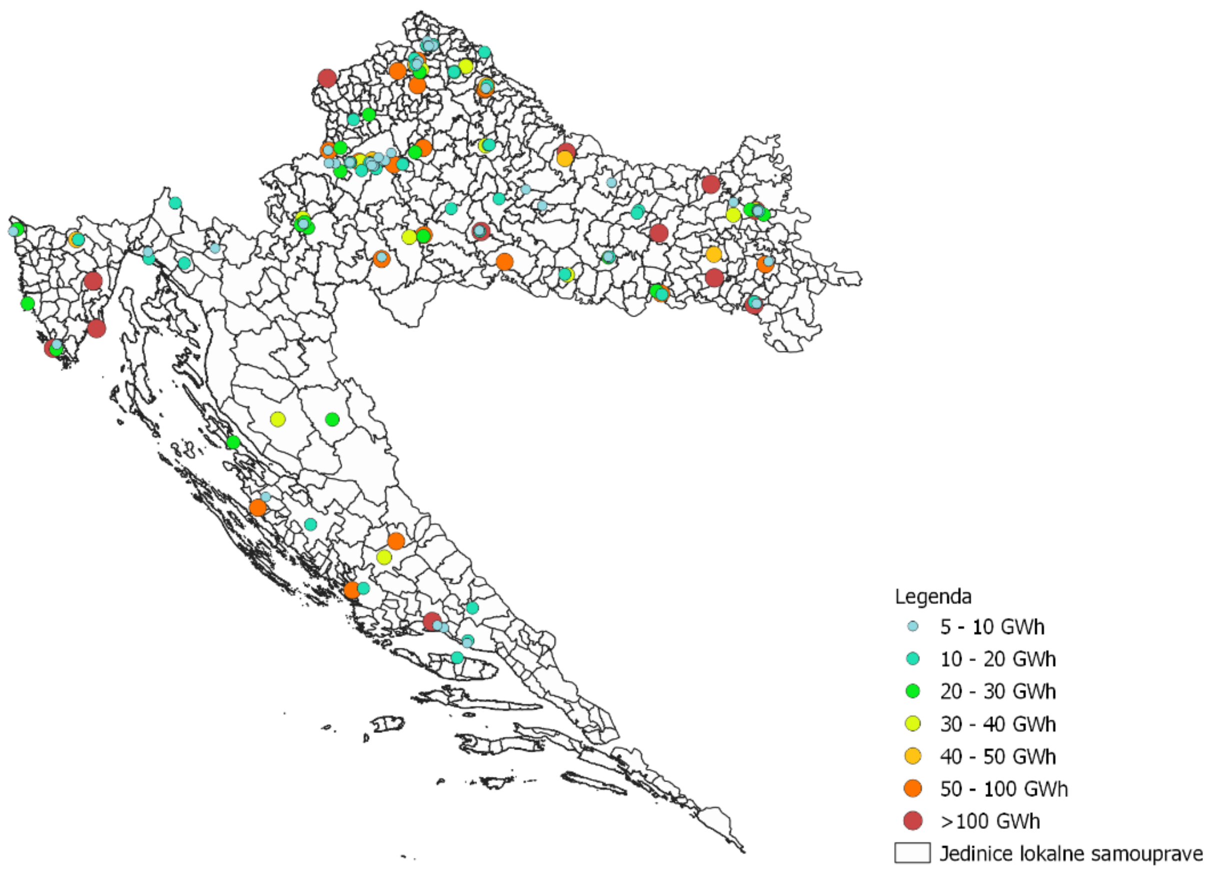


Figure I.60: INDUSTRY SECTOR – Large enterprises in Croatia with the total energy delivered for heating/cooling purposes exceeding 5 GWh/a

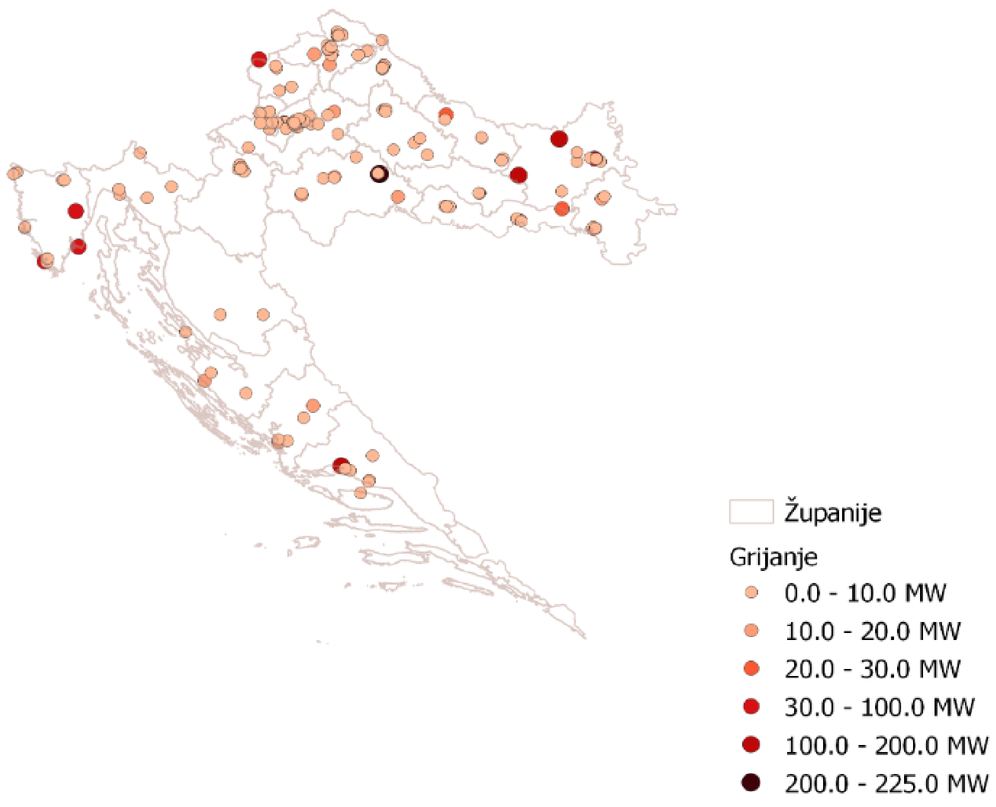


Figure I.61: INDUSTRY SECTOR – Representation of the maximum heating load, in MW

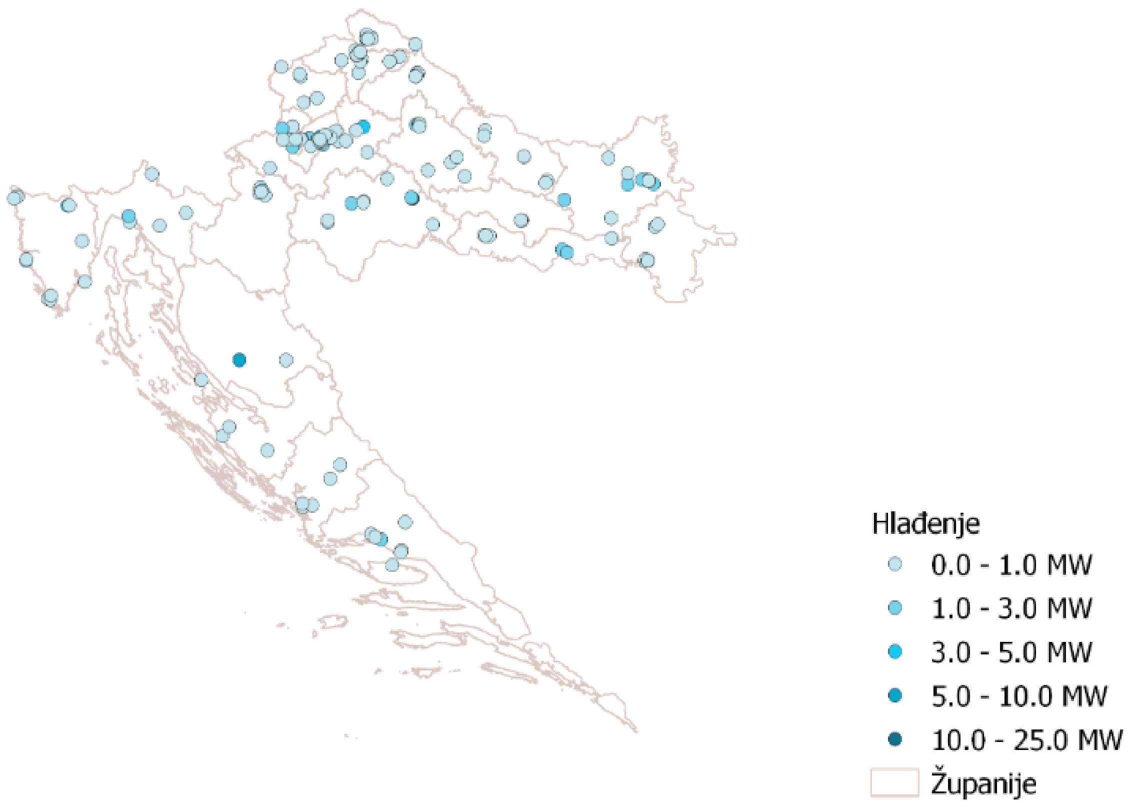


Figure I.62: INDUSTRY SECTOR – Representation of the maximum cooling load, in MW

CROATIAN	ENGLISH
Legenda	Key
Jedinice lokalne samouprave	Local self-government units
Županije	Counties
Grijanje	Heating
Hlađenje	Cooling

3.2 MAP OF CROATIA – DISTRICT HEATING SYSTEMS

A district heating system consists of a heat generation installation and a distribution network.

3.2.1 GENERATION INSTALLATIONS OF EXISTING DISTRICT HEATING SYSTEMS

Generation installations of existing district heating systems are shown on the map below.

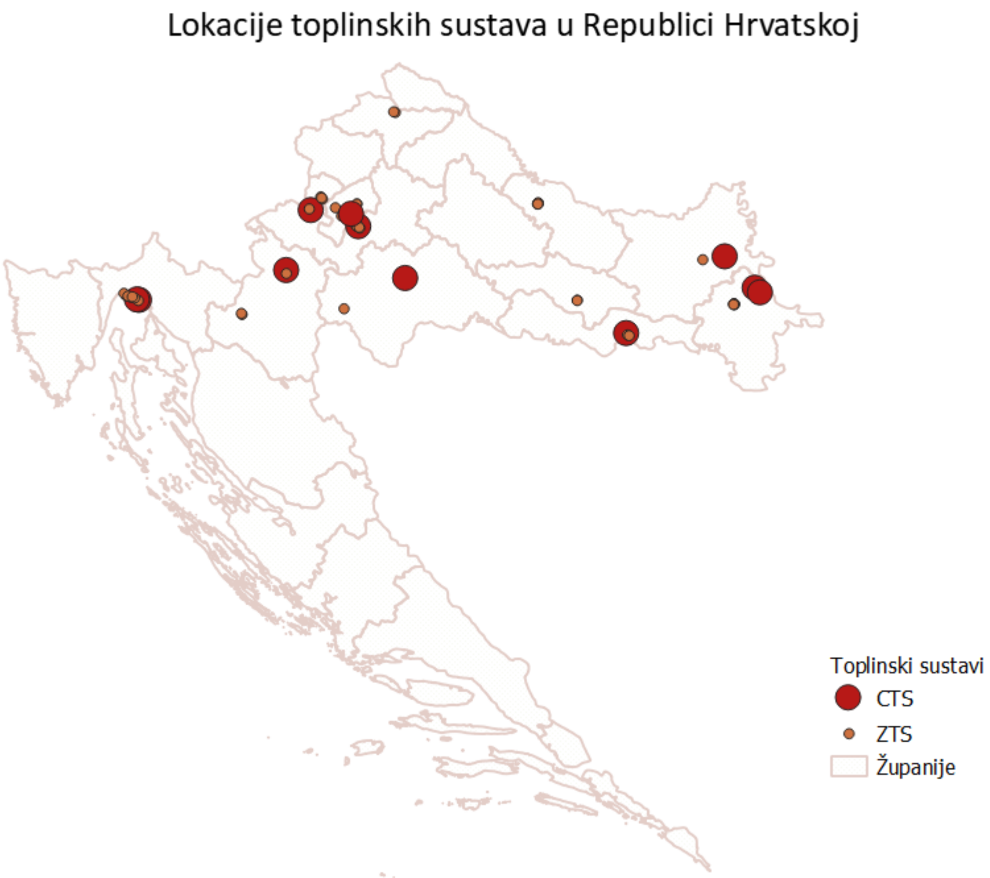


Figure I.63: Representation of heating system sites in Croatia

CROATIAN	ENGLISH
Lokacije toplinskih sustava u Republici Hrvatskoj	Heating system sites in Croatia
Toplinski sustavi	Heating systems
CTS	DHS
ZTS	CHS
Županije	Counties

3.2.2 GENERATION INSTALLATIONS OF PLANNED DISTRICT HEATING SYSTEMS

In the next period, a consolidation of existing closed heating systems and independent heating systems, together with neighbouring existing consumption, into district heating systems in the cities of Rijeka, Samobor and Velika Gorica.

New generation installations may also be expected at sites near the existing district heating systems in order to exploit the potential of geothermal energy in Karlovac, Vukovar, Velika Gorica, Sisak, Topusko, Zagreb, Osijek, Zaprešić, and Požega. The likelihood of construction and timeliness will depend on a number of factors with an impact on the development of the heat market, as well as on the availability of incentives for thermal energy generation from renewable energy sources.

3.2.3 DISTRIBUTION NETWORK OF EXISTING DISTRICT HEATING SYSTEMS

Companies managing district heating systems were asked to provide infrastructure data on individual district heating systems. Georeferenced infrastructure data in the official appropriate projection coordinate reference system of the Republic of Croatia (HTRS96/TM) in the preferred .shp or .dwg format was requested.

Table I.85: provides an overview of data provided by data format for each company and city or town.

Table I.85: Overview of the formats of provided infrastructure data on district heating systems

Company	Brod Plin	Energo	Tehnostan	HEP Toplinarstvo					Gradska Toplana
City	Slav. Brod	Rijeka	Vukovar	Zagreb	Osijek	Sisak	Samobor	Velika Gorica	Karlovac
shp	No	No	No	Yes	No	Yes	No	No	No
dwg	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
pdf	Yes	Yes	Yes	No	No	No	No	No	No

Difficulties arising in the processing of data provided were mainly due to the following facts:

- data was not submitted in required formats;
- data was provided in required formats but included a lot of other data, making it very difficult or impossible to distinguish which data referred to the infrastructure data of district heating systems and which to other infrastructure;
- different parts of the same district heating system were provided in different formats;
- the data was not provided in the appropriate projection coordinate reference system (HTRS96/TM).

The following figures show results of the processing of infrastructure data provided, and spatial infrastructure data provided in the appropriate formats and appropriate projection coordinate reference system.

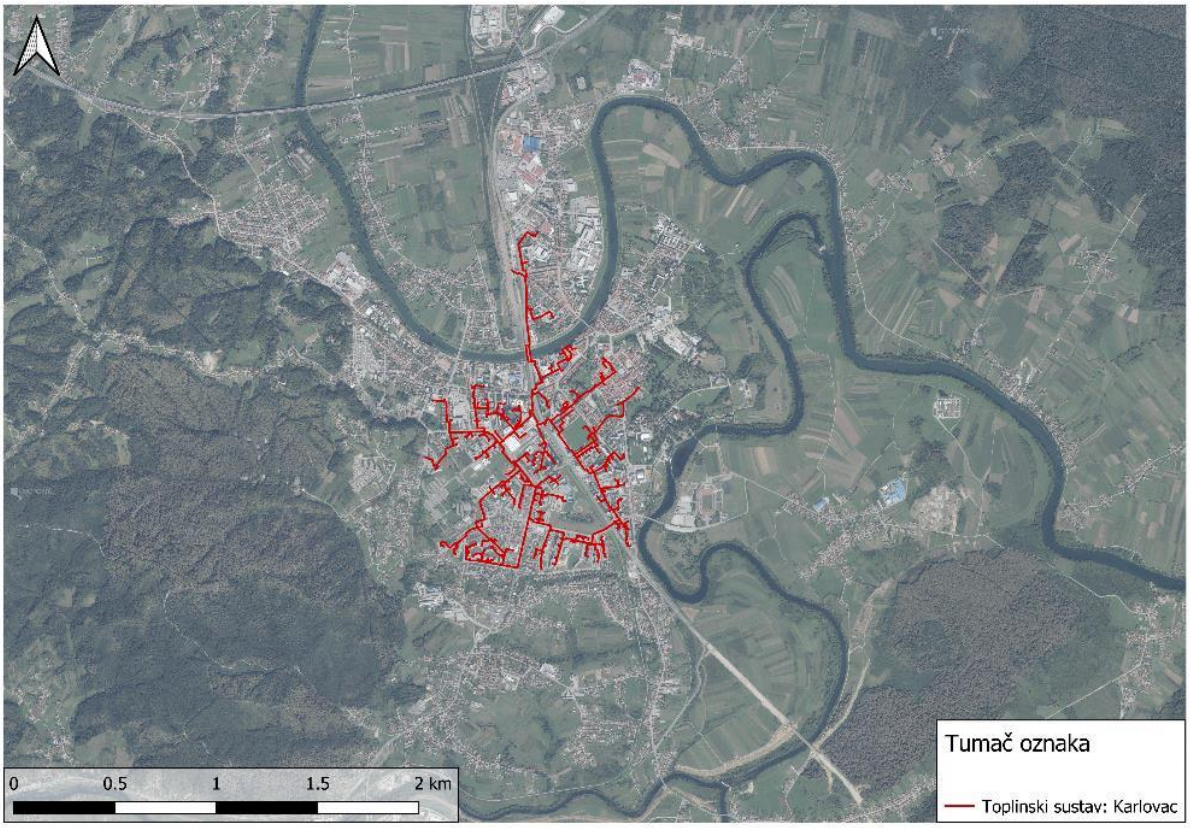


Figure I.64: Thermal system representation – Karlovac

CROATIAN	ENGLISH

Tumač oznaka	Key
Toplinski sustav	Thermal system

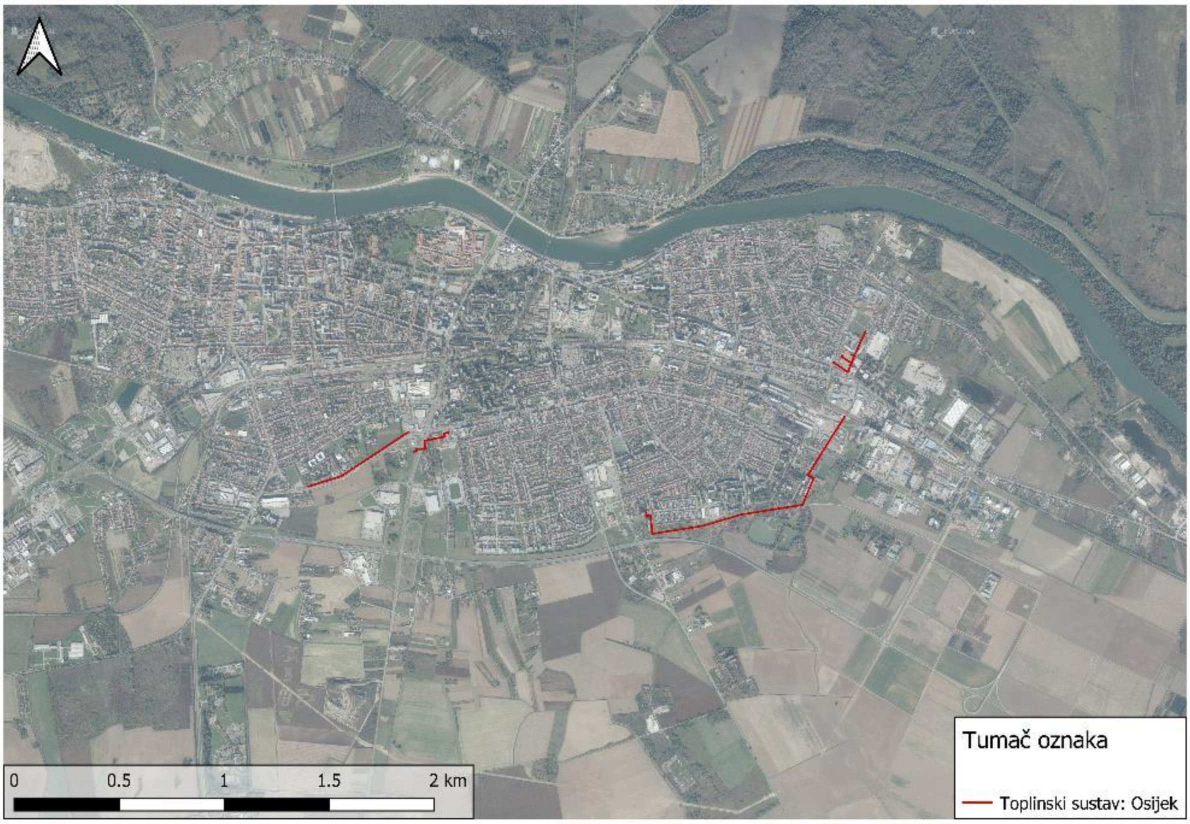


Figure I.65: Thermal system representation – Osijek

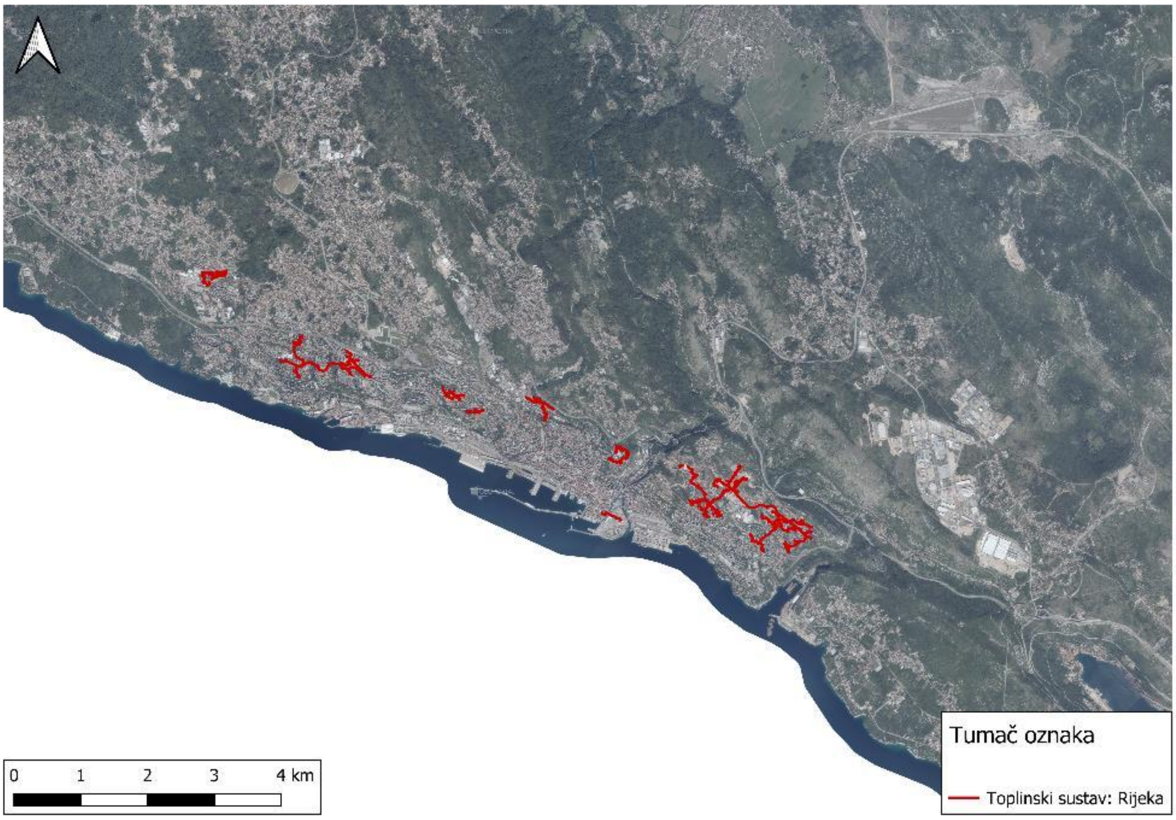


Figure I.66: Thermal system representation– Rijeka

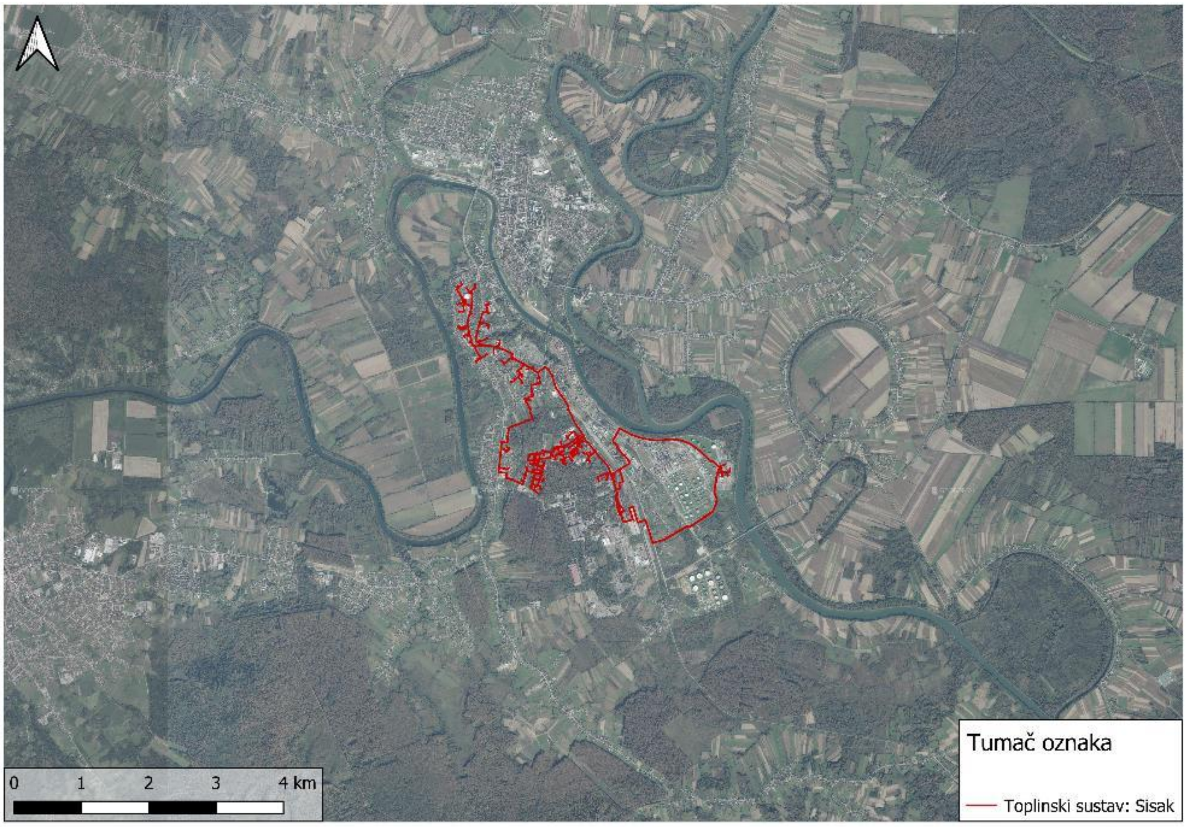


Figure I.67: Thermal system representation – Sisak

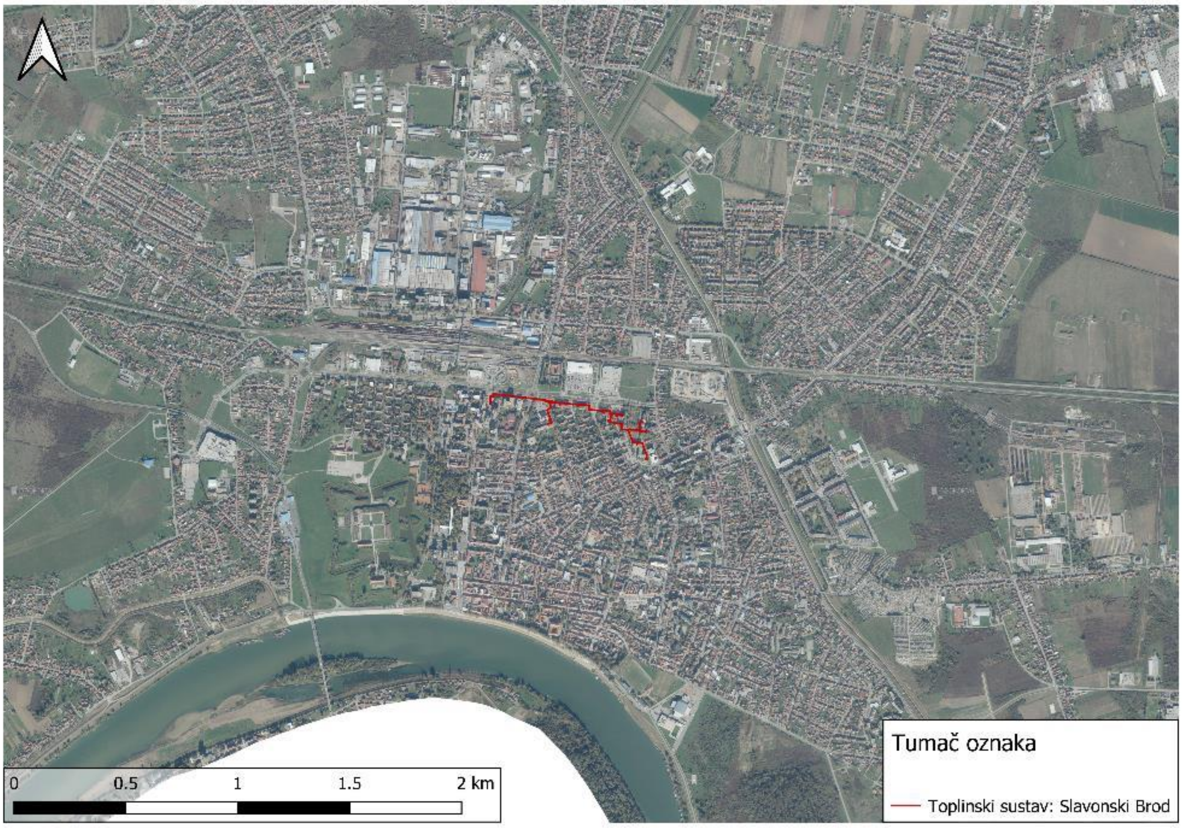


Figure I.68: Thermal system representation– Slavonski Brod

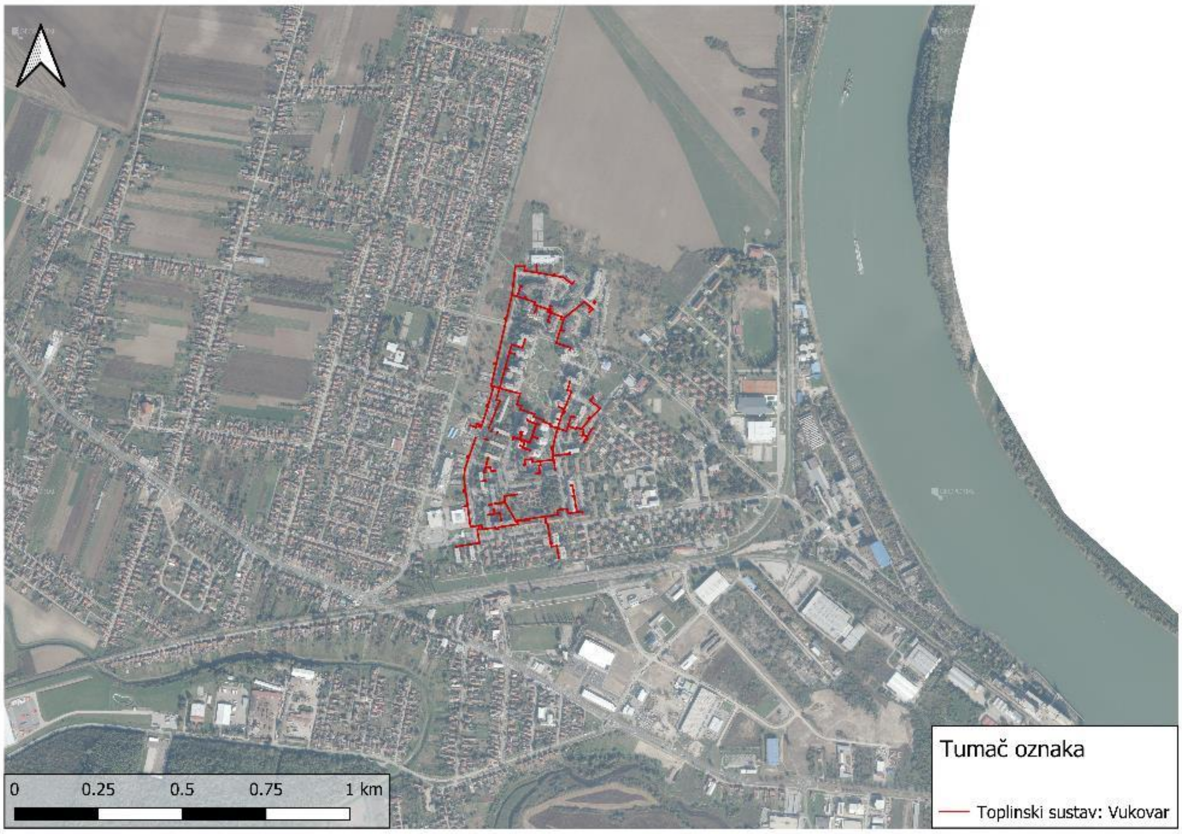


Figure I.69: Thermal system representation– Vukovar

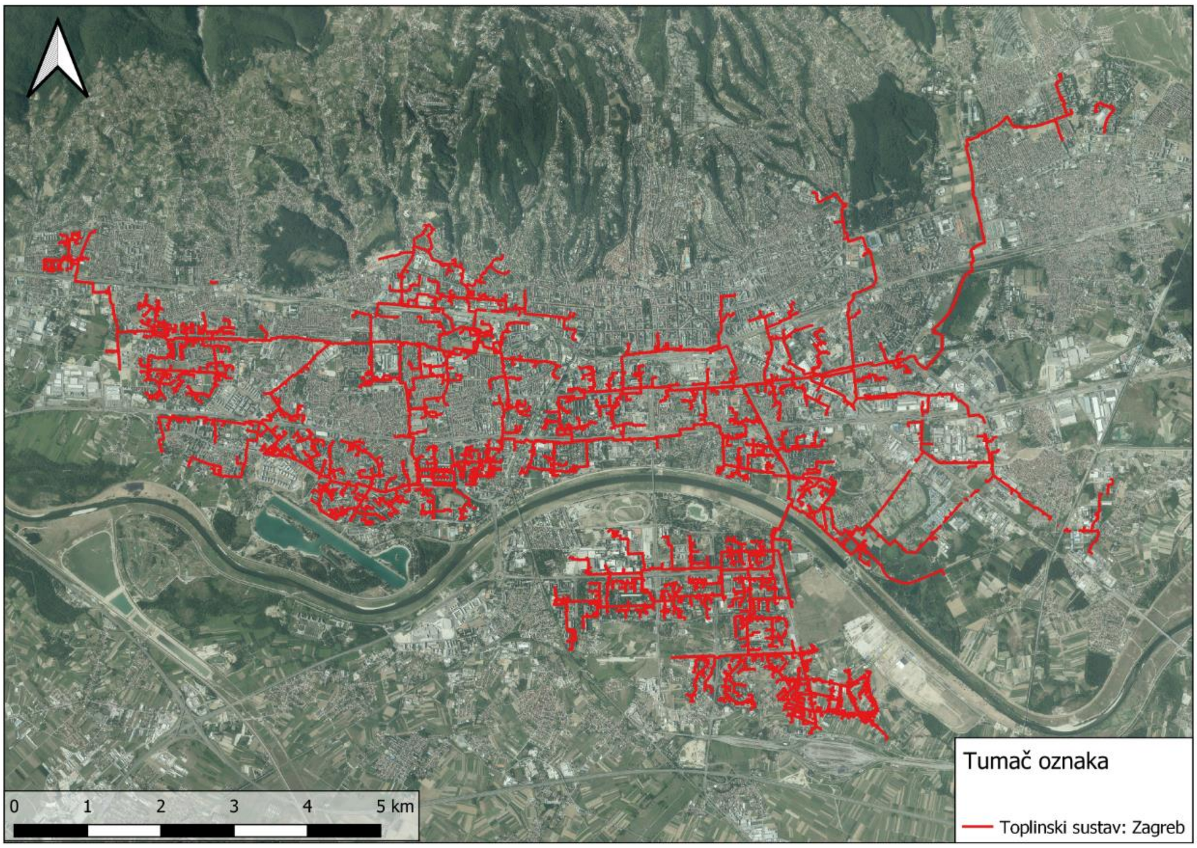


Figure I.70: Thermal system representation– Zagreb

3.3 MAP OF CROATIA – SUPPLY POINTS OF INDUSTRIAL FACILITIES GENERATING WASTE HEAT

This chapter provides a spatial representation of the existing supply points of industrial installations generating waste heat. The available average power and values of waste heat available from industrial installations are provided. Data obtained was based on the data analysed in Chapter 2.2.4.

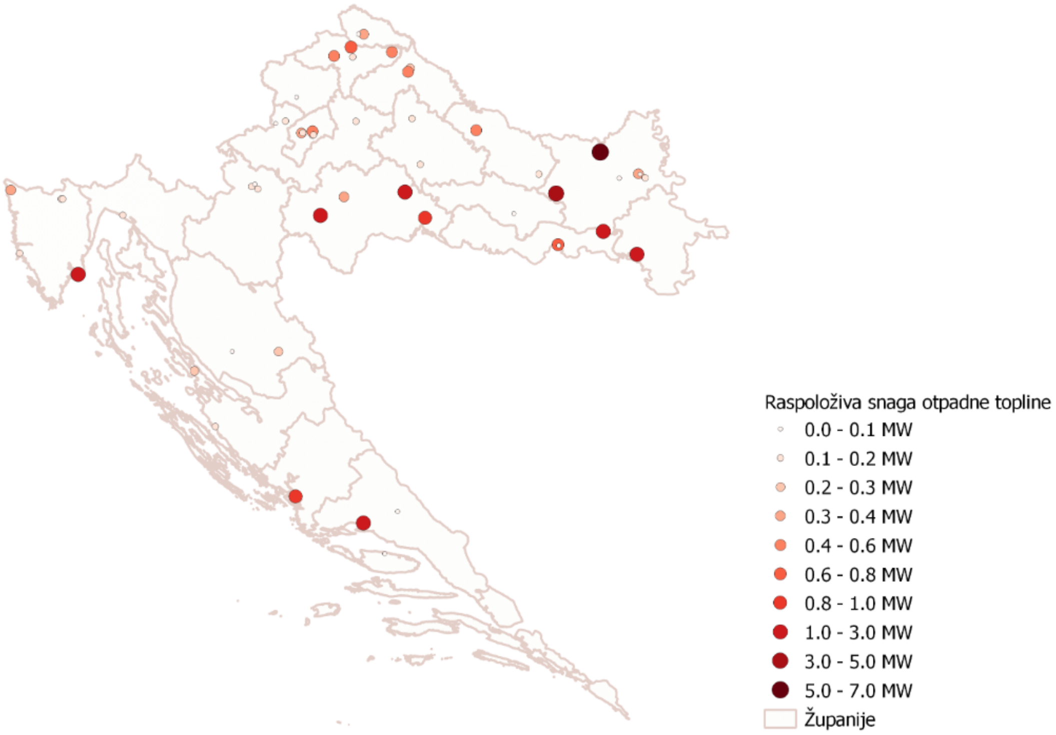


Figure I.71: Available waste heat power of industrial installations in MW

CROATIAN	ENGLISH
Raspoloživa snaga otpadne topline	Available waste heat power
Županije	Counties

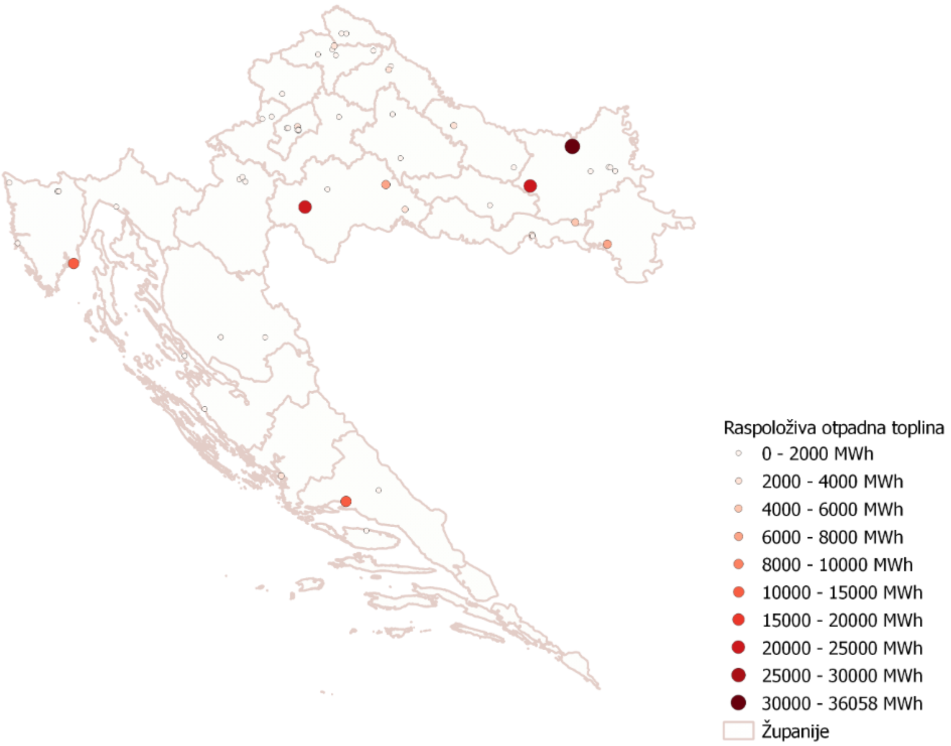


Figure I.72: Waste thermal energy available from industrial installations, in MWh

CROATIAN	ENGLISH
Raspoloživa otpadna toplina	Available waste heat
Županije	Counties

3.4 MAP OF CROATIA – GEOTHERMAL SPRINGS

This chapter presents the existing exploitation and exploration areas of geothermal energy sources (a detailed description is provided in Chapter 2.3).

3.4.1 EXISTING EXPLOITATION SOURCES OF GEOTHERMAL ENERGY

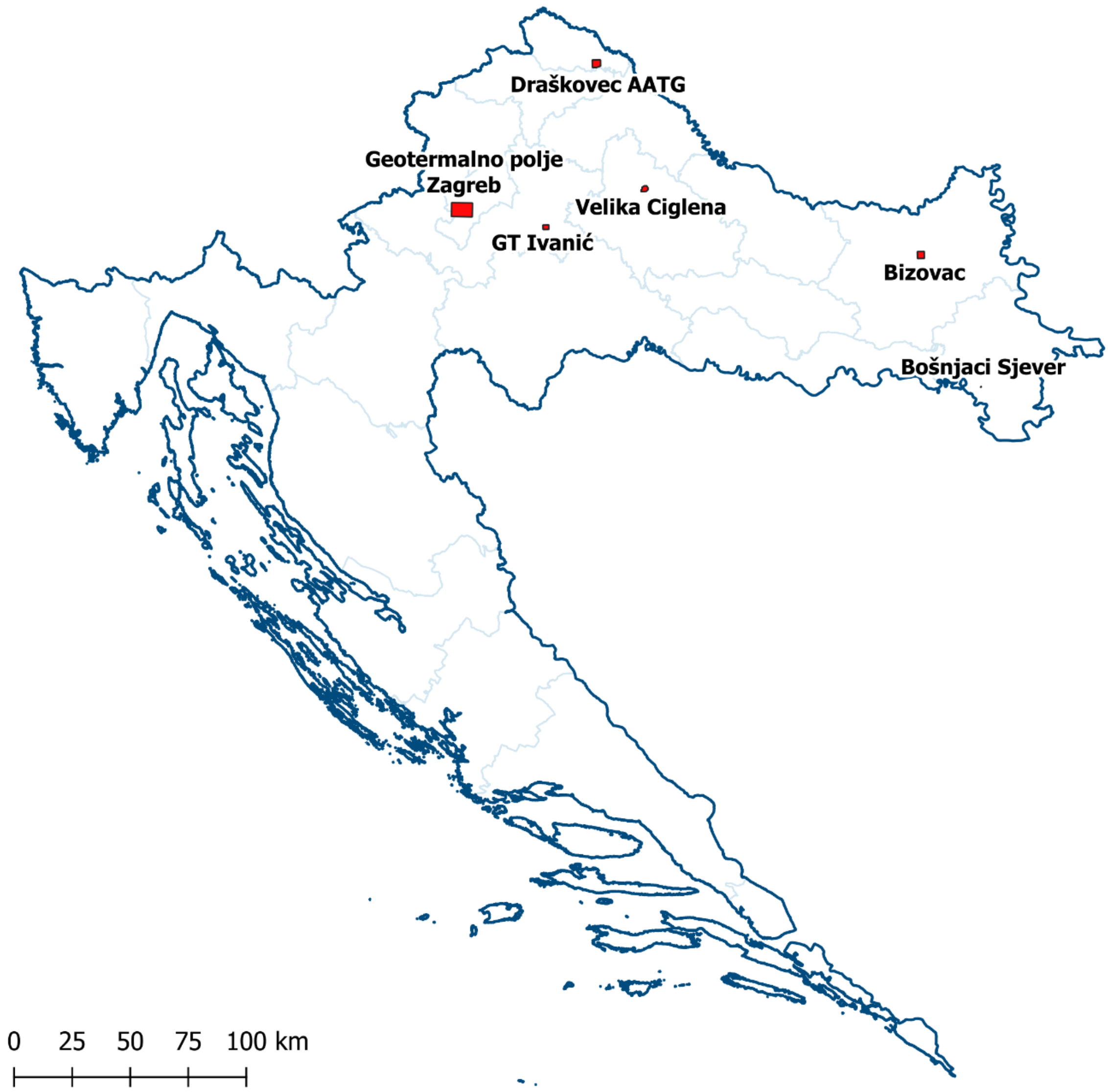


Figure I.73: Existing exploitation sources of geothermal energy

3.4.2 EXPLORATION AREAS FOR SOURCES OF GEOTHERMAL ENERGY

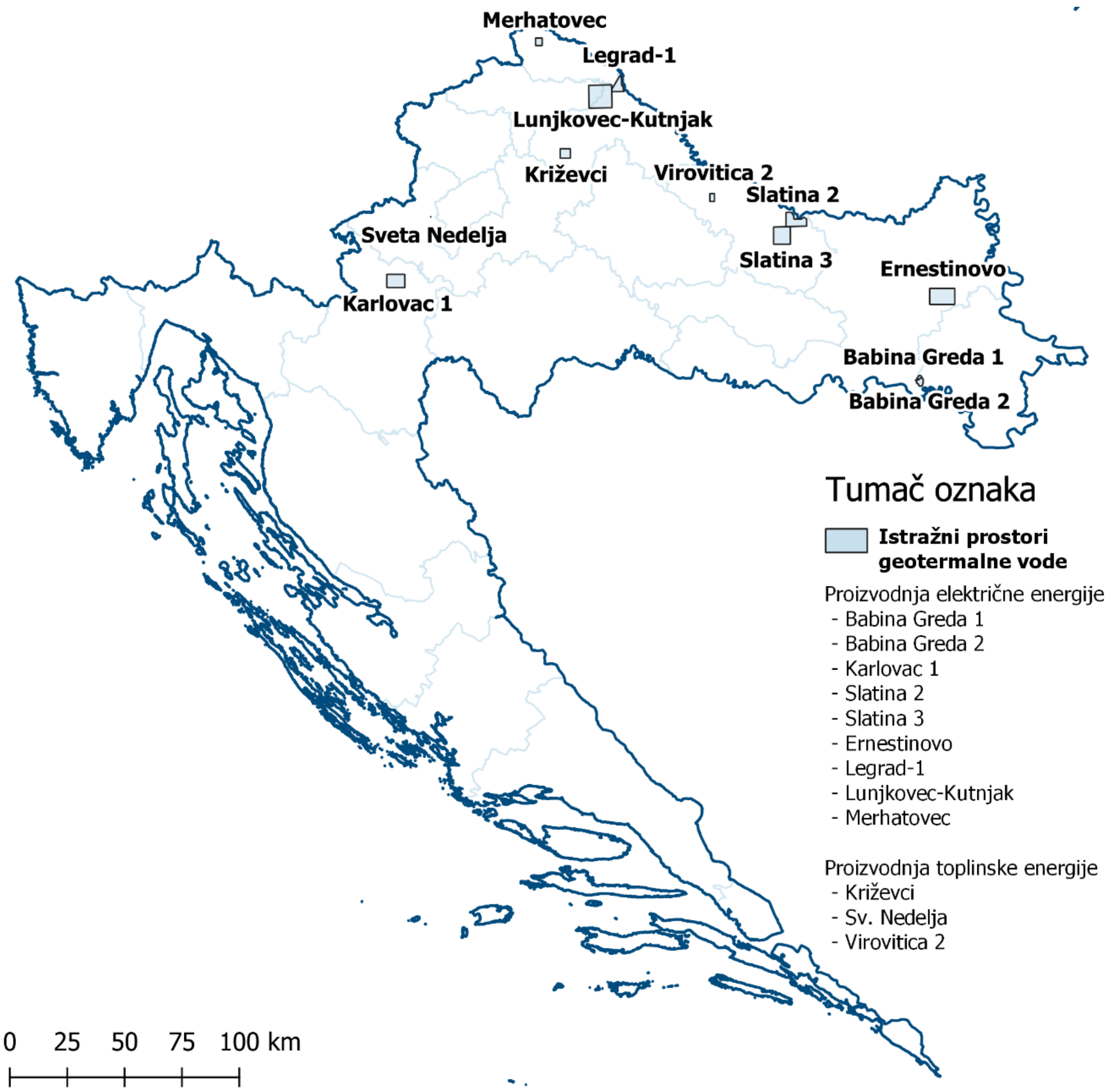


Figure I.74: Exploration areas for sources of geothermal energy

CROATIAN	ENGLISH
Tumač oznaka	Key
Istražni prostori geotermalne vode	Exploration areas for geothermal water
Proizvodnja električne energije	Electricity generation
Proizvodnja toplinske energije	Heat production

4 FORECAST OF DEVELOPMENTS IN ANNUAL USEFUL [ENERGY] DELIVERED AND NEEDED FOR HEATING/COOLING IN THE NEXT 10 AND 30 YEARS

Given that trends in the building stock and, consequently, the energy consumption in those buildings, are predominantly influenced by changes in population size, projections of demographic trends in Croatia are analysed first in this chapter. Next, projections of developments in the residential and non-residential building stock are analysed and presented by county for the period until 2050, along with a forecast of the developments in useful energy delivered and needed for heating and cooling. The method used to obtain these projections is described in more detail below.

4.1 PROJECTIONS OF DEMOGRAPHIC TRENDS

The projection of Croatia's demographic trends was taken from the analyses conducted by the Zagreb Institute of Economics [17]. The population projections were made using the cohort component method according to Rowland's methodology for an open population, by analysing three variants (detailed in the Chapter *METHODOLOGICAL APPROACH AND INPUT DATA USED IN PREPARING THE COMPREHENSIVE ANALYSIS*).

The projection of population size was made at the level of municipalities, cities or towns, and City of Zagreb districts, with Variant 2 used in all further analyses included in the Comprehensive Assessment. Therefore, the table below shows the developments in population size until 2050 only for this specific variant, with the projections provided at county level for the sake of simplicity.

Table I.86: Projection of Croatia's population size until 2030 by county – Variant 2

	County name	Year						
		2021	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
1	Zagreb County	301 485	294 420	288 153	280 833	272 476	263 550	254 346
2	Krapina-Zagorje	124 885	121 906	118 694	115 008	110 869	106 492	102 050
3	Sisak-Moslavina	140 644	131 681	126 556	121 300	115 983	110 926	106 371
4	Karlovac	111 126	105 024	100 737	96 419	91 995	87 610	83 468
5	Varaždin	165 301	160 806	156 886	152 413	147 349	141 874	136 250
6	Koprivnica-Križevci	107 513	104 563	102 234	99 591	96 669	93 684	90 806
7	Bjelovar-Bilogora	105 844	101 596	98 899	95 939	92 772	89 661	86 824
8	Primorje-Gorski Kotar	270 427	258 409	247 278	235 056	222 760	211 028	199 906
9	Lika-Senj	42 061	39 274	37 525	35 860	34 249	32 733	31 359
10	Virovitica-Podravina	74 264	71 329	69 563	67 508	65 194	62 823	60 603
11	Požega-Slavonia	65 476	62 408	61 045	59 474	57 689	55 937	54 389
12	Slavonski Brod-Posavina	136 989	131 624	129 099	126 156	122 728	119 171	115 895
13	Zadar	160 414	157 124	153 839	150 147	146 366	142 650	139 054
14	Osijek-Baranja	273 372	263 219	256 123	248 010	238 903	229 436	220 221
15	Šibenik-Knin	92 194	87 058	83 854	80 513	77 217	74 157	71 517
16	Vukovar-Syrmia	151 197	144 107	140 982	137 458	133 476	129 366	125 552
17	Split-Dalmatia	432 598	424 042	416 913	407 800	397 414	386 224	374 980
18	Istria	197 461	191 310	184 655	177 196	169 356	161 506	153 782
19	Dubrovnik-Neretva	116 049	114 546	113 095	111 307	109 425	107 677	106 096
20	Međimurje	109 390	108 180	107 272	106 092	104 625	103 058	101 540
21	City of Zagreb	776 207	760 898	742 492	721 836	700 487	679 276	657 086
	TOTAL	**3 954 897**	**3 833 524**	**3 735 894**	**3 625 916**	**3 508 002**	**3 388 839**	**3 272 095**

4.2 PROJECTIONS OF TRENDS IN THE NATIONAL BUILDING STOCK

4.2.1 HOUSEHOLD SECTOR

Trends in the building stock are predominantly influenced by developments in population size and the expected improvement in living standards by 2050. A comparison of residential building stock data from the 2001 and the 2011 population census indicates a decline in the share of permanently occupied dwellings in the total stock, with a doubling of the floor area of temporarily and permanently vacant dwellings, and dwellings used occasionally and for other purposes. A decline in the share of permanently occupied dwellings is directly related to a decline in the number of inhabitants in the same period. Available inputs were used to model the potential condition of the residential building stock in the period until 2050. Linear regression was applied for the forecast, with a 95% probability of results falling between its upper and lower limit.

The modelling was based on trends in the total stock of permanently occupied residential buildings between 1996 and 2017. Such an approach was applied because the trend in the past eight years is not a sufficiently reliable basis for forecasting an increase in the floor area of buildings over the next 30 years. The 20-year range of inputs also includes periods of slower economic growth, return to the previous level of activity, credit expansion, recession and subsequent gradual recovery, changes in the ownership structure of the residential building stock (tenant purchase), as well as constant population outflows, thus providing a more realistic picture of long-term developments in the floor area of the building stock. Results of this analysis indicate the potential floor area of buildings to be 162 891 454 m² in 2050, ranging between 157 101 752 m² and 168 681 156 m² with a 95% probability.

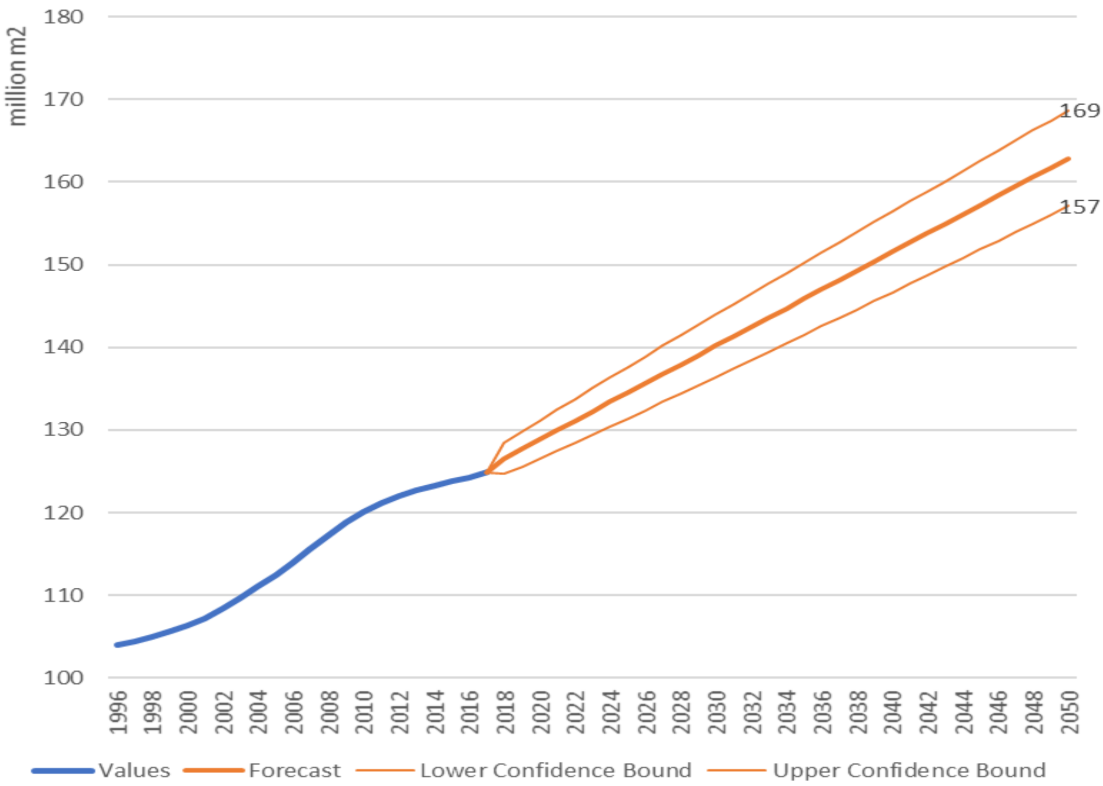


Figure I.75: Forecast of trends in the floor area of Croatia's residential building stock based on the 1996–2017 data series

The ratio of the total floor area of family houses and multi-apartment buildings is maintained at 2019 levels, due to the relatively large potential deviation in the forecast of the buildings' total floor area.

The projection of an increase in the number of residential buildings and useful floor area was made under the assumption of uniform growth of the built-up building area by county, in accordance with changes in the building stock at national level between 1996 and 2017. The total floor area of residential buildings is expected to be 138 562 785 m², with the ratio of family houses to multi-apartment buildings remaining equal to that of today.

Table I.87: Projection of trends in Croatia's residential building stock by county until 2050

HOUSEHOLD SECTOR – Overview of the national building stock									
	Year	**2030**				**2050**			
	Building type	**Family houses**		**Multi-apartment buildings**		**Family houses**		**Multi-apartment buildings**	
	County name	Total number [-]	Total useful floor area of the heated part of the building [m²]	Total number [-]	Total useful floor area of the heated part of the building [m²]	Total number [-]	Total useful floor area of the heated part of the building [m²]	Total number [-]	Total useful floor area of the heated part of the building [m²]
1	Zagreb County	77 465	8 073 748	4 777	1 879 575	76 458	7 775 805	5 200	2 021 971
2	Krapina-Zagorje	39 075	3 619 434	909	340 343	46 848	4 508 953	5 931	2 064 677
3	Sisak-Moslavina	51 918	4 638 740	2 260	981 061	36 575	3 409 901	1 715	713 989
4	Karlovac	33 562	2 813 311	2 150	1 148 242	38 119	3 321 466	2 710	1 380 503
5	Varaždin	46 100	4 397 649	840	941 957	51 284	4 821 475	1 699	893 096
6	Koprivnica-Križevci	34 506	3 390 346	780	448 370	45 579	4 494 896	2 133	1 105 405
7	Bjelovar-Bilogora	36 911	3 376 694	1 534	518 634	55 639	5 174 833	3 460	1 339 949
8	Primorje-Gorski Kotar	45 639	4 842 700	15 983	5 458 379	49 233	5 221 649	7 445	2 597 451
9	Lika-Senj	15 700	1 318 217	1 427	437 971	19 862	1 802 359	1 833	633 162
10	Virovitica-Podravina	28 029	2 497 763	479	254 039	38 225	3 656 985	12 432	5 671 172
11	Požega-Slavonia	23 442	2 196 095	983	297 624	15 460	1 413 788	621	261 473
12	Slavonski Brod-Posavina	44 204	4 119 774	2 014	811 735	42 782	4 144 567	11 833	4 158 805
13	Zadar	38 553	4 169 337	6 708	2 307 402	56 200	5 680 415	3 248	1 212 889
14	Osijek-Baranja	83 694	7 726 301	4 482	2 446 890	126 695	11 891 263	8 444	4 624 545
15	Šibenik-Knin	25 975	2 510 597	3 508	1 183 197	28 348	2 678 855	1 580	587 985
16	Vukovar-Syrmia	52 159	4 731 777	2 117	902 255	44 422	4 143 256	582	238 687
17	Split-Dalmatia	60 499	6 294 314	15 068	7 103 047	78 347	7 891 218	11 295	4 595 541
18	Istria	45 220	5 015 377	8 191	3 221 441	41 407	4 397 634	2 889	1 122 688
19	Dubrovnik-Neretva	22 230	2 383 277	3 207	1 596 298	29 212	2 992 327	3 272	1 625 195
20	Međimurje	32 335	3 501 660	466	416 719	34 214	3 669 125	511	442 257
21	City of Zagreb	82 294	8 100 374	18 150	16 149 511	93 863	9 239 117	20 701	18 419 795
	TOTAL	**919 510**	**89 717 484**	**96 034**	**48 844 692**	**1 048 774**	**102 329 888**	**109 534**	**55 711 235**

4.2.2 SERVICE SECTOR

Changes in the non-residential building stock are partially consistent with the trends in the residential sector, primarily due to increased economic activity; however, they are not directly comparable. Modelling of the non-residential building stock is based on analysed data from the IEC database (Chapter b.2.2 *Overview of the national building stock – service sector*). Future trends in the non-residential building stock were taken from the *Energy Development Strategy of the Republic of Croatia until 2030 with an Outlook to 2050*, according to which there will be 12 m² of non-residential buildings per capita in 2030. It is important to point out that, according to the *Rules governing energy audits and energy performance certification of buildings* (NN 88/17) [18], all public buildings exceeding 250 m² in total floor area must have an energy performance certificate. Therefore, service sector buildings with a floor area of less than 250 m² are not included in the analysis forecasting the national non-residential building stock within the Comprehensive Assessment. However, the table below also provides data from the *Long-term strategy for national building stock renovation by 2050* [20]. Based on a comparison of the data, it can be concluded that 10.6% of non-residential buildings are not in the IEC database, meaning that they have a floor area of less than 250 m² or do not possess an energy performance certificate.

Table I.88: Projection of trends in Croatia's non-residential building stock by county until 2050

	Data source	2021	2026	2031	2036	2041	2046	2051
Heated floor area [m²]	IEC database	38 075 119.57	39 505 678.82	41 032 437.25	42 282 819.56	43 286 151.43	44 113 337.77	44 812 072.28
Total floor area [m²]		53 305 167.40	55 035 698.68	56 794 128.76	58 145 077.68	59 136 055.53	59 869 949.62	60 496 297.58
Heated floor area [m²]	Long-term strategy for national building stock renovation by 2050	42 119 653.05	43 702 173.60	46 774 316.40	47 884 227.30	48 799 281.60	49 572 239.25	46 774 316.40
Total floor area [m²]		58 967 514.27	60 881 871.41	62 827 090.91	64 321 544.52	65 417 789.09	66 229 641.15	66 922 522.99

4.3 Projections of developments in useful energy delivered and needed for heating/cooling

Projections of the developments in the useful energy delivered and needed for heating/cooling were made for the following scenarios:

- reference or BAU (business-as-usual) scenario, which presume the development with the application of existing measures; and
- scenario with the application of additional measures according to the Integrated National Energy and Climate Plan for the Republic of Croatia (NECP) [21].

Projections of energy developments in terms of the useful energy needed and delivered energy under each scenario are presented below, including a distribution of these energy types by sector and by purpose. In addition, the distribution of the total energy delivered to household and service sectors is also presented according to energy products.

4.3.1 Projections of energy developments – BAU scenario

4.3.1.1 Delivered energy

The table below shows projections of the developments in the total annual energy delivered for heating/cooling purposes to household, service and industrial sectors in Croatia between 2019 and 2050 (presented graphically in Figure I.76:).

Table I.89: BAU scenario – projections of developments in total annual delivered energy by sector, 2019–2050

BAU scenario – projections of developments in the annual energy delivered for heating/cooling by sector [GWh/a]							
Sector	2019	2025	2030	2035	2040	2045	2050
HOUSEHOLDS	20 927.62	22 290.03	23 518.82	23 411.25	21 964.77	20 102.36	18 190.13
SERVICES	5 843.58	6 357.64	6 836.02	7 757.52	7 746.93	7 524.80	7 013.24
INDUSTRY	6 733.98	6 856.34	6 958.77	6 914.95	6 835.79	6 652.38	6 452.36
TOTAL	**33 505.18**	**35 504.02**	**37 313.61**	**38 083.72**	**36 547.50**	**34 279.54**	**31 655.73**

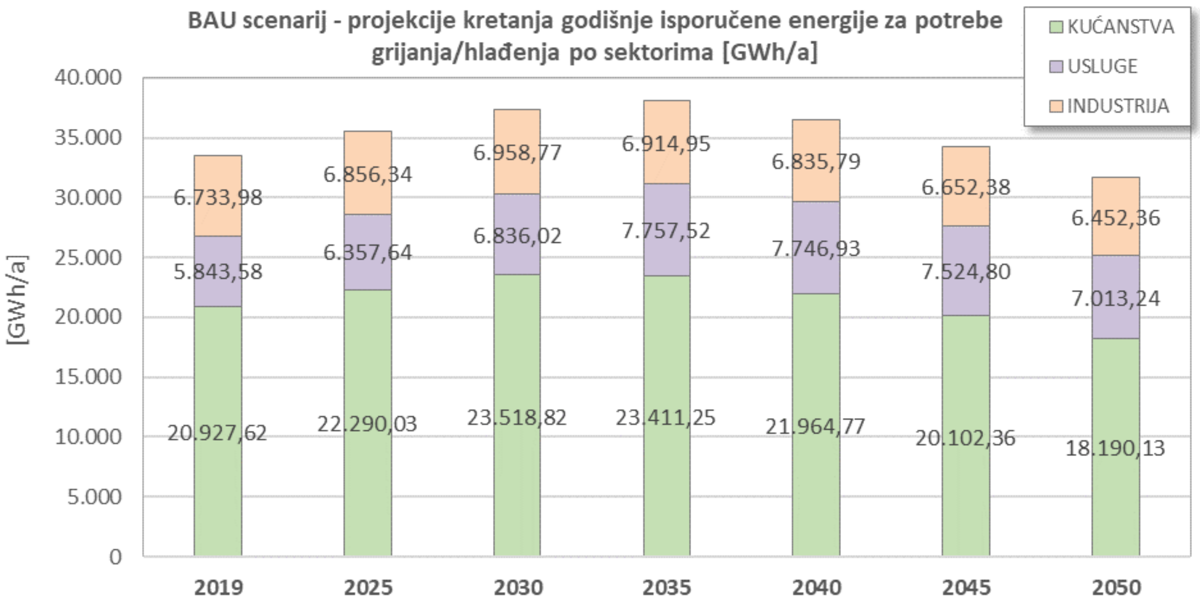


Figure I.76: BAU scenario – projections of developments in total annual delivered energy by sector, 2019–2050

CROATIAN	ENGLISH
BAU scenarij - projekcije kretanja godišnje isporučene energije za potrebe grijanja/hlađenja po sektorima [GWh/a]	BAU scenario – projections of developments in the annual energy delivered for heating/cooling by sector [GWh/a]
KUĆANSTVA	HOUSEHOLDS

USLUGE	SERVICES
INDUSTRIJA	INDUSTRY

In addition, projections of the developments in total annual energy delivered for heating/cooling purposes to Croatia's household, service and industrial sectors were analysed according to purpose, as shown inTable I.90: (presented graphically in Figure I.77:).

Table I.90: BAU scenario – projections of developments in total annual energy delivered by purpose for 2019–2050

BAU scenario – projections of developments in annual energy delivered for heating/cooling by purpose [GWh/a]							
Purpose	2019	2025	2030	2035	2040	2045	2050
Space heating and DHW preparation	25 519.93	27 272.02	28 946.35	29 712.45	28 233.12	26 134.51	23 692.80
Heating in the production process	5 772.19	5 899.07	5 967.58	5 905.90	5 788.77	5 581.21	5 358.05
Space cooling	1 942.74	2 056.66	2 114.68	2 177.39	2 235.53	2 273.42	2 315.26
Cooling in the production process	270.31	276.27	284.99	287.98	290.08	290.39	289.62
TOTAL	**33 505.18**	**35 504.02**	**37 313.61**	**38 083.72**	**36 547.50**	**34 279.54**	**31 655.73**

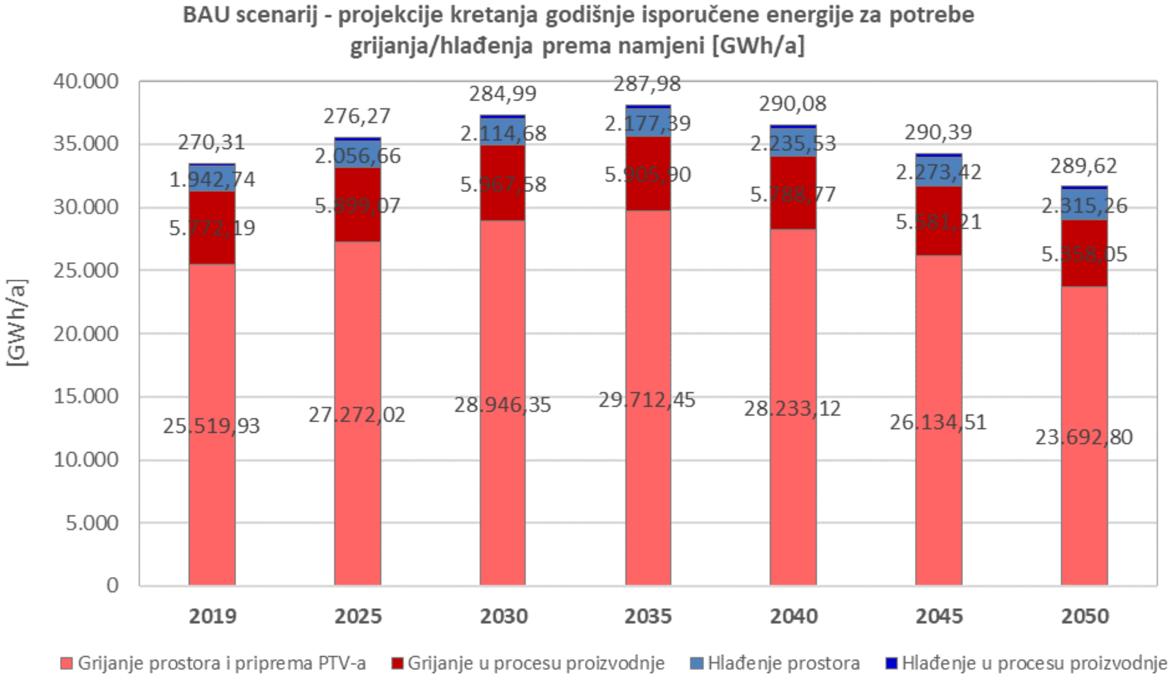


Figure I.77: BAU scenario – projections of developments in total annual energy delivered by purpose for 2019–2050

CROATIAN	ENGLISH
BAU scenarij - projekcije kretanja godišnje isporučene energije za potrebe grijanja/hlađenja prema namjeni [GWh/a]	BAU scenario – projections of developments in annual energy delivered for heating/cooling by purpose [GWh/a]
Grijanje prostora i priprema PTV-a	Space heating and DHW preparation
Grijanje u procesu proizvodnje	Heating in the production process
Hlađenje prostora	Space cooling
Hlađenje u procesu proizvodnje	Cooling in the production process

As previously mentioned, the distribution of the total energy delivered to household and service sectors was further analysed according to energy products (Table I.91:). The aggregate total energy delivered to these sectors by energy product and by purpose is presented in tabular form.

Table I.91: BAU scenario – projections of developments in total annual energy delivered to household and service sectors by purpose and energy product

BAU scenario – projections of developments in the annual energy delivered for heating/cooling by purpose and energy product [GWh/a]							
Energy product	**2019**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**

	Space heating and DHW preparation						
Traditional biomass	10 526.19	11 185.32	11 618.14	10 598.51	8 727.85	6 258.67	3 510.20
Modern biomass	801.22	821.12	1 020.01	1 518.67	1 948.64	2 636.72	3 487.70
Electricity	3 335.49	3 458.98	3 552.12	3 280.88	2 939.88	2 500.95	2 096.15
District heating	1 683.37	1 864.20	2 036.47	2 323.48	2 344.21	2 346.33	2 078.93
Solar energy	179.10	236.92	294.74	371.01	462.48	577.07	708.78
LPG	195.96	166.27	137.27	116.17	92.90	68.55	45.65
Other*	66.66	0.00	0.00	0.00	0.00	0.00	0.00
ELFO	903.00	966.07	1 028.51	666.78	379.03	137.94	0.00
Natural gas	7 035.56	7 666.34	8 193.59	9 654.18	10 016.46	10 185.71	10 240.79
Geothermal energy	45.36	155.52	255.81	350.80	445.79	511.36	576.94
RES from the environment	168.27	185.10	222.12	231.01	240.25	252.26	264.87
Total	**24 940.18**	**26 705.86**	**28 358.78**	**29 111.51**	**27 597.49**	**25 475.57**	**23 010.01**
	Space cooling						
Electricity	1 801.37	1 911.57	1 965.22	2 025.80	2 082.13	2 118.86	2 159.97
Other	29.64	30.24	30.84	31.46	32.09	32.73	33.38
TOTAL	**1 831.02**	**1 941.81**	**1 996.06**	**2 057.26**	**2 114.22**	**2 151.59**	**2 193.36**

*The IEC database contains the energy product Other – for the service sector. Since it the energy product included under this item is not known, it was excluded from further projections.

4.3.1.2 USEFUL ENERGY NEEDS

The table below shows projections of the developments in the total annual useful energy for heating/cooling purposes in household, service and industrial sectors in Croatia between 2019 and 2050 (presented graphically in Figure I.78:).

Table I.92: BAU scenario – projections of developments in total annual useful energy by sector for 2019–2050

BAU scenario – projections of developments in annual useful energy for heating/cooling by sector [GWh/a]							
Sector	2019	2025	2030	2035	2040	2045	2050
HOUSEHOLDS	16 647.46	18 116.03	19 549.02	20 054.80	19 595.94	19 001.76	18 492.84
SERVICES	9 095.45	10 004.33	10 849.17	12 123.23	12 528.33	12 644.98	12 500.47
INDUSTRY	6 623.28	6 762.78	6 935.12	6 951.42	6 939.07	6 810.17	6 679.27
TOTAL	**32 366.20**	**34 883.13**	**37 333.31**	**39 129.44**	**39 063.34**	**38 456.91**	**37 672.57**

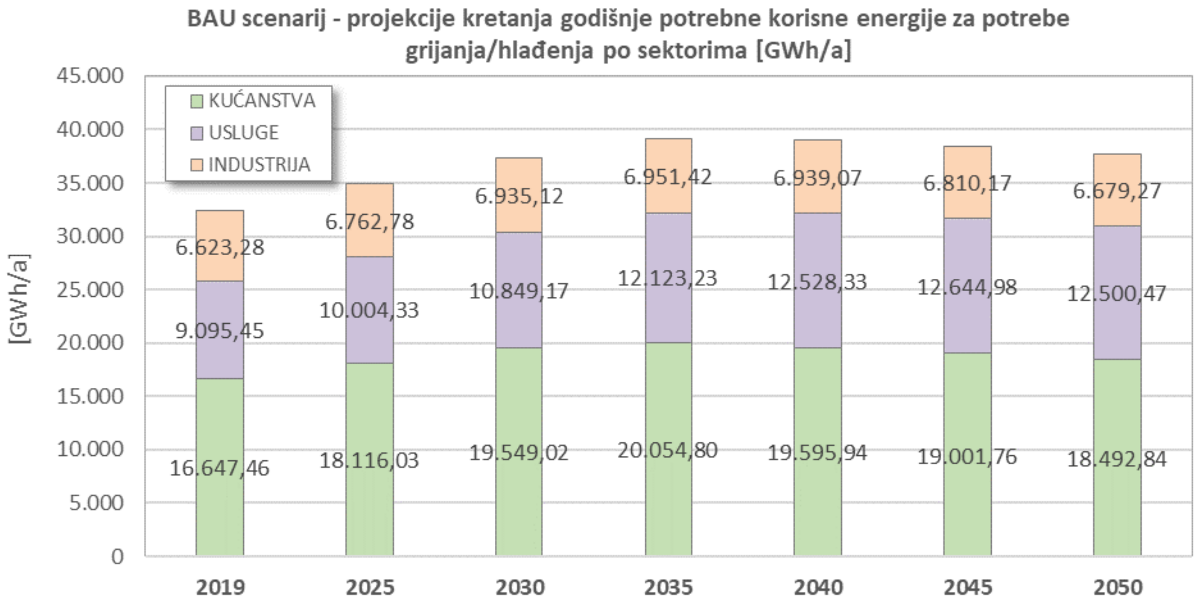


Figure I.78: BAU scenario – projections of developments in total annual useful energy by sector for 2019–2050

CROATIAN	ENGLISH
BAU scenarij - projekcije kretanja godišnje potrebne korisne energije za potrebe grijanja/hlađenja po sektorima [GWh/a]	BAU scenario – projections of developments in annual useful energy needs for heating/cooling by sector [GWh/a]
KUĆANSTVA	HOUSEHOLDS
USLUGE	SERVICES

INDUSTRIJA	INDUSTRY

In addition, projections of the developments in total annual useful energy for heating/cooling purposes in Croatia's household, service and industrial sectors were analysed according to purpose, as shown in Table I.93: (presented graphically in Figure I.79:).

Table I.93: BAU scenario – projections of developments in total annual useful energy by purpose for 2019–2050

BAU scenario – projections of developments in annual useful energy for heating/cooling by purpose [GWh/a]							
Purpose	2019	2025	2030	2035	2040	2045	2050
Space heating and DHW preparation	20 893.92	22 758.21	24 683.71	25 874.80	25 225.68	24 150.46	22 835.72
Heating in the production process	5 020.77	5 143.05	5 227.66	5 210.19	5 121.37	4 955.00	4 789.00
Space cooling	5 687.42	6 198.16	6 584.38	7 197.01	7 834.73	8 467.24	9 164.23
Cooling in the production process	764.09	783.71	837.56	847.44	881.57	884.20	883.62
TOTAL	**32 366.20**	**34 883.13**	**37 333.31**	**39 129.44**	**39 063.34**	**38 456.91**	**37 672.57**

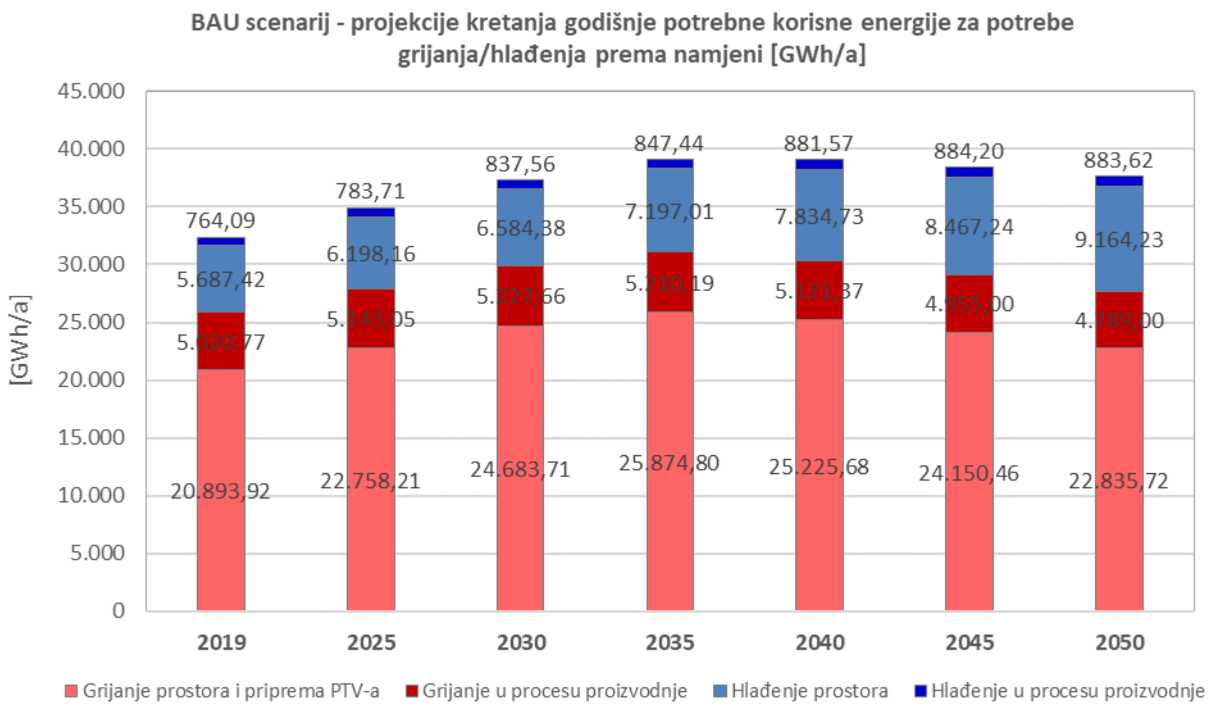


Figure I.79: BAU scenario – projections of developments in total annual useful energy by purpose for 2019–2050

CROATIAN	ENGLISH
BAU scenarij - projekcije kretanja godišnje potrebne korisne energije za potrebe grijanja/hlađenja prema namjeni [GWh/a]	BAU scenario – projections of developments in annual useful energy needs for heating/cooling by purpose [GWh/a]
Grijanje prostora i priprema PTV-a	Space heating and DHW preparation
Grijanje u procesu proizvodnje	Heating in the production process
Hlađenje prostora	Space cooling
Hlađenje u procesu proizvodnje	Cooling in the production process

4.3.2 PROJECTIONS OF ENERGY DEVELOPMENTS – SCENARIO WITH INTEGRATED MEASURES

4.3.2.1 DELIVERED ENERGY

The table below shows projections of the developments in the total annual energy delivered for heating/cooling purposes to household, service and industrial sectors in Croatia between 2019 and 2050 (presented graphically in Figure I.80:).

Table I.94: Scenario with integrated measures – projections of developments in the total annual energy delivered by sector, 2019–2030

Scenario with integrated measures – projections of developments in the annual energy delivered for heating/cooling by sector [GWh/a]			
Sector	2019	2030	2050
HOUSEHOLDS	20 927.63	21 599.44	13 675.18
SERVICES	5 843.57	5 958.06	4 826.27
INDUSTRY	6 733.98	6 794.87	5 902.01
TOTAL	**33 505.17**	**34 352.38**	**24 403.46**

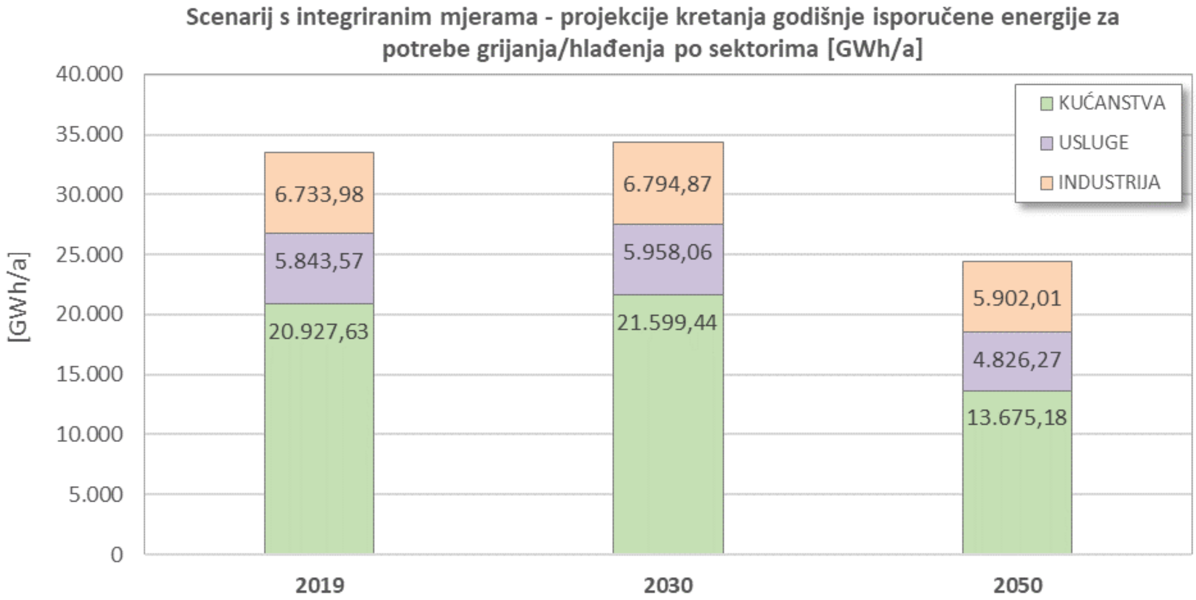


Figure I.80: Scenario with integrated measures – projections of developments in total annual energy delivered by sector for 2019–2050

CROATIAN	ENGLISH
Scenarij s integriranim mjerama - projekcije kretanja godišnje isporučene energije za potrebe grijanja/hlađenja po sektorima [GWh/a]	Scenario with integrated measures – projections of developments in the annual energy delivered for heating/cooling by sector [GWh/a]
KUĆANSTVA	HOUSEHOLDS
USLUGE	SERVICES
INDUSTRIJA	INDUSTRY

In addition, projections of the developments in total annual energy delivered for heating/cooling purposes to Croatia's household, service and industrial sectors were analysed according to purpose, as shown inTable I.95: (presented graphically in Figure I.81:).

Table I.95: Scenario with integrated measures – projections of developments in the total annual energy delivered by purpose, 2019–2050

Scenario with integrated measures – projections of developments in the annual energy delivered for heating/cooling by sector [GWh/a]			
Purpose	2019	2030	2050
Space heating and DHW preparation	25 519.92	26 442.28	17 134.76

Heating in the production process	5 772.19	5 876.44	5 002.83
Space cooling	1 942.74	1 778.99	2 026.79
Cooling in the production process	270.31	254.67	239.08
TOTAL	**33 505.17**	**34 352.38**	**24 403.46**

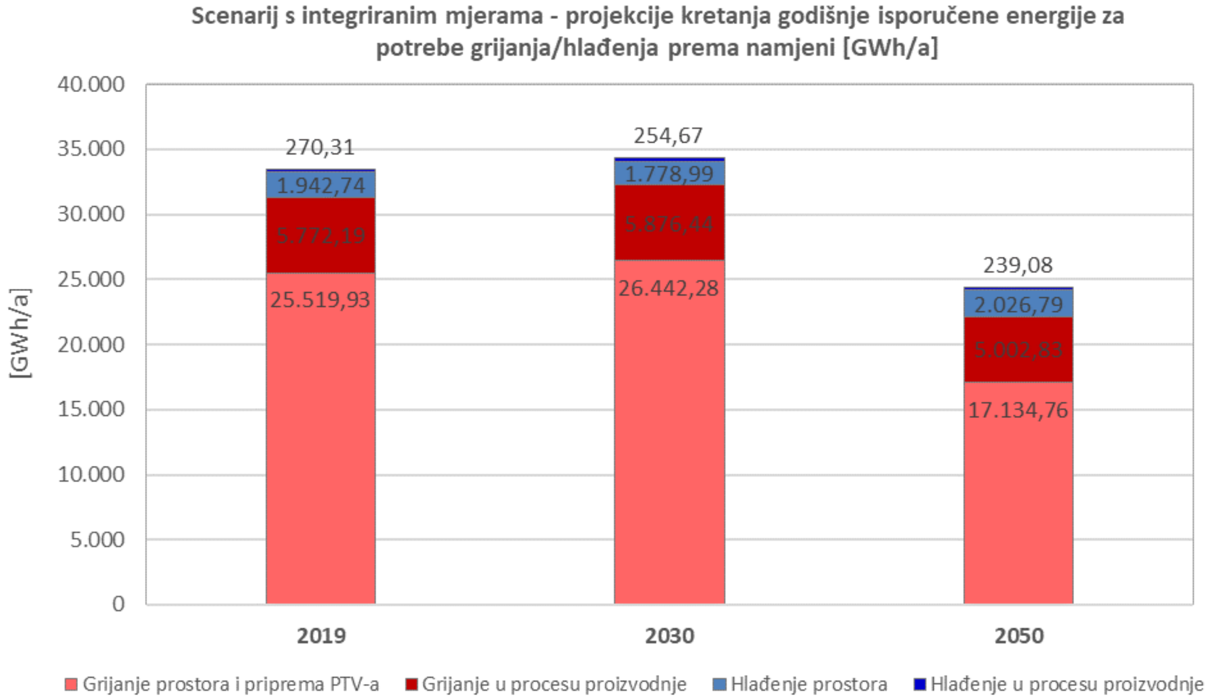


Figure I.81: Scenario with integrated measures – projections of developments in the total annual energy delivered by purpose, 2019–2050

CROATIAN	ENGLISH
Scenarij s integriranim mjerama - projekcije kretanja godišnje isporučene energije za potrebe grijanja/hlađenja prema namjeni [GWh/a]	Scenario with integrated measures – projections of developments in the annual energy delivered for heating/cooling by purpose [GWh/a]
Grijanje prostora i priprema PTV-a	Space heating and DHW preparation
Grijanje u procesu proizvodnje	Heating in the production process
Hlađenje prostora	Space cooling
Hlađenje u procesu proizvodnje	Cooling in the production process

As previously mentioned, the distribution of the total energy delivered to household and service sectors was further analysed according to energy products (Table I.96:). The aggregate total energy delivered to these sectors by energy product and by purpose is presented in tabular form.

Table I.96: Scenario with integrated measures – projections of developments in the total annual energy delivered to household and service sectors by purpose and energy product

Scenario with integrated measures – projections of developments in the annual energy delivered for heating/cooling by purpose and energy product [GWh/a]			
Energy product	2019	2030	2050
	Space heating and DHW preparation		
Traditional biomass	10 526.19	10 530.27	162.16
Modern biomass	801.22	1 808.01	6 153.04
Electricity	3 335.50	3 347.81	4 538.89
District heating	1 683.37	1 607.22	1 712.53
Solar energy	179.10	910.91	727.34
LPG	195.96	70.77	28.09
Other*	70.74	0.00	0.00
ELFO	903.00	155.21	0.00
Natural gas	7 035.56	6 375.88	4 719.05
Geothermal energy	45.36	415.17	318.45

Hydrogen	0.00	95.20	191.07
Biomethane	0.00	210.86	988.28
RES from the environment	168.27	491.83	663.96
Total	**24 944.27**	**26 019.13**	**20 202.87**
		Space cooling	
Electricity	1 801.37	1 633.43	1 885.32
Other	29.64	36.59	38.42
Total	**1 831.02**	**1 670.02**	**1 923.74**

*The IEC database contains the energy product Other – for the service sector. Since it the energy product included under this item is not known, it was excluded from further projections.

4.3.2.2 USEFUL ENERGY NEEDS

The table below shows projections of the developments in the total annual useful energy for heating/cooling purposes in household, service and industrial sectors in Croatia between 2019 and 2050 (presented graphically in Figure I.82:).

Table I.97: Scenario with integrated measures – projections of developments in total annual useful energy by sector for 2019–2050

Scenario with integrated measures – projections of developments in annual useful energy for heating/cooling purposes by sector [GWh/a]			
Sector	2019	2030	2050
HOUSEHOLDS	16 647.46	18 077.68	14 611.11
SERVICES	9 095.45	9 353.02	9 884.01
INDUSTRY	6 623.28	6 752.12	6 157.98
TOTAL	**32 366.20**	**34 182.82**	**30 653.10**

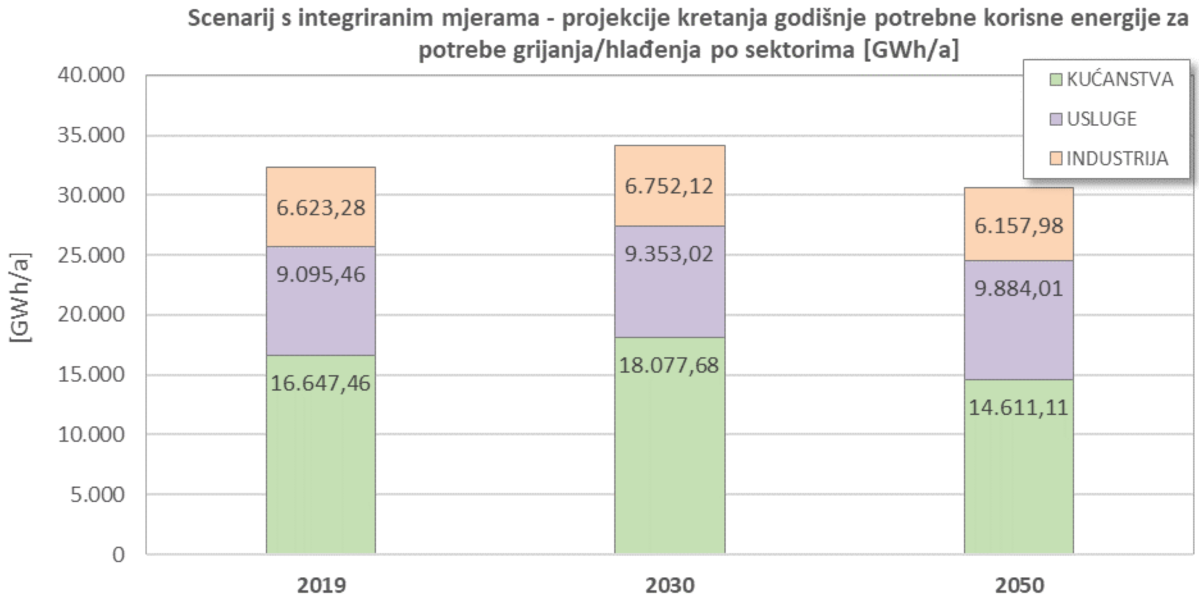


Figure I.82: Scenario with integrated measures – projections of developments in total annual useful energy by sector for 2019–2050

CROATIAN	ENGLISH
Scenarij s integriranim mjerama - projekcije kretanja godišnje potrebne korisne energije za potrebe grijanja/hlađenja po sektorima [GWh/a]	Scenario with integrated measures – projections of developments in annual useful energy needs for heating/cooling by sector [GWh/a]
KUĆANSTVA	HOUSEHOLDS
USLUGE	SERVICES
INDUSTRIJA	INDUSTRY

In addition, projections of the developments in total annual useful energy for heating/cooling purposes in Croatia's household, service and industrial sectors were analysed according to purpose, as shown in Table I.98: (presented graphically in Figure I.83:).

Table I.98: Scenario with integrated measures – projections of developments in total annual useful energy by purpose for 2019–2050

Scenario with integrated measures – projections of developments in annual useful energy for heating/cooling by purpose [GWh/a]			
Purpose	2019	2030	2050
Space heating and DHW preparation	20 893.92	22 756.13	17 434.35
Heating in the production process	5 020.77	5 157.61	4 487.26
Space cooling	5 687.42	5 518.27	7 996.53
Cooling in the production process	764.09	750.81	734.96
TOTAL	**32 366.20**	**34 182.82**	**30 653.10**

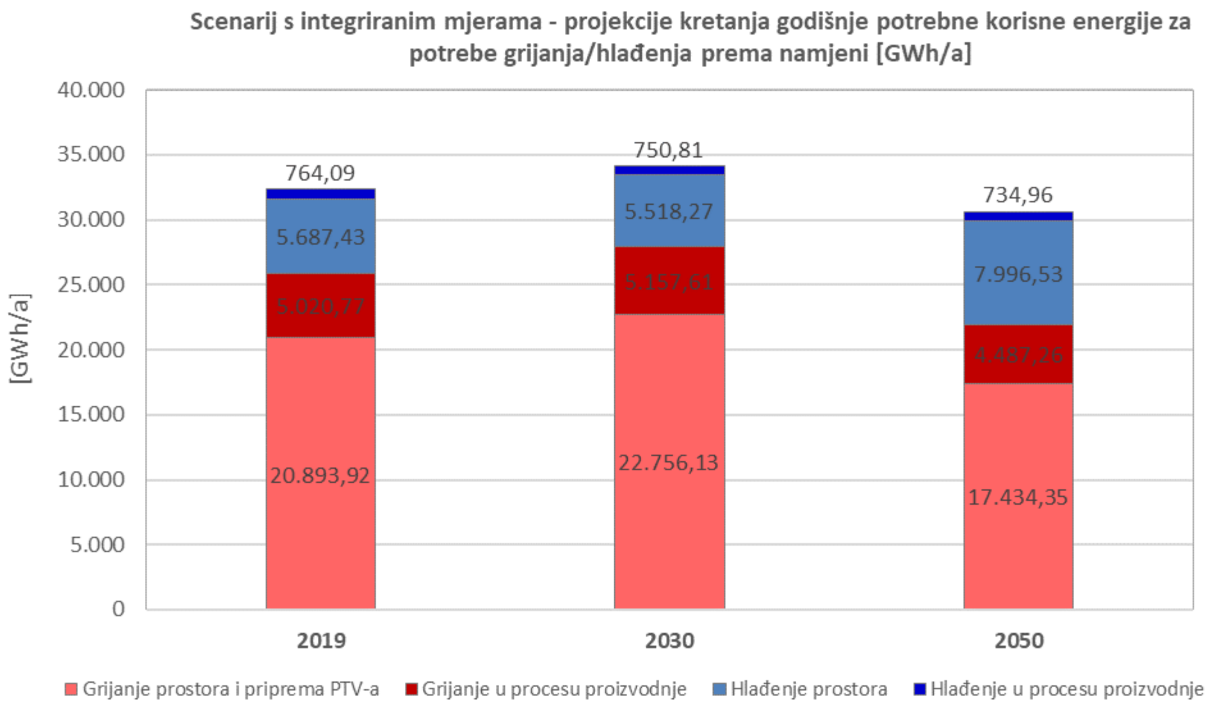


Figure I.83: Scenario with integrated measures – projections of developments in total annual useful energy by purpose for 2019–2050

CROATIAN	ENGLISH
Scenarij s integriranim mjerama - projekcije kretanja godišnje potrebne korisne energije za potrebe grijanja/hlađenja prema namjeni [GWh/a]	Scenario with integrated measures – projections of developments in annual useful energy needs for heating/cooling by purpose [GWh/a]
Grijanje prostora i priprema PTV-a	Space heating and DHW preparation
Grijanje u procesu proizvodnje	Heating in the production process
Hlađenje prostora	Space cooling
Hlađenje u procesu proizvodnje	Cooling in the production process

DIO II. OBJECTIVES, STRATEGIES AND POLICY MEASURES

5 CROATIA'S PLANNED CONTRIBUTION WITH ITS NATIONAL OBJECTIVES, TARGETS AND CONTRIBUTIONS TO THE FIVE DIMENSIONS OF THE ENERGY UNION

Croatia has already adopted its national objectives and targets relating to the five dimensions of the Energy Union in the Integrated National Energy and Climate Plan (NECP) for 2021–2030[20], the latest version of which was adopted in December 2020. In June 2021, amendments to the NECP were prepared in order to increase the target for the share of RES in heating and cooling for 2030. Information provided below concerns the role of heating and cooling systems in achieving the objectives and targets defined in the NECP for individual dimensions.

5.1 Decarbonisation

Under the decarbonisation dimension, objectives and targets are set for reducing greenhouse gas emissions and increasing RES share in gross final energy consumption by 2030.

The targets for reducing greenhouse gas emissions by 2030 are as follows:

- in the ETS sector: by at least 43% compared to the 2005 level;
- for non-ETS sectors: by at least 7% compared to the 2005 level.

As greater utilisation of RES is crucial to achieving decarbonisation targets, the following RES targets have been set for 2030:

- RES share of 39.4% in gross final energy consumption,
- RES share of 47.8% in gross final energy consumption for heating and cooling.

The indicative trajectory of increase in the share of RES for heating and cooling is shown in Figure II.1:, and the share of individual technologies in Figure II.2:.

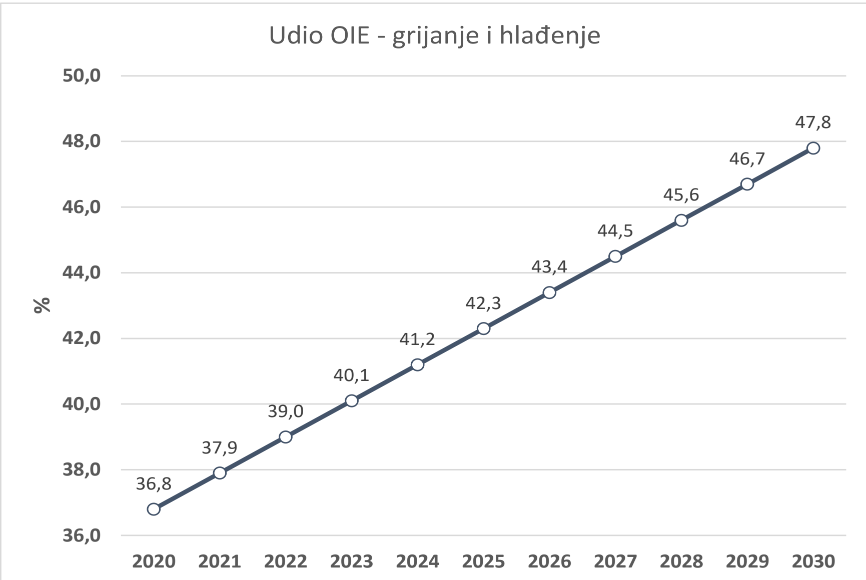


Figure II.1: Indicative trajectories of RES share in heating and cooling (Source: NECP)

[20] The NECP was initially adopted in December 2019, while its amendments were adopted in December 2020. The NECP version in force is available at: https://vlada.gov.hr/sjednice/33-sjednica-vlade-republike-hrvatske-31158/31158 (accessed on 18 February 2021).

CROATIAN	ENGLISH
Udio OIE - grijanje i hlađenje	RES share – heating and cooling

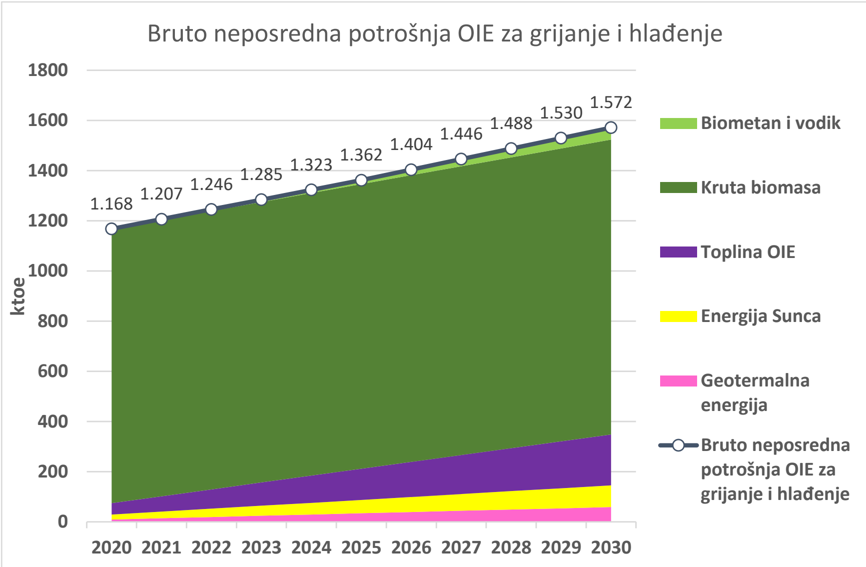


Figure II.2: Share of individual RES in target gross final energy consumption (Source: NECP)

CROATIAN	ENGLISH
Bruto neposredna potrošnja OIE za grijanje i hlađenje	Gross final RES consumption for heating and cooling
Biometan i vodik	Biomethane and hydrogen
Kruta biomasa	Solid biomass
Toplina OIE	Heat from RES
Energija Sunca	Solar energy
Geotermalna energija	Geothermal energy
Bruto neposredna potrošnja OIE za grijanje i hlađenje	Gross final RES consumption for heating and cooling
ktoe	ktoe

It is evident that biomass contributes most to the share of RES in gross final energy consumption, although its share in the gross final consumption of RES for heating and cooling is projected to decrease from 93.6% in 2020 to 74.8% in 2030. In 2030, the use of solar energy will have increased almost 4.5 times and the use of geothermal energy 6 times compared to 2020, with the use of heat generated from RES in district systems increasing around 4.5 times, as shown in Table II.1..

Table II.1. Estimated contribution of RES technologies in heating and cooling (Source: NECP)

ktoe	**2020**	2021	2022	2023	2024	2025	2026	2027	2028	2029	**2030**
Gross final RES consumption for heating and cooling	**1 167.8**	**1 206.7**	**1 245.6**	**1 284.5**	**1 323.4**	**1 362.3**	**1 404.2**	**1 446.0**	**1 487.9**	**1 529.7**	**1 571.6**
Solar energy	**19.5**	26.3	33.1	39.9	46.7	53.5	60.1	66.8	73.4	80.0	**86.6**
Solid biomass	**1 093.5**	1 101.7	1 109.8	1 118.0	1 126.1	1 134.3	1 142.4	1 150.6	1 158.7	1 166.9	**1 175.0**
Geothermal energy	**9.4**	14.4	19.3	24.3	29.3	34.3	39.2	44.2	49.2	54.2	**59.1**
Heat from RES	**45.5**	61.2	77.0	92.8	108.5	124.3	140.0	155.7	171.5	187.2	**202.9**
Biomethane and hydrogen	**0.0**	3.2	6.4	9.6	12.8	16.0	22.4	28.7	35.1	41.5	**47.9**

5.2 Energy efficiency

The NECP expresses energy efficiency targets as absolute amounts of primary and final energy consumption for 2030, which must not exceed 8.23 Mtoe and 6.85 Mtoe, respectively. The NECP does not set specific targets for heating and cooling. Nevertheless, the importance of heating and cooling can be seen from the NECP determinants described below.

The structure of final energy consumption in 2030 is dominated by the building segment (households and services) at 47.43%, followed by transport at 32.29%, industry at 17.28% and agriculture at 3%. In view of the share of heating requirements in the total energy needs of a building, it is evident that measures aimed at both reducing the heating needs of buildings and the use of heating and cooling technologies of higher energy efficiency will play a major role in achieving national energy efficiency targets. It is extremely important to achieve synergy with the objectives of increasing the share of RES, that is, enable both the use of RES-based heating and cooling technologies and the electrification of heating and cooling systems, with an increase in RES share in electricity generation.

In addition, the NECP has set a target of cumulative energy savings of 2 993.7 ktoe (125.3 PJ) for 2021–2030, in accordance with Article 7 of Directive (EU) 2018/2002 amending Directive 2012/27/EU on energy efficiency. The target is not specified by sector, but it is expected to be achieved through a combination of the energy efficiency obligation scheme for energy suppliers and alternative policy measures, which include predominantly programmes for the energy renovation of buildings (more information on these programmes is provided in Chapter 6).

The importance of buildings is also clearly set out in the Long-term strategy for national building stock renovation by 2050, which was adopted in December 2020. The Long-term strategy envisages a transformation of the existing building stock into a highly energy-efficient and decarbonised building stock by 2050. The current renovation rate (2014–2019) of 0.7% of the total floor area of the building stock, or 1.35 million m^2 per year is foreseen to increase gradually. The target renovation rate will rise from 1% in 2021 and 2022, 1.5% in 2023 and 2024, 2.0% in 2025 and 2026, 2.5% in 2027 and 2028, and 3% in 2029 and 2030 to 3.5% between 2031 and 2040, and 4% between 2041 and 2050. The energy renovation of buildings will be predominantly based on deep energy renovation, comprising energy efficiency measures for the envelope and technical systems and reducing the annual consumption for heating ($Q_{H,nd}$) and primary energy (E_{prim}) [kWh/(m^2a)] by at least 50% compared to pre-renovation energy consumption, which clearly shows the importance of buildings, as well as heating and cooling in buildings, in achieving the objectives of reducing energy consumption.

5.3 ENERGY SECURITY

The most important objective under the energy security dimension is to ensure a continuous, secure and high-quality supply of all energy products. Energy efficiency improvements and the use of renewable energy sources are the main mechanisms for achieving this objective, primarily by reducing the need to import fossil fuels.

According to the energy transition objective, the total energy consumption will decline by about 16% in 2050 compared to 2017. Own supply will increase to 55.2% in 2030 before decreasing to 51.7% in 2050, mostly due to the depletion of own oil and natural gas resources.

Heating is of special importance for security of supply, given the developed gas network in the continental part of Croatia and the fact that natural gas is the dominant energy product in existing district heating systems. The NECP envisages measures to enable the injection of hydrogen and biomethane into the natural gas transmission/distribution network. The transition to heating technologies using RES or heating technologies using electricity generated from RES will play an important role in reducing dependence on natural gas imports. On the other hand, it is also necessary to ensure the integration of RES into existing DHSs, as well as their further development, which is why the NECP envisages the introduction of zoning in the district heating area, as has already been done in other EU Member States.

5.4 INTERNAL ENERGY MARKET

The internal market dimension addresses issues of electricity interconnection, electricity and gas transmission, integration of the electricity market and energy poverty.

Electricity interconnection in Croatia is already at a high level (above the target of 15% at EU level), which is very important for the further development of the electricity market, as well as for the integration of RES. Increasing the share of RES in electricity generation is also crucial for the decarbonisation of heating and cooling systems, since it enables the electrification of such systems by using efficient technologies (e.g. heat pumps) based on electricity generated from RES.

When it comes to natural gas, the NECP recognises the importance of building new storage facilities as well as facilities for the reception, storage and regasification or decompression of liquefied natural gas (LNG) and compressed natural gas (CNG), and the integration of biomethane and hydrogen into the gas system, which is also important for the decarbonisation of heating and cooling systems.

The NECP envisages the development of a comprehensive Programme to combat energy poverty for 2021–2030, which will provide for energy consulting for all energy-poor citizens in Croatia, establish a measuring and monitoring system for indicators describing energy poverty at national level and a system to increase energy efficiency at the level of energy-poor households and households at risk of energy poverty. The comprehensive renovation of buildings of energy-poor citizens is considered a key measure for alleviating energy poverty, which will reduce the energy needs of those households (through energy efficiency measures). Their reduced energy needs, primarily in relation to heating, will be met by means of energy-efficient technologies based on RES. This will allow for a fair energy transition and ensure an accessible energy supply even for the most vulnerable groups of citizens.

5.5 RESEARCH, INNOVATION AND COMPETITIVENESS

This dimension of the NECP addresses the funding targets for public and private research and innovation relating to the Energy Union, objectives related to the promotion of clean and low-carbon technologies, and the improvement of national competitiveness. The NECP does not set quantitative targets related to the Energy Union in any of these areas. However, it envisages the establishment of a committee for cross-sectoral coordination of policies and measures for climate change mitigation and adaptation, whose task will be to identify national objectives and targets for this dimension, indicators needed for monitoring the achievement of the objectives and targets, and sources of data necessary for progress monitoring and evaluation.

It is expected that the research and development of new clean and low-carbon technologies, including heating and cooling technologies, will be largely funded by the Modernisation and the Innovation Fund, established following the revision of the ETS Directive. The programming of the use of European cohesion funds will be based on strategic objectives and key areas of intervention, defined in the National Development Strategy for the period until 2030. One of these strategic objectives is the green and digital transition, which will be achieved, inter alia, by a shift to clean energy and a decarbonisation of buildings, thus highlighting the significance of and the need for further development of efficient and low-carbon heating and cooling systems.

6 GENERAL OVERVIEW OF EXISTING POLICIES AND MEASURES

The policies and measures for achieving energy and climate objectives are defined in the NECP. An overview of key measures according to NECP dimensions, which are directly related to heating and cooling systems and have been described in detail in the NECP, is provided below.

NECP code	Title of measure
MS-5	CO_2 emissions tax for non-EU ETS stationary sources
GO-5	Use of biogas for biomethane production and electricity and thermal energy generation
OIE-3	Promoting the use of RES for electricity and thermal energy generation
OIE-4	Developing a regulatory framework for RES use
OIE-5	Promoting the use of biomethane and hydrogen from RES for thermal energy generation
ENU-3	Energy renovation programme for multi-apartment buildings
ENU-4	Energy renovation programme for family houses
ENU-5	Energy renovation programme for public buildings
ENU-6	Energy renovation programme for buildings with cultural heritage status
ENU-17	Increasing the efficiency of district heating systems
ENU-19	Increasing energy efficiency and RES use in the manufacturing industries
ES-4	Development and maintenance of centralised production systems
UET-6	Programme to combat energy poverty, including the use of RES in residential buildings in assisted areas and in areas of special state concern for 2021–2025

Of the cross-sectoral measures (MS) defined in the NECP, the most significant is the taxation of CO_2 emissions for non-EU ETS stationary sources. This would allow for a penalisation of heating and cooling systems using fossil fuels, focusing the transition of heating and cooling systems on the use of RES and electrification.

In the waste management sector (GO), stronger utilisation of methane generated from the anaerobic digestion of the biodegradable fraction of waste is envisaged for electricity and thermal energy generation, as well as for the injection of biomethane into the gas grid.

In the RES segment, the NECP envisages plans to develop a system of incentives for thermal energy obtained from RES while considering the possibility of co-financing construction of the necessary infrastructure, e.g. fields of solar thermal collectors, thermal energy storage facilities, installation of heat pumps. The regulatory segment envisages a further refinement of general gas supply conditions, aimed of enabling the injection of hydrogen and biomethane into the natural gas transmission/distribution network. The establishment of financial incentives for the use of biomethane and hydrogen originating from RES for heat production is also planned.

Under the energy efficiency dimension (ENU), the key measures for encouraging improved efficiency of existing heating and cooling systems, as well as their decarbonisation, are programmes for the energy renovation of buildings (multi-apartment buildings, family houses, public buildings, buildings with cultural heritage status, and buildings in areas with specific development needs and a predominantly energy-poor population). All the programmes envisage a reduction in the heating requirements of buildings by applying thermal insulation of the external envelope, as well as the replacement of thermotechnical systems, with incentives provided only for those using RES. It is precisely these programmes that are expected to contribute most to both the reduction of energy consumption in the building sector and to the decarbonisation of the heating and cooling systems used in those buildings. Energy efficiency and RES will also be encouraged in industry, which is extremely important in order to utilise the potential for the use of waste heat.

The NECP also plans to improve the DHS by reducing losses in the distribution network (measure ENU-17), as well as through its further development, which includes RES integration and the introduction of heat storage tanks in the DHS (measure ES-4).

DIO III. ANALYSIS OF THE ECONOMIC POTENTIAL FOR EFFIECIENT HEATING AND COOLING

7 ANALYSIS OF THE ECONOMIC POTENTIAL OF DIFFERENT HEATING AND COOLING TECHNOLOGIES

After defining and forecasting the trends in useful heat delivered and needed for heating and cooling, to analyse the economic potential of different heating and cooling technologies, it is necessary to do the following in order:

- calculate the average and maximum heating/cooling loads;
- calculate the peak load for the heat source (DHS);
- define the technical criteria necessary for heat network connection (distance limits, consumption density);
- determine the technical potential according to the baseline BAU scenario by proposing measures at the local level, as well as at the level of individual systems;
- analyse costs and benefits for each proposed measure separately.

7.1 CALCULATION OF AVERAGE AND MAXIMUM HEATING AND COOLING LOAD

This chapter considers three sectors (households, services and industry) and determines the following types of load for each of them:

- average heating load for heating;
- peak (maximum) heating load for heating;
- average cooling load for space cooling;
- peak (maximum) cooling load for space cooling.

These loads, which have been calculated using the formulae proposed by the European Commission in [1], are shown separately for each sector in the table below.

NOTE: In household and service sectors, the term heating includes space heating and DHW preparation, while the term cooling refers to space cooling only. In the industrial sector, the term heating includes space heating and DHW preparation, as well as heating and DHW preparation for industrial processes, while the term cooling includes space cooling and cooling for industrial processes.

The total maximum heating load for heating in household, service and industrial sectors in Croatia is 11 501.67 MW, with the total maximum cooling load for cooling purposes in those sectors standing at 1 380.17 MW.

When it comes to heating, the largest share of the total maximum heating load is accounted for by the household sector (66.87%), followed by the service sector (19.35%) and the industrial sector (13.79%).

In terms of cooling, the service sector (71.46%) has the largest share in the maximum cooling load, followed by the industrial sector (15.10%) and the household sector (13.44%).

Table III.1: Average and maximum heating/cooling load for heating/cooling by sector:

Sector name	HEATING		COOLING	
	Average heating load Q_{AVG} [MW]	Maximum heating load Q_{MAX} [MW]	Average cooling load Q_{AVG} [MW]	Maximum cooling load Q_{MAX} [MW]
HOUSEHOLDS	3 864.01	7 690.97	113.74	185.50
SERVICES	1 105.05	2 225.02	598.29	986.29
INDUSTRY	1 165.35	1 585.68	153.14	208.38
TOTAL	**6 134.42**	**11 501.67**	**865.17**	**1 380.17**

The distribution of the total maximum heating and cooling load for heating and cooling is provided by sector and by county. It can be observed that the highest maximum heating load for heating purposes is in the City of Zagreb (1 943.64 MW), followed by the Osijek-Baranja County (1 071.50 MW). In the case of cooling, the highest maximum cooling load can also be found in the City of Zagreb (292.51 MW), followed by the Split-Dalmatia County (209.57 MW).

Table III.2: Maximum heating load for heating by sector and by county

	HEATING	Maximum heating load Q_{MAX} [MW]			
	County	HOUSEHOLDS	SERVICES	INDUSTRY	TOTAL
1	Zagreb County	640.87	153.73	54.19	**848.79**
2	Krapina-Zagorje	272.09	69.52	87.03	**428.64**
3	Sisak-Moslavina	385.72	49.11	292.07	**726.89**
4	Karlovac	316.70	60.09	23.69	**400.47**
5	Varaždin	296.25	107.63	91.59	**495.46**
6	Koprivnica-Križevci	239.75	54.34	39.29	**333.37**
7	Bjelovar-Bilogora	236.05	40.57	20.57	**297.19**
8	Primorje-Gorski Kotar	566.74	176.12	14.20	**757.07**
9	Lika-Senj	162.72	26.62	8.86	**198.20**
10	Virovitica-Podravina	167.67	26.55	43.07	**237.29**
11	Požega-Slavonia	170.57	49.13	12.20	**231.90**
12	Slavonski Brod-Posavina	309.93	60.76	31.25	**401.93**
13	Zadar	268.84	58.02	20.71	**347.56**
14	Osijek-Baranja	602.79	145.73	322.98	**1 071.50**
15	Šibenik-Knin	188.22	43.86	38.11	**270.19**
16	Vukovar-Syrmia	304.26	45.81	42.43	**392.50**
17	Split-Dalmatia	528.64	264.97	155.63	**949.24**
18	Istria	330.01	157.41	163.92	**651.34**
19	Dubrovnik-Neretva	141.55	55.15	0.96	**197.67**
20	Međimurje	236.27	59.80	24.76	**320.83**
21	City of Zagreb	1 325.35	520.12	98.18	**1 943.64**
	TOTAL	**7 690.97**	**2 225.03**	**1 585.68**	**11 501.67**

Table III.3: Maximum cooling load for cooling by sector and by county

	COOLING	Maximum cooling load Q_{MAX} [MW]			
	County	HOUSEHOLDS	SERVICES	INDUSTRY	TOTAL
1	Zagreb County	13.94	55.47	22.25	**91.66**
2	Krapina-Zagorje	4.71	16.07	3.81	**24.59**
3	Sisak-Moslavina	7.12	17.07	29.03	**53.22**
4	Karlovac	5.09	19.11	5.58	**29.78**
5	Varaždin	6.60	29.60	14.52	**50.71**
6	Koprivnica-Križevci	4.54	18.11	11.95	**34.60**
7	Bjelovar-Bilogora	5.08	11.85	4.74	**21.67**
8	Primorje-Gorski Kotar	13.68	89.11	4.83	**107.62**
9	Lika-Senj	1.82	6.94	8.54	**17.29**

	COOLING	Maximum cooling load Q_{MAX} [MW]			
	County	HOUSEHOLDS	SERVICES	INDUSTRY	TOTAL
10	Virovitica-Podravina	3.63	8.94	1.86	**14.43**
11	Požega-Slavonia	3.11	13.24	1.85	**18.19**
12	Slavonski Brod-Posavina	5.71	19.78	6.59	**32.08**
13	Zadar	7.63	40.41	3.10	**51.14**
14	Osijek-Baranja	13.50	52.20	14.89	**80.59**
15	Šibenik-Knin	5.38	27.01	1.07	**33.46**
16	Vukovar-Syrmia	8.05	18.14	5.16	**31.35**
17	Split-Dalmatia	19.35	180.28	9.94	**209.57**
18	Istria	9.78	82.29	13.33	**105.40**
19	Dubrovnik-Neretva	6.25	46.94	0.65	**53.83**
20	Međimurje	4.53	15.36	6.59	**26.48**
21	City of Zagreb	36.02	218.38	38.11	**292.51**
	TOTAL	**185.50**	**986.29**	**208.38**	**1 380.17**

7.2 DEFINING TECHNICAL CRITERIA NECESSARY FOR HEAT NETWORK CONNECTION

In order to assess the technical potential for heating and cooling efficiency, the following criteria have been applied:

- heat density – annual useful heating/cooling energy needs per unit area of the territory under observations;
- population density of the settlement / municipality / town or city in which the heat source (waste heat, geothermal springs) is located;
- average and maximum load of the settlement / municipality / town or city / city district in which the heat source is located;
- available amount and power of waste heat of an installation or a geothermal spring;
- distance of an area from its supply points (waste heat, geothermal energy) – observed only for the areas at a distance of less than 15 km.

7.3 DETERMINING THE TECHNICAL POTENTIAL

The assessment of technical potential is based purely on technical aspects with the main aim of obtaining the theoretical maximum amount of energy that could be generated through efficient heating and cooling. An economic assessment will be conducted later to determine which part of the technical potential can economically be met by the proposed efficient solutions for heating and cooling.

There is a number of solutions for efficient heating and cooling which could meet the identified useful thermal energy needs for heating and cooling. Generally speaking, a solution for heating and cooling efficiency is a combination of the following three elements:

- energy source (e.g. waste heat, biomass, electricity);
- the technology used to convert the energy source into a form of energy useful for the consumer (e.g. heat recovery, efficient boilers, heat pumps);
- distribution system delivering the useful energy to the consumer (centralised or decentralised).

Technical solutions, or measures for efficient heating and cooling proposed in the Comprehensive Assessment, are divided into measures relating to:

- decentralised (individual) systems – each consumer has their own separate source of heating and cooling energy;
- centralised systems – district heating and cooling systems distributing heat from the source to the consumer.

It is also important to mention that all the measures are based on data in the reference or BAU scenario (*Chapter: Projections of energy developments – BAU* scenario) with the tendency of achieving the energy consumption provided in the scenario with implemented measures from the Integrated National Energy and Climate Plan for the Republic of Croatia (*Chapter: Projections of energy developments – scenario with integrated* measures).

7.3.1 Proposed measures for district heating systems

Energy efficiency measures for district heating systems include:

- increasing the efficiency and expanding the distribution network of existing district heating systems in densely populated urban areas;
- modernising the generation installations of existing district heating systems;
    - using geothermal energy sources;
    - utilisation of waste heat from industrial installations;
    - energy-from-waste;
    - using renewable energy sources (biomass, solar collectors);
    - applying biomass and natural gas high-efficiency cogeneration;
    - using a heat-carrying medium in the summer to power the central absorption chiller for cooling spaces in larger non-residential buildings (e.g. hospitals, hotels, shops, etc.) which are already connected to the district heating system (this measure has not been analysed in this Comprehensive Assessment, but it remains an option).

It is extremely important to improve the DHS, especially by reducing heat losses in the existing distribution network (NECP measure ENU-17), as well as by further developing generation installation of existing district heating systems, which implies the integration of renewable energy sources and a reduction in the use of fossil fuels.

When it comes to waste heat from existing industrial installations and the heat available from geothermal energy sources, their distance from the closest existing district heating system was taken into account first, with the use of available thermal energy within the existing district heating systems envisaged for industrial installations and geothermal sources at a distance of less than 15 km from the existing district heating systems. For installations at a distance of more than 15 km from the closest DHS, the parameters stated above underwent further analysis:

- heat density – annual useful heating/cooling energy needs per unit area of the territory under observations;
- population density of the settlement / municipality / town or city in which the heat source (waste heat, geothermal springs) is located;
- average and maximum load of the settlement / municipality / town or city / city district in which the heat source is located;
- available amount and power of waste heat of an installation or a geothermal spring.

District heating systems deliver heat to all three sectors observed (households, services, industry). The energy delivered from the DHS is not split into sectors, but rather the three analysed sectors represent one consumer.

Table III.4: shows the total annual consumption of thermal energy at the entry point to the distribution network of the district heating systems broken down by type of generation technology in:

- 2019 (reference year),
- 2030 (BAU and SIM scenarios),
- 2050 (BAU and SIM scenarios).

Table III.4: DHS – total annual energy delivered at the entry point to the distribution network of district heating systems in 2019, 2030 and 2050

Total annual energy delivered at the entry point to the distribution network of district heating systems [GWh/a]					
Name of energy product/technology	**2019**	**BAU – 2030**	**BAU – 2050**	**SIM – 2030**	**SIM – 2050**
DHS – natural gas boilers	1 326.77	1 250.00	1 050.00	661.90	200.00
DHS – fuel oil boilers	34.70	31.53	0.00	0.00	0.00
DHS – biomass boilers	3.76	5.00	10.00	7.00	13.34
DHS – natural gas – high-efficiency cogeneration	38.51	101.99	136.99	250.00	237.39
DHS – biomass – high-efficiency cogeneration	105.51	131.89	225.37	150.00	256.28
DHS – natural gas – cogeneration	197.80	190.00	140.00	0.00	0.00
DHS – geothermal energy	113.94	170.00	250.00	422.27	477.14
DHS – solar energy	2.05	4.00	10.00	24.80	33.49
DHS – heat pumps – electrically driven	0.00	0.00	0.00	14.20	24.15
DHS – heat pumps – RES from the environment	0.00	0.00	0.00	48.30	82.10
DHS – industrial waste heat	0.00	0.00	0.00	15.00	22.67
DHS – thermal waste treatment heat	0.00	0.00	0.00	130.00	195.76
TOTAL	**1 823.04**	**1 884.41**	**1 822.36**	**1 723.47**	**1 542.31**
BAU – business-as-usual scenario, SIM – scenario with integrated measures					

Figure III.1: and Figure III.2: show the development in total annual energy delivered at the entry point to the distribution network in the BAU and the SIM scenario for 2030 and 2050 according to the technologies and energy products of generation installation.

Looking at the year 2019, it can be seen that:

- 72.78% of the total delivered energy is generated in natural gas boilers;
- 10.85% of the total delivered energy is generated by natural gas cogeneration;
- 6.25% of the total delivered energy is generated from geothermal energy;
- 5.79% of the total delivered energy is generated by biomass high-efficiency cogeneration;
- only 2.11% of the total delivered energy is generated by natural gas high-efficiency cogeneration.

Therefore, boilers fired by fossil fuels (mainly natural gas, with fuel oil still used as well) are the most common type of generation installation technology in the existing district heating systems.

The BAU scenario for 2030 and 2050 forecasts a slight decrease in natural gas boilers, a complete decommission of fuel oil boilers by 2030, a decline in natural gas cogeneration and an increase in the use of geothermal energy, and biomass and natural gas high-efficiency cogeneration.

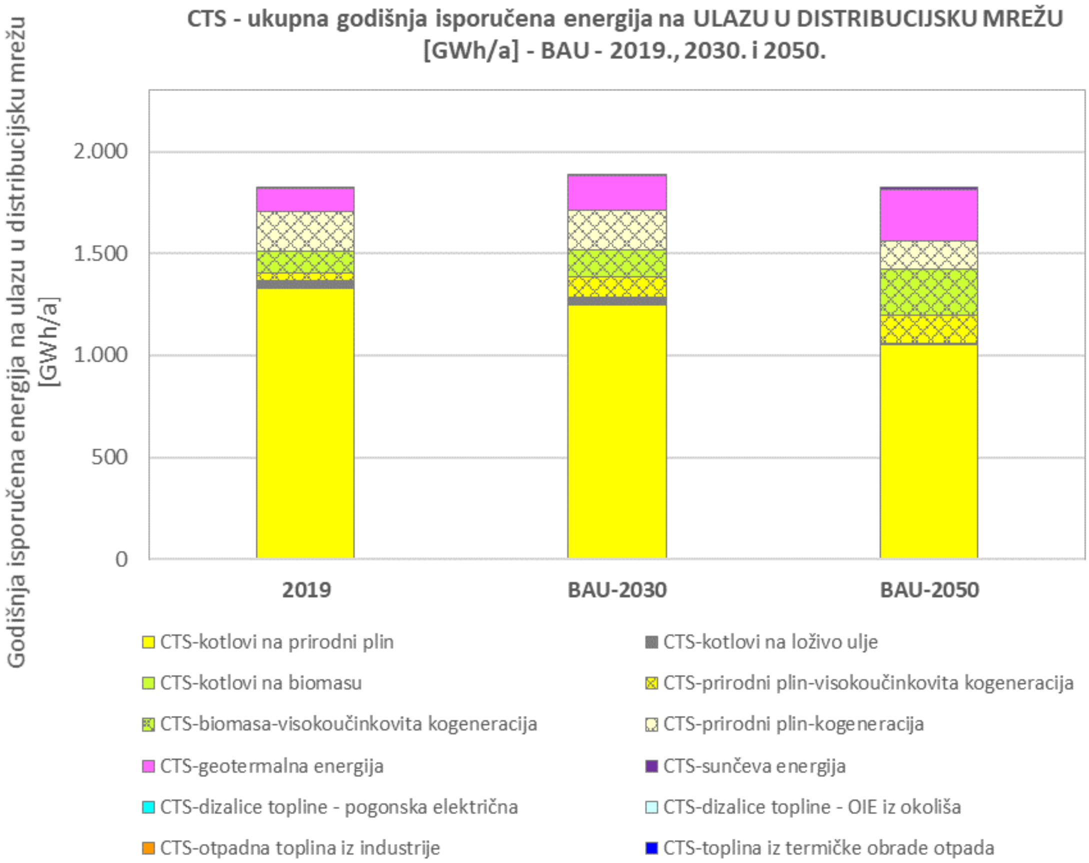


Figure III.1: DHS – total annual energy delivered at the entry point to the distribution network of district heating systems in 2019, 2030 and 2050 – BAU scenario

CROATIAN	ENGLISH
CTS - ukupna godišnja isporučena energija na ULAZU U DISTRIBUCIJSKU MREŽU [GWh/a] - BAU - 2019., 2030. i 2050.	DHS – total annual energy delivered at the ENTRY POINT TO THE DISTRIBUTION NETWORK [GWh/a] – BAU for 2019, 2030 and 2050
Godišnja isporučena energija na ulazu u distribucijsku mrežu [GWh/a]	Annual energy delivered at the entry point to the distribution network [GWh/a]
BAU-2030	BAU – 2030
BAU-2050	BAU – 2050
CTS-kotlovi na prirodni plin	DHS – natural gas boilers
CTS-kotlovi na biomasu	DHS – biomass boilers
CTS-biomasa-visokoučinkovita kogeneracija	DHS – biomass – high-efficiency cogeneration
CTS-geotermalna energija	DHS – geothermal energy
CTS-dizalice topline - pogonska električna	DHS – heat pumps – electrically driven
CTS-otpadna toplina iz industrije	DHS – industrial waste heat
CTS-kotlovi na loživo ulje	DHS – fuel oil boilers
CTS-prirodni plin-visokoučinkovita kogeneracija	DHS – natural gas – high-efficiency cogeneration
CTS-prirodni plin-kogeneracija	DHS – natural gas – cogeneration
CTS-sunčeva energija	DHS – solar energy
CTS-dizalice topline - OIE iz okoliša	DHS – heat pumps – RES from the environment
CTS-toplina iz termičke obrade otpada	DHS – thermal waste treatment heat

The SIM scenario measures for 2030 and 2050 (Figure III.2:) foresees the following:

- complete decommissioning of fuel oil boilers (by 2030);
- complete phase-out of natural gas cogeneration;
- significant decrease in natural gas boilers;

- increase in biomass high-efficiency cogeneration;
- significant increase in geothermal energy use;
- use of heat from thermal waste treatment (significant potential in densely populated urban areas) – the figure shows electricity used as drive energy and heat taken from the environment;
- use of water-to-water compression heat pumps;
- use of industrial waste heat (small portion);
- use of solar energy (small portion).

The proposed measures would ensure a reduction in CO_2 emissions from district heating systems by 193 967.87 tonnes of CO_2 and 833.18 GWh in primary energy savings by 2030.

Between 2030 and 2050, the proposed measures would ensure a reduction in CO_2 emissions from district heating systems by 171 045.64 tonnes of CO_2 and 678.98 GWh in primary energy savings.

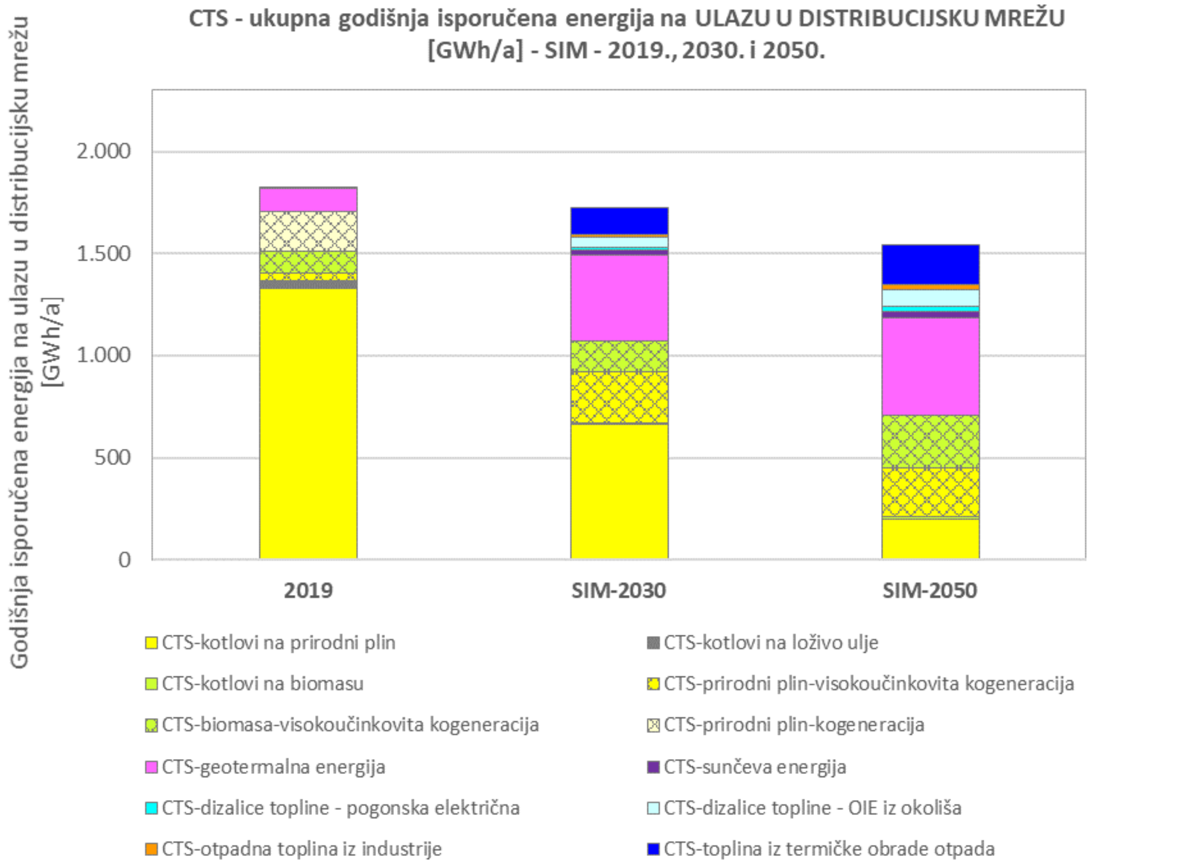


Figure III.2: DHS – total annual energy delivered at the entry point to the distribution network of district heating systems in 2019, 2030 and 2050 – SIM scenario

CROATIAN	ENGLISH
CTS - ukupna godišnja isporučena energija na ULAZU U DISTRIBUCIJSKU MREŽU [GWh/a] - SIM - 2019., 2030. i 2050.	DHS – total annual energy delivered at the ENTRY POINT TO THE DISTRIBUTION NETWORK [GWh/a] – SIM for 2019, 2030 and 2050
Godišnja isporučena energija na ulazu u distribucijsku mrežu [GWh/a]	Annual energy delivered at the entry point to the distribution network [GWh/a]
SIM-2030	SIM – 2030
SIM-2050	SIM – 2050
CTS-kotlovi na prirodni plin	DHS – natural gas boilers
CTS-kotlovi na biomasu	DHS – biomass boilers
CTS-biomasa-visokoučinkovita kogeneracija	DHS – biomass – high-efficiency cogeneration

CTS-geotermalna energija	DHS – geothermal energy
CTS-dizalice topline - pogonska električna	DHS – heat pumps – electrically driven
CTS-otpadna toplina iz industrije	DHS – industrial waste heat
CTS-kotlovi na loživo ulje	DHS – fuel oil boilers
CTS-prirodni plin-visokoučinkovita kogeneracija	DHS – natural gas – high-efficiency cogeneration
CTS-prirodni plin-kogeneracija	DHS – natural gas – cogeneration
CTS-sunčeva energija	DHS – solar energy
CTS-dizalice topline - OIE iz okoliša	DHS – heat pumps – RES from the environment
CTS-toplina iz termičke obrade otpada	DHS – thermal waste treatment heat

Today, Croatia has inefficient district heating systems, designed for high temperatures in distribution networks and an inefficient, mostly unrenovated residential building stock. The prevailing heating systems in Croatia are second-generation heating systems, which need to be upgraded to third- or fourth-generation systems. This implies new, modern generation installations, access to new sources of renewable energy, efficient distribution infrastructure, highly efficient buildings renovated for low-temperature thermal energy supply, improved control of the heating system and heat metering with charging based on the actual consumption.

Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 **on energy efficiency** (EED) includes the following definition:

> **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.

Energy efficiency measures for district heating systems include the improvement of heat networks by renovating and reconstructing certain sections, the replacement of fuel oil boilers with heat pumps, replacement of natural gas in heat production with geothermal energy, replacement of natural gas in heat production with solar energy, replacement of old and inefficient blocks with two new high-efficiency combined-cycle cogeneration blocks, the use of waste heat from industrial installations and heat from waste incineration plants. The proposed measures are presented in more detail in the table below. The required thermal capacity of the source that needs to be installed, as well as the annual savings in delivered energy and CO_2 emissions after the implementation of the measures have been calculated and presented for each measure. CO_2 emissions savings have been calculated based on the emissions factors provided in the *Rules governing the energy savings monitoring, measuring and verification system* [22].

Table III.5. DHS – Installed capacity needed and annual primary energy and CO_2 emissions savings after the implementation of the proposed measures

Measure code	Description of the measure	Installed thermal capacity needed [MW]		Annual primary energy savings from driving energy product at entry point to DHS [GWh]		Annual CO_2 emissions savings after measure implementation [t CO_2]	
		2030	2050	2030	2050	2030	2050
00-dis	Reduction of heat losses in the DHS distribution network	–	–	334.53	–	68 590.66	–
01-boilers_ELFO-boilers_biomass	Replacement of fuel oil boilers with biomass boilers	1.25	–	3.54	–	926.45	–
02-boilers_ELFO-HP	Replacement of fuel oil boilers with water-to-water heat pumps	2.25	–	28.51	–	8 574.50	–
03-cogeneration_NG-HEC_NG	Replacement of natural gas cogeneration with high-efficiency natural gas cogeneration	161.27	113.30	75.68	70.89	15 219.12	14 256.67
04-boilers_NG-HP	Replacement of natural gas boilers with water-to-water compression heat pumps	3.43	9.66	34.76	97.88	7 759.26	21 850.04
05-boilers_NG-HEC_NG	Replacement of natural gas boilers with natural gas high-efficiency cogeneration	–	4.90	–	-6.63	–	-1 333.91
06-boilers_NG-heat_industry	Replacement of natural gas boilers – industrial waste heat utilisation	6.12	9.25	19.32	29.20	3 885.88	5 872.12
07-boilers_NG-heat_waste	Replacement of natural gas boilers – waste heat utilisation	37.90	57.07	34.82	52.43	33 677.65	50 713.80
08-boilers_NG-solar_energy	Replacement of natural gas boilers – solar energy harnessing	8.70	10.12	27.46	31.92	5 369.34	6 241.95
09-boilers_NG-HEC_biomass	Replacement of natural gas boilers with high-efficiency biomass cogeneration	28.20	48.16	35.47	63.67	6 329.66	11 433.00
10-boilers_NG-boilers_biomass	Replacement of natural gas boilers with biomass boilers	–	2.18	–	5.13		970.11
11-boilers_NG-geothermal_energy	Replacement of natural gas boilers – geothermal energy exploitation	75.76	105.98	239.10	334.48	43 635.35	61 041.85
TOTAL				833.18	678.98	193 967.87	171 045.64

The first measure for district heating systems is aimed at reducing heat losses in the distribution network of district heating systems. Only after that, taking into account a lower value of the delivered energy at the entry point to the distribution network due to reduced heat losses, followed the measures relating to the modernisation of generation installations of existing district heating systems:

- phase-out and complete replacement of fuel oil boilers by 2030;
- replacement of natural gas cogeneration with high-efficiency natural gas cogeneration;
- replacement of natural gas boilers (with several solutions).

7.3.1.1 IMPROVEMENT OF HEAT NETWORKS THROUGH SECTION RENOVATION AND RECONSTRUCTION

As the run-down distribution network is the cause of major losses in the existing large district heating systems, this measure provides for continued replacement of hot water pipelines with deteriorated steel pipe insulation with new pre-insulated piping and a technological shift towards fourth-generation of district heating.

In good engineering practice, losses for modern heating systems using pre-insulated pipes are estimated at 6%–8%. Thanks to the resistance of pre-insulated piping material to external factors, the expected service life of the new pre-insulated pipes is up to 50 years.

The expected outcome of the heat network renovation include increased energy efficiency of the heating system, more reliable heat supply, a decrease in the number of emergency system interventions, enhanced satisfaction of the final consumers of heat, reduction of heat losses and losses in process water refilling, as well as reduced pollutant emissions into the environment.

In order for district heating systems to be sustainable by the rules of the profession and according to best practices, the existing network should be renovated to reach a level at which losses are taken to be 7% by 2030.

Total investment is estimated at around HRK 1 650 million, with support from the European Regional Development Fund through the Operational Fund for Competitiveness and Cohesion.

7.3.1.2 REPLACEMENT OF FUEL OIL BOILERS BY 2030

Given that fuel oil is an environmentally unacceptable fossil fuel with a high CO_2 emissions factor, a complete phase-out of fuel oil as the energy product powering district heating systems is foreseen under SIM scenario measures by 2030. Two measures have been proposed: replacement of fuel oil boilers with biomass boilers (wood chips) and water-to-water heat pumps. The proposed measures should result in a reduction of CO_2 emissions by 9 500.95 tonnes and in 32.05 GWh in primary energy savings from drive energy products at the entry point to the DHS by 2030.

7.3.1.3 REPLACEMENT OF NATURAL GAS COGENERATION WITH HIGH-EFFICIENCY NATURAL GAS COGENERATION

The proposed measures provide for the complete replacement of existing natural gas cogeneration with high-efficiency natural gas cogeneration by 2050. These measures would ensure CO_2 emissions savings of 29 475.79 tonnes by 2050 and 146.58 GWh in primary energy savings from drive energy products at the entry point to the DHS.

A description of the two measures for EL-TO Zagreb and TE-TO Osijek, integrated into the BAU scenario, is provided below.

IMPLEMENTATION OF A NEW HIGH-EFFICIENCY COMBINED-CYCLE COGENERATION BLOCK AT EL-TO ZAGREB

In accordance with guidelines on energy efficiency, which form an integral part of the EU and Croatian strategic energy documents, *Hrvatska elektroprivreda* – HEP d.d. will build a new combined-cycle cogeneration block KKE EL-TO Zagreb. The block, characterised by high primary energy savings, will partially replace a portion of the deteriorated and outdated units at the EL-TO Zagreb site (block A, block B and boiler K-7).

The new high-efficiency combined-cycle cogeneration block KKE EL-TO Zagreb with an electrical capacity of 150 MW_e and thermal capacity of 114 MW_t will provide a reliable source of safe of electricity and heat supply to the City of Zagreb, minimising its potential interruptions.

When developing the project, HEP ensured continuous generation at the EL-TO Zagreb site to meet the needs of heat and process steam customers in the western part of the City of Zagreb even after 1 January 2018, when Croatia became subject to the provisions of EU Industrial Emissions Directive.

Since this heat-generating facility will be fuelled solely by gas, significantly lower specific CO_2 emissions per kWh of energy produced will be generated compared to the current situation at the site.

Table III.6: Basic information on the KKE EL-TO Zagreb project

Investor:	*Hrvatska elektroprivreda* – HEP d.d.
Location:	City of Zagreb, EL-TO Zagreb plant
Name:	KKE EL-TO Zagreb
Product type:	electricity / heat / process steam
Type of power plant:	New CCCGT block
Type of fuel:	natural gas
Capacity/efficiency:	150 MWe and 114 MWt / 90%
Annual production/regime:	675 GWh electricity, 450 GWh heat for the DHS and 160 GWh process steam for industry / base load plant
Investment value:	HRK 900 million
Funding:	Own funds / loan
Project status:	Main works on the construction of the energy-producing block began in December 2019
Length of construction:	3 years

IMPLEMENTATION OF A NEW HIGH-EFFICIENCY COMBINED-CYCLE COGENERATION BLOCK AT TE-TO OSIJEK

Hrvatska elektroprivreda – HEP d.d. is developing a project to replace and expand the capacity of the existing energy installation of the thermal power and heating plant *Termoelektrana-Toplana Osijek* by constructing a new and modern combined-cycle gas-fired power plant, KKE Osijek 500, aimed at generating electricity primarily for the needs of Croatia's electricity system, as well as heat for the city of Osijek. This is a highly efficient generation facility, which will use gas as its primary fuel in a combined cycle (gas and steam turbine), with an installed electrical capacity of 450 MW_e and thermal capacity of 160 MW_t. Having a degree of efficiency higher than 58% and applying technical measures to achieve the highest environmental protection standards, the power plant will have low greenhouse gas emissions, especially of carbon dioxide. It will supplement the lack of generation capacities and ensure the sufficiency of heat sources in the city of Osijek, while also providing for a timely start of the process of replacing existing installations whose service life is expiring. The local community will generate an additional annual income of around HRK 15 million a year from fees for the use of space, with at least 40% of the construction to be done by domestic industry.

Table III.7: Basic information on the KKE Osijek 500 project

Investor:	*Hrvatska elektroprivreda* – HEP d.d.
Location:	City of Osijek, TE-TO Osijek plant
Name:	KKE Osijek 500
Product type:	electricity / heat / process steam
Type of power plant:	New CCCGT block
Type of fuel:	natural gas

Capacity/efficiency:	450 MWe and 160 MWt / > 58%
Investment value:	HRK 450 million
Funding:	Own funds / loan
Project status:	Project under development

7.3.1.4 Replacement of natural gas boilers

Considering that 72.78% of the total energy delivered in 2019 was generated in natural gas boilers, making such boilers prevalent in Croatia's district heating systems, replacing them is certainly not a simple task. This Comprehensive Assessment analyses the following available technologies and potential energy sources for the replacement of natural gas boilers:

- water-to-water heat pumps;
- high-efficiency natural gas cogeneration;
- industrial waste heat utilisation;
- energy-from-waste;
- solar energy harnessing (solar collectors);
- high-efficiency biomass cogeneration (wood chips);
- biomass (wood chip) boilers;
- geothermal energy.

By 2050 the measures proposed for natural gas boilers would ensure a reduction in CO_2 emissions by 257 446.11 tonnes of CO_2 and 999.01 GWh in primary energy savings of the drive energy product at the entry point to the DHS.

WATER-TO-WATER HEAT PUMPS

Similarly to fuel oil, natural gas boilers will be partially replaced by water-to-water heat pumps. Heat pumps are not represented significantly in the technology mix of Croatia's DHS compared to other proposed replacement technologies and are primarily used in DHSs located by a river.

HIGH-EFFICIENCY NATURAL GAS COGENERATION

Since the SIM scenario does not envisage eliminating natural gas from use, but rather its reduction, it is important to use natural gas as efficiently as possible. In order to utilise the natural gas employed to its fullest potential, natural gas boilers are proposed to be replaced with high-efficiency natural gas cogeneration.

INDUSTRIAL WASTE HEAT UTILISATION

Sources of industrial waste heat constitute considerable thermal energy potential which could be utilised in district heating systems. That potential depends significantly on the characteristics of the observed industrial sectors and depends on fuels, conversions and process characteristics even in the industrial production of the same product.

The analysis of heat generated in industry has at least two dimensions – the distinction between industrial sectors or production processes, and that between the energy products used. In order to determine the amount of usable waste heat from different industrial processes, the analysis based on the energy products used first distinguishes between electricity and energy products for heat generation. Although electricity is also used in certain processes for heat generation, waste heat generated in the process typically has no usable potential, so this energy product is omitted.

Thus, the observed heat generation energy products are the following:

– conventional fossil fuels: natural gas, extra light and special fuel oil, high-sulphur fuel oil, low-sulphur fuel oil, diesel fuels other than for transport, petrol other than for transport, liquefied gas, hard coal and its briquettes, brown coal and its briquettes, coke (metallurgical, foundry and petroleum);

- energy transformation media (DHS, boiler rooms): steam and water at temperatures lower than or equal to 200 °C; steam and water at temperatures higher than 200 °C;
- biomass: firewood, wood pellets and chips, wood and plant waste;
- fuels from residues: waste oils and emulsions, old tyres, DSS, RDF and others.

By breaking down the important factors at the given level and taking into account the most common types of energy use, the following sources are considered for their considerable potential for utilising industrial waste heat:

- transformed forms of energy – steam and hot water, separately for temperatures lower than or equal to 200 °C and higher than 200 °C;
- natural gas;
- all other fuels.

This makes it possible to derive the total available potential of residual heat and determine the realistically usable share based on the temperature level. The estimates made are relatively conservative. The analyses are conducted for industrial facilities in Croatia with the highest heat consumption.

At the current level, such an analysis points to the available annual waste heat to total 165 130 MWh/year at the installed thermal capacity of the extraction installation of 33.8 MW (economisers and other exchangers, use of waste steam, etc.).

However, due to location characteristics and temperature levels, only a small portion of those capacities can actually be utilised in district heating systems. Therefore, of the industrial installations observed, only those at a distance of less than 15 km from a potential connection to the existing (or possibly planned) DHS have been taken into account. This implies the construction of a heat transport pipeline and connection interfaces at both the source and the DHS end.

Of the total potential indicated above, the installation of 6.12 MW_t in capacities for industrial heat transfer to DHSs is presumed by 2030, generating 15.31 GWh_t of heat a year. Investment in the utilisation of industrial heat is presumed to continue until 2050 with the aim of achieving total capacities of 9.25 MW_t for the industrial heat transfer to DHSs, generating 23.13 GWh_t or heat a year.

INTRODUCTION OF ENERGY-FROM-WASTE

In order to facilitate waste management, the waste in Croatia is classified according to place of origin as municipal and industrial waste and, according to its properties, as hazardous, non-hazardous or inert waste (Croatian Government, 2017).

Municipal waste refers to waste generated in the household and waste similar in nature and composition to household waste, except for production waste, and waste from agriculture and forestry[21]. The first step in the entire system of solid municipal waste management is to ensure the implementation of waste prevention measures defined in the *Waste management plan* (Croatian Government, 2017). The most important measures include the establishment of waste management centres (WMCs) and re-use centres, as well as the provision of equipment required for home composting. The next step consists in establishing a system for the separate collection of municipal waste by ensuring the required infrastructure for municipal waste separation: at the place of its

[21] Sustainable Waste Management Act (NN Nos 94/13, 73/17, 14/19, 98/19).

generation, at civic amenity sites, on public surfaces and through the implementation of regulations on special waste categories (SWC).

Separately collected bio-waste will be delivered to biological treatment facilities for material recovery (composting or anaerobic digestion) in order to produce compost or digestates and biogas. Mixed municipal waste (residual waste) will be collected as part of a public collection service for mixed municipal waste rendered by the service providers and delivered to WMCs directly or through transfer stations (Figure III.3:).

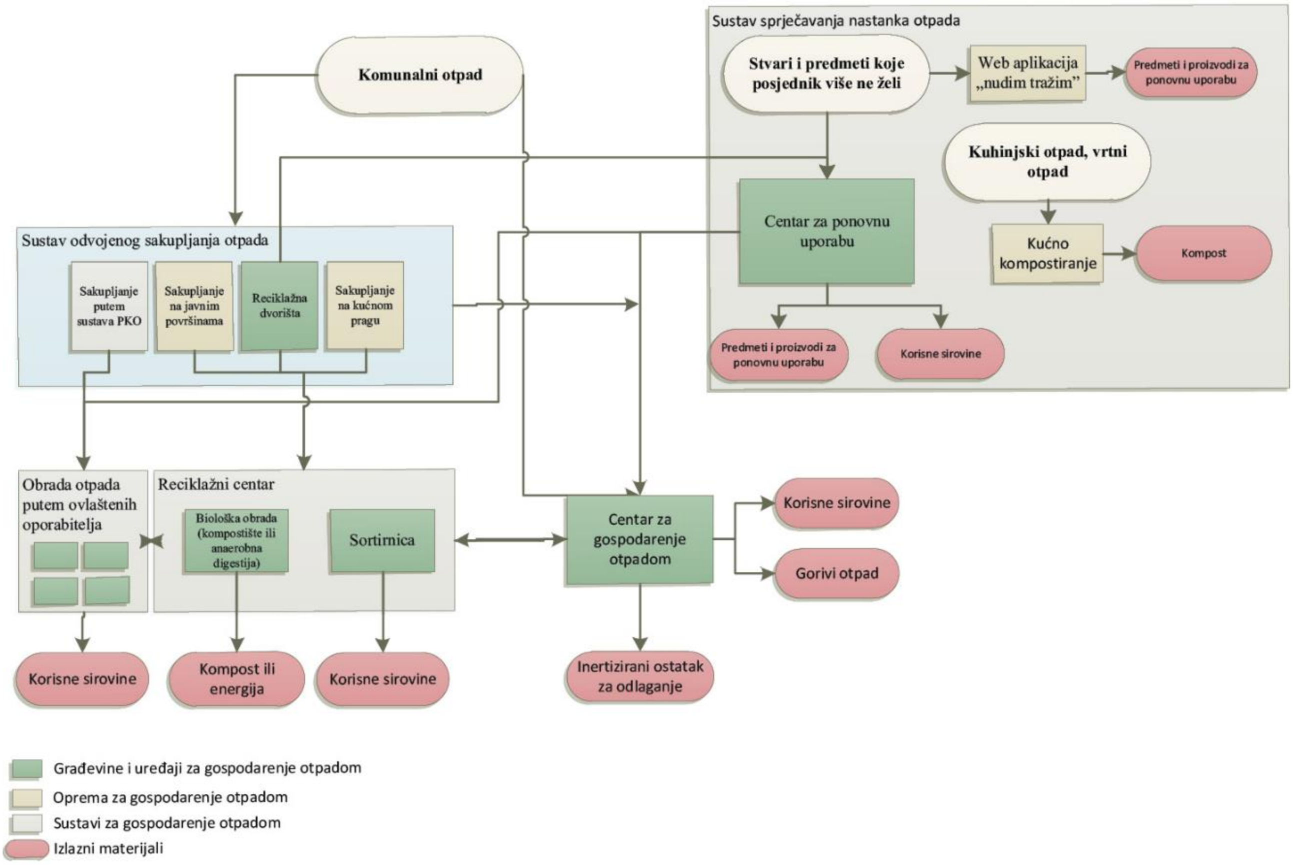


Figure III.3: Scheme of the municipal waste management system in Croatia[22]

CROATIAN	ENGLISH
Komunalni otpad	Municipal waste
Sustav odvojenog sakupljanja otpada	Separate waste collection system
Sakupljanje putem sustava PKO	SWC system collection
Sakupljanje na javnim površinama	Collection on public surfaces
Reciklažna dvorišta	Civic amenity sites
Sakupljanje na kućnom pragu	Door-to-door collection
Obrada otpada putem ovlaštenih oporabitelja	Waste treatment by certified recovery operators
Reciklažni centar	Recycling centre
Biološka obrada (kompostište ili anaerobna digestija)	Biological treatment (composting site or anaerobic digestion)
Sortirnica	Sorting facility
Korisne sirovine	Useful raw materials
Kompost ili energija	Compost or energy
Centar za gospodarenje otpadom	Waste management centre
Gorivi otpad	Combustible waste
Inertizirani ostatak za odlaganje	Inert residue for disposal

[22] https://narodne-novine.nn.hr/clanci/sluzbeni/2017_01_3_120.html

Sustav sprječavanja nastanka otpada	Waste prevention system
Stvari i predmeti koje posjednik više ne želi	Objects not wanted by their owner
Web aplikacija „nudim tražim”	‘Offering – Looking for’ web application
Predmeti i proizvodi za ponovnu uporabu	Objects and products for re-use
Kuhinjski otpad, vrtni otpad	Kitchen waste, garden waste
Centar za ponovnu uporabu	Re-use centre
Kućno kompostiranje	Home composting
Kompost	Compost
Predmeti i proizvodi u ponovnu uporabu	Objects and products for re-use
Građevine i uređaji za gospodarenje otpadom	Waste management facilities and devices
Oprema za gospodarenje otpadom	Waste management equipment
Sustavi za gospodarenje otpadom	Waste management systems
Izlazni materijali	Output materials

The above measures of the *Waste management plan* (Croatian Government, 2017) provide, together with the establishment of WMCs, for the use of existing and future waste management facilities, i.e. waste collection and waste treatment facilities. These include (CAEN data for 2019 and 2020[23]):

- civic amenity sites (a total of 173 stationary and 107 mobile sites);
- facilities for biological waste treatment (aerobic biological bio-waste treatment by composting is done at 10 composting plants);
- other facilities for material recovery of waste;
- facilities for energy recovery and waste incineration (35 energy recovery plants, with most energy recovery from waste done outside of Croatia);
- waste management centres; and
- landfills (116 landfills).

[23] http://www.haop.hr/hr/tematska-podrucja/otpad-registri-oneciscavanja-i-ostali-sektorski-pritisci/gospodarenje-otpadom-0

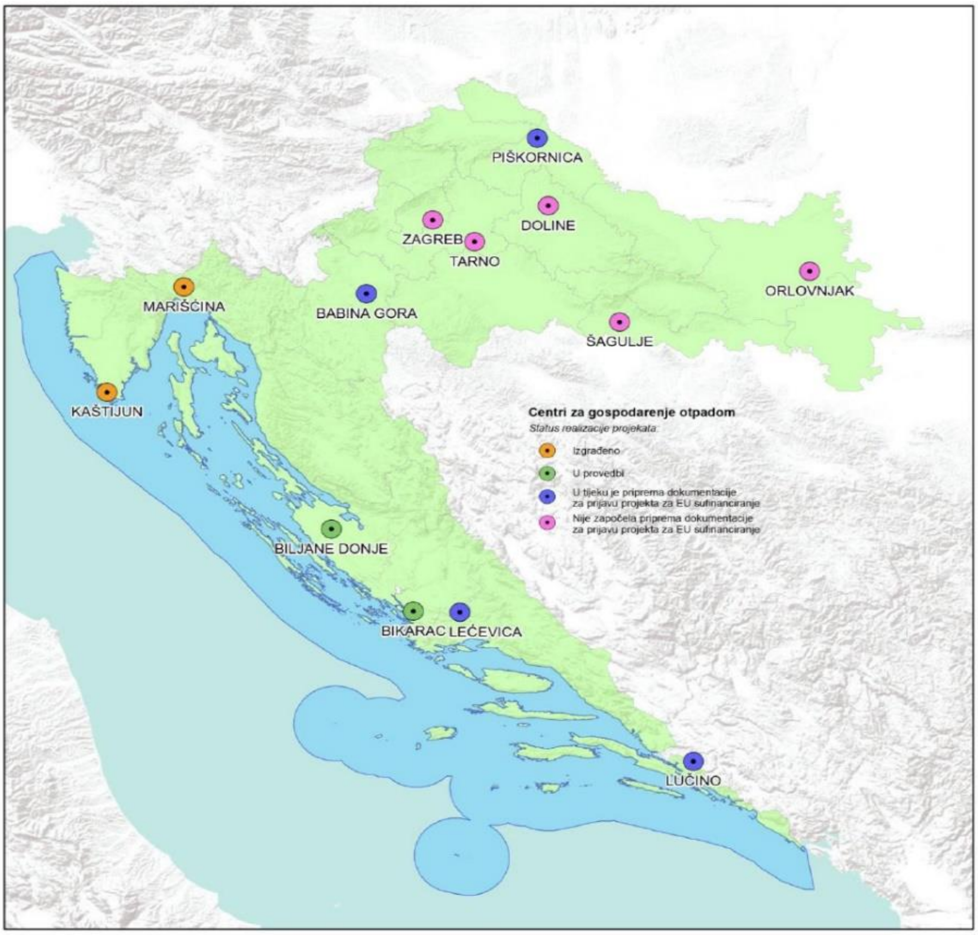


Figure III.4: Locations of waste management centres in Croatia[24]

CROATIAN	ENGLISH
Centri za gospodarenje otpadom	Waste management centres
Status realizacije projekata:	Project implementation status:
Izgrađeno	Built
U provedbi	Under development
U tijeku je priprema dokumentacije za prijevu projekta za EU sufinanciranje	Preparation of application documentation for EU project co-financing under way
Nije započela priprema dokumentacije za prijavu projekta za EU sufinanciranje	Preparation of application documentation for EU project co-financing not yet under way

The construction of 13 WMCs is planned for the treatment of mixed municipal waste and generated waste which cannot be recycled beforehand (Figure III.4:).

It is necessary to take into account that the WMCs sites envisaged in the *Waste management plan* date from 2016, so the status of certain WMCs has changed over time. Their current status and locations are presented in tabular form (Table III.8:) and graphically (Figure III.5:).

[24] https://narodne-novine.nn.hr/clanci/sluzbeni/2017_01_3_120.html

Table III.8: Representation of the status of waste management centres in Croatia (source: EIHP)

Name	Status according to the Plan[25]	Current status	County	County seat
WMC BIKARAC	Under development	Under development - contract for the design and execution of works signed	Šibenik-Knin	Šibenik
WMC BILJANE DONJE	Under development	Under construction	Zadar	Zadar
WMC PIŠKORNICA	preparation of application documentation for EU project co-financing under way	Under development - Grant contract for the WMC project signed	Koprivnica-Križevci	Koprivnica
WMC KAŠTIJUN	Built	Built	Istria	Pazin
WMC MARIŠĆINA	Built	Built	Primorje-Gorski Kotar	Rijeka
WMC BABINA GORA	Preparation of application documentation for EU project co-financing under way	Under development - public procurement procedure for Design and execution of works on WMC construction conducted	Karlovac	Karlovac
WMC DOLINE	Preparation of application documentation for EU project co-financing not yet under way	- **construction of the WMC abandoned**		
WMC LEĆEVICA	Preparation of application documentation for EU project co-financing under way	Under development - public procurement procedure for Design and execution of WMC construction works under way	Split-Dalmatia	Split
WMC ORLOVNJAK	Preparation of application documentation for EU project co-financing not yet under way	Under development - Study and project documentation preparation ongoing	Osijek-Baranja	Osijek
WMC ŠAGULJE	Preparation of application documentation for EU project co-financing not yet under way	Under development - contracts for the preparation of study and project documentation signed	Slavonski Brod-Posavina	Slavonski Brod
WMC LUČINO RAZDOLJE	Preparation of application documentation for EU project co-financing under way	Under development - Grant contract signed	Dubrovnik-Neretva	Dubrovnik
WMC TARNO	Preparation of application documentation for EU project co-financing not yet under way	- **construction of the WMC abandoned**		
WMC ZAGREB	Preparation of application documentation for EU project co-financing not yet under way	Under development - study and project documentation preparation	City of Zagreb	Zagreb

25 Waste management plan of the Republic of Croatia for 2017–2022 (NN No 3/17).

The technology envisaged for WMCs according to the *Waste management plan* is mechanical biological treatment (MBT), since it contributes to the targets for reducing the share of biodegradable waste sent to landfills and the total volume of waste landfilled. However, MBT is not enough to achieve the targets for increasing the level of municipal waste recycling. Therefore, the principle of separate waste collection from households and industry into the waste management system should be introduced, along with providing the infrastructure necessary to increase the quality of separately collected waste and preparation of waste for recycling.

Improving waste prevention measures and waste management requires action during the product life cycle, rather than in the final phase only. Factors such as the design and selection of input material play an important role in determining the service life of a product and its ability to be repaired, re-used or recycled. Despite the fact that waste recovery increases year after year, the most common type of treatment in Croatia is still the disposal of waste at landfill sites.

However, since the strategic and legislative frameworks are focused on recycling and re-use, the only waste components that can undergo energy recovery are refuse-derived fuel (hereinafter: RDF), generated in mechanical biological treatment facilities, and the separated biodegradable portion of municipal waste.

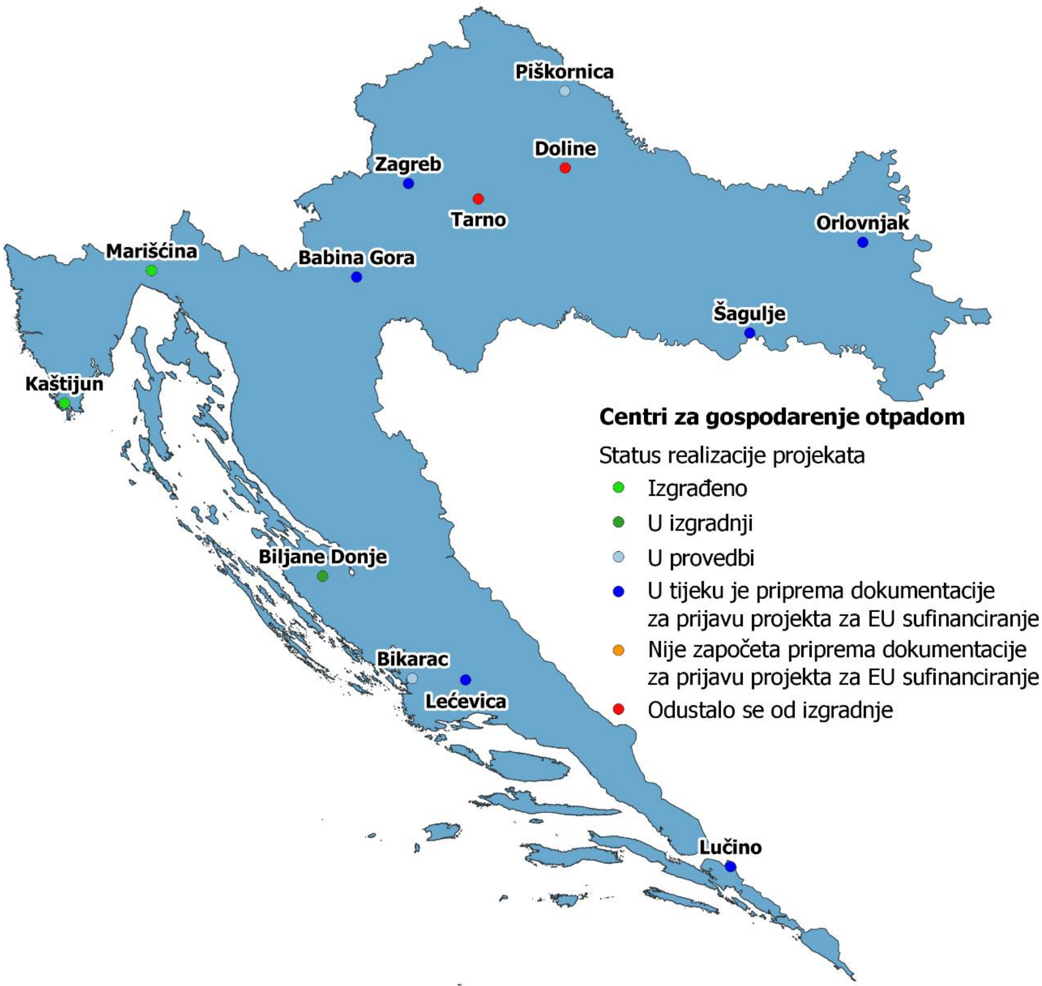


Figure III.5: Sites and status of waste management centres at national level (source: EIHP)

CROATIAN	ENGLISH
Centri za gospodarenje otpadom	Waste management centres
Status realizacije projekata	Project implementation status
Izgrađeno	Built
U izgradnji	Under construction

U provedbi	Under development
U tijeku je priprema dokumentacije za prijavu projekta za EU sufinanciranje	Preparation of application documentation for EU project co-financing under way
Nije započeta priprema dokumentacije za prijavu projekta za EU sufinanciranje	Preparation of application documentation for EU project co-financing not yet under way
Odustalo se od izgradnje	Construction abandoned

According to European analyses, 1 million tonnes of RDF will be generated in waste management centres every year starting from 2018. However, as can be seen in Figure III.5:, most of the planned WMCs are still in the phase of project documentation preparation, resulting in the current RDF generation of around 37 000.00 tonnes at CWMC Marišćina and 11 000.00 tonnes at CWMC Kaštijun.

The generated fuel has been sold through public procurement calls for the provision of services transferring fuel from WMCs which has mostly been burnt at the existing cement plants (Holcim, Našicecement and Cemex) to date. However, considering the current capacities of the cement plants, the amounts of generated RDF envisaged will partly require the construction of 2–4 waste-to-energy plants with a treatment capacity of 150 000–400 000 tonnes of RDF per year.

Taking into account the need for additional energy in DHSs, the RDF generated in waste-to-energy plants can be utilised for the sites being considered. WMCs at those sites whose RDF would be used are the following:

- County waste management centre (CWMC) Marišćina;
- Regional waste management centre (RWMC) Orlovnjak;
- Regional waste management centre (RWMC) Šagulje;
- Waste management centre of the Karlovac County – WMC Babina Gora; and
- Waste management centre of the City of Zagreb (ZWMC).

Due to the current status of those WMCs (in respect of most of which study and project documentation preparation is still ongoing), only approximate estimates can be made of the future amounts of generated RDF to be used in waste-to-energy plants. In doing so, it is necessary to take into account that the currently estimated quantities to be treated at WMCs are going to decrease in line with bioeconomy and circular economy concepts, with more emphasis being placed on the waste prevention step. This will also lead to a significant decrease in the amount of RDF generated, which is to be used in the plants.

Given the current development and construction of WMCs, the increase in the amount of total municipal waste and in the separate collection of municipal waste (Figure III.6:), it can be concluded that RDF in WMCs will be able to significantly contribute to meeting DHS needs in the period under observation(by 2050).

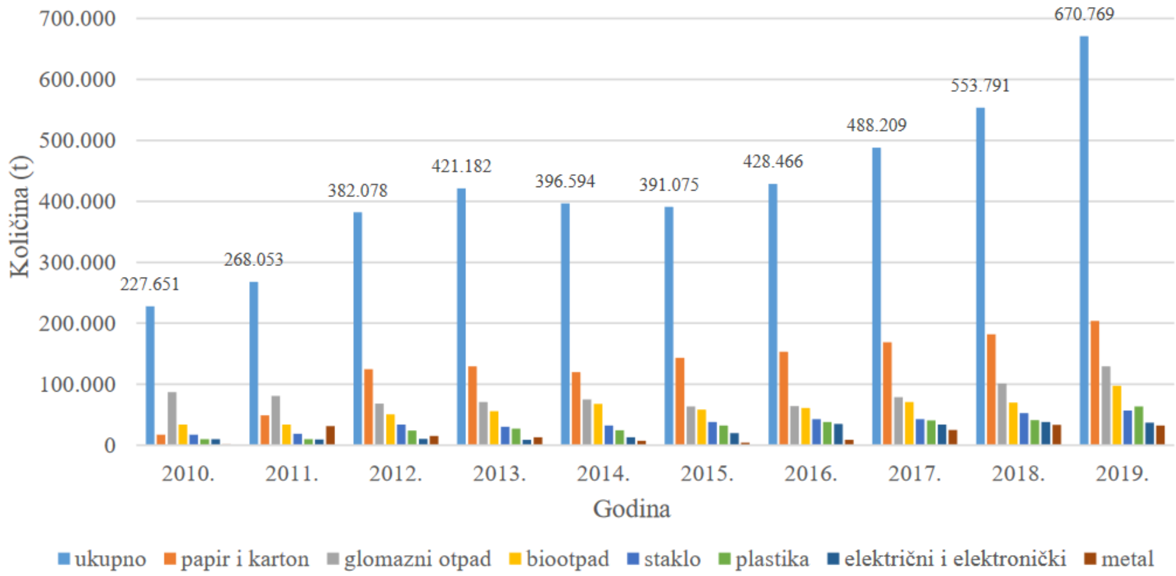


Figure III.6: Quantities of separately collected municipal waste in Croatia, 2010–2019

CROATIAN	ENGLISH
Količina (t)	Amount (t)
Godina	Year
ukupno	total
papir i karton	paper and cardboard
glomazni otpad	bulky waste
biootpad	bio-waste
staklo	glass
plastika	plastic
električni i elektronički	electrical and electronic
metal	metal

In order to determine the potential for heat from thermal waste treatment that may actually be exploited in district heating systems, the above WMC sites within reach of the DHSs, i.e. less than 15 km away from a potential DHS connection, have been taken into account. The RWMC Šagulje site has been eliminated due to its remoteness to the heat network and consumers (Slavonski Brod) and excessively low capacity of networked heat consumers. The following data refer to the remaining WMC sites and the capacities derived for generating useful heat from thermal waste treatment:

Table III.9: Potential of the utilised energy from thermal waste treatment

City	WMC	Municipal waste treated at WMC [t/a]	Amount of RDF generated [t/a]	Total energy potential [GJ/a]	Electricity [GWh_{el}/a] from cogen.	Heat from cogen. in DHS [GWh_t/a]
Rijeka	CWMC Marišćina	76 896.00	37 000.00	518 000–777 000	**37.00**	**44**
Vukovar Osijek	RWMC Orlovnjak	60 000.00	28 870.16	404 180–606 270	**28.87**	**34**
Karlovac	WMC Babina Gora	29 052.00	5 688.00	91 000–125 135	**5.69**	**7**
Samobor V. Gorica Zagreb	Zagreb waste mgmt. centre (ZWMC)	180 000.00	86 610.49	1 212 545– 1 818 820	**86.61**	**105**

Of the potential indicated above, the installation of capacities of 37.90 MW_t for the transfer of heat to DHSs with an annual heat generation of 132.65 GWh_t is presumed by 2030. Further investment in the utilisation of heat from waste treatment is assumed by 2050 with the aim of achieving a total of 57.07 MW_t in capacities for the transfer of industrial heat to DHSs with an annual heat generation of 199.76 GWh_t. Such heat will replace other sources of heat within DHSs.

HARNESSING OF SOLAR ENERGY (solar collectors)

This measure connects solar energy potential with the locations of the existing district heating systems by 2050. It is expected that more than 61 500 m^2 of thermal collectors will be installed in the heating sector by 2050, with the total investment estimated at HRK 307 million.
A greater integration of RES into district heating systems is estimated to result in a competitive price of heat in the market, which will in turn generate the need to construct new and expand existing distribution infrastructure. The harnessing of solar energy reduces the consumption of fossil fuels, which has a positive impact on the environment.

HIGH-EFFICIENCY BIOMASS COGENERATION (wood chips)

Biomass is considered a renewable energy source, so the SIM scenario provides for increased use of high-efficiency cogeneration technology using biomass (wood chips).

BIOMASS (wood chip) BOILERS

Considering a significant reduction in the use of natural gas by 2050, the SIM scenario provides for the replacement of natural gas boilers with biomass boilers.

GEOTHERMAL ENERGY EXPLOITATION

This measure connects the available geothermal energy potential presented in the chapter *Sources of geothermal energy – existing and* potential with the sites of the existing district heating systems by 2050. It is estimated that the installed [capacity] in district heating systems will reach 181.73 MW_t by 2050.

A greater integration of RES into district heating systems is believed to result in the supply of heat at a highly competitive prices in the market, which will in turn generate the need to build new and expand existing distribution infrastructure. Apart from geothermal heat plants, geothermal power plants or energy installations are also noteworthy, especially those of the base load type operating throughout the year with few short interruptions. In addition to electricity generation, geothermal power plant projects also enable the cascade use of the remaining geothermal water heat for different purposes (district heating, space heating, dryers, aquaculture, etc.). Such systems increase the efficiency of geothermal installations, and thus the cost-effectiveness of the entire geothermal project. Geothermal energy use reduces the consumption of fossil fuels, which has a positive impact on the environment.

7.3.2 PROPOSED MEASURES FOR DECENTRALISED (INDIVIDUAL) SYSTEMS

The chapter concerned includes proposes measures relating to individual systems at the level of buildings. The measures are presented separately for the household sector and the service sector, along with the achieved in delivered energy and CO_2 emissions savings as a result of their implementation. Moreover, the measures are also presented according to purpose: heating, DHW preparation and cooling, with the course of their implementation provided for two target years: 2030 and 2050. It is important to note that the measures below refer solely to heating, DHW preparation and cooling technologies, and that their drafting was based on data from the reference or BAU scenario, aimed at achieving the energy consumption provided in the scenario with implemented measures referred to in the Integrated National Energy and Climate Plan for the Republic of Croatia (NECP) [21].

7.3.2.1 HOUSEHOLD SECTOR

Energy efficiency measures for the household sector include the replacement of fossil fuels with renewable energy sources, the introduction of more efficient technologies such as condensing boilers and heat pumps, as well as the use of solar energy for heating and DHW preparation. The proposed measures are presented in more detail in the tables below. The required thermal capacity of the source that needs to be installed, as well as the annual savings in delivered energy and CO_2 emissions resulting from the implementation of certain measures have been calculated and presented for each measure. CO_2 emissions savings have been calculated based on the emissions factors provided in the *Rules governing the energy savings monitoring, measuring and verification system* [22].

Table III.10: HOUSEHOLD SECTOR – Installed capacity needed and annual primary energy and CO_2 emissions savings after the implementation of measures for efficient space heating

Measure code	Description of the measure	Installed thermal capacity needed [MW]		Annual primary energy savings after measure implementation [GWh]		Annual CO_2 emissions savings after measure implementation [tCO_2]	
		2030	2050	2030	2050	2030	2050
H_TB_1	Replacement of room-based wood-fired centralised space heating with wood-fired district space heating	1 160.57	–	379.31	–	11 034.20	–
H_TB_2	Replacement of traditional biomass boilers with modern biomass boilers	434.47	1 211.29	473.21	1 495.55	-2 080.47	-673.11
H_TB_3	Replacement of traditional biomass boilers with heat pumps	–	209.22	–	706.83	–	-21 187.61
H_TB_4	Solar heating combined with heat pumps (after H_TB_3 measure implementation)	–	21.35	–	30.44	–	725.96
H_ELLU_1	Replacement of fuel oil boilers with modern biomass boilers	156.19	–	201.14	–	52 652.29	–
H_ELLU_2	Replacement of fuel oil boilers with heat pumps	52.99	–	189.40	–	60 557.31	–
H_ELLU_3	Solar heating combined with heat pumps (after H_ELLU_2 measure implementation)	5.41	–	8.01	–	2 067.41	–
H_UNP_1	Replacement of LPG boilers with modern biomass boilers	8.77	3.61	10.78	4.44	2 358.50	970.62
H_UNP_2	Replacement of LPG boilers with heat pumps	1.19	0.65	4.00	2.19	1 061.16	582.28
H_UNP_3	Solar heating combined with heat pumps (after H_UNP_2 measure implementation)	0.28	0.23	0.40	0.33	88.41	72.77
H_PP_1	Replacement of standard boilers with condensing boilers	1 220.53	1 920.49	313.64	571.43	63 070.75	114 911.36
H_PP_2	Natural gas micro-CHP	217.95	160.79	-5.90	0.00	-1 185.54	0.00
H_PP_3	Solar heating combined with condensing boilers (after H_PP_1 measure implementation)	33.63	17.40	44.57	23.06	8 711.23	4 508.11
H_PP_4	Replacement of natural gas boilers with heat pumps	125.54	460.92	379.03	1 391.61	88 190.78	323 791.82
H_PP_5	Replacement of natural gas boilers with modern biomass boilers	–	298.26	–	339.32	–	64 930.72
H_EE_1	Increase in the share of heat pumps vs. electric resistance heating	141.39	196.58	242.39	337.02	35 264.07	49 030.57

Table III.11: HOUSEHOLD SECTOR – Installed capacity needed and annual primary energy and CO_2 emissions savings after the implementation of measures for DHW preparation

Measure code	Description of the measure	Installed thermal capacity needed [MW]		Annual primary energy savings after measure implementation [GWh]		Annual CO_2 emissions savings after measure implementation [tCO_2]	
		2030	2050	2030	2050	2030	2050
H_TB_2_a	Replacement of traditional biomass boilers with modern biomass boilers	22.16	33.15	132.89	198.76	532.53	796.52
H_TB_3_a	Replacement of traditional biomass boilers with heat pumps	–	5.74	–	99.15	–	-1 841.34
H_TB_4_a	Installation of solar collectors for DHW preparation (where traditional biomass is currently used as energy product)	–	13.67	–	93.17	–	2 288.60
H_ELLU_1_a	Replacement of fuel oil boilers with modern biomass boilers	0.82	–	4.68	–	1 226.68	–
H_ELLU_2_a	Replacement of fuel oil boilers with heat pumps	0.39	–	6.32	–	1 987.11	–
H_ELLU_3_a	Installation of solar collectors for DHW preparation (where fuel oil is currently used as energy product)	0.80	–	5.18	–	1 340.17	–
H_UNP_1_a	Replacement of LPG boilers with modern biomass boilers	0.41	0.35	2.06	1.77	451.34	387.04
H_UNP_2_a	Replacement of LPG boilers with heat pumps	0.11	0.09	1.53	1.31	406.14	348.29
H_UNP_3_a	Installation of solar collectors for DHW preparation (where LPG is currently used as energy product)	1.78	0.34	10.40	1.98	2 284.15	435.28
H_PP_1_a	Replacement of standard boilers with condensing boilers	5.85	–	6.20	–	1 246.53	–
H_PP_2_a	Natural gas micro-CHP	7.14	13.96	0.00	0.00	0.00	0.00
H_PP_3_a	Installation of solar collectors for DHW preparation (where natural gas is currently used as energy product)	20.89	22.29	114.19	121.84	22 318.09	23 813.49
H_PP_4_a	Replacement of natural gas boilers with heat pumps	6.73	16.46	83.76	204.95	19 487.68	47 686.79
H_PP_5_a	Replacement of natural gas boilers with modern biomass boilers	–	54.87	–	266.50	–	51 085.27
H_EE_1_a	Installation of heat pumps for DHW preparation	–	69.08	–	488.35	–	71 046.93
H_EE_2_a	Replacement of electric boilers with solar collectors	36.28	–	273.23	–	38 631.55	–

Table III.12: HOUSEHOLD SECTOR – Installed capacity needed and annual primary energy and CO_2 emissions savings after the implementation of measures for efficient space cooling

Measure code	Description of the measure	Installed thermal capacity needed [MW]		Annual primary energy savings after measure implementation [GWh]		Annual CO_2 emissions savings after measure implementation [tCO_2]	
		2030	2050	2030	2050	2030	2050
H_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	10.24	10.34	53.25	53.73	7 746.32	7 816.89

The implementation of the described measures will result in a significant reduction of fossil fuel consumption and, consequently, in greenhouse gas emissions too. Whenever technically feasible, fossil fuel boilers are to be replaced with renewable energy sources and more efficient technologies such as heat pumps. The percentage of individual energy product increase/decrease resulting from the implementation of these measures with regard to consumption in the reference BAU scenario for 2030 and 2050 is provided in the table below.

Table III.13: HOUSEHOLD SECTOR – Percentage of energy product increase/decrease under the BAU scenario after the implementation of measures for efficient heating, DHW preparation and cooling

Energy product	Space heating		DHW preparation		Space cooling	
	2030	2050	2030	2050	2030	2050
Traditional biomass	-8.53%	-91.00%	-20.00%	-97.00%	–	–
Modern biomass	77.09%	54.84%	75.09%	111.11%	–	–
Electricity	7.92%	128.89%	-7.15%	-27.09%	-9.09%	-4.90%
Solar energy	241.30%	136.80%	237.60%	53.76%	–	–
LPG	-46.00%	-26.00%	-65.00%	-30.00%	–	–
Fuel oil	-64.00%	–	-75.00%	–	–	–
Natural gas	-19.11%	-50.69%	-22.04%	-55.50%	–	–

7.3.2.2 SERVICE SECTOR

Similarly to the household sector, service sector energy efficiency measures the include the replacement of fossil fuels with renewable energy sources, the introduction of more efficient technologies such as condensing boilers and heat pumps, as well as the use of solar energy for heating and DHW preparation. The proposed measures are presented in more detail in the tables below. The required thermal capacity of the source that needs to be installed, as well as the annual savings in delivered energy and CO_2 emissions resulting from the implementation of certain measures have been calculated and presented for each measure.

Table III.14: SERVICE SECTOR – Installed capacity needed and annual primary energy and CO_2 emissions savings resulting from the implementation of measures for efficient space heating

Measure code	Description of the measure	Installed thermal capacity needed [MW]		Annual primary energy savings after measure implementation [GWh]		Annual CO_2 emissions savings after measure implementation [tCO_2]	
		2030	2050	2030	2050	2030	2050
S_ELLU_1	Replacement of fuel oil boilers with modern biomass boilers	30.27	–	38.98	–	10 204.18	–
S_ELLU_2	Replacement of fuel oil boilers with heat pumps	27.39	–	97.88	–	31 296.52	–
S_ELLU_3	Solar heating combined with heat pumps (after S_ELLU_2 measure implementation)	15.65	–	23.17	–	5 983.36	–
S_UNP_1	Replacement of LPG boilers with modern biomass boilers	10.77	–	13.24	–	2 895.99	–
S_UNP_2	Replacement of LPG boilers with heat pumps	1.62	–	5.45	–	1 447.77	–
S_UNP_3	Solar heating combined with heat pumps (after S_UNP_2 measure implementation)	2.90	–	4.12	–	904.70	–
S_PP_1	Replacement of standard boilers with condensing boilers	552.93	566.76	142.09	168.63	28 572.76	33 911.40
S_PP_2	Natural gas micro-CHP	115.19	194.76	-3.12	5.27	-626.60	1 059.38
S_PP_3	Solar heating combined with condensing boilers (after S_PP_1 measure implementation)	59.24	24.98	78.52	33.11	15 347.20	6 472.14
S_PP_4	Replacement of natural gas boilers with heat pumps	55.29	251.12	166.94	894.02	38 843.02	203 726.09
S_PP_5	Replacement of natural gas boilers with modern biomass boilers	–	227.35	–	267.76	–	51 328.11
S_PP_6	Connection of users to district heating source	–	107.43	–	-28.10	–	-10 824.00
S_EE_1	Increase in the share of heat pumps vs. electric resistance heating	103.77	227.98	177.90	390.85	25 880.95	56 862.29

Table III.15: SERVICE SECTOR – Installed capacity needed and annual primary energy and CO_2 emissions savings resulting from the implementation of measures for efficient DHW preparation

Measure code	Description of the measure	Installed thermal capacity needed [MW]		Annual primary energy savings after measure implementation [GWh]		Annual CO_2 emissions savings after measure implementation [tCO_2]	
		2030	2050	2030	2050	2030	2050
S_ELLU_1_a	Replacement of fuel oil boilers with modern biomass boilers	0.46	–	2.43	–	635.48	–
S_ELLU_2_a	Replacement of fuel oil boilers with heat pumps	0.87	–	12.80	–	4 092.98	–
S_ELLU_3_a	Installation of solar collectors for DHW preparation (where fuel oil is currently used as energy product)	5.14	–	31.39	–	8 104.55	–
S_UNP_1_a	Replacement of LPG boilers with modern biomass boilers	0.05	–	0.24	–	52.66	–
S_UNP_2_a	Replacement of LPG boilers with heat pumps	0.06		0.89	–	236.92	–
S_UNP_3_a	Installation of solar collectors for DHW preparation (where LPG is currently used as energy product)	0.92	–	5.39	–	1 184.40	–
S_PP_1_a	Replacement of standard boilers with condensing boilers	8.90	8.21	9.43	10.07	1 896.76	2 026.04
S_PP_2_a	Natural gas micro-CHP	1.67	3.36	-0.19	0.37	-37.44	75.35
S_PP_3_a	Installation of solar collectors for DHW preparation (where natural gas is currently used as energy product)	17.17	8.96	93.82	49.46	18 338.37	9 669.77
S_PP_4_a	Replacement of natural gas boilers with heat pumps	–	7.58	–	111.28	–	25 357.54
S_PP_5_a	Replacement of natural gas boilers with modern biomass boilers	–	2.84	–	13.77	–	2 639.75
S_EE_1_a	Replacement of electric boilers with solar collectors	28.42	2.86	214.04	21.56	30 262.95	3 048.17
S_EE_2_a	Installation of heat pumps for DHW preparation	2.41	9.70	17.05	68.58	2 480.46	9 976.91

Table III.16: SERVICE SECTOR – Installed capacity needed and annual primary energy and CO_2 emissions savings resulting from the implementation of measures for efficient space cooling

Measure code	Description of the measure	Installed thermal capacity needed [MW]		Annual primary energy savings after measure implementation [GWh]		Annual CO_2 emissions savings after measure implementation [tCO_2]	
		2030	2050	2030	2050	2030	2050
S_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	73.33	32.84	381.12	170.68	55 446.30	24 830.49
S_EE_2_b	Absorption cooling – connections of users to district cooling	–					

The implementation of the described measures will result in a significant reduction of fossil fuel consumption (complete phase-out of LPG and fuel oil in the service sector by 2050) and, consequently, in greenhouse gases emissions. Whenever technically feasible, fossil fuel boilers are to be replaced with renewable energy sources and more efficient technologies such as heat pumps. The percentage of individual energy product increase/decrease resulting from the implementation of these measures with regard to consumption in the reference BAU scenario for 2030 and 2050 is provided in the table below.

Table III.17: SERVICE SECTOR – Percentage of energy product increase/decrease under the BAU scenario after the implementation of measures for efficient heating, DHW preparation and cooling

Energy product	Space heating		DHW preparation		Space cooling	
	2030	2050	2030	2050	2030	2050
Modern biomass	43.59%	121.85%	75.71%	122.53%	–	–
Electricity	-20.67%	3.24%	-40.59%	-4.87%	-14.77%	-7.27%
Solar energy	82.63%	34.73%	180.31%	16.90%	–	–
LPG	-23.44%	–	-52.00%	–	–	–
Fuel oil	-73.00%	–	-98.00%	–	–	–
Natural gas	-18.31%	-59.65%	-39.55%	-72.87%	–	–
District heating	–	43.95%	–	–	–	–
Other	–	–	–	–	4.72%	15.06%

All the economic parameters which include energy product prices, CO_2 emissions, prices of heat sources and others are presented below.

8 COST-BENEFIT ANALYSIS

After the technical potential was assessed, the next logical step was to undertake a cost-benefit analysis to identify technical solutions which might be more cost-effective than all recognised heating and cooling solutions.

Croatia has completed a cost-benefit analysis: for its territory based on climate conditions, economic feasibility and technical suitability, in accordance with Annex I to Commission Delegated Regulation (EU) 2019/826 of 4 March 2019 amending Annexes VIII and IX to Directive 2012/27/EU of the European Parliament and of the Council on the contents of comprehensive assessments of the potential for efficient heating and cooling [5]. The cost-benefit analysis contributes to the easier identification of the most effective solutions for meeting heating and cooling demand, with regard to energy sources and their cost. The analysis was conducted for individual systems in the segments of households and services, and separately for DHS.

The cost-benefit analysis also took into account all relevant centralised or decentralised supply sources available within the system and geographical boundaries. To ensure that the analysis would be comprehensive, it included the following steps:

- the analysis was based on predefined technical potential (Chapter 7.3) for low-carbon and energy efficient heating and cooling;
- the baseline scenario and all relevant alternative scenarios were defined at the level of Croatia;
- financial and economic analysis was prepared, taking into account all relevant costs;
- a sensitivity analysis for all variables recognised as critical was conducted; and
- the methodology used for the calculation and defined assumptions on which the analysis is based were described in detail.

The economic and financial analyses use net present value (NPV) as a criterion for assessment. The appropriate discount rate has been applied in the calculation. Discounting enables future cash flows to be expressed in present value to determine the most cost-effective and useful heating or cooling option in Croatia and take an appropriate decision for the planning of optimal heating and cooling systems.

8.1.1 DEFINING SCENARIOS

This analysis compares the costs and benefits between the following two scenarios:

- reference or BAU (business-as-usual) scenario, which presumes development with the application of existing measures; and
- SIM (scenario with integrated measures) according to the Integrated National Energy and Climate Plan for the Republic of Croatia (NECP).

The baseline scenario serves as a point of reference against which alternative scenarios are assessed. It takes into account all the existing measures and policies at the time of preparing this comprehensive assessment, in accordance with national and EU law, and is based on energy efficiency and renewable energy scenarios with existing measures (WEM), developed under the provisions of the Regulation on the Governance of the Energy Union. It describes the current situation and its potential evolution if none of the parameters of the existing situation change.

Technologies envisaged under the baseline scenario do not have to be limited to the currently used options. They can also include high-efficiency cogeneration (HEC) or efficient district heating and cooling (DHC), if the baseline scenario provides for such development.

Table III.18: Energy products and technologies in the BAU scenario

Energy product	Technology	Heating	DHW	Cooling
SERVICES				
Fuel oil	Fuel oil boilers	x	x	
LPG	LPG boilers	x	x	
Natural gas	Natural gas boilers	x	x	
Electricity	Heat pumps	x	x	x
HOUSEHOLDS				
Traditional biomass	Room-based firewood stoves	x		
Traditional biomass	Firewood boilers	x	x	
Fuel oil	Fuel oil boilers	x	x	
LPG	LPG boilers	x	x	
Natural gas	Natural gas boilers	x	x	
Electricity	Electric resistance heating	x		
Electricity	Individual electric boilers		x	
Electricity	Individual compression cooling units			x

The analysis of the economic potential of different heating and cooling technologies has been conducted for the entire country through the cost-benefit analysis, identifying alternative scenarios for more efficient heating and cooling technologies using the energy from renewable sources, distinguishing between the energy derived from fossil fuels and energy derived from renewable sources. All relevant scenarios have been compared to the baseline scenario, including the role of efficient individual heating and cooling. Each scenario provides the following elements compared to those under the baseline scenario:

- economic potential of technologies examined, using the net present value as criterion;
- reducing greenhouse gas emissions;
- primary energy savings in GWh per year;
- impact on the share of renewables in the national energy mix.

Scenarios that are not feasible for technical reasons, excluding financial reasons or national regulation at an early stage of the cost-benefit analysis where justified based on careful, explicit and well-documented considerations. The assessment and decision-making have taken into account costs and energy savings from the increased flexibility in energy supply and from improved operation of the electricity networks, including avoided costs and savings resulting from reduces infrastructure investment in the analysed scenarios.

Table III.19: Overview of energy products and technologies in alternative scenarios

Type	Source	Technology	Purpose	Decentralised systems	DHS
Recovered resources	Industrial or electricity generation waste heat	Heat exchanger for industrial waste heat utilisation	Heating		√
RES	Geothermal energy	Heat exchanger for geothermal heat utilisation	Heating		√
	Solar energy	Solar collectors	Heating, DHW	√	√
	Biomass	Biomass boilers	Heating, DHW		√
		Modern biomass boilers	Heating, DHW	√	
		Firewood boilers	Heating	√	

Type	Source	Technology	Purpose	Decentralised systems	DHS
		Biomass high-efficiency cogeneration	Heating, DHW, electricity generation		√
	Energy from waste	Waste heat utilisation heat exchanger	Heating		√
Conventional sources	Fossil fuels	Boilers			√
		Natural gas high-efficiency cogeneration	Heating, DHW, electricity generation		√
		Natural gas micro-CHP	Heating, electricity generation	√	
	Electricity	Heat pumps	Heating, DHW, cooling	√	
		Compression heat pumps	Heating, DHW, cooling		√
		Central compression cooling unit	Cooling	√	

8.1.1 INPUT DATA

The first step in undertaking the analysis is the assessment of costs and benefits. They are assessed separately for the baseline scenario and the alternative scenario. Costs and benefits that remain constant in both scenarios do not have to be taken into account because they would cancel each other in the process of assessing their change between both scenarios. The same applies when implementing partial measures in the given year. A part of the baseline scenario that has not been replaced by a measure is not assessed because the same values appear in both scenarios. Also, heating and cooling consumption is the same in both scenarios, which is why it is not necessary to show these values.

Costs and benefits include:

BENEFITS

- value of output to the consumer (heating, cooling and electricity);
- external benefits such as environmental, greenhouse gas emissions and health and safety benefits, to the extent possible;
- labour market effects, energy security and competitiveness, to the extent possible.

COSTS

- capital costs of plants and equipment (CAPEX);
- capital costs of associated energy networks;
- variable and fixed operating costs (OPEX);
- energy costs;
- environmental, health and safety costs, to the extent possible.

Technical solutions, or measures for efficient heating and cooling proposed in the Comprehensive Assessment, are divided into measures relating to:

- decentralised (individual) systems – each consumer has their own separate source of heating and cooling energy;

- centralised systems (DHS) – district heating systems used for heat distribution from the source to consumers.

This division has been taken into account in the assessment of costs and benefits.

8.1.1.1 COST ESTIMATE

COSTS OF INVESTMENT OR CAPITAL EXPENDITURE (CAPEX)

Capital expenditures for heating and cooling systems include the funds necessary for the implementation of an individual technology. In the context of heating and cooling, certain equipment will differ from case to case: equipment for heat generation/recycling, pumps (in individual systems), pipelines for heat transfer in centralised systems, boilers and the like.

The cost of investment into measures related to decentralised (individual) systems have been taken from the database used for the draft Analysis of energy efficiency measures specifying unit prices and total prices of the renovation of multi-apartment buildings and public buildings and the study entitled Determining minimum requirements for energy performance of buildings. The cost of investment into measures related to centralised systems have been estimated by experience and based on the data received from heat producers/suppliers. Both have been shown in Table III.20:.

Table III.20: Overview of specific costs of investment by technology (CAPEX)

Technology	Cost of investment [HRK/kW]***
Investment for decentralised (individual) systems	
Fuel oil boilers	995.000
LPG boilers	995.000
Natural gas boilers	1 045.000
Firewood boilers	1 146.000
Modern biomass boilers	1 075.000
Heat pumps	4 413.000
Solar collectors***	5 000.000
Natural gas micro-CHP	5 520.000
Investment for centralised systems	
Fuel oil boilers	760.870
Natural gas boilers	760.870
Natural gas cogeneration	6 300.000
Biomass boilers	760.87
High-efficiency natural gas cogeneration	8 000.00
Water-to-water compression heat pump	3 971.700
Geothermal plant with plate and pipe heat exchanger for geothermal heat exploitation	20 625.000
Solar collectors***	5 000.000
CHP EL-TO Zagreb – measure integrated into BAU scenario	7 894.737
CHP EL-TO Osijek – measure integrated into BAU scenario	2 812.500
Industrial waste heat plants	14 500.000
Waste incinerators	11 500.000

****The price of solar collectors is expressed in HRK/m^2.*

BAU scenario provides for the regular replacement of the currently used heat generation equipment, since service lives of certain capacities are to end during the observation period. Replacement rate has been determined based on the expected service life of technologies, which is 20 years in most cases. Thus, a 5% annual replacement rate has been used, except in the cases in which it has been assumed that replacement of the entire capacity is necessary, where the total replacement has been linearly distributed over the observation period.

Construction period

Time required for plant construction should be specified in order to distribute the cost over the time required to complete the construction of an individual system. In order to simplify the analysis, a one-year period is assumed as the construction period for all individual system technologies. In the case of DHS, a longer period has been foreseen for the renovation of the existing plants, so the replacement costs have been distributed over more years, depending on the technology used.

MANAGEMENT AND MAINTENANCE COSTS (OPEX)

Operational costs refer to the consumption of material, maintenance, administration, cost of labour etc. They can be fixed or variable.

Fixed costs of maintenance and management (OPEX) include labour, insurance, regular maintenance and routine replacement of plant components, such as boilers, carburettors, raw material handling equipment, etc. Replacement parts and additional servicing costs constitute the greatest share of **variable costs** of management and maintenance. These can also include other costs, such as the cost of biomass ash management. In this analysis, due to their nature and limited data availability, the variable costs of management and maintenance for individual systems have been estimated jointly with the fixed costs. In the case of DHS, fixed and variable costs of management and maintenance have been considered separately. Under the alternative scenario, the share of OPEX in CAPEX technologies ranges between 0.14% (solar collectors) and 23.44% (modern biomass boilers). In the case of DHS, this share is significantly lower, primarily due to the economies of scale, so it ranges between 0.14% (solar collectors) and 3.68% (biomass boilers).

Fixed costs of management and maintenance are calculated by multiplying the installed capacity of the observed technology by fixed costs of individual technology expressed in [HRK/kW].

In the case of DHS, variable costs of maintenance are calculated by multiplying the annual energy consumption of the drive energy product for the observed technology by variable costs of individual technology expressed in [HRK/kW].

In the case of DHS, variable costs of maintenance are calculated by multiplying the annual energy consumption of the drive energy product for the observed technology by variable costs of individual technology expressed in [HRK/kW].

The specific values of fixed and variable costs of maintenance applied for individual technology in decentralised (individual) and centralised systems are provided in Table III.21:.

Table III.21: Overview of maintenance costs of individual technologies (OPEX)

System type	Name of technology	Fixed maintenance costs [HRK/kW]	Variable maintenance costs [HRK/kWh]
	Room-based firewood stoves	50.00	–
	Firewood boilers	100.00	–
	Natural gas condensing boilers	120.00	–
	Natural gas boilers	120.00	–
	LPG boilers	120.00	–
Decentralised system	Fuel oil boilers	180.000	–
	Modern biomass boilers	252.000	–
	Heat pumps	120.000	–
	Electric resistance heating	1.000	–
	Individual electric boilers	1.000	–
	Individual compression cooling units	100.000	–

System type	Name of technology	Fixed maintenance costs [HRK/kW]	Variable maintenance costs [HRK/kWh]
	Central compression cooling unit	120.000	–
	Solar collectors	10.000[26]	–
	Natural gas micro-CHP	240.000	–
	Heating substation within the building	2.000	–
Central systems	Solar collectors	10.000Error! Bookmark not defined.	0.000
	Water-to-water compression heat pump	29.800	0.0010
	Heat exchanger for industrial waste heat utilisation	55.000	0.1000
	Waste heat utilisation heat exchanger	55.000	0.1000
	Heat exchanger for geothermal heat utilisation	55.000	0.1000
	Fuel oil boilers	25.000	0.0034
	Natural gas boilers	22.350	0.0030
	Natural gas and fuel oil blocks	25.000	0.0030
	Natural gas and gas oil blocks	25.000	0.0030
	Natural gas cogeneration	45.000	0.0400
	High-efficiency natural gas cogeneration	40.000	0.0370
	High-efficiency, biomass cogeneration	50.000	0.0500
	DHS pipeline distribution – HRK/m	52.150[27]	0.0000

COSTS OF ENERGY PRODUCTS AND CO_2 EMISSIONS

Costs of energy products are determined separately. The total amount is derived by multiplying total energy consumption, expressed in MW, with the relative price of a specific energy product, multiplied by 1 000.

The prices of energy products and CO_2 emissions that have been used can be found in TableIII.22:. The table shows a lower and a higher price28.

Sources of energy products prices and CO_2 emission prices

Unit prices of drive energy products in 2019 have been taken to be average market values, excluding fees and VAT. Price projections for drive energy products (natural gas, electricity, crude petroleum distillates) for 2030 and 2050 are based on data reported in the Green Paper [16], while unit price trends for woody biomass (firewood, wood pellets / wood chips / briquettes) for the period up to 2050 have been estimated by experience.

The unit price of electricity in 2019, excluding levies and VAT, has been taken from the EUROSTAT website:

- household sector https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_204/default/table?lang=en
- service sector

[26] [HRK/m^2]

[27] [HRK/m]

[28] The effect of applying a higher price will be examined in the sensitivity analysis.

https://ec.europa.eu/eurostat/databrowser/view/nrg_pc_205/default/table?lang=en

The price of CO_2 emissions has been taken from the European Commission. The data have been corrected, taking into account the actual price trends.

Given that the chosen methodology of assessing the cost-effectiveness of each measure (net present value) requires data for costs and benefits for each year of the period under observation, and based on the known values of unit prices of energy products and CO_2 emissions in 2019, 2030 and 2050, linear interpolation was applied to determine unit prices in the remaining years of the period covered by the analysis, between 2020 and 2050.

TableIII.22: Unit prices of energy and CO_2 emission in 2019, 2030 and 2050

Unit prices of energy and CO_2 emissions		**2019**		**2030**				**2050**			
				Lower price	Higher price	Lower emission	Higher emission	Lower price	Higher price	Lower emission	Higher emission
Sector	Drive energy product	Unit price without VAT [HRK/kWh]	Price of CO_2 emissions [HRK/tonne CO_2]	Unit price without VAT [HRK/kWh]	Unit price without VAT [HRK/kWh]	Price of CO_2 emissions [HRK/tonne CO_2]	Price of CO_2 emissions [HRK/tonne CO_2]	Unit price without VAT [HRK/kWh]	Unit price without VAT [HRK/kWh]	Price of CO_2 emissions [HRK/tonne CO_2]	Price of CO_2 emissions [HRK/tonne CO_2]
HOUSEHOLDS	Traditional biomass (firewood)	0.0964	–	0.1043	0.1252	–	–	0.1148	0.1721	–	–
	Modern biomass (wood pellets / wood chips)	0.2731	–	0.3550	0.4260	–	–	0.4793	0.7189	–	–
	Electricity	0.7627	–	1.1271	1.2399	–	–	1.5724	1.8868	–	–
	LPG	0.5051	–	0.8632	0.9927	–	–	1.2559	1.4443	–	–
	Fuel oil	0.3652	–	0.6241	0.7802	–	–	0.9081	1.1351	–	–
	Natural gas	0.2386	–	0.3478	0.3999	–	–	0.4321	0.4969	–	–
SERVICES	Traditional biomass (firewood)	0.0964	–	0.1043	0.1252	–	–	0.1148	0.1721	–	–
	Modern biomass (wood pellets / wood chips)	0.2731	–	0.3550	0.4260	–	–	0.4793	0.7189	–	–
	Electricity	0.6584	–	0.9730	1.0703	–	–	1.3573	1.6288	–	–
	LPG	0.5051	–	0.8632	0.9927	–	–	1.2559	1.4443	–	–
	Fuel oil	0.3331	–	0.5693	0.7116	–	–	0.8283	1.0353	–	–
	Natural gas	0.2280	–	0.3324	0.3822	–	–	0.4129	0.4748	–	–
DHS – drive energy products	Natural gas	0.2100	184.16	0.3061	0.3520	491.70	735.12	0.3803	0.4373	685.87	1 109.38
	Fuel oil	0.4106	184.16	0.7018	0.8773	491.70	735.12	1.0211	1.2763	685.87	1 109.38
	Fuel oil – medium	0.3015	184.16	0.5154	0.6442	491.70	735.12	0.7498	0.9373	685.87	1 109.38
	Wood chips	0.0589	184.16	0.0619	0.0743	491.70	735.12	0.0681	0.1021	685.87	1 109.38
	Wood pellets	0.2600	184.16	0.3380	0.4056	491.70	735.12	0.4563	0.6845	685.87	1 109.38
	Biogas	0.2100	184.16	0.3061	0.3520	491.70	735.12	0.3803	0.4373	685.87	1 109.38
	Electricity	0.6584	184.16	0.9730	1.0703	491.70	735.12	1.3573	1.6288	685.87	1 109.38
	Industrial waste heat	0.0800	184.16	0.1000	0.1100	491.70	735.12	0.1000	0.1100	685.87	1 109.38

Calculation of annual greenhouse gas emissions

Formula for the calculation of annual greenhouse gas emissions:

$$E_{CO2} = FES \times e/1000$$

Where:

E_{CO2} [t CO_2/yr] – greenhouse gas emission;

FES [kWh/yr] – total annual final energy savings;

e [kg CO_2 / kWh] emissions factor, depending on the energy product.

The following are provided in tabular form:

- primary energy factors (source *Methodology of energy audits of buildings 2021*) and
- CO_2 emissions factors [tonne of CO_2/GWh] (source *Draft revision of the Rules for monitoring, measuring and verifying energy savings,* ANNEX B, Table 5).

Table III.23: Primary energy factors and CO_2 emissions factors

Energy product	Primary energy factor [–]	CO_2 emissions factor [t CO_2/GWh] [kg CO_2/MWh]
Traditional biomass (firewood)	1.000	29.09
Modern biomass (wood pellets / wood chips)	0.139	38.38
Electricity	1.614	234.81
District heating	1.494	362.49
Solar energy	0.000	7.04
LPG	1.160	260.88
Fuel oil	1.138	299.57
Natural gas	1.095	220.20
Geothermal energy	0.000	23.48
Hydrogen	–	–
Biomethane	–	–

Modern biomass refers to wood pellets and wood chips. Given that these energy products have somewhat different factor values according to the *Methodology of energy audits of buildings 2021*, modern biomass has been calculated as the average factor value for wood pellets and wood chips.

8.1.1.2 Assessment of benefits

In this analysis, the following main benefits of the implementation of the proposed measures have been recognised:

a. **Differential cost of energy used for heating or cooling**

Energy product costs are usually lower in alternative scenarios compared to BAU scenario. Only the measures envisaging the use of more expensive energy products compared to the ones used in BAU scenario (e.g. biomass over firewood or electricity over firewood) actually generate higher energy product costs for consumers. Such measures are recommended to be implemented if economically feasible due to greater reduction in CO_2 emissions. Their implementation usually requires some form of government incentives.

b. **Revenues from sale of electricity (only in HEC)**

Electricity generation in the use of high-efficiency cogeneration for thermal energy production provides revenues from the sale of electricity.

c. **Residual value**

This is the residual value of technology, which represents its market value or liquidation value if it is sold off at the end of the year under observation. For certain technologies whose service life (usually 20 years) will not have ended by then the residual value at the end of the observation period (years 2030 and 2050) has been estimated. That value was added to total income under alternative and BAU scenarios. A positive difference between the residual values in an alternative scenario and BAU scenario represents income and contributes to a higher NPV of measure implementation. The opposite is true as well.

d. **Difference in CO_2 emissions**

In the economic analysis, positive difference in CO_2 emissions between an alternative scenario and BAU scenario represents additional value for society. The amount of CO_2 emission reduction is expressed in tonnes [t CO_2/a] and monetised by multiplying it with the appropriate emission price.

In addition, the government may provide incentives or subsidies for certain technologies. No such cases are included in this analysis.

8.1.2 ANALYSIS PROCEDURE

The present value of expected cash flows is calculated for the entire assessment period by discounting annual cash flows, which represent differential cost and benefits of the implementation of a certain measure in respect of the current situation. The following formula is used in the calculation:

$$S_0 = \sum_{t=1}^{T} \frac{Vt}{(1+k)t}$$

Where:

- S_0 – net present value;
- T – total assessment period;
- V_t – cash flow in year t;
- k – discount factor (opportunity cost).

The net present value of a measure compared to the situation with no change (baseline scenario or BAU scenario) is calculated by adding up discounted differences in benefits and cost differential in a single year within the observation period. According to the net present value criterion, the higher the net present value, the more cost-effective the measure is.

The analysis is conducted separately for the measures to be taken by 2030 and those referring to the period between 2031 and 2050. The analysis assumes that the measures referring to the period up to 2030 are to be implemented in phases during the 11-year period from 2020 to 2030. The measures are to be introduced in phases, at the same intensity over those 11 years, that is, with 1/11 of total expected costs of investment under the alternative scenario in each year. The measures defined for the period up to 2050 are to be implemented in phases, starting from 2031 until 2050. The measures are envisaged to be introduced in phases, at the same intensity over those 20 years, that is, with 1/20 of total costs of investment envisaged in each year.

The residual value at the end of the assessment period, separately for 2030 and 2050, has been forecast both under baseline and alternative scenarios, depending on the expected replacement rate under the baseline scenario, or the pace of new technology introduction under the alternative scenario.

NPV is calculated separately for each measure, in respect of the part of the baseline scenario to which the measure applies. Then, the NPV of a measure is divided by the total number of replaced energy product units under the baseline scenario in order to calculate the NPV by unit of energy [HRK/MWh].

Financial and economic analysis

Cost-benefit analysis includes financial analysis from the point of view of the investor, as well as economic analysis which also considers socioeconomic and environmental factors and includes costs of CO_2 emissions. In calculating NPV, the financial analysis applies the financial discount rate, representing opportunity cost for the consumer, while the economic analysis applies the economic discount rate to assess the justification of the project for society as a whole. A measure is financially justified if the financial NPV is above zero. Otherwise, the measure is not cost-effective for the consumer. If a measure has a negative financial NPV and a positive economic NPV, subsidies for the implementation of the measure or some other form of support is proposed because the implementation of such a measure is considered desirable for society as a whole.

The economic analysis serves to support the adoption of appropriate policies. The benefit of conducting the analysis from both perspectives consists in identifying potential areas in which appropriate policies should be implemented, considering the gap between the cost-effectiveness of the measure and its benefit from the point of view of society. Based on that gap, actions to support or promote the measure or the cancellation of the existing or planned support mechanisms, if the assessment proves it not to be justified society-wise, are proposed.

Discount rate used in the economic analysis to calculate the net present value is chosen according to European or national guidelines. A 2% financial discount rate and a 5% social discount rate are applied in this analysis. In the absence of national guidelines, the discount rate values used are similar to those used by other EU Member States in their analyses.

By applying an appropriate discount rate, future costs and benefits can be expressed in the corresponding present value to render them comparable over time.

Changes in relative prices

The analysis is conducted using constant prices defined in the base year, given that a real discount rate is applied. When a significant change in the prices of some input variables or products is expected, either above or below the average inflation rate, that difference should be taken into account in respective cash flow projections. In this analysis, this primarily applies to price trends of energy products, including electricity. The prices of energy product have thus been corrected by the expected 2% inflation rate in the observed period.

8.1.3 RESULTS OF COST-BENEFIT ANALYSIS

The analysis was conducted separately for the 2020-2030 period in respect of the measures foreseen up to 2030, and additionally for the 2021-2050 period in respect of the measures foreseen up to 2050. In the case of individual systems, measures for households and services have been analysed separately. DHS measures refer to all sectors under observation in this study (household sector, service sector, industrial sector) taken together. Results of the cost-benefit analysis are provided below.

8.1.3.1 INDIVIDUAL SYSTEMS

The results of financial and economic analysis for households and services are provided below.

A total of 15 heating measures, 16 DHW measure and one cooling measure were analysed for households. Alternatives to traditional biomass, fuel oil, LPG, natural gas and electricity have been proposed for heating and cooling, New alternatives are modern biomass and solar energy. The use of traditional biomass, natural gas and electricity is to be maintained by applying a more efficient technology. Fuel oil should be dropped from use, with LPG use reduced by 2030. In cooling, the use of centralised instead of individual cooling units is recommended.

Figure III.7: andFigure III.8: show investment (CAPEX) and maintenance costs (OPEX) and the costs of drive energy products for all technologies of individual household and service sector systems sector for two scenarios (BAU or baseline scenario, and SIM or alternative scenario) and the two periods under observation (up to 2030, and 2030–2050).

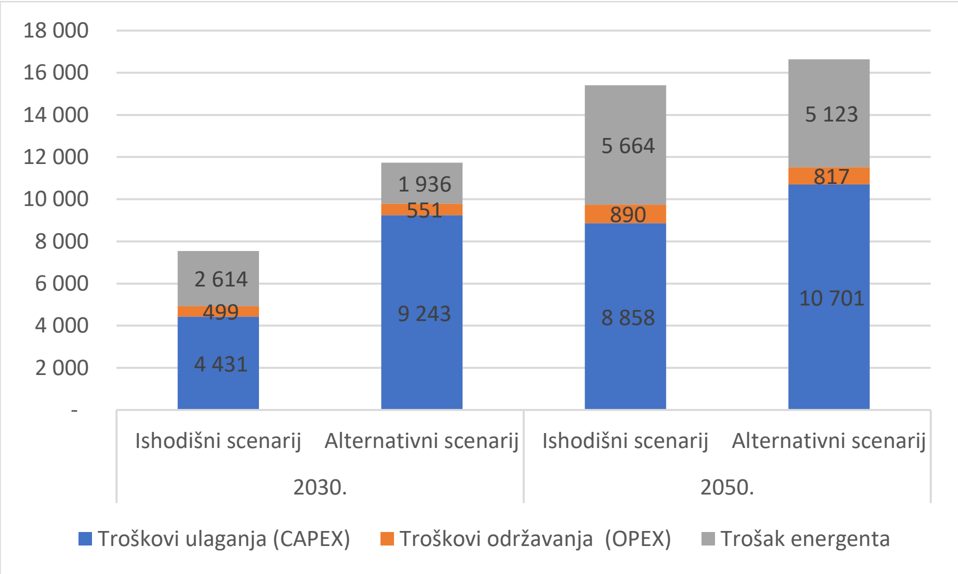


Figure III.7: HOUSEHOLD SECTOR – 2030 and 2050 cost distribution, in HRK mil.

CROATIAN	ENGLISH
Ishodišni scenarij	Baseline scenario
Alternativni scenarij	Alternative scenario
Troškovi ulaganja (CAPEX)	Investment costs (CAPEX)
Troškovi održavanja (OPEX)	Maintenance costs (OPEX)
Trošak energenta	Cost of energy product

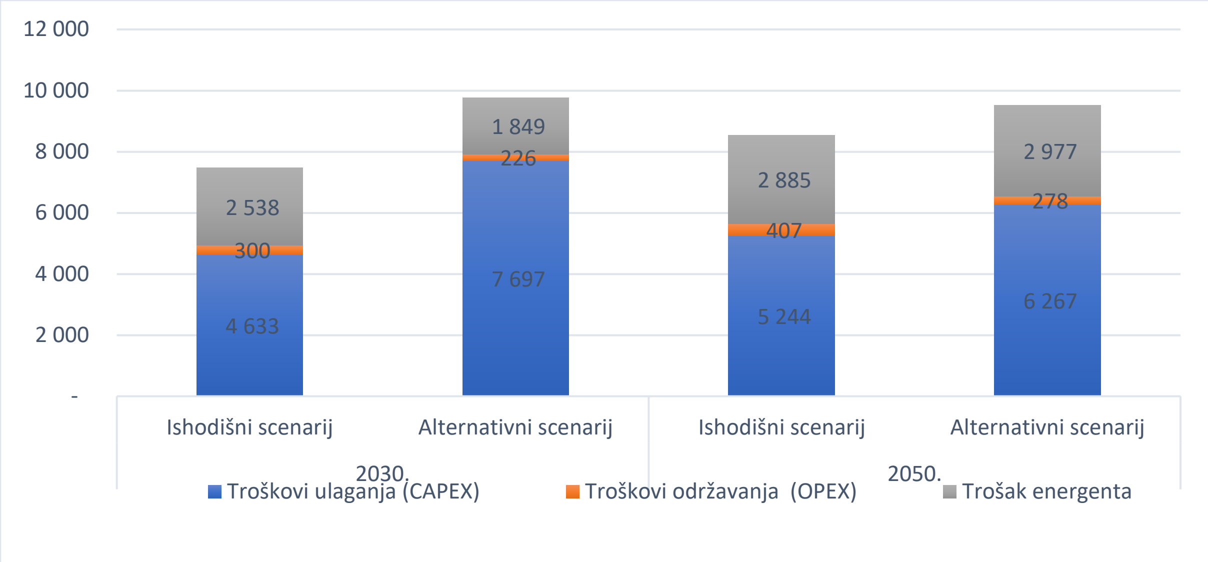


Figure III.8: SERVICE SECTOR – 2030 and 2050 cost distribution, in HRK mil.

CROATIAN	ENGLISH
Ishodišni scenarij	Baseline scenario
Alternativni scenarij	Alternative scenario
Troškovi ulaganja (CAPEX)	Investment costs (CAPEX)
Troškovi održavanja (OPEX)	Maintenance costs (OPEX)
Trošak energenta	Cost of energy product

The costs of drive energy products are lower in SIM or alternative scenarios than in BAU scenarios, which is among the main benefits of the implementation of measures.

The results of completed financial and economic cost-benefit analysis for proposed household sector measures in the period up to 2030 and between 2031 and 2050 are presented in Table III.24:.

The results of completed financial and economic cost-benefit analysis for proposed service sector measures in the period up to 2030 and between 2031 and 2050 are presented inTable III.25:.

Table III.24: HOUSEHOLD SECTOR – results of completed financial and economic cost-benefit analysis up to 2030, and in 2031–2050

HOUSEHOLD SECTOR – results of the cost-benefit analysis – financial and economic NPV					**up to 2030**		**2031–2050**	
Measure code	Purpose	Title of measure	Existing technology	Replacement technology	FNPV [HRK/MWh]	ENPV [HRK/MWh]	FNPV [HRK/MWh]	ENPV [HRK/MWh]
H_TB_1	space heating	Replacement of individual firewood stoves with central firewood boilers	individual firewood stoves	firewood boilers	-161.25	-140.03	n/a	n/a
H_TB_2	space heating	Replacement of central firewood boilers with central modern biomass boilers	firewood boilers	modern biomass boilers	-1,116.64	-1,419.89	-911.74	-1,876.07
H_TB_3	space heating	Replacement of traditional biomass boilers with heat pumps	firewood boilers	heat pumps	n/a	n/a	-294.92	-712.32
H_TB_4	space heating	Solar heating combined with heat pumps after H_TB_3 measure is implemented	firewood boilers	solar collectors	n/a	n/a	-374.41	-191.65
H_ELLU1	space heating	Replacement of central fuel oil boilers with central modern biomass boilers	fuel oil boilers	modern biomass boilers	969.34	1 756.45	n/a	n/a
H_ELLU2	space heating	Replacement of central fuel oil boilers with heat pumps	fuel oil boilers	heat pumps	1 848.30	2 811.10	n/a	n/a
H_ELLU3	space heating	Solar heating combined with heat pumps after ELLU2 measure is implemented	fuel oil boilers	solar collectors	1 307.22	2 704.65	n/a	n/a
H_UNP1	space heating	Replacement of central LPG boilers with central modern biomass boilers	LPG boilers	modern biomass boilers	1 433.03	2 263.41	1 978.13	4 917.49
H_UNP2	space heating	Replacement of central LPG boilers with heat pumps	LPG boilers	heat pumps	2 366.92	3 383.97	2 696.34	6 272.55
H_UNP3	space heating	Solar heating combined with heat pumps after UNP2 measure is implemented	LPG boilers	solar collectors	1 792.03	3 270.87	2 603.86	6 878.93
H_PP1	space heating	Replacement of standard natural gas boilers with condensing natural gas boilers	natural gas boilers	condensing natural gas boilers	376.40	531.59	385.88	930.34
H_PP2	space heating	Natural gas micro-CHP	natural gas boilers	natural gas micro-CHP	-839.27	-598.30	-201.21	123.25
H_PP3	space heating	Solar heating combined with a condensing boiler after PP1 measure is implemented	natural gas boilers	solar collectors	22.35	971.04	348.48	2 146.08
H_PP4	space heating	Replacement of natural gas boilers with heat pumps	natural gas boilers	heat pumps	604.11	1 085.57	442.12	1 532.69

HOUSEHOLD SECTOR – results of the cost-benefit analysis – financial and economic NPV					**up to 2030**		**2031–2050**	
Measure code	Purpose	Title of measure	Existing technology	Replacement technology	FNPV [HRK/MWh]	ENPV [HRK/MWh]	FNPV [HRK/MWh]	ENPV [HRK/MWh]
H_PP_5	space heating	Replacement of natural gas boilers with modern biomass boilers	natural gas boilers	modern biomass boilers	n/a	n/a	-284.54	161.69
H_EE_1	space heating	Increase in the share of heat pumps vs. electric resistance heating -– heat pump installation	electric resistance heating	heat pumps	-67.47	342.82	1 776.66	4 303.53
H_TB_2_a	DHW preparation	Replacement of traditional biomass boilers with modern biomass boilers	firewood boilers	modern biomass boilers	-500.91	-628.34	-583.34	-1,177.72
H_TB_4_a	DHW preparation	Installation of solar collectors for DHW preparation	firewood boilers	heat pumps	n/a	n/a	219.64	630.74
H_TB_3_a	DHW preparation	Installation of heat pumps for DHW preparation	firewood boilers	solar collectors	n/a	n/a	-372.52	-821.77
H_ELLU1_a	DHW preparation	Replacement of fuel oil boilers with modern biomass boilers	fuel oil boilers	modern biomass boilers	1 130.27	1 965.71	n/a	n/a
H_ELLU2_a	DHW preparation	Replacement of fuel oil boilers with heat pumps	fuel oil boilers	heat pumps	1 463.78	2 339.31	n/a	n/a
H_ELLU3_a	DHW preparation	Installation of solar collectors for DHW preparation	fuel oil boilers	solar collectors	669.57	1 952.60	n/a	n/a
H_UNP1_a	DHW preparation	Replacement of LPG boilers with modern biomass boilers	LPG boilers	modern biomass boilers	1 738.06	2 643.97	2 215.95	5 394.85
H_UNP2_a	DHW preparation	Replacement of LPG boilers with heat pumps	LPG boilers	heat pumps	2 116.04	3 067.38	2 500.39	5 875.10
H_UNP3_a	DHW preparation	Installation of solar collectors for DHW preparation	LPG boilers	solar collectors	1 215.93	2 629.11	2 162.04	6 080.82
H_PP1_a	DHW preparation	Replacement of standard boilers with condensing boilers	natural gas boilers	condensing natural gas boilers	265.28	407.60	n/a	n/a
H_PP2_a	DHW preparation	Natural gas micro-CHP	natural gas boilers	natural gas micro-CHP	688.67	968.36	904.96	1 955.06
H_PP3_a	DHW preparation	Installation of solar collectors for DHW preparation	natural gas boilers	solar collectors	-565.67	318.10	-102.29	1 334.28
H_PP4_a	DHW preparation	Replacement of natural gas boilers with heat pumps	natural gas boilers	heat pumps	345.03	761.52	240.04	1 126.15

HOUSEHOLD SECTOR – results of the cost-benefit analysis – financial and economic NPV					**up to 2030**		**2031–2050**	
Measure code	Purpose	Title of measure	Existing technology	Replacement technology	FNPV [HRK/MWh]	ENPV [HRK/MWh]	FNPV [HRK/MWh]	ENPV [HRK/MWh]
H_PP_5_a	DHW preparation	Replacement of natural gas boilers with modern biomass boilers	natural gas boilers	modern biomass boilers	n/a	n/a	-2.71	734.36
H_EE_1_a	DHW preparation	Installation of heat pumps for DHW preparation	electric boilers	heat pumps	n/a	n/a	1 606.06	3 680.50
H_EE_2_a	DHW preparation	Replacement of electric boilers with solar collectors	electric boilers	solar collectors	1 966.66	3 566.42	n/a	n/a
H_EE_1_b	space cooling	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	split AC units	central chiller	209.85	351.53	79.25	266.11

Table III.25: SERVICE SECTOR – results of completed financial and economic cost-benefit analysis up to 2030, and in 2031–2050

SERVICE SECTOR – results of the cost-benefit analysis – financial and economic NPV					**up to 2030**		**2031–2050**	
Measure code	Purpose	Title of measure	Existing technology	Replacement technology	FNPV [HRK/MWh]	ENPV [HRK/MWh]	FNPV [HRK/MWh]	ENPV [HRK/MWh]
S_ELLU1	space heating	Replacement of fuel oil boilers with modern biomass boilers	fuel oil boilers	modern biomass boilers	776.73	1 515.37	n/a	n/a
S_ELLU2	space heating	Replacement of fuel oil boilers with heat pumps	fuel oil boilers	heat pumps	1 783.83	2 730.03	n/a	n/a
S_ELLU3	space heating	Solar heating combined with heat pumps after ELLU2 measure is implemented	fuel oil boilers	solar collectors	1 114.61	2 463.57	n/a	n/a
S_UNP1	space heating	Replacement of LPG boilers with modern biomass boilers	LPG boilers	modern biomass boilers	1 433.03	2 263.41	n/a	n/a
S_UNP2	space heating	Replacement of LPG boilers with heat pumps	LPG boilers	heat pumps	2 503.08	3 553.99	n/a	n/a
S_UNP3	space heating	Solar heating combined with heat pumps after UNP2 measure is implemented	LPG boilers	solar collectors	1 792.03	3 270.87	n/a	n/a
S_PP1	space heating	Replacement of standard boilers with condensing boilers	natural gas boilers	natural gas boilers	366.22	518.88	374.39	907.24
S_PP2	space heating	Natural gas micro-CHP	natural gas boilers	natural gas micro-CHP	-999.79	-798.75	-323.14	-117.98

SERVICE SECTOR – results of the cost-benefit analysis – financial and economic NPV					up to 2030		2031–2050	
Measure code	Purpose	Title of measure	Existing technology	Replacement technology	FNPV [HRK/MWh]	ENPV [HRK/MWh]	FNPV [HRK/MWh]	ENPV [HRK/MWh]
S_PP3	space heating	Solar heating combined with a condensing boiler after PP1 measure is implemented	natural gas boilers	solar collectors	-33.80	900.91	292.17	2 032.82
S_PP4	space heating	Replacement of natural gas boilers with heat pumps	natural gas boilers	heat pumps	685.61	1 187.36	669.32	2 002.31
S_PP5	space heating	Replacement of natural gas boilers with modern biomass boilers	natural gas boilers	Modern biomass boilers	n/a	n/a	-274.23	183.17
S_PP6	space heating	Connecting user to DHS	natural gas boilers	Heating substation within the building	n/a	n/a	810.06	1 129.51
S_EE_1	space heating	Increase in the share of heat pumps vs. electric resistance heating	heat pumps	heat pumps	317.98	542.21	1 347.49	3 018.53
S_ELLU1_a	DHW preparation	Replacement of fuel oil boilers with modern biomass boilers	fuel oil boilers	modern biomass boilers	850.25	1 613.04	n/a	n/a
S_ELLU2_a	DHW preparation	Replacement of fuel oil boilers with heat pumps	fuel oil boilers	heat pumps	1 334.14	2 171.55	n/a	n/a
S_ELLU3_a	DHW preparation	Installation of solar collectors for water heating	fuel oil boilers	solar collectors	358.83	1 599.06	n/a	n/a
S_UNP1_a	DHW preparation	Replacement of LPG boilers with modern biomass boilers	LPG boilers	modern biomass boilers	1 738.06	2 643.97	n/a	n/a
S_UNP2_a	DHW preparation	Replacement of LPG boilers with heat pumps	LPG boilers	heat pumps	2 252.20	3 237.39	n/a	n/a
S_UNP3_a	DHW preparation	Installation of solar collectors for water heating	LPG boilers	solar collectors	1 215.93	2 629.11	n/a	n/a
S_PP1_a	DHW preparation	Replacement of standard boilers with condensing boilers	natural gas boilers	natural gas boilers	255.10	394.89	278.43	733.62
S_PP2_a	DHW preparation	Natural gas micro-CHP	natural gas boilers	natural gas micro-CHP	509.64	737.34	747.18	1 652.82
S_PP3_a	DHW preparation	Solar heating combined with a condensing boiler after PP1 measure is implemented	natural gas boilers	solar collectors	-621.93	247.87	-143.26	1 244.95

SERVICE SECTOR – results of the cost-benefit analysis – financial and economic NPV					up to 2030		2031–2050	
Measure code	Purpose	Title of measure	Existing technology	Replacement technology	FNPV [HRK/MWh]	ENPV [HRK/MWh]	FNPV [HRK/MWh]	ENPV [HRK/MWh]
S_PP4_a	DHW preparation	Replacement of natural gas boilers with heat pumps	natural gas boilers	heat pumps	n/a	n/a	439.65	1 550.04
S_PP5_a	DHW preparation	Replacement of natural gas boilers with modern biomass boilers	natural gas boilers	modern biomass boilers	n/a	n/a	-59.10	620.98
S_EE_1_a	DHW preparation	Replacement of electric boilers with solar collectors	electric boilers	solar collectors	1 406.03	2 866.37	2 252.73	6 222.58
S_EE_2_a	DHW preparation	Increase in the share of heat pumps vs. electric resistance warming	heat pumps	heat pumps	1 122.00	1 549.35	2 256.90	5 049.36
S_EE_1_b	space cooling	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	heat pumps	heat pumps	725.75	1 022.40	917.26	2 089.04

HOUSEHOLD SECTOR – Analysis of the results of cost-benefit analysis

Firewood is largely in use in households as drive energy product either in individual room stoves or in central firewood boilers.

Based on the cost-benefit analysis, the **measure of replacing individual firewood stoves** with central firewood boilers up to 2030 proved not to be cost-effective (FNPV > 0 and ENPV > 0).

Furthermore, the **measure involving the replacement of central firewood boilers** with central modern biomass boilers for space heating and DHW preparation also proved not be cost-effective (FNPV > 0 and ENPV > 0) given that the cost of modern biomass is higher than the cost of firewood. Moreover, modern biomass has a somewhat higher CO_2 emissions factor than firewood.

The measure involving central firewood boiler replacement with heat pumps also proved not to be cost-effective (FNPV > 0 and ENPV > 0).

Under the proposed measures in the household sector, **a complete cessation of fuel oil use** as a drive energy product for space heating and DHW preparation is foreseen by 2030. The measures propose the replacement of existing fuel oil-fired sources of heat with modern biomass boilers and heat pumps, and installation of solar collectors notably for the purpose of DHW preparation. All proposed measures of replacing fuel oil-fired sources of thermal energy for space heating and DHW preparation are cost-effective without support (FNPV > 0 and ENPV > 0). The result is expected given that fuel oil is an environmentally unacceptable energy product with a high CO_2 emissions factor (299.57 tonnes of CO_2/GWh) compared to modern biomass or electricity. Furthermore, the price per unit of fuel oil is considerably higher than modern biomass price. Where heat pumps are used, the decisive element is, naturally, the fact that heat pump efficiency (SPF) is considerably higher than that of fuel oil-fired thermal energy sources.

Measures in the household sector envisage a gradual **replacement of liquefied petroleum gas (LPG) sources of heat** for space heating and DHW preparation in the period up to 2030 and between 2031 and 2050. The measures propose the replacement of existing LPG-fuelled sources of heat with modern biomass boilers and heat pumps, as well as the installation of solar collectors notably for the purpose of DHW preparation. All proposed measures of replacing LPG-fuelled thermal energy sources for space heating and DHW preparation are cost-effective without support (FNPV > 0 and ENPV > 0). The price per unit of LPG is higher than the fuel oil price per unit, so FNPV and ENPV amounts for the same proposed technologies (modern biomass boilers, heat pumps) are higher when replacing LPG-fuelled sources of heat than when fuel oil is replaced.

A series of measures has been proposed to **replace natural gas-fuelled sources of heat** (individual and central) for space heating and DHW preparation in the household sector in the period up to 2030 and between 2031 and 2050: condensing natural gas boilers, natural gas micro-CHP, heat pumps and modern biomass boilers, as well as the installation of solar collectors notably for DHW preparation. The measure involving solar collector installation for DHW preparation is cost-effective with public support (FNPV < 0 and ENPV > 0) in both periods under observation. The measure involving the replacement of existing standard natural gas boilers with condensing natural gas boilers is cost-effective (FNPV < 0 and ENPV > 0) without support in the period up to 2030, where a portion of outdated boilers with substantially more cost-effective condensing boilers (but their cost-effectiveness depends largely on the temperature regime, that is, on the flow/return water temperature in the heating system; however, it is important to renovate the building's external envelope, in turn providing for a lower temperature regime). In addition to condensing natural gas boilers, it is also important to install solar collectors for DHW preparation to at least partially increase the use of renewable energy sources.

The measure involving natural gas boiler replacement with natural gas micro-CHP for space heating is cost-effective with public support (FNPV < 0 and ENPV > 0) between 2031 and 2050. The measure is not cost-effective in the preceding, shorter period up to 2030. The economic NPV is positive because of an additional contribution of electricity generation in micro CHP, in parallel with required heat generation.

The replacement of natural gas boilers with heat pumps for space heating and DHW preparation is cost-effective (FNPV < 0 and ENPV > 0) in both periods under observation. The decisive element here is a considerably higher efficiency if heat pumps (which, similar to condensing boilers, are a low-temperature heat source, more efficient in lower temperature regimes or at lower flow/return water temperatures within the heating system) are used.

Between 2031 and 2050, a portion of natural gas boilers is to be replaced by modern biomass boilers. The cost-benefit analysis has proven the measure to be cost-effective with support (FNPV < 0 and ENPV > 0). Modern biomass (wood pellets and wood chips) is considered a renewable energy source, with a low CO_2 emissions factor and low primary energy factor compared to natural gas. However, the forecast price of modern biomass is higher than natural gas price, so the measure is not financially justified and requires public support to achieve the benefits mentioned above (the measure is to achieve primary energy and CO_2 emission savings, increase the share of renewable energy sources, while also increasing the costs of drive energy product).

The **replacement of direct electric resistance space heating** with compression heat pumps in the household sector is definitely cost-effective (FNPV < 0 and ENPV > 0) with support in the period up to 2030; however, the measure is cost-effective without support between 2031 and 2050 in view of a considerably higher efficiency (SPF) of heat pumps compared to electric resistance space heating.

And finally, where household DHW preparation is concerned, it is important to prepare domestic hot water efficiently, avoiding direct DHW heating in electric boilers. The cost-benefit analysis demonstrated the cost-effectiveness of the measure involving electric DHW preparation boiler replacement with heat pumps and solar collectors.

SERVICE SECTOR – Analysis of the results of cost-benefit analysis

As in the household sector, **a complete cessation of fuel oil use** as a drive energy product for space heating and DHW preparation is foreseen in the service sector by 2030 under the proposed measures. The measures propose the replacement of existing fuel oil-fired sources of heat with modern biomass boilers and heat pumps, and the installation of solar collectors notably for the purpose of DHW preparation (in service sector buildings where technically feasible and justified). All proposed measures of replacing fuel oil-fired sources of thermal energy for space heating and DHW preparation are cost-effective without support (FNPV > 0 and ENPV > 0). The result is expected given that fuel oil is an environmentally unacceptable energy product with a high CO_2 emissions factor (299.57 tonnes of CO_2/GWh) compared to modern biomass or electricity. Furthermore, the price per unit of fuel oil is considerably higher than modern biomass price. Where heat pumps are used, the decisive element is, naturally, the fact that heat pump efficiency (SPF) is considerably higher than that of fuel oil-fired thermal energy sources.

Under the proposed measures in service sector, **a complete cessation of fuel oil use** as a drive energy product for space heating and DHW preparation is foreseen by 2030. The measures propose the replacement of existing LPG-fuelled boilers as sources of heat with modern biomass boilers and heat pumps, and installation of solar collectors notably for DHW preparation (in service sector buildings where technically feasible and justified). All proposed measures of replacing LPG-fuelled thermal energy sources for space heating and DHW preparation are also cost-effective in the service sector without support (FNPV > 0 and ENPV > 0). The price per unit of LPG is higher than the fuel oil price per unit, so FNPV and ENPV amounts for the same proposed technologies (modern biomass boilers, heat pumps) are higher when replacing LPG-fuelled sources of heat than when fuel oil is replaced.

A series of measures has been proposed to **replace natural gas-fuelled sources of heat** for central space heating and DHW preparation in the sector in the period up to 2030 and between 2031 and

2050: condensing natural gas boilers, natural gas micro-CHP, heat pumps and modern biomass boilers, as well as the installation of solar collectors notably for DHW preparation.

The measure involving solar collector installation for DHW preparation is cost-effective with public support (FNPV < 0 and ENPV > 0) in both periods under observation.

The measure involving the replacement of standard natural gas boiler with condensing natural gas boilers for space heating and DHW preparation is cost-effective (FNPV < 0 and ENPV > 0) without support in both periods under observation. In addition to condensing natural gas boilers, it is also important to install solar collectors for DHW preparation (as a cost-effective measure with support) to at least partially increase the use of renewable energy sources.

The measure involving natural gas boiler replacement with natural gas micro-CHP for space heating in the service sector is not cost-effective with public support (FNPV < 0 and ENPV < 0) in both periods under observation.

The replacement of natural gas boilers with heat pumps for space heating and DHW preparation in the service sector is cost-effective (FNPV > 0 and ENPV > 0) in both periods under observation. The decisive element here is a considerably higher efficiency if heat pumps (which, similar to condensing boilers, are a low-temperature heat source, more efficient in lower temperature regimes or at lower flow/return water temperatures within the heating system) are used.

Between 2031 and 2050, a portion of natural gas boilers is to be replaced by modern biomass boilers in the service sector. The cost-benefit analysis has proven the measure to be cost-effective with support (FNPV < 0 and ENPV > 0). Modern biomass (wood pellets and wood chips) is considered a renewable energy source, with a low CO_2 emissions factor and low primary energy factor compared to natural gas. However, the forecast price of modern biomass is higher than natural gas price, so the measure is not financially justified and requires public support to achieve the benefits mentioned above (the measure is to achieve primary energy and CO_2 emission savings, increase the share of renewable energy sources, while also increasing the costs of drive energy product).

The replacement of natural gas boilers and connection of service sector customers to the district heating system wherever possible is a cost-effective measure without support.

The **replacement of direct electric resistance space heating** in the service sector with heat pumps is a cost-effective measure without support (FNPV > 0 and ENPV > 0) in both periods under observation periods in view of a considerably higher efficiency (SPF) of heat pumps compared to electric resistance space heating.

Similarly to the household sector, it is important to prepare domestic hot water efficiently in the service sector too, avoiding direct DHW heating in electric boilers. The cost-benefit analysis demonstrated the cost-effectiveness of the measure involving electric DHW preparation boiler replacement with heat pumps and solar collectors (in service sector buildings where technically feasible and justified).

8.1.3.2 DHS

When it comes to district heating systems, financial and economic NPV is calculated for total demand, irrespective of the sector (household sector, service sector, industrial sector) because the outcomes of the measure will affect overall demand as a whole.

The first measure, which must be implemented even though it has not been cost-benefit analysed, is increased efficiency and expansion of the distribution network of existing district heating systems in densely populated urban areas, that is, heat loss reduction in the existing distribution network and its expansion. It is planned to be implemented by 2030 at a total investment of HRK 1 650 000 000.00. The proposed measure would achieve savings of 68 590.66 tonnes of CO_2 and 334.53 GWh in primary energy savings.

Generation installations at existing district heating systems are to be modernised gradually in the period up to 2030 and between 2031 and 2050.

Figure III.9: shows investment (CAPEX) in the period of measure implementation, annual maintenance costs (OPEX) and annual costs of drive energy products for all technologies of individual systems within the DHS sector for two scenarios (BAU or baseline scenario, and SIM or alternative scenario) and the two periods under observation (up to 2030, and 2030–2050).

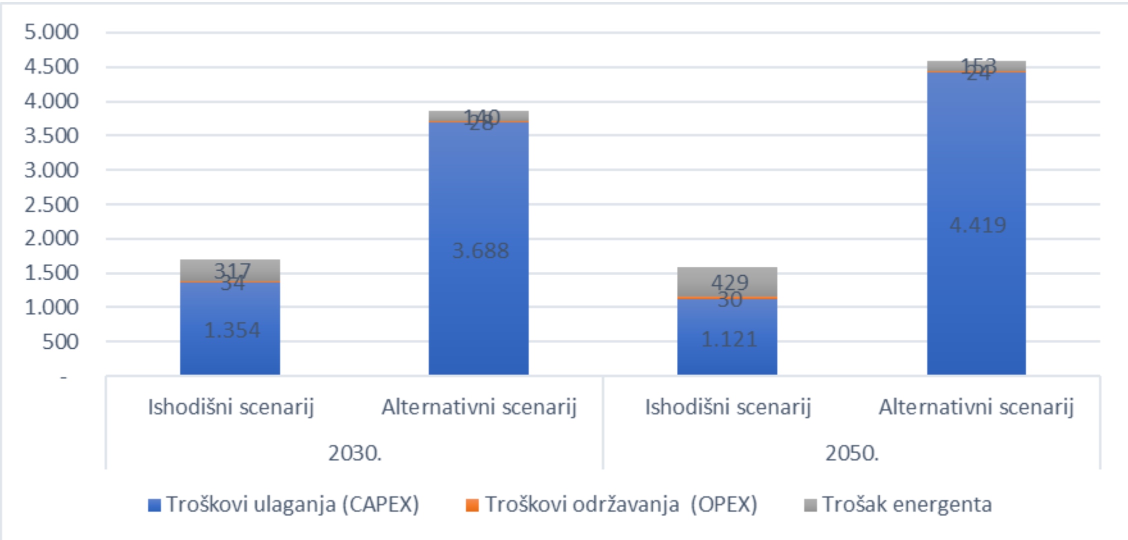


Figure III.9: DHS – 2030 and 2050 cost distribution, in mil. HRK

CROATIAN	ENGLISH
Ishodišni scenarij	Baseline scenario
Alternativni scenarij	Alternative scenario
Troškovi ulaganja (CAPEX)	Investment costs (CAPEX)
Troškovi održavanja (OPEX)	Maintenance costs (OPEX)
Trošak energenta	Cost of energy product

The results of completed financial and economic cost-benefit analysis for a total of 11 proposed measures relating to DHS generation installations in the period up to 2030, and between 2031 and 2050 are presented in Table III.26:.

Given that the measures are to be implemented over two periods (a shorter period up to 2030 and a longer one, between 2031 and 2050), some measures turned out not to be cost-effective in the shorter observation period (FNPV < 0 and ENPV < 0), while in the longer observation period the same measures proved cost-effective when supported (FNPV < 0 and ENPV > 0) or even without the necessary support (FNPV > 0 and ENPV > 0).

Table III.26: DHS – results of completed financial and economic cost-benefit analysis up to 2030, and in 2031–2050

DHS – results of the cost-benefit analysis – financial and economic NPV				**up to 2030**		**2031–2050**	
Number of measure	Title of measure	Existing technology	Replacement technology	**FNPV [HRK/GWh]**	**ENPV [HRK/GWh]**	**FNPV [HRK/GWh]**	**ENPV [HRK/GWh]**
01	Replacement of fuel oil boilers with biomass boilers	fuel oil boilers	Biomass boilers	956.89	1 817.17	n/a	n/a
02	Replacement of fuel oil boilers with water-to-water heat pumps	fuel oil boilers	heat pumps	831.44	1 655.72	n/a	n/a
03	Replacement of natural gas cogeneration with natural gas high-efficiency cogeneration	natural gas cogeneration	natural gas high-efficiency cogeneration	-2 675.91	-1 580.62	154.14	1 707.28
04	Replacement of natural gas boilers with water-to-water compression heat pumps	natural gas boilers	heat pumps	27.82	504.51	582.19	2 256.78
05	Replacement of natural gas boilers with natural gas high-efficiency cogeneration	natural gas boilers	Natural gas high-efficiency cogeneration	n/a	n/a	728.95	3 949.12
06	replacement of natural gas boilers – industrial waste heat utilisation	natural gas boilers	industrial waste heat	-5 362.01	-6 654.38	-172.22	1 516.99
07	Replacement of natural gas boilers – waste heat utilisation	natural gas boilers	waste heat	-2 762.25	-3 205.81	605.12	2 695.00
08	Replacement of natural gas boilers – solar energy harnessing	natural gas boilers	solar energy	-2 298.84	-2 591.02	733.71	2 884.83
09	Replacement of natural gas boilers with high-efficiency biomass cogeneration	natural gas boilers	Biomass high-efficiency cogeneration	-5 125.54	-6 326.39	1 788.97	5 629.86
10	Replacement of natural gas boilers with biomass boilers	natural gas boilers	Biomass boilers	n/a	n/a	1 215.71	3 495.39
11	Replacement of natural gas boilers – geothermal energy exploitation	natural gas boilers	geothermal energy	-7 890.91	-10 009.02	-920.14	387.72

The replacement of natural gas boilers poses the greatest challenge given that 72.78% of the total energy delivered in 2019 was produced in natural gas boilers. The proposed **measures to replace natural gas boilers** are as follows: water-to-water heat pumps, high-efficiency natural gas cogeneration, industrial waste heat utilisation, energy-from-waste, solar energy harnessing, high-efficiency biomass cogeneration, biomass boilers and geothermal energy exploitation.

The measure of replacing natural gas boilers with water-to-water compression heat pumps is cost-effective (FNPV > 0 and ENPV > 0) without support in both periods under observation, which is in fact fitting given the high efficiency of water-to-water heat pumps (SPF) compared to natural gas boilers.

The replacement of natural gas boilers with high-efficiency natural gas cogeneration is proposed as another cost effective measure (FNPV > 0 and ENPV > 0) for the period between 2031 and 2050 in view of the efficient use of natural gas as the driving energy product, whose input leads to greater output (simultaneous generation of electricity and thermal energy) compared to natural gas boilers.

Geothermal energy exploitation as an alternative to using natural gas boilers is a cost-effective measure only when supported (FNPV < 0 and ENPV > 0) due to the extremely high investment costs. The same is true for industrial waste heat utilisation.

Energy-from-waste, solar energy utilisation, high-efficiency biomass cogeneration and biomass boilers are all cost-effective measures with no need for public support (FNPV > 0 and ENPV > 0) aimed at replacing existing natural gas boilers between 2031 and 2050. Biomass (wood chips) is considered a renewable energy source, with a low CO_2 emissions factor and low primary energy factor compared to natural gas.

The **measure of natural gas cogeneration replacement** with high-efficiency natural gas cogeneration is also cost-effective with no need for public support (FNPV > 0 and ENPV > 0) in the 2031–2050 period under observation. In the observation period up to 2030, due to its shortness, the cost-benefit analysis found this measure not to be cost-effective (FNPV < 0 and ENPV < 0).

It is important to note that both proposed measures (biomass boilers and heat pumps), which are aimed at replacing **fuel oil boilers**, are cost-effective without support (FNPV > 0 and ENPV > 0). Biomass is a renewable energy source with a low CO_2 emissions factor and a low primary energy factor, while heat pumps operate by extracting a certain amount of heat from the environment, which is considered a renewable energy source, and by using electrical energy to bring the heat taken from the environment to a higher temperature level.

8.2 SENSITIVITY ANALYSIS

The results of the economic analysis presented above in respect of different heating and cooling alternatives depend on changes in the parameters covered by the analysis, in particular on developments in the prices of energy products and CO_2 emissions. Therefore, in order to ensure that the analysis of potential is complete, it is also necessary to conduct a sensitivity analysis to identify the parameters whose variations have a significant impact on the cost-effectiveness of a measure, and thus also on the NPV amount. The sensitivity analysis is aimed at examining uncertainty or a range of the outcomes. To this end, the impact of possible changes in technical and economic assumptions is investigated and the effect of such changes on the results of the cost-benefit analysis is examined from a microeconomic and macroeconomic perspective. These are usually increases/decreases in the unit cost of technologies, increases in energy product prices, variations in CO_2 prices, changes in discount rates, etc. The results of the analysis serve for estimating the absolute change in NPV in an individual scenario caused by a change to a certain parameter and also to assess the extent of any changes in the relationships (relative advantages) between alternative scenarios.

The results of the sensitivity analysis in respect of a change in individual critical variables are presented below.

The sensitivity analysis was conducted separately to obtain results for the measures up to 2030, and separately for the measures in the 2031–2050 period.

The following parameters were varied in the sensitivity analysis:

- investment costs (CAPEX),+-20%,
- higher price of electricity and energy products (TableIII.22:),
- higher price of CO_2 emissions (TableIII.22:), and
- discount rate (10% financial discount rate and 4% economic discount rate).

A total of seven calculations is performed. Of the above parameters, variations in CO_2 prices and changes in the social discount rate have an impact on the outcome of the economic analysis. The remaining parameters primarily affect the outcome of the financial analysis.

An increase in investment costs for all the technologies included in the alternative scenario is presumed. The assumption of a decrease in investment costs makes sense only in relation to renewable technologies and industrial waste heat as further research and economies of scale may be presumed for those technologies.

Higher energy product prices and CO_2 emissions are presumed to be possible.

Results of the conducted analysis are shown below for individual systems and DHSs. The results of individual calculations are presented in their entirety in the Annex (Table 0.30 – Table 0.36).

The proposed measures for households show no major sensitivity to an increase in investment costs, so a 20% increase in costs does not affect the final outcome in respect of the cost-effectiveness of the measure (no new negative NPVs). In services, however, certain measures are sensitive to changes in investment costs, specifically: solar heating combined with a condensing boiler after the PP1 measure is implemented (2031–2050) and the installation of solar collectors for DHW preparation (up to 2030). In the case of DHS, only the implementation of the measure for replacing natural gas cogeneration with natural gas HEC shows a more significant response to changes in investment costs.

Reducing the investment value would lead to a shift in the results for several measures in the household sector, such as natural gas micro-CHP, the installation of solar collectors for DHW preparation and replacement of natural gas boilers with modern biomass between 2031 and 2050, and for the measure involving an increase in the share of heat pumps vs. electric resistance heating, such as the installation of heat pumps by 2030. In the service sector, the same would be true in respect of the outcome of the measure involving solar heating combined with a condensing boiler after the PP1 measure is implemented for heating up to 2030, and for DHW between 2031 and 2050. With regard to DHS, there is no significant impact where the measure’s cost-effectiveness is concerned: the most sensitive measure is the replacement of natural gas cogeneration with natural gas HEC between 2031 and 2050.

Increases in energy product prices most frequently affected NPV growth under respective measures, indicating that the prices of fossil fuels increased more under the BAU scenario than under alternative scenarios in the same period. The measure involving the replacement of natural gas boilers with modern biomass proved to be the most sensitive to changes in the prices of energy products for households and services.

An increase in emissions prices has the effect of actually increasing the monetised benefits of reducing CO_2 emissions. For households, the use of measures involving natural gas micro-CHP and the installation of solar collectors for DHW preparation becomes economically justified when higher emissions price are applied. For services, such measures are those involving the replacement of natural gas boilers with modern biomass boilers and solar heating combined with a condensing boiler after the PP1 measure is implemented, and for DHSs, those involving the replacement of natural gas boilers with water-to-water compression heat pumps.

The measure for the replacement of natural gas boilers with modern biomass boilers (in the period up to 2050) proved to be the most sensitive to changes in the discount rate for households and services. Increasing the discount rate to 7% did not affect the cost-effectiveness of the measures. For households, reducing the financial discount rate to 3% leads to the cost-effectiveness of the measure involving the installation of solar collectors for DHW preparation; when it comes to services, it is the measure involving solar heating combined with a condensing boiler after the PP1 measure is implemented for both heating and DHW preparation.

By reducing the financial discount rate to 3% in the case of DHSs, three measures become financially viable with no need for support: the replacement of natural gas cogeneration with high-efficiency natural gas cogeneration, as well as the replacement of natural gas boilers with high-efficiency natural gas cogeneration, and industrial waste heat utilisation.

Increasing the economic discount rate to 4% reduces the economic outcome of the measures in most cases, except where the cost of CO_2 emissions is higher exceptionally under the BAU scenario than under the alternative scenario (e.g. replacement of central firewood boilers with central modern biomass boilers). Neither in individual systems nor in DHSs does an increase in the economic discount rate affect the outcome in terms of changes in the economic viability of the measures.

8.3 DISCUSSION AND CONCLUSION

The aim of this Comprehensive Assessment, which needs to be prepared regularly every five years under Article 14 of Directive 2012/27/EU, has been to determine the economic potential for covering heating/cooling needs in household, service and industrial sectors in an energy-efficient manner, primarily by using as many renewable energy sources as possible and waste heat. The content of the Comprehensive Assessment is laid down in Annex VIII to Directive 2012/27/EU. The net present value method was used as part of the cost-benefit analysis for assessing the cost-effectiveness of the investment under the proposed measures. The main outcome of the cost-benefit analysis consists in the most cost-efficient solutions for meeting heating and cooling needs.

A reduction of CO_2 emissions, use of energy from renewable energy sources, energy efficiency, and energy interconnection were also among the objectives considered in the Integrated National Energy and Climate Plan for the Republic of Croatia for 2021–2030. Among other things, that document sets Croatia's objectives and targets for 2030 in terms of reducing greenhouse gas emissions and increasing the share of renewable energy sources in final energy consumption (industry, transport, general consumption (households, services, agriculture, construction)).

The ultimate goal is to achieve climate neutrality in Croatia by 2050. While the share of fossil fuels in 2030 will still be considerable, the use of fossil fuels for heating/cooling purposes should be kept to a minimum by 2050.

Figure III.10: and Figure III.11: provide an overview of the energy products to cover space heating/cooling needs and DHW preparation in the three observed sectors (household, services, industry) for the following two scenarios: BAU (reference, baseline scenario) scenario and SIM scenario (scenario with integrated measures) for 2019–2050.

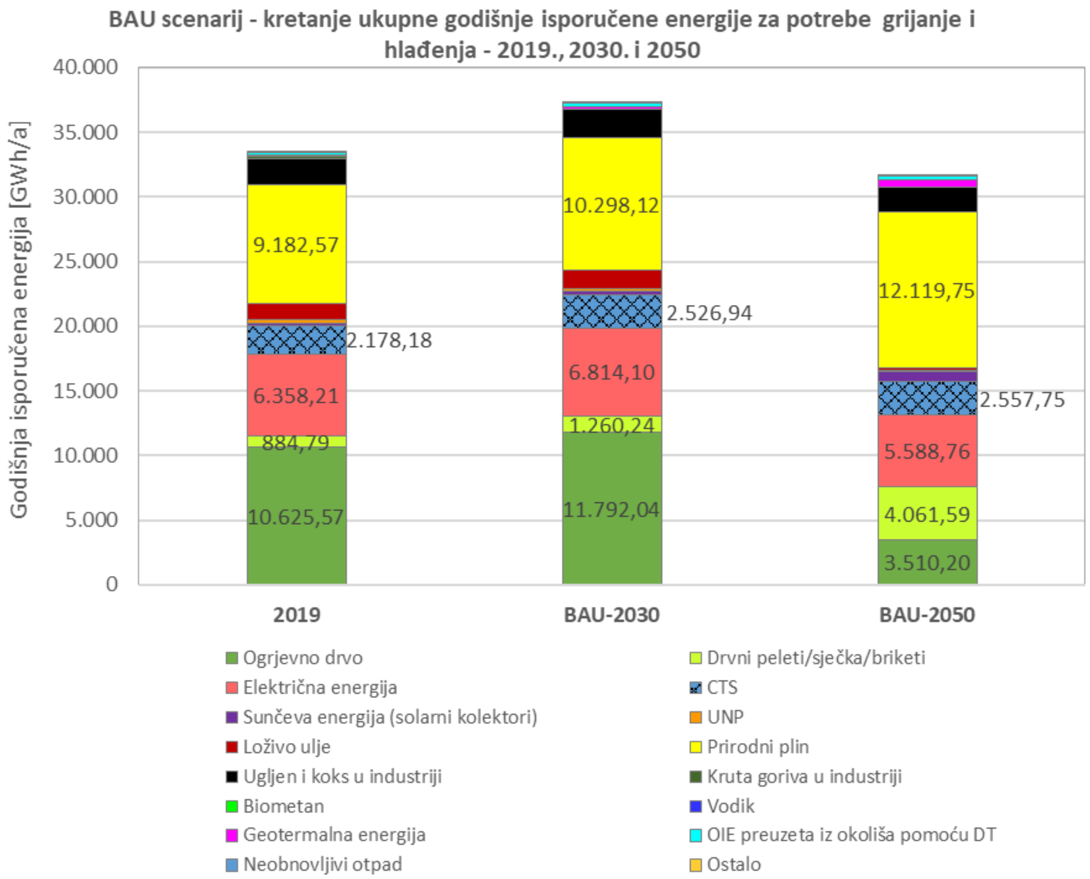


Figure III.10: HOUSEHOLD, SERVICE AND INDUSTRIAL SECTOR – BAU scenario – overview of energy products to cover space heating/cooling needs and DHW preparation – 2019–2050

CROATIAN	ENGLISH
BAU scenarij - kretanje ukupne godišnje isporučene energije za potrebe grijanje i hlađenja - 2019., 2030. i 2050	BAU scenario – developments in total annual energy delivered for heating and cooling – 2019, 2030 and 2050
Godišnja isporučena energija [GWh/a]	Annual energy delivered [GWh/a]
BAU-2030	BAU – 2030
BAU-2050	BAU – 2050
Ogrjevno drvo	Firewood
Električna energija	Electricity
Sunčeva energija (solarni kolektori)	Solar energy (solar collectors)
Loživo ulje	Fuel oil
Ugljen i koks u industriji	Coal and coke in industry
Biometan	Biomethane
Geotermalna energija	Geothermal energy
Neobnovljivi otpad	Non-renewable waste
Drvni peleti/sječka/briketi	Wood pellets / wood chips / briquettes
CTS	DHS
UNP	LPG
Prirodni plin	Natural gas
Kruta goriva u industriji	Solid fuels in industry
Vodik	Hydrogen
OIE preuzeta iz okoliša pomoću DT	RES taken from the environment using heat pumps
Ostalo	Other

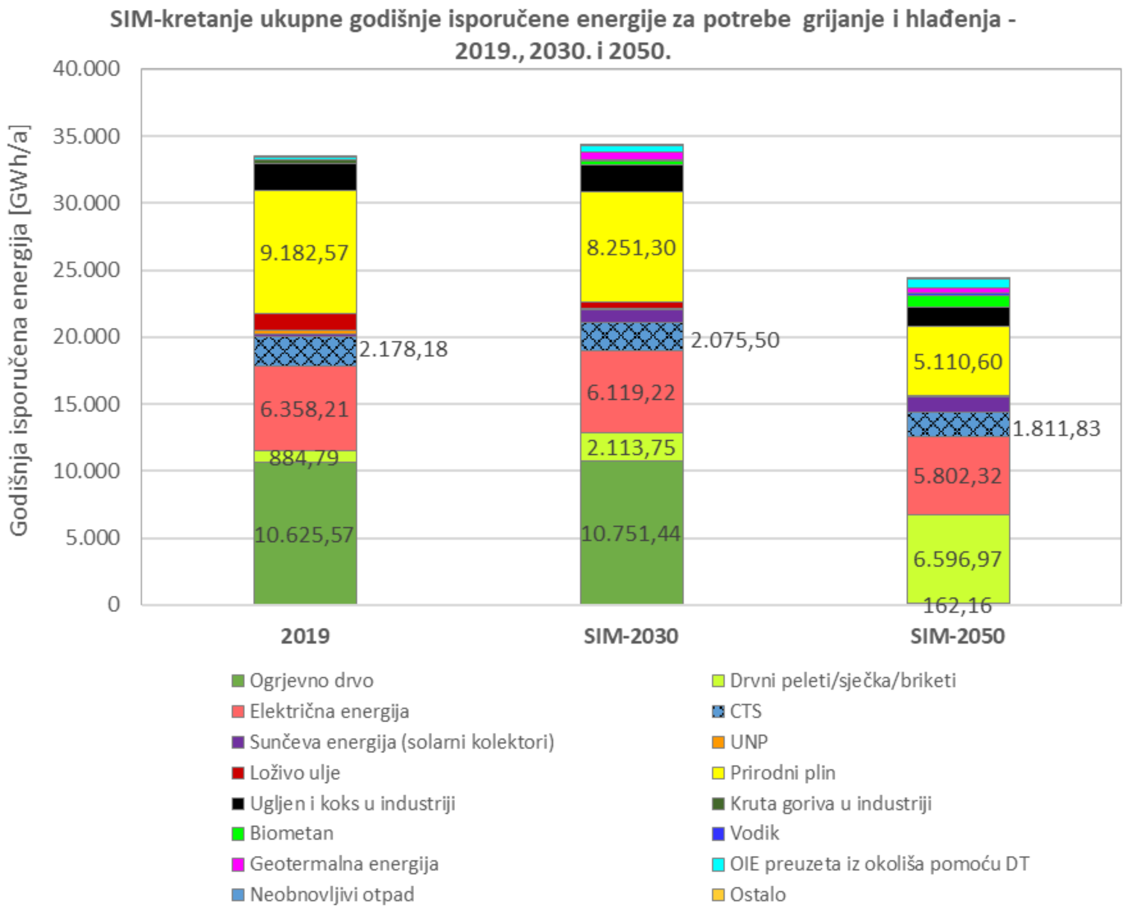


Figure III.11: HOUSEHOLD, SERVICE AND INDUSTRIAL SECTOR – SIM scenario (scenario with integrated measures) – overview of energy products to cover space heating/cooling needs and DHW preparation – 2019–2050

CROATIAN	ENGLISH
SIM-kretanje ukupne godišnje isporučene energije za potrebe grijanje i hlađenja - 2019., 2030. i 2050.	SIM – developments in total annual energy delivered for heating and cooling – 2019, 2030 and 2050

Godišnja isporučena energija [GWh/a]	Annual energy delivered [GWh/a]
BAU-2030	BAU – 2030
BAU-2050	BAU – 2050
Ogrjevno drvo	Firewood
Električna energija	Electricity
Sunčeva energija (solarni kolektori)	Solar energy (solar collectors)
Loživo ulje	Fuel oil
Ugljen i koks u industriji	Coal and coke in industry
Biometan	Biomethane
Geotermalna energija	Geothermal energy
Neobnovljivi otpad	Non-renewable waste
Drvni peleti/sječka/briketi	Wood pellets / wood chips / briquettes
CTS	DHS
UNP	LPG
Prirodni plin	Natural gas
Kruta goriva u industriji	Solid fuels in industry
Vodik	Hydrogen
OIE preuzeta iz okoliša pomoću DT	RES taken from the environment using heat pumps
Ostalo	Other

In the period between 2019 and 2050, the SIM scenario shows a decrease in the consumption of firewood, a gradual increase in the consumption of modern biomass (pellets and wood chips), a decline in fossil fuel consumption (natural gas, fuel oil and LPG), the use of biomethane and hydrogen in the gas grid, and greater use of geothermal energy and solar energy.

Figure III.12: provides an overview of the structure of energy products and technologies in the total energy delivered from the DHS in the reference year 2019, as well as in 2030 and 2050.

The projected reduction in the consumption of energy delivered from the DHS results from the following:

- increasing the efficiency (reducing heat losses) and expanding the distribution network of existing district heating systems in densely populated urban areas;
- modernising the generation installations of existing district heating systems;
    - using geothermal energy sources;
    - high-efficiency cogeneration from natural gas and biomass (wood chips);
    - energy-from-waste;
    - using renewable energy sources through heat pumps and, to a lesser extent, solar collectors;
    - utilising waste heat from industrial installations.

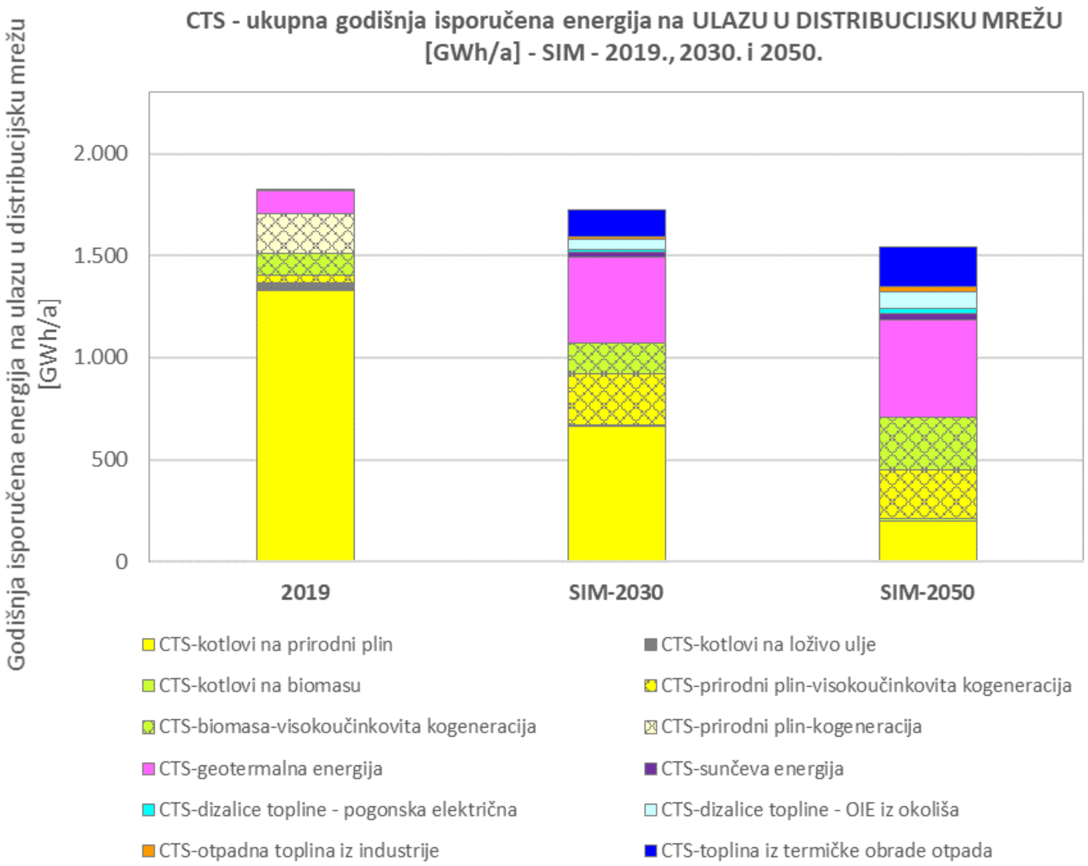


Figure III.12: HOUSEHOLD, SERVICE AND INDUSTRIAL SECTORS – DHS – SIM scenario (scenario with integrated measures) – overview of energy product/technology structure – 2019–2050

CROATIAN	ENGLISH
CTS - ukupna godišnja isporučena energija na ULAZU U DISTRIBUCIJSKU MREŽU [GWh/a] - SIM - 2019., 2030. i 2050.	DHS – total annual energy delivered at the ENTRY POINT TO THE DISTRIBUTION NETWORK [GWh/a] – SIM for 2019, 2030 and 2050
Godišnja isporučena energija na ulazu u distribucijsku mrežu [GWh/a]	Annual energy delivered at the entry point to the distribution network [GWh/a]
SIM-2030	SIM – 2030
SIM-2050	SIM – 2050
CTS-kotlovi na prirodni plin	DHS – natural gas boilers
CTS-kotlovi na biomasu	DHS – biomass boilers
CTS-biomasa-visokoučinkovita kogeneracija	DHS – biomass – high-efficiency cogeneration
CTS-geotermalna energija	DHS – geothermal energy
CTS-dizalice topline - pogonska električna	DHS – heat pumps – electrically driven
CTS-otpadna toplina iz industrije	DHS – industrial waste heat
CTS-kotlovi na loživo ulje	DHS – fuel oil boilers
CTS-prirodni plin-visokoučinkovita kogeneracija	DHS – natural gas – high-efficiency cogeneration
CTS-prirodni plin-kogeneracija	DHS – natural gas – cogeneration
CTS-sunčeva energija	DHS – solar energy
CTS-dizalice topline - OIE iz okoliša	DHS – heat pumps – RES from the environment
CTS-toplina iz termičke obrade otpada	DHS – thermal waste treatment heat

Based on the outcome of the cost-benefit analysis, certain measures are cost-effective with no need for public support:

- INDIVIDUAL SYSTEMS[29] – HOUSEHOLD SECTOR:
  - replacement of central fuel oil boilers with central modern biomass boilers for space heating and DHW preparation, and installation of solar collectors for DHW preparation (by 2030);
  - replacement of central fuel oil boilers with heat pumps for space heating and DHW preparation, and installation of solar collectors for DHW preparation (by 2030);
  - replacement of central LPG boilers with central modern biomass boilers, and installation of solar collectors for DHW preparation (by 2050);
  - replacement of central LPG boilers with heat pumps, and installation of solar collectors for DHW preparation (by 2050);
  - replacement of standard natural gas boilers with condensing natural gas boilers for space heating and DHW preparation (by 2030);
  - replacement of natural gas boilers with heat pumps;
  - replacement of individual electric boilers for DHW preparation with heat pumps and solar collectors;

- INDIVIDUAL SYSTEMS – SERVICE SECTOR:
  - replacement of central fuel oil boilers with central modern biomass boilers for space heating and DHW preparation, and installation of solar collectors for DHW preparation (by 2030);
  - replacement of central fuel oil boilers with heat pumps for space heating and DHW preparation, and installation of solar collectors for DHW preparation (by 2030);
  - replacement of central LPG boilers with central modern biomass boilers, and installation of solar collectors for DHW preparation (by 2030);
  - replacement of central LPG boilers with heat pumps, and installation of solar collectors for DHW preparation (by 2030);
  - replacement of standard natural gas boilers with condensing natural gas boilers for space heating and DHW preparation (by 2030);
  - replacement of natural gas boilers with heat pumps;
  - connection of service sector consumers to the DHS (by 2050);
  - replacement of individual electric space heaters with heat pumps (by 2050);
  - replacement of individual electric boilers for DHW preparation with heat pumps and solar collectors (by 2050);

- DISTRICT HEATING SYSTEMS:
  - replacement of fuel oil boilers with biomass boilers (by 2030);
  - replacement of fuel oil boilers with water-to-water heat pumps (by 2030);
  - replacement of natural gas cogeneration with high-efficiency natural gas cogeneration (by 2050);
  - replacement of natural gas boilers with water-to-water compression heat pumps (by 2050);
  - replacement of natural gas boilers – waste heat utilisation (by 2050);

[29] Each consumer has their own separate source of heating and/or cooling energy.

- replacement of natural gas boilers – solar energy harnessing (do 2050.),

  ;
- replacement of natural gas boilers with high-efficiency biomass cogeneration (by 2050);
- replacement of natural gas boilers with biomass boilers (by 2050).

Due to the shorter length of the observation period, all the above measures – except those involving the replacement of fuel oil boilers – are not cost-effective in the period until 2030 but they become cost-effective in the period between 2031 and 2050.

The measures which are cost-effective with public support, where the economic NPV is positive and the financial NPV negative, are provided in tabular form in Part IV.

In order to carry out decarbonisation in household, service and industrial sectors, solely in terms of covering the needs for space heating, DHW preparation or space cooling, it is necessary to:

- build all new buildings as nearly zero-energy buildings (NZEB), where at least 30% of the annual energy delivered for the operation of the building's technical systems must be provided from the renewable energy sources of the building (requirement laid down in the *Technical regulation amending the Technical regulation on energy economy and heat retention in buildings* (NN No 102/2020));
- carry out major renovation[30] and reconstruction[31] of existing buildings – the renovation and reconstruction of existing buildings is extremely important as it enables the efficient use of low-temperature energy sources, notably of compression heat pumps as decentralised heat sources, as well as of other low-temperature heat sources within the DHS (industrial waste heat utilisation); external building envelope retrofitting enables the transition to a low-temperature heating system, entailing a much more efficient operation of low-temperature energy sources at low consumption of drive energy products, and low heat losses in all segments of the heating system (production subsystem, distribution subsystem, spatial heat emissions subsystem);
- implement the building automation and control system in both new and existing non-residential buildings with a space heating system, combined space heating and ventilation system, space cooling system, combined space cooling and ventilation system with a rated heating/cooling capacity exceeding 290 kW (service sector) (requirement laid down in the *Technical regulation amending the Technical regulation on energy economy and heat retention in buildings* (NN No 102/2020), which will enter into force on 1 January 2025), with the main aim of ensuring the optimal production, distribution, storage and use of energy for heating/cooling purposes;
- use electricity generated from renewable energy sources (wind farms, hydropower plants, photovoltaics) to drive compression heat pumps;
- strive to primarily use energy delivered from district heating systems (DHS) for heating or DHW preparation in densely populated urban areas, while taking the following mandatory steps:
  - expanding the distribution network of existing district heating systems in densely populated urban areas;
  - renovating the existing distribution network (appropriate thermal insulation serving to reduce heat losses in the distribution network);

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[30] Major building renovation means the renovation or reconstruction of a building where more than 25% of the building envelope undergoes renovation.

[31] Reconstruction of an existing building means a partial or complete renovation of 75% or more of the envelope of the heated part of the building.

- modernising the generation installations of existing district heating systems by combining different heat generation technologies:
  - → using geothermal energy sources;
  - → energy-from-waste;
  - → utilisation of waste heat from industrial installations;
  - → utilisation of renewable energy sources through the use of heat pumps (heating plants by rivers) and, to a lesser extent, solar collectors;
  - → high-efficiency cogeneration from natural gas and biomass (in 2050, there will be significantly fewer gas boilers compared to the reference year 2019, with biogas and hydrogen blended into natural gas);
  - → use of a DHS heat-carrying medium in the summer to power the central absorption chiller for cooling spaces in larger non-residential buildings (e.g. hospitals, hotels, shops, etc.) which are already connected to the district heating system – removal of compression chillers with environmentally unacceptable refrigerants and installation of absorption chillers powered by hot water from the DHS (remains as an option to be elaborated);
- increasing the share of biomethane and hydrogen in the existing gas grid (costs of biomethane and hydrogen production have not been considered in this Comprehensive Assessment).

In view of the sensitivity analysis, it is important to take the following into account:

- measures in the service sector are more sensitive to increases in investment costs than those in the household sector;
- reducing the investment value would lead to a shift in the results for several measures in the household and service sector;
- increases in energy product prices most often affected the growth of NPV of the measures, which indicates that the prices of fossil fuels in the BAU scenario increased more than those in alternative scenarios in the same period;
- an increase in emissions prices has the effect of increasing the monetised benefits of reducing CO_2 emissions, so certain measures that were not economically viable become viable measures;
- increasing the discount rate to 7% did not affect the cost-effectiveness of the measures. By reducing the financial discount rate to 3%, certain measures that were not cost-effective with a rate of 5% become cost-effective;
- neither in individual systems nor in DHSs does an increase in the economic discount rate affect the outcome in terms of changes in the economic viability of the measures.

The comprehensive assessment of the potential for efficient heating and cooling in Croatia under Annex VIII to Directive 2012/27/EU shows notably the existence of great potential for an efficient district heating system in Croatia, based on the use of renewable energy sources (primarily geothermal energy) and high-efficiency cogeneration from natural gas and biomass, as well as considerable potential through the application of measures relating to individual systems in household and service sectors.

DIO IV. POTENTIAL NEW STRATEGIES AND POLICY MEASURES

9 OVERVIEW OF NEW LEGISLATIVE AND NON-LEGISLATIVE POLICY MEASURES

This chapter presents potential new strategies and strategic policy measures[32] aimed at realising the economic potential for heating and cooling efficiency, identified in Part III ANALYSIS OF THE ECONOMIC POTENTIAL FOR EFFICIENT HEATING AND COOLING, together with their foreseen:

- greenhouse gas emission reductions;
- primary energy savings in GWh per year;
- impact on the share of high-efficiency cogeneration;
- impact on the share of renewables in the national energy mix and in the heating and cooling sector;
- links to national financial programming and cost savings for the public budget and market participants;
- estimated public support measures (if any), with their annual budget and identification of the potential aid element.

As part of the cost-benefit analysis conducted, two financial parameters were obtained for each measure: financial NPV (FNPV) and economic NPV (ENPV), which may serve to identify policy measures to support or promote those solutions, as well as to remove existing or planned measures if the cost-benefit analysis finds the observed solutions not to be socially justified.

Based on the two economic parameters stated above, policy measures were defined using the following rules:

- FNPV < 0 and ENPV > 0 → socially justified measure requiring public support;
- FNPV > 0 and ENPV > 0 → cost-effective measure not requiring support (if the measure is already receiving support, public authorities should consider whether the existing support is appropriate and whether it should be reduced);
- ENPV < 0 and ENPV < 0 → the measure is not justified from a social perspective (if the measure is already receiving support, the withdrawal of support should be considered).

Based on the results of the analysis of the economic potential for efficient heating and cooling (DIO III), the following potential new strategies and strategic measures have been obtained (listed clearly in Table IV.1: with corresponding savings):

- INDIVIDUAL SYSTEMS[33] – HOUSEHOLD SECTOR:
  - replacement of natural gas boilers with combined heat and power (micro-CHP) system, fuelled by natural gas (between 2030 and 2050);
  - installation of solar collectors for DHW preparation where natural gas central boilers are used for DHW preparation;
  - replacement of natural gas boilers with modern biomass boilers for space heating and DHW preparation, and installation of solar collectors for DHW preparation;

[32] This overview includes financing measures and programmes that may be adopted over the period of the comprehensive assessment, not prejudging a separate notification of the public support schemes for a State aid assessment.

[33] Each consumer has their own separate source of heating and/or cooling energy.

  - replacement of individual electric space heaters with heat pumps (by 2030);
- INDIVIDUAL SYSTEMS – SERVICE SECTOR:
  - installation of solar collectors for DHW preparation where natural gas central boilers are used for DHW preparation;
  - replacement of natural gas boilers with modern biomass boilers for space heating and DHW preparation, and installation of solar collectors for DHW preparation (where technically feasible and justified in service sector buildings);
- DISTRICT HEATING SYSTEMS[34] – increased efficiency and expansion of the distribution network of existing district heating systems in densely populated urban areas;
- DISTRICT HEATING SYSTEMS – modernisation of generation facilities of existing district heating systems:
  - replacement of natural gas boilers – industrial waste heat utilisation;
  - replacement of natural gas boilers – geothermal energy exploitation.

In order to reduce the consumption of fossil fuels (in this case, natural gas) by 2030, it is important to encourage the installation of solar collectors for DHW preparation in both household-sector and service-sector buildings where this is technically feasible and justified (e.g. hospitals, hotels).

Fuel oil, as an environmentally highly unacceptable fossil fuel with a high CO_2 emissions factor, should be eliminated from use entirely by 2030 in the household and service sectors, and as the fuel used to power boilers in the DHS.

An identical measure in the household and service sectors, which has the values FNPV < 0 and ENPV > 0 and thus requires public support, refers to the replacement of natural gas boilers with modern biomass boilers for the purpose of space heating and DHW preparation, and the installation of solar collectors for DHW preparation between 2030 and 2050.

After fuel oil is eliminated from use, it is also important to gradually reduce the consumption of natural gas between 2030 and 2050. Modern biomass (wood pellets and wood chips) is considered a renewable energy source with a low CO_2 emissions factor (carbon-neutral fuel, assuming that the burning of biomass releases the same amount of CO_2 as is captured from the atmosphere through photosynthesis) and a low primary energy factor compared to natural gas. However, the projected price of modern biomass is slightly higher than the price of natural gas, so the measure is not financially justified and requires public support on account of the above benefits.

With regard to the modernisation of district heating system production facilities, the cost-benefit analysis revealed two measures requiring public support. The measure that must certainly be implemented first is the reduction of heat losses in the DHS distribution network. This is to be followed by a modernisation of the production facilities of existing district heating systems. The measure achieving the most significant savings, while requiring public support, is the exploitation of geothermal energy. The total potential power of geothermal energy sources at 52 sites is estimated at 546 MW_e and almost 2 000 MW_t, while the installed thermal capacity is planned to be 181.73 MW under the proposed measure. In addition, the provision of public aid is very important for the measure involving industrial waste heat utilisation.

Croatia must move towards increased development and expansion of the DHS, particularly in densely populated urban areas (avoiding individual systems, which are based primarily on the combustion of fossil fuel, as well as biomass – no form of combustion in urban areas), by using available waste heat (industrial waste heat, energy-from-waste) and renewable energy sources (geothermal energy, solar

[34] District heating systems used for heat distribution from the source (generation installation) to consumers.

energy, biomass) and by applying only high-efficiency cogeneration from natural gas and biomass, in order to obtain more from the fuel input (simultaneous generation of electricity and thermal energy).

Table IV.1: Overview of strategic measures and corresponding savings

Short description of potential new strategy or policy measure	Objective of new strategy or policy measure	Expected reduction in CO_2 emissions [tonne of CO_2/a]	Primary energy savings [GWh/a]	Impact on high-efficiency cogeneration share	Impact on share of renewables in the national energy mix and the heating and cooling sector	Link to national financial programming	Public support measures
HOUSEHOLD SECTOR – Replacement of natural gas boilers with natural gas micro-CHP	Simultaneous generation of electricity and thermal energy	(2030–2050) no savings	(2030–2050) no savings	–	–	Energy renovation programme for family houses for 2021–2030 (NECP measure ENU-3) Energy renovation programme for multi-apartment buildings for 2021–2030 (NECP measure ENU-4)	Co-financing through grants from EPEEF's auctioning of emission allowances for family houses Co-financing through grants and financial instrument implementation using available resources from the NRRP and ESI funds for multi-apartment buildings
HOUSEHOLD SECTOR – Installation of solar collectors for DHW preparation where natural gas central boilers are used for DHW preparation	Phasing out of fossil fuels and CO_2 emissions, increase of RES share	(2030) 22 318.09	(2030) 114.19	–	(2030) Use of captured solar energy at 91.51 GWh	Energy renovation programme for family houses for 2021–2030 (NECP measure ENU-3) Energy renovation programme for multi-apartment buildings for 2021–2030 (NECP measure ENU-4)	Co-financing through grants from EPEEF's auctioning of emission allowances for family houses Co-financing through grants and financial instrument implementation using [available funds from NRRP and ESI funds for multi-apartment buildings]
HOUSEHOLD SECTOR – replacement of natural gas boilers: • with modern biomass boilers for the	Reduced consumption of fossil fuels and CO_2 emissions, increase of RES share for the	(2030–2050) 139 829.49	(2030–2050) 727.65	–	(2030–2050) Use of delivered modern biomass energy at 557.29 GWh and	Energy renovation programme for family houses for 2021–2030 (NECP measure ENU-3)	Co-financing through grants from EPEEF's auctioning of emission allowances for family houses

Short description of potential new strategy or policy measure	Objective of new strategy or policy measure	Expected reduction in CO_2 emissions [tonne of CO_2/a]	Primary energy savings [GWh/a]	Impact on high-efficiency cogeneration share	Impact on share of renewables in the national energy mix and the heating and cooling sector	Link to national financial programming	Public support measures
purpose of space heating and DHW preparation, • installation of solar collectors for DHW preparation	purpose of space heating and DHW preparation				captured solar energy at 97.64 GWh	Energy renovation programme for multi-apartment buildings for 2021–2030 (NECP measure ENU-4)	Co-financing through grants and financial instrument implementation using available resources from the NRRP and ESI funds for multi-apartment buildings
HOUSEHOLD SECTOR – replacement of individual electric space heaters with heat pumps	Reduced consumption of electricity, increase of RES share for space heating purposes	(2030) 35 264.07	(2030) 242.39	–	(2030) Reduction in electricity consumption from 514.18 GWh to 364 GWh	Energy renovation programme for family houses for 2021–2030 (NECP measure ENU-3) Energy renovation programme for multi-apartment buildings for 2021–2030 (NECP measure ENU-4)	Co-financing through grants from EPEEF’s auctioning of emission allowances for family houses Co-financing through grants and financial instrument implementation using available resources from the NRRP and ESI funds for multi-apartment buildings
SERVICE SECTOR – Installation of solar collectors for DHW preparation where natural gas central boilers are used for DHW preparation	Phasing out of fossil fuels and CO_2 emissions, increase of RES share	(2030) 18 338.37	(2030) 93.82	–	(2030) Use of captured solar energy at 75.19 GWh	Energy renovation programme for public buildings for 2021–2030 (NECP measure ENU-5)	Co-financing through grants, financial instrument and ESCO model implementation using available resources from the NRRP and ESI funds Provision of financial instruments through development banks, funds and credit facilities in the form of preferential loans,

Short description of potential new strategy or policy measure	Objective of new strategy or policy measure	Expected reduction in CO_2 emissions [tonne of CO_2/a]	Primary energy savings [GWh/a]	Impact on high-efficiency cogeneration share	Impact on share of renewables in the national energy mix and the heating and cooling sector	Link to national financial programming	Public support measures
							guarantees and other loans
SERVICE SECTOR – Replacement of natural gas boilers: • with modern biomass boilers for the purpose of space heating and DHW preparation, • installation of solar collectors for DHW preparation (in service sector buildings where this is technically feasible and justified)	Reduced consumption of fossil fuels and CO_2 emissions, increase of RES share for the purpose of space heating and DHW preparation	(2030–2050) 63 637.63	(2030–2050) 330.99	–	(2030–2050) Use of delivered modern biomass energy at 253.91 GWh and captured solar energy at 39.24 GWh	Energy renovation programme for public buildings for 2021–2030 (NECP measure ENU-5)	Co-financing through grants, financial instrument and ESCO model implementation using available resources from the NRRP and ESI funds Provision of financial instruments through development banks, funds and credit facilities in the form of preferential loans, guarantees and other loans
DHS – increased efficiency and expansion of the distribution network of existing district heating systems in densely populated urban areas	Reduction of heat losses in the existing distribution network and its expansion	(2030) 68 590.66	(2030) 334.53	Increase of high-efficiency cogeneration from 233.88 GWh to around 400 GWh in 2030	Increase in the share of renewables	NECP measure ENU-17: Increasing the efficiency of district heating systems	Use of ESI funds for the revitalisation of the heating distribution network
DHS – replacement of natural gas boilers – **industrial waste heat utilisation**	Reduced consumption of natural gas, reduction of CO_2 emissions	(2030–2050) 5 872.12	(2030–2050) 29.20	–	–	NECP measure ES-4: Development and maintenance of centralised thermal energy production systems	Use of NRRP resources for district heating system decarbonisation
DHS – replacement of natural gas boilers –	Reduced consumption of natural gas,	(2030–2050) 61 041.85	(2030–2050) 334.48	–	Increase of RES share by utilising additional geothermal energy	NECP measure ES-4: Development and maintenance of	Use of NRRP resources for district heating system decarbonisation

Short description of potential new strategy or policy measure	Objective of new strategy or policy measure	Expected reduction in CO_2 emissions [tonne of CO_2/a]	Primary energy savings [GWh/a]	Impact on high-efficiency cogeneration share	Impact on share of renewables in the national energy mix and the heating and cooling sector	Link to national financial programming	Public support measures
exploitation of geothermal energy	reduction of CO_2 emissions,- increase of RES share				amounting to 264.94 GWh	centralised thermal energy production systems	

It is clear from the measures presented in the table above that they have already been included in national programmes (NECP, NRRP); in other words, increasing energy efficiency and improvements in renewable energy in the heating and cooling sector are already linked to national goals set by Croatia. These measures will be elaborated further through those very programmes, which will describe and define more precisely the annual budgets and potential aid elements.

9.1.1 A LOOK AT ENERGY-FROM-WASTE

Efficient waste management is ensured by the Croatian Government and the Ministry of Economy and Sustainable Development (formerly the Ministry of Environment and Energy; hereinafter: the Ministry), as the ministry responsible for waste management, by laying down waste management measures, issuing legislation and strategic planning documents.

Croatia's core documents related to waste management are as follows:

- *Sustainable Waste Management Act (NN Nos 94/13, 73/17, 14/19, 98/19),*
- *Waste Management Strategy of the Republic of Croatia (NN No 130/05),*
- *Waste Management Plan of the Republic of Croatia for 2017–2022 (NN No 3/17),*
- *Environmental Protection Act (NN Nos 80/13, 153/13, 78/15, 12/18, 118/18), and*
- *National Environmental Protection Strategy of the Republic of Croatia (NN No 46/2002).*

These documents are aligned with European legislation and strategies and based on the principles advocated in the EU legislative and strategic framework. Their purpose is to establish a framework for reducing the amount of waste generated by Croatia, as well as the sustainable management of the waste already generated in accordance with the principles of the circular economy and bioeconomy. The documents create frameworks within which sustainable waste management processes are implemented and planned, while defining the following:

- basic objectives and measures relating to waste management,
- measures concerning hazardous waste management, and
- guidelines for waste recovery and disposal.

In order for the establishment and implementation of a sustainable system to be feasible, waste management and circular economy activities need to be implemented at all levels (national to local), while being reflected in other sectors, such as water management, mining, veterinary medicine, physical planning, etc.

As of 1 January 2019, the Croatian Agency for the Environment and Nature (CAEN) was merged with the Ministry, so its activities are performed by the Institute for Environmental and Nature Protection of the Ministry (hereinafter: the Institute). The Institute collects, consolidates and keeps data in accordance with the *Sustainable Waste Management Act* and implementing regulations, maintains the waste management information system, prepares reports on the state of waste management and carries out reporting in the field of waste management as required by EU regulations.

The implementing body at state level is the Environmental Protection and Energy Efficiency Fund (hereinafter: the Fund). The Fund provides additional resources for the financing of projects, programmes and similar activities in the field of environmental protection and improvement, has the authority to issue administrative acts related to the payment of fees and special charges, and keeps a register of taxpayers.

At the regional and local level, waste management is the responsibility of the local and regional self-government unit (hereinafter: the LRSGU), which is required to provide the conditions and ensure the implementation of prescribed waste management measures in its area of governance. Multiple LRSGUs may ensure, by mutual agreement, the joint implementation of waste management measures. In municipalities/cities, waste management tasks are carried out by different administrative bodies (usually single administrative departments).

These public and administrative bodies implement legislative and strategic frameworks related to waste management, as set out in the EU strategic frameworks. Among them is the order of priorities in waste management, defined in EU Directive 2008/98/EC on waste, which presents the hierarchy and most preferred steps in the waste management process. The most preferred option is waste prevention, followed by preparation for re-use, recycling and other recovery procedures, while the waste disposal procedure, which includes landfilling, is the least preferred waste management option.

Figure IV.1: Order of priorities in waste management

CROATIAN	ENGLISH
PRIPREMA ZA PONOVNU UPORABU	PREPARING FOR RE-USE
RECIKLIRANJE	RECYCLING
DRUGI POSTUPCI OPORABE	OTHER RECOVERY PROCEDURES
ZBRINJAVANJE OTPADA	WASTE DISPOSAL
Najpoželjnija opcija	Most preferred option

MISCELLANEOUS

ANNEXES

Table 0.1: Floor area of Croatia's non-residential building stock by energy product used for space heating

SERVICE SECTOR – ENERGY PRODUCTS USED FOR HEATING													
County name		Total useful floor area of the heated part of the building [m²]											
		DHS	Woody biomass	Electricity	Solid fuels	Fuel oil	Firewood	Waste heat	Natural gas	Solar energy	LPG	Other	None
1	Zagreb County	108 848.50	32 904.50	263 881.33	583.00	118 196.17	28 127.50	–	1 657 493.00	141.00	42 136.00	122 662.50	49 299.50
2	Krapina-Zagorje	2 975.00	13 663.50	121 852.67	312.00	45 809.50	9 752.50	–	724 488.67	–	2 703.00	23 658.50	7 606.00
3	Sisak-Moslavina	63 073.50	36 368.50	83 473.83	198.00	183 032.33	30 962.00	–	417 205.00	–	14 776.00	9 849.50	19 959.00
4	Karlovac	154 375.17	38 868.50	144 612.00	601.00	301 978.67	44 370.50	–	216 084.17	–	10 914.00	12 411.00	49 341.00
5	Varaždin	12 768.50	7 179.00	191 378.83	1 179.00	19 328.00	23 408.50	–	1 401 677.83	–	15 996.00	27 654.00	19 511.00
6	Koprivnica-Križevci	2 585.50	2 155.50	56 069.50	–	128 448.50	12 637.50	–	713 927.00	–	1 173.00	2 190.50	17 810.00
7	Bjelovar-Bilogora	2 523.00	8 953.00	54 637.17	199.50	6 163.00	38 282.50	–	512 308.67	–	1 364.00	2 527.50	1 804.00
8	Primorje-Gorski Kotar	37 941.00	17 780.00	1 164 988.33	2 578.50	993 645.50	43 862.17	–	534 545.50	488.00	201 167.83	26 629.00	122 157.50
9	Lika-Senj		30 071.00	85 972.17	222.50	158 055.67	29 959.50	–	18 407.50	–	48 923.00	3 760.00	8 930.00
10	Virovitica-Podravina	7 654.00	6 487.00	31 457.50	148.00	7 476.00	12 972.50	–	345 345.50	–	3 728.00	23 663.50	4 033.00
11	Požega-Slavonia	6 623.50	6 677.50	131 783.67	–	16 440.00	37 869.50	–	432 405.17	–	9 567.50	3 081.50	6 678.00
12	Slavonski Brod-Posavina	49 347.00	7 465.50	77 565.17	791.00	140 654.67	30 317.50	–	639 517.00	–	11 230.00	18 150.50	24 806.00
13	Zadar	19 342.00	1 047.50	669 424.00		466 735.00	4 086.00	804.00	36 141.50	–	16 406.00	17 203.50	38 053.50
14	Osijek-Baranja	482 293.50	46 841.00	196 933.67	5 904.50	102 006.83	61 407.00	–	1 242 415.83	–	15 741.50	58 869.00	32 187.50
15	Šibenik-Knin	78.00	266.00	399 579.50	–	317 537.00	2 668.50	–	28 803.50	127.00	65 453.50	4 355.00	9 187.00
16	Vukovar-Syrmia	14 761.50	21 533.00	95 768.83	4 685.00	72 632.33	10 927.50	–	510 714.17	–	3 020.00	21 545.00	9 036.00
17	Split-Dalmatia	2 273.00	11 846.50	3 521 780.17	1 926.00	842 881.17	7 560.50	–	81 721.00	5 935.00	108 095.00	17 260.50	41 546.50
18	Istria	15 179.00	4 733.00	1 316 640.67	–	881 416.17	18 031.67	–	637 184.50	305.00	93 110.83	42 250.50	98 764.00
19	Dubrovnik-Neretva		108.00	610 697.17	–	431 292.50	829.00	–	31 358.00	–	60 860.33	18 773.00	41 252.00
20	Međimurje	3 638.50	23 870.50	58 821.67	66.00	10 882.67	43 207.50	1 738.00	745 933.33	–	16 562.50	3 952.00	6 585.00
21	City of Zagreb	2 361 347.00	12 953.50	719 265.17	16 698.00	317 065.17	14 983.50	–	4 821 037.00	–	13 215.83	157 545.50	290 155.00
	TOTAL	**3 347 627.17**	**331 772.50**	**9 996 583.00**	**36 092.00**	**5 561 676.83**	**506 223.33**	**2 542.00**	**15 748 713.84**	**6 996.00**	**756 143.83**	**617 992.00**	**898 701.50**
	SHARE	**8.85%**	**0.88%**	**26.44%**	**0.10%**	**14.71%**	**1.34%**	**0.01%**	**41.65%**	**0.02%**	**2.00%**	**1.63%**	**2.38%**

Table 0.2: Floor area of Croatia's non-residential building stock by energy product used for DHW preparation

SERVICE SECTOR – ENERGY PRODUCTS USED FOR DHW PREPARATION													
County name		Total useful floor area of the heated part of the building [m²]											
		DHS	Woody biomass	Electricity	Solid fuels	Fuel oil	Firewood	Waste heat	Natural gas	Solar energy	LPG	Other	None
1	Zagreb County	70 812.50	19 947.00	621 938.00	242.00	55 309.67	5 089.00	–	1 342 448.67	12 080.50	24 030.00	107 850.50	164 525.50
2	Krapina-Zagorje	2 975.00	9 378.33	332 249.83	197.00	13 914.00	223.00	–	511 574.50	163.00	2 703.00	6 220.50	73 222.50
3	Sisak-Moslavina	42 861.00	9 967.50	332 394.00	–	70 419.00	14 464.00	–	278 121.50	6 451.50	7 799.00	21 243.00	75 177.50
4	Karlovac	49 181.83	12 020.50	526 252.00	391.00	117 363.00	7 848.50	–	91 556.17	7 320.50	5 765.00	15 678.00	140 178.50
5	Varaždin	–	1 555.50	448 249.67	–	4 130.00	6 057.00	–	1 058 344.67	7 529.00	2 517.00	47 411.00	144 286.50
6	Koprivnica-Križevci	2 585.50	138.00	222 222.00	32.00	5 406.50	2 279.00	540.00	538 776.50	4 444.00	767.00	6 565.00	153 241.50
7	Bjelovar-Bilogora	2 429.00	3 418.50	236 196.50	–	–	3 455.50	–	326 343.00	1 345.50	655.00	4 251.00	50 668.00
8	Primorje-Gorski Kotar	43 588.50	3 465.00	1 724 708.33	571.00	653 705.33	4 155.50	11 260.00	299 970.67	42 949.00	101 119.17	29 578.00	230 713.50
9	Lika-Senj	4 894.50	17 045.00	253 197.00	–	43 497.00	10 607.50	–	7 701.50	4 431.50	8 634.00	3 867.00	30 426.00
10	Virovitica-Podravina	–	3 496.50	160 366.50	–	4 118.00	677.00	–	229 733.50	–	384.00	8 960.00	35 229.50
11	Požega-Slavonia	8 435.50	3 231.00	252 802.83	–	3 651.00	23 234.50	2 410.00	308 054.83	2 147.50	2 983.00	13 223.00	30 952.50
12	Slavonski Brod-Posavina	9 163.00	1 184.00	368 821.00	–	26 628.50	1 311.00	1 616.50	428 499.50	5 067.00	4 812.00	23 168.00	129 573.50
13	Zadar	1 644.00	315.50	747 094.50		333 697.50	304.00		32 483.00	11 278.00	8 297.00	17 983.00	116 146.50
14	Osijek-Baranja	144 487.00	3 178.50	1 164 317.50	4 692.00	15 970.00	13 124.50	–	701 521.00	3 970.50	4 396.00	16 698.00	172 246.00
15	Šibenik-Knin	–	134.67	540 773.00	–	130 466.00	–	–	21 108.33	24 055.50	50 377.00	4 489.00	56 651.50
16	Vukovar-Syrmia	63.00	5 681.50	333 906.67	–	16 430.50	137.00	–	314 015.67	1 797.00	2 259.50	3 599.50	86 732.00
17	Split-Dalmatia	2 467.50	1 449.50	3 723 876.50	239.50	473 883.33	–	164.50	81 866.00	76 111.67	82 978.83	20 379.00	179 409.00
18	Istria	42 885.50	1 610.00	1 688 640.67		598 482.50	1 073.50		486 111.17	14 118.17	50 850.83	15 674.50	208 168.50
19	Dubrovnik-Neretva	–	–	734 914.33	349.00	224 245.33	370.00	–	9 753.50	40 918.83	47 366.33	25 447.50	111 805.50
20	Međimurje	360.50	506.00	220 592.00	–	2 191.00	29 240.50	–	532 005.50	3 561.50	13 335.00	14 532.00	98 934.00
21	City of Zagreb	1 643 045.50	1 811.00	2 517 392.00	–	173 672.83	5 343.00	52 234.00	3 053 298.83	10 497.50	8 882.00	98 969.50	1 159 121.50
	TOTAL	**2 071 879.33**	**99 533.50**	**17 150 904.83**	**6 713.50**	**2 967 181.00**	**128 994.00**	**68 225.00**	**10 653 288.00**	**280 237.67**	**430 910.67**	**505 787.00**	**3 447 409.50**
	SHARE	**5.48%**	**0.26%**	**45.36%**	**0.02%**	**7.85%**	**0.34%**	**0.18%**	**28.18%**	**0.74%**	**1.14%**	**1.34%**	**9.12%**

Table 0.3: Floor area of Croatia's non-residential building stock by energy product used for space cooling

SERVICE SECTOR – ENERGY PRODUCTS USED FOR COOLING				
		Total useful floor area of the heated part of the building [m^2]		
	County name	Electricity	Other *(absorption cooling)*	None
1	Zagreb County	1 987 334.00	32 911.00	404 027.00
2	Krapina-Zagorje	680 064.50	12 670.00	260 086.00
3	Sisak-Moslavina	619 926.00	2 370.00	236 602.00
4	Karlovac	721 431.00	7 553.00	244 571.00
5	Varaždin	1 235 829.50	10 813.00	473 438.00
6	Koprivnica-Križevci	744 994.50	6 214.00	185 788.00
7	Bjelovar-Bilogora	421 966.50	5 531.00	201 264.00
8	Primorje-Gorski Kotar	2 713 501.00	38 657.00	393 626.00
9	Lika-Senj	286 258.00	988.00	97 055.00
10	Virovitica-Podravina	321 231.00	5 774.00	115 960.00
11	Požega-Slavonia	485 056.50	14 550.00	151 519.00
12	Slavonski Brod-Posavina	762 212.00	4 907.00	232 724.00
13	Zadar	1 123 801.50	8 850.00	136 592.00
14	Osijek-Baranja	1 769 277.50	37 637.00	437 688.00
15	Šibenik-Knin	729 152.50	6 187.00	92 716.00
16	Vukovar-Syrmia	550 722.00	17 367.00	196 533.00
17	Split-Dalmatia	4 357 714.50	29 531.00	255 578.00
18	Istria	2 668 757.00	26 951.00	411 907.00
19	Dubrovnik-Neretva	1 105 094.00	12 877.00	77 202.00
20	Međimurje	657 088.00	7 868.00	250 302.00
21	City of Zagreb	7 577 744.50	209 919.00	936 605.00
	TOTAL	**31 519 156.00**	**500 125.00**	**5 791 783.00**
	SHARE	**83.36%**	**1.32%**	**15.32%**

WASTE PREVENTION

Table 0.4: Reference values – specific energy required for heating [19]

Condition of external envelope	**Building purpose**	**Continental**			**Coastal**		
		up to 1970	**1970–2005**	**after 2006**	**up to 1970**	**1970–2005**	**after 2006**
		kWh/m²					
SHD_{init}	Offices	150	110	60	90	70	40
	Educational buildings	140	120	60	80	70	40
	Hotels and restaurants	140	130	75	90	80	50
	Hospitals	180	140	70	100	80	65
	Sports halls	210	180	110	130	110	80
	Trade	150	90	70	80	60	40
	Other buildings	200	140	60	120	80	50
SHD_{nnew}	Offices	52			38		
	Educational buildings	47			32		
	Hotels and restaurants	70			33		
	Hospitals	54			60		
	Sports halls	90			59		
	Trade	60			36		

	Other buildings	50	46

Table 0.5: Reference values – specific energy needed for DHW preparation [23]

Building purpose	**Continental and coastal**
	kWh/m²
Offices	4.71
Educational buildings	8.13
Hotels and restaurants	35.51
Hospitals	26.64
Sports halls	15.82
Trade	0.74
Other buildings	6.42

Table 0.6: Reference values – specific energy required for cooling [19]

Building purpose	**Continental**			**Coastal**		
	up to 1970	**1970–2005**	**after 2006**	**up to 1970**	**1970–2005**	**after 2006**
	kWh/m²					
Offices	30	30	40	50	45	50
Educational buildings	35	25	50	45	60	60
Hotels and restaurants	40	45	50	70	70	75
Hospitals	60	50	50	90	100	90
Sports halls	30	15	15	45	20	25
Trade	60	50	85	90	70	150
Other buildings	30	30	40	50	50	50

Table 0.7: Estimated efficiency of the technology used based on energy products in the IEC database

Energy product	Heating	DHW preparation	Cooling
DHS	0.980	0.980	–
Woody biomass	0.800	0.800	–
Electricity	2.100	0.980	3.000
Solid fuels	0.700	0.700	–
Fuel oil	0.800	0.800	–
Firewood	0.650	0.650	–
Other	0.650	0.650	1.100
Waste heat	0.900	0.900	–
Natural gas	0.850	0.850	–
Solar energy	0.980	0.980	–
LPG	0.850	0.850	–

Table 0.8: SERVICE SECTOR – Energy delivered for heating by building type at county level

SERVICE SECTOR										
		Energy delivered for heating [GWh/a]								
	County name	Office buildings	Educational buildings	Hotels and restaurants	Hospitals	Sports halls	Trade buildings	Other non-residential buildings	**TOTAL**	**SHARE**
1	Zagreb County	45.828	32.333	8.829	7.726	12.909	39.016	137.010	**283.651**	7.79%
2	Krapina-Zagorje	15.168	20.677	9.253	15.875	6.292	6.932	38.134	**112.330**	3.09%
3	Sisak-Moslavina	18.459	20.491	3.468	9.088	3.494	11.587	18.874	**85.461**	2.35%
4	Karlovac	13.711	16.549	5.194	5.600	3.864	9.099	31.885	**85.902**	2.36%
5	Varaždin	31.331	27.102	7.266	23.686	15.045	24.105	80.889	**209.423**	5.75%
6	Koprivnica-Križevci	19.481	12.635	3.696	9.505	5.051	12.563	41.556	**104.487**	2.87%
7	Bjelovar-Bilogora	13.921	16.610	3.398	11.538	10.850	6.833	15.582	**78.730**	2.16%
8	Primorje-Gorski Kotar	43.780	30.624	65.376	11.554	13.807	38.586	38.865	**242.592**	6.67%
9	Lika-Senj	4.679	3.270	8.921	2.613	1.673	3.498	9.209	**33.863**	0.93%
10	Virovitica-Podravina	9.813	13.451	2.501	6.572	4.291	5.144	11.742	**53.514**	1.47%
11	Požega-Slavonia	13.050	9.225	5.831	10.330	8.337	9.341	20.453	**76.567**	2.10%
12	Slavonski Brod-Posavina	20.941	17.974	2.946	8.767	9.405	17.800	30.268	**108.100**	2.97%
13	Zadar	12.067	9.705	21.219	5.984	2.625	18.220	9.682	**79.502**	2.18%
14	Osijek-Baranja	46.535	50.292	10.058	15.575	19.174	44.759	66.824	**253.216**	6.96%
15	Šibenik-Knin	8.036	7.616	10.485	8.736	1.825	9.090	12.534	**58.323**	1.60%
16	Vukovar-Syrmia	17.910	11.655	5.734	8.554	8.209	14.708	17.664	**84.434**	2.32%
17	Split-Dalmatia	38.495	23.338	61.348	15.408	15.335	109.149	51.819	**314.893**	8.65%
18	Istria	38.629	16.442	74.629	12.080	8.681	36.788	53.255	**240.504**	6.61%
19	Dubrovnik-Neretva	8.784	5.534	40.203	7.432	4.004	6.497	8.829	**81.283**	2.23%
20	Međimurje	21.956	11.849	4.940	7.242	10.387	11.635	49.051	**117.061**	3.22%
21	City of Zagreb	338.997	122.994	34.307	80.645	46.210	144.210	167.853	**935.216**	25.70%
	TOTAL	**781.569**	**480.368**	**389.601**	**284.509**	**211.469**	**579.560**	**911.978**	**3 639.053**	100.00%
	SHARE	21.48%	13.20%	10.71%	7.82%	5.81%	15.93%	25.06%	100.00%	

Table 0.9: SERVICE SECTOR – Energy delivered for DHW preparation by building type at county level

SERVICE SECTOR										
		Energy delivered for DHW preparation [GWh/a]								
County name		Office buildings	Educational buildings	Hotels and restaurants	Hospitals	Sports halls	Trade buildings	Other non-residential buildings	**TOTAL**	**SHARE**
1	Zagreb County	3.663	4.644	5.618	3.028	1.945	0.516	11.256	**30.670**	4.48%
2	Krapina-Zagorje	1.183	2.921	4.744	5.863	1.348	0.115	2.830	**19.004**	2.78%
3	Sisak-Moslavina	1.471	3.780	1.803	3.629	0.546	0.161	1.569	**12.960**	1.89%
4	Karlovac	1.345	3.059	2.796	2.340	0.635	0.150	3.231	**13.557**	1.98%
5	Varaždin	2.453	3.793	3.692	9.006	2.257	0.304	6.258	**27.763**	4.06%
6	Koprivnica-Križevci	1.199	1.802	1.771	3.160	0.782	0.165	3.524	**12.403**	1.81%
7	Bjelovar-Bilogora	1.078	2.099	1.703	3.830	1.823	0.103	1.117	**11.753**	1.72%
8	Primorje-Gorski Kotar	5.139	6.064	47.512	7.260	2.748	0.745	4.464	**73.933**	10.81%
9	Lika-Senj	0.587	0.808	6.078	2.026	0.369	0.066	0.783	**10.718**	1.57%
10	Virovitica-Podravina	0.769	1.793	1.262	2.217	0.658	0.075	0.793	**7.567**	1.11%
11	Požega-Slavonia	1.053	1.304	4.205	3.545	1.421	0.153	1.732	**13.412**	1.96%
12	Slavonski Brod-Posavina	1.728	2.861	1.680	2.833	1.843	0.222	2.391	**13.558**	1.98%
13	Zadar	1.461	2.227	18.173	2.243	0.560	0.412	1.514	**26.591**	3.89%
14	Osijek-Baranja	3.677	8.480	4.765	5.252	3.163	0.652	5.275	**31.263**	4.57%
15	Šibenik-Knin	1.213	2.294	11.488	5.709	0.628	0.218	1.006	**22.555**	3.30%
16	Vukovar-Syrmia	1.382	1.992	3.654	2.910	1.424	0.177	1.440	**12.979**	1.90%
17	Split-Dalmatia	5.264	7.223	57.641	11.801	4.097	2.791	7.049	**95.867**	14.01%
18	Istria	3.965	3.761	60.774	6.124	2.054	0.676	5.549	**82.902**	12.12%
19	Dubrovnik-Neretva	1.187	1.764	36.196	4.979	1.216	0.157	1.387	**46.886**	6.85%
20	Međimurje	1.665	1.668	2.806	2.493	1.461	0.146	3.362	**13.600**	1.99%
21	City of Zagreb	24.908	15.920	17.902	26.136	4.329	2.005	13.040	**104.241**	15.24%
	TOTAL	**66.389**	**80.258**	**296.263**	**116.384**	**35.307**	**10.011**	**79.569**	**684.182**	100.00%
	SHARE	9.70%	11.73%	43.30%	17.01%	5.16%	1.46%	11.63%	100.00%	

Table 0.10: SERVICE SECTOR – Energy delivered for cooling by building type at county level

SERVICE SECTOR										
		Energy delivered for cooling [GWh/a]								
County name		Office buildings	Educational buildings	Hotels and restaurants	Hospitals	Sports halls	Trade buildings	Other non-residential buildings	**TOTAL**	**SHARE**
1	Zagreb County	13.453	8.616	3.623	3.634	1.316	28.477	28.819	**87.938**	5.78%
2	Krapina-Zagorje	3.862	3.890	3.800	7.832	0.399	5.449	6.685	**31.917**	2.10%
3	Sisak-Moslavina	4.877	6.192	1.053	4.005	0.279	8.128	3.842	**28.375**	1.87%
4	Karlovac	4.438	5.198	1.769	4.230	0.393	7.583	8.439	**32.049**	2.11%
5	Varaždin	8.119	6.075	2.136	11.843	1.017	14.167	13.417	**56.773**	3.73%
6	Koprivnica-Križevci	7.115	3.298	0.979	4.095	0.296	8.678	8.415	**32.876**	2.16%
7	Bjelovar-Bilogora	3.606	3.019	1.269	5.343	0.358	4.859	1.841	**20.296**	1.33%
8	Primorje-Gorski Kotar	17.393	15.336	40.201	10.007	1.883	35.962	10.795	**131.579**	8.65%
9	Lika-Senj	1.606	1.387	3.356	2.482	0.215	2.926	1.691	**13.664**	0.90%
10	Virovitica-Podravina	2.563	3.557	0.715	3.006	0.173	2.726	1.898	**14.638**	0.96%
11	Požega-Slavonia	3.372	2.558	3.174	4.384	0.606	6.344	3.172	**23.611**	1.55%
12	Slavonski Brod-Posavina	5.739	6.423	0.862	3.776	0.778	12.371	5.203	**35.152**	2.31%
13	Zadar	5.676	5.893	14.542	5.343	0.368	22.429	4.011	**58.262**	3.83%
14	Osijek-Baranja	12.428	15.982	2.920	7.100	1.050	31.631	13.322	**84.432**	5.55%
15	Šibenik-Knin	4.026	4.318	7.155	7.944	0.175	10.024	3.308	**36.950**	2.43%
16	Vukovar-Syrmia	4.637	4.023	1.543	3.594	0.553	9.517	3.072	**26.939**	1.77%
17	Split-Dalmatia	17.575	15.576	41.028	14.160	1.928	129.574	19.320	**239.161**	15.73%
18	Istria	15.075	7.832	50.153	8.583	1.234	33.269	14.123	**130.270**	8.57%
19	Dubrovnik-Neretva	4.200	4.141	26.960	7.738	0.371	7.591	3.887	**54.888**	3.61%
20	Međimurje	5.481	2.914	1.936	3.127	0.340	8.242	7.444	**29.484**	1.94%
21	City of Zagreb	101.850	48.772	14.161	40.535	4.545	107.467	33.751	**351.081**	23.09%
	TOTAL	**247.093**	**175.001**	**223.336**	**162.763**	**18.279**	**497.416**	**196.453**	**1 520.340**	100.00%
	SHARE	16.25%	11.51%	14.69%	10.71%	1.20%	32.72%	12.92%	100.00%	

Table 0.11: SERVICE SECTOR – Energy delivered for heating by energy product at county level

SERVICE SECTOR										
		Energy delivered for heating [GWh/a]								
	County name	LPG	Fuel oil	Natural gas	Total RES	DHS	Electricity	Other	**TOTAL**	**SHARE**
1	Zagreb County	6.861	5.434	211.054	9.828	12.148	18.926	19.400	**283.651**	7.79%
2	Krapina-Zagorje	0.424	2.619	92.682	3.613	0.382	8.848	3.762	**112.330**	3.09%
3	Sisak-Moslavina	2.213	8.186	50.241	10.179	7.575	5.697	1.368	**85.461**	2.35%
4	Karlovac	1.754	14.348	27.051	12.667	17.229	10.946	1.907	**85.902**	2.36%
5	Varaždin	2.863	0.830	180.002	5.394	1.647	14.305	4.382	**209.423**	5.75%
6	Koprivnica-Križevci	0.166	5.594	91.579	2.562	0.329	3.949	0.309	**104.487**	2.87%
7	Bjelovar-Bilogora	0.216	0.249	65.470	8.353	0.317	3.743	0.382	**78.730**	2.16%
8	Primorje-Gorski Kotar	30.871	45.739	65.244	10.314	4.287	82.058	4.078	**242.592**	6.67%
9	Lika-Senj	8.322	7.222	2.040	9.735	0.000	6.023	0.521	**33.863**	0.93%
10	Virovitica-Podravina	0.632	0.401	42.501	3.283	0.861	2.147	3.689	**53.514**	1.47%
11	Požega-Slavonia	1.562	0.815	55.736	8.037	0.741	9.246	0.430	**76.567**	2.10%
12	Slavonski Brod-Posavina	1.838	6.503	79.101	6.762	5.348	5.661	2.887	**108.100**	2.97%
13	Zadar	2.380	20.722	4.336	0.922	2.084	46.383	2.675	**79.502**	2.18%
14	Osijek-Baranja	2.435	4.678	150.271	18.657	54.340	13.984	8.851	**253.216**	6.96%
15	Šibenik-Knin	10.992	15.252	3.635	0.542	0.008	27.318	0.574	**58.323**	1.60%
16	Vukovar-Syrmia	0.489	3.340	64.385	4.631	1.448	6.859	3.281	**84.434**	2.32%
17	Split-Dalmatia	17.616	38.969	9.875	6.571	0.289	238.703	2.871	**314.893**	8.65%
18	Istria	14.895	40.985	78.147	3.875	1.694	94.211	6.697	**240.504**	6.61%
19	Dubrovnik-Neretva	10.162	20.535	3.806	0.154	0.000	43.692	2.934	**81.283**	2.23%
20	Međimurje	2.511	0.549	96.891	12.146	0.386	4.010	0.567	**117.061**	3.22%
21	City of Zagreb	2.172	14.097	577.159	4.508	263.076	48.595	25.608	**935.216**	25.70%
	TOTAL	**121.376**	**257.067**	**1 951.209**	**142.734**	**374.190**	**695.303**	**97.173**	**3 639.053**	100.00%
	SHARE	3.34%	7.06%	53.62%	3.92%	10.28%	19.11%	2.67%	100.00%	

Table 0.12: SERVICE SECTOR – Energy delivered for DHW preparation by energy product at county level

SERVICE SECTOR										
		Energy delivered for DHW preparation [GWh/a]								
	County name	LPG	Fuel oil	Natural gas	Total RES	DHS	Electricity	Other	**TOTAL**	**SHARE**
1	Zagreb County	0.329	0.448	16.160	2.104	0.972	9.289	1.369	**30.670**	4.48%
2	Krapina-Zagorje	0.179	0.242	11.843	0.201	0.066	6.235	0.237	**19.004**	2.78%
3	Sisak-Moslavina	0.167	0.520	4.030	0.952	1.210	5.615	0.467	**12.960**	1.89%
4	Karlovac	0.266	1.142	1.529	1.188	0.663	8.456	0.312	**13.557**	1.98%
5	Varaždin	0.042	0.036	18.037	0.961	0.000	7.193	1.494	**27.763**	4.06%
6	Koprivnica-Križevci	0.008	0.031	8.689	0.226	0.094	3.186	0.169	**12.403**	1.81%
7	Bjelovar-Bilogora	0.009	0.000	7.731	0.372	0.043	3.515	0.083	**11.753**	1.72%
8	Primorje-Gorski Kotar	4.337	11.345	4.721	8.971	0.641	42.815	1.104	**73.933**	10.81%
9	Lika-Senj	0.456	0.418	0.411	2.323	0.075	6.820	0.214	**10.718**	1.57%
10	Virovitica-Podravina	0.007	0.059	4.768	0.091	0.000	2.486	0.158	**7.567**	1.11%
11	Požega-Slavonia	0.097	0.034	6.864	0.630	0.466	4.806	0.516	**13.412**	1.96%
12	Slavonski Brod-Posavina	0.203	0.179	6.556	0.736	0.211	5.015	0.657	**13.558**	1.98%
13	Zadar	0.564	3.918	0.484	2.089	0.091	18.612	0.835	**26.591**	3.89%
14	Osijek-Baranja	0.142	0.085	9.943	0.532	2.503	17.455	0.602	**31.263**	4.57%
15	Šibenik-Knin	2.686	1.804	0.317	4.607	0.000	13.053	0.088	**22.555**	3.30%
16	Vukovar-Syrmia	0.140	0.106	6.271	0.557	0.000	5.800	0.106	**12.979**	1.90%
17	Split-Dalmatia	3.397	6.830	0.852	13.799	0.102	69.808	1.079	**95.867**	14.01%
18	Istria	2.070	11.045	7.541	3.342	1.876	56.342	0.687	**82.902**	12.12%
19	Dubrovnik-Neretva	3.357	4.165	0.023	9.399	0.000	28.655	1.286	**46.886**	6.85%
20	Međimurje	0.136	0.028	8.794	1.325	0.004	2.975	0.339	**13.600**	1.99%
21	City of Zagreb	0.106	1.066	44.926	1.747	25.521	29.023	1.852	**104.241**	15.24%
	TOTAL	**18.698**	**43.500**	**170.489**	**56.151**	**34.537**	**347.154**	**13.653**	**684.182**	100.00%
	SHARE	2.73%	6.36%	24.92%	8.21%	5.05%	50.74%	2.00%	100.00%	

Table 0.13: SERVICE SECTOR – Delivered cooling energy by energy product at county level

SERVICE SECTOR					
	County name	Energy delivered for cooling [GWh/a]			
		Electricity	Other	**TOTAL**	**SHARE**
1	Zagreb County	86.292	1.646	**87.938**	5.78%
2	Krapina-Zagorje	31.247	0.671	**31.917**	2.10%
3	Sisak-Moslavina	28.243	0.132	**28.375**	1.87%
4	Karlovac	31.651	0.398	**32.049**	2.11%
5	Varaždin	56.133	0.640	**56.773**	3.73%
6	Koprivnica-Križevci	32.553	0.323	**32.876**	2.16%
7	Bjelovar-Bilogora	20.033	0.263	**20.296**	1.33%
8	Primorje-Gorski Kotar	129.646	1.934	**131.579**	8.65%
9	Lika-Senj	13.617	0.047	**13.664**	0.90%
10	Virovitica-Podravina	14.330	0.308	**14.638**	0.96%
11	Požega-Slavonia	22.814	0.797	**23.611**	1.55%
12	Slavonski Brod-Posavina	34.926	0.226	**35.152**	2.31%
13	Zadar	57.778	0.484	**58.262**	3.83%
14	Osijek-Baranja	82.308	2.124	**84.432**	5.55%
15	Šibenik-Knin	36.659	0.291	**36.950**	2.43%
16	Vukovar-Syrmia	25.957	0.982	**26.939**	1.77%
17	Split-Dalmatia	237.504	1.657	**239.161**	15.73%
18	Istria	128.785	1.485	**130.270**	8.57%
19	Dubrovnik-Neretva	54.241	0.647	**54.888**	3.61%
20	Međimurje	29.127	0.356	**29.484**	1.94%
21	City of Zagreb	336.853	14.229	**351.081**	23.09%
	TOTAL	**1 490.698**	**29.642**	**1 520.340**	100.00%
	SHARE	98.05%	1.95%	100.00%	

Table 0.14: SERVICE SECTOR – Heating energy needed by building type at county level

SERVICE SECTOR										
		Heating energy needed [GWh/a]								
	County name	Office buildings	Educational buildings	Hotels and restaurants	Hospitals	Sports halls	Trade buildings	Other non-residential buildings	**TOTAL**	**SHARE**
1	Zagreb County	43.829	29.022	9.740	6.800	11.301	37.900	122.375	**260.967**	*6.59%*
2	Krapina-Zagorje	14.050	18.436	8.535	16.095	5.772	8.386	33.974	**105.248**	*2.66%*
3	Sisak-Moslavina	17.765	17.534	3.139	8.656	2.990	11.718	16.960	**78.761**	*1.99%*
4	Karlovac	13.881	14.385	4.614	4.896	3.518	9.469	35.338	**86.100**	*2.17%*
5	Varaždin	28.489	23.954	6.339	24.148	13.421	23.571	74.361	**194.283**	*4.91%*
6	Koprivnica-Križevci	17.160	11.055	3.602	8.219	4.355	11.925	36.669	**92.985**	*2.35%*
7	Bjelovar-Bilogora	12.543	14.331	2.969	9.806	9.446	7.574	13.418	**70.087**	*1.77%*
8	Primorje-Gorski Kotar	59.723	29.326	84.120	13.108	15.609	54.287	48.442	**304.613**	*7.69%*
9	Lika-Senj	5.108	2.845	9.874	2.703	1.327	4.402	8.315	**34.575**	*0.87%*
10	Virovitica-Podravina	9.105	11.452	2.266	5.578	3.734	5.226	9.650	**47.012**	*1.19%*
11	Požega-Slavonia	12.669	8.487	8.553	8.853	7.688	10.845	18.052	**75.148**	*1.90%*
12	Slavonski Brod-Posavina	19.497	15.261	2.686	7.806	8.111	16.584	27.632	**97.575**	*2.46%*
13	Zadar	19.497	10.854	36.691	4.926	4.043	31.542	16.565	**124.119**	*3.14%*
14	Osijek-Baranja	44.476	45.983	9.376	14.545	16.716	41.625	62.358	**235.079**	*5.94%*
15	Šibenik-Knin	12.953	9.930	18.696	8.000	2.149	16.710	14.326	**82.765**	*2.09%*
16	Vukovar-Syrmia	16.836	10.339	5.838	7.338	7.351	13.976	17.564	**79.241**	*2.00%*
17	Split-Dalmatia	68.326	33.013	104.743	23.749	24.260	220.994	88.638	**563.723**	*14.24%*
18	Istria	48.550	19.382	113.606	17.116	10.846	49.461	59.437	**318.397**	*8.04%*
19	Dubrovnik-Neretva	16.619	7.132	58.031	9.729	4.135	12.215	14.202	**122.063**	*3.08%*
20	Međimurje	19.584	10.229	4.339	5.984	8.924	11.823	41.755	**102.638**	*2.59%*
21	City of Zagreb	322.926	116.121	33.495	73.412	40.469	138.720	158.368	**883.511**	*22.32%*
	TOTAL	**823.589**	**459.072**	**531.249**	**281.467**	**206.163**	**738.952**	**918.397**	**3 958.889**	*100.00%*
	SHARE	*20.80%*	*11.60%*	*13.42%*	*7.11%*	*5.21%*	*18.67%*	*23.20%*	*100.00%*	

Table 0.15: SERVICE SECTOR – Energy needed for DHW preparation by building type at county level

SERVICE SECTOR										
		Energy needed for DHW preparation [GWh/a]								
	County name	Office buildings	Educational buildings	Hotels and restaurants	Hospitals	Sports halls	Trade buildings	Other non-residential buildings	**TOTAL**	**SHARE**
1	Zagreb County	3.331	4.140	5.160	2.762	1.687	0.463	9.741	**27.285**	*4.32%*
2	Krapina-Zagorje	1.067	2.680	4.056	5.195	1.237	0.108	2.561	**16.904**	*2.68%*
3	Sisak-Moslavina	1.355	3.467	1.617	3.317	0.467	0.146	1.413	**11.783**	*1.86%*
4	Karlovac	1.291	2.925	2.424	2.101	0.567	0.143	3.063	**12.512**	*1.98%*
5	Varaždin	2.221	3.430	3.154	7.707	1.933	0.276	5.510	**24.231**	*3.83%*
6	Koprivnica-Križevci	1.085	1.617	1.567	2.702	0.680	0.148	3.152	**10.951**	*1.73%*
7	Bjelovar-Bilogora	0.977	1.921	1.487	3.303	1.601	0.097	1.046	**10.433**	*1.65%*
8	Primorje-Gorski Kotar	4.916	5.750	43.757	6.846	2.518	0.710	4.251	**68.747**	*10.88%*
9	Lika-Senj	0.564	0.771	5.547	1.939	0.343	0.065	0.730	**9.959**	*1.58%*
10	Virovitica-Podravina	0.721	1.597	1.098	1.943	0.571	0.069	0.712	**6.711**	*1.06%*
11	Požega-Slavonia	0.969	1.219	3.761	3.089	1.253	0.141	1.494	**11.926**	*1.89%*
12	Slavonski Brod-Posavina	1.606	2.640	1.503	2.370	1.673	0.203	2.149	**12.145**	*1.92%*
13	Zadar	1.405	2.116	17.269	1.765	0.522	0.397	1.460	**24.934**	*3.95%*
14	Osijek-Baranja	3.467	8.033	4.311	4.817	2.928	0.610	4.850	**29.016**	*4.59%*
15	Šibenik-Knin	1.177	2.205	10.941	5.278	0.609	0.214	0.936	**21.359**	*3.38%*
16	Vukovar-Syrmia	1.278	1.852	3.338	2.550	1.277	0.164	1.347	**11.805**	*1.87%*
17	Split-Dalmatia	5.086	6.998	54.953	11.304	3.924	2.727	6.816	**91.808**	*14.53%*
18	Istria	3.740	3.578	57.114	5.586	1.916	0.639	5.200	**77.772**	*12.31%*
19	Dubrovnik-Neretva	1.156	1.698	34.174	4.662	1.135	0.152	1.348	**44.324**	*7.01%*
20	Međimurje	1.474	1.491	2.438	2.123	1.233	0.134	2.919	**11.813**	*1.87%*
21	City of Zagreb	23.073	14.766	15.947	23.967	3.779	1.855	12.052	**95.439**	*15.10%*
	TOTAL	**61.957**	**74.895**	**275.617**	**105.325**	**31.855**	**9.459**	**72.751**	**631.858**	*100.00%*
	SHARE	*9.81%*	*11.85%*	*43.62%*	*16.67%*	*5.04%*	*1.50%*	*11.51%*	*100.00%*	

Table 0.16: SERVICE SECTOR – Cooling energy needed by building type at county level

SERVICE SECTOR										
		Cooling energy needed [GWh/a]								
	County name	Office buildings	Educational buildings	Hotels and restaurants	Hospitals	Sports halls	Trade buildings	Other non-residential buildings	**TOTAL**	**SHARE**
1	Zagreb County	39.088	25.339	10.869	10.724	3.947	85.043	85.677	**260.687**	*5.79%*
2	Krapina-Zagorje	11.585	11.331	10.935	23.496	1.198	16.331	19.602	**94.478**	*2.10%*
3	Sisak-Moslavina	14.616	18.575	3.076	11.966	0.837	24.384	11.420	**84.873**	*1.88%*
4	Karlovac	13.227	15.337	5.306	12.689	1.180	22.585	25.068	**95.391**	*2.12%*
5	Varaždin	24.260	18.195	6.358	35.528	3.034	41.962	39.768	**169.104**	*3.75%*
6	Koprivnica-Križevci	21.219	9.894	2.937	12.285	0.889	25.875	24.915	**98.015**	*2.18%*
7	Bjelovar-Bilogora	10.716	8.864	3.783	16.029	1.075	14.577	5.344	**60.388**	*1.34%*
8	Primorje-Gorski Kotar	51.335	44.992	120.389	30.022	5.314	107.050	31.963	**391.064**	*8.68%*
9	Lika-Senj	4.750	4.161	10.047	7.447	0.644	8.779	5.074	**40.902**	*0.91%*
10	Virovitica-Podravina	7.689	10.602	2.146	8.845	0.519	8.177	5.351	**43.329**	*0.96%*
11	Požega-Slavonia	9.801	7.321	8.720	13.153	1.809	19.033	9.483	**69.320**	*1.54%*
12	Slavonski Brod-Posavina	17.138	19.186	2.587	11.329	2.335	37.110	15.341	**105.027**	*2.33%*
13	Zadar	16.689	17.650	43.106	16.030	1.105	67.272	12.016	**173.867**	*3.86%*
14	Osijek-Baranja	35.448	47.733	8.675	20.822	3.149	93.767	39.668	**249.261**	*5.53%*
15	Šibenik-Knin	11.632	12.932	21.410	23.833	0.524	30.042	9.925	**110.298**	*2.45%*
16	Vukovar-Syrmia	13.508	11.454	4.630	10.781	1.652	27.915	9.010	**78.950**	*1.75%*
17	Split-Dalmatia	52.726	46.655	122.198	42.465	5.697	387.999	56.597	**714.336**	*15.86%*
18	Istria	44.512	23.496	150.031	25.219	3.702	99.532	41.496	**387.990**	*8.61%*
19	Dubrovnik-Neretva	12.410	11.756	80.746	23.186	1.114	22.753	11.469	**163.435**	*3.63%*
20	Međimurje	16.194	8.743	5.807	9.382	1.020	24.714	21.915	**87.774**	*1.95%*
21	City of Zagreb	299.818	144.962	41.374	109.494	13.516	316.392	100.654	**1 026.210**	*22.78%*
	TOTAL	**728.359**	**519.181**	**665.128**	**474.724**	**54.259**	**1 481.293**	**581.756**	**4 504.700**	*100.00%*
	SHARE	*16.17%*	*11.53%*	*14.77%*	*10.54%*	*1.20%*	*32.88%*	*12.91%*	*100.00%*	

Table 0.17: Results of the calculation of high-efficiency cogeneration status

HEP d.d. thermal power plants		$Q_{f,\ fuel\ 1}$	$Q_{f,\ fuel\ 2}$	E_{del}	E_L	Q_{cogen}	H_u	h_u	Verification: Cogeneration	h_e	h_t	$h_{R,e}$	$h_{ref,e}$	$h_{ref,t}$	PES	Verification: HEC
		MJ	MJ	MWh_e	MWh_e	MJ	MJ	%	–	%	%	%	%	%	%	–
Installation	**Block**	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	Electricity consumed on site	Useful heat generated in cogeneration process at cogen. plant	Total annual heat generated at cogen. plant	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 electr. efficiency value of reference power plant	Elect. 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 B	54 758 665	0	0	343.38	50 703 186	50 703 186	94.851	**NO**	0.000	92.594	50.000	0.000	90.000	0.000	**NO**
	Block H	1 315 912 326	–	84 140	252.08	818 957 020	818 957 020	85.322	**YES**	23.087	62.235	50.000	49.529	90.000	13.617	**YES**
	Block J	1 321 283 344	–	88 817	327.63	822 611 526	822 611 526	86.547	**YES**	24.289	62.259	50.000	49.529	90.000	15.409	**YES**
TETO Zagreb	Block C	0	0	0	0.00	0	0	0.000	**NO**	0.000	0.000	0.000	0.000	0.000	0.000	**NO**
	Block K	5 988 899 239	0	760 236	0.00	946 075 540	946 075 540	61.496	**YES**	15.007	15.797	51.700	51.207	90.000	-113.404	**NO**
	Block L	5 064 276 462	–	583 281	0.00	2 099 810 900	2 099 810 900	82.926	**YES**	41.463	41.463	52.500	51.995	90.000	20.518	**YES**
TETO Osijek	Block 45 MW	1 065 935 563	6 416 713	56 209	5 290.29	486 255 585	486 255 585	65.991	**YES**	20.405	45.345	49.938	49.360	89.994	-9.020	**NO**
	Block PTA 1	2 160	0	0	0.00	0	0	0.000	**NO**	0.000	0.000	50.000	0.000	90.000	0.000	**NO**
	Block PTA 2	0	0	0	107.60	0	0	0.000	**NO**	0.000	0.000	0.000	0.000	0.000	0.000	**NO**
TE Sisak	Block A	0	0	0	0.00	0	0	0.000	**NO**	0.000	0.000	0.000	0.000	0.000	0.000	**NO**
	Block B	0	0	0	0.00	0	0	0.000	**NO**	0.000	0.000	0.000	0.000	0.000	0.000	**NO**
	Block C	5 207 795 369	–	719 922	4 068.03	63 292 139	63 292 139	51.263	**YES**	1.155	1.215	52.500	52.764	90.000	-2 726.016	**NO**

Table 0.18: Basic data on Croatia's DHS systems for 2019

	City	Company	Toplana	Winter peak load [kW]	Summer peak load [kW]	Winter average load [kW]	Summer average load [kW]	Annual thermal energy generated [MWh/a]	Annual thermal energy delivered [MWh/a]	Annual network heat losses [MWh/a]	Fuel
1	Rijeka	Energo	Gornja Vežica	12 000	2 950	1 000	2 950	15 903	10 753	5 150	natural gas, fuel oil
2	Rijeka	Energo	Vojak	11 300	3 740	1 300	3 740	12 966	10 188	2 778	natural gas, fuel oil
3	Vukovar	Tehnostan	Borovo Naselje	8 000				11 770	9 768	2 002	natural gas
4	Vukovar	Tehnostan	Olajnica	2 000				4 765	3 923	841	natural gas
5	Slavonski Brod	Brod Plin	Slavonija I	9 000				13 198	11 184	2 014	natural gas
6	Karlovac	Gradska Toplana	Tina Ujevića 6	50 000	0	23 311	0	65 085	49 505	15 580	natural gas
7	Samobor	HEP Toplinarstvo	Slavonska 5	4 000	900	1 540	370	8 600	7 633	967	natural gas
8	Velika Gorica	HEP Toplinarstvo	Cvjetno naselje 17	25 000	4 200	4 500	1 920	38 778	35 594	3 184	natural gas, fuel oil
9	Zagreb	HEP Toplinarstvo	M. Gavazzija 2	8 800	–	2 660	–	14 276	13 306	970	natural gas
10	Osijek	HEP Toplinarstvo	TETO + BETO	90 000	–	30 000	–	164 581	159 421	5 160	natural gas, biomass
11	Sisak	HEP Toplinarstvo	TETO + BETO	17 000	4 000	7 000	1 870	65 131	47 479	17 653	natural gas, biomass
12	Zagreb	HEP Toplinarstvo	TETO + ELTO	660 000	62 108	206 070	48 880	1 341 352	1 081 447	259 905	natural gas

Table 0.19: Basic data on Croatia's CHS systems for 2019

	City	Company	Toplana	Winter peak load [kW]	Summer peak load [kW]	Winter average load [kW]	Summer average load [kW]	Annual thermal energy generated [MWh/a]	Annual thermal energy delivered [MWh/a]	Annual network heat losses [MWh/a]	Fuel
1	Rijeka	Energo	V44	2 530	–	–	–	980	549	431	fuel oil
2	Rijeka	Energo	Zamet	4 600	2 300	1 400	2 300	6 205	4 120	2 085	fuel oil
3	Rijeka	Energo	PO-48	5 900	3 500	1 100	3 500	8 490	6 404	2 086	natural gas, extra light fuel oil
4	Rijeka	Energo	Podmurvice	2 900	–	–	–	2 055	1 426	629	natural gas, extra light fuel oil
5	Rijeka	Energo	Malonji	2 750	890	300	890	2 297	1 650	647	natural gas, extra light fuel oil
6	Rijeka	Energo	Kozala	3 740	1 900	700	1 900	5 070	3 943	1 127	natural gas, extra light fuel oil
7	Rijeka	Energo	Srdoči	3 700	–	–	–	3 922	2 613	1 309	natural gas, extra light fuel oil
8	Rijeka	Energo	Krnjevo	4 720	–	–	–	2 652	1 587	1 065	natural gas, extra light fuel oil
9	Rijeka	Energo	Škurinje	5 500	1 900	700	1 900	7 884	6 348	1 536	natural gas, extra light fuel oil
10	Vukovar	Tehnostan	Internati					420	299	121	natural gas
11	Vukovar	Tehnostan	D6					1 255	1 118	137	natural gas
12	Vukovar	Tehnostan	D2					713	623	90	pellets, fuel oil
13	Slavonski Brod	Brod Plin	Kralj Tomislav					2 329	2 137	192	natural gas
14	Slavonski Brod	Brod Plin	Mikrorajon					2 883	2 636	246	natural gas
15	Vinkovci	GTG	HŽ					583	583	0	natural gas
16	Vinkovci	GTG	A1					2 716	2 602	114	fuel oil
17	Vinkovci	GTG	S-96					706	687	19	natural gas
18	Vinkovci	GTG	S-103					1 140	1 047	93	natural gas
19	Vinkovci	GTG	S-108					626	587	39	natural gas
20	Vinkovci	GTG	S-122					1 638	1 728	90	natural gas
21	Karlovac	Gradska Toplana	Bašćinska cesta 41	500	0	265	0	659	481	179	natural gas
22	Požega	Komunalac	V. Nazora 1					–	1 310	1 310	natural gas
23	Požega	Komunalac	Krleže 1					–	582	582	natural gas
24	Samobor	HEP Toplinarstvo	Matoševa 1A	1 800	400	620	100	3 178	2 861	317	natural gas
25	Velika Gorica	HEP Toplinarstvo	J. Dobrile 40a	2 200	600	660	260	3 969	3 658	311	natural gas
26	Velika Gorica	HEP Toplinarstvo	J. Dobrile 7	1 100	300	230	80	1 258	1 172	86	fuel oil
27	Velika Gorica	HEP Toplinarstvo	Šibenska 20	1 000	300	270	100	1 420	1 244	176	natural gas
28	Velika Gorica	HEP Toplinarstvo	Domjanićeva 2	1 100	300	330	90	2 116	1 949	167	fuel oil

	City	Company	Toplana	Winter peak load [kW]	Summer peak load [kW]	Winter average load [kW]	Summer average load [kW]	Annual thermal energy generated [MWh/a]	Annual thermal energy delivered [MWh/a]	Annual network heat losses [MWh/a]	Fuel
29	Velika Gorica	HEP Toplinarstvo	Laszowskog 34	400	200	90	30	469	419	50	fuel oil
30	Velika Gorica	HEP Toplinarstvo	Trg kralja Tomislava 33	900	200	210	70	1 078	987	91	fuel oil
31	Zaprešić	HEP Toplinarstvo	TŽF 6 - Krajačića - Kodrmanova	2 200	–	420	–	1 977	1 781	196	natural gas
32	Zaprešić	HEP Toplinarstvo	Mokrićka 61 - A. Mihanovića 28	4 000	800	1 460	480	8 042	7 242	800	natural gas
33	Zaprešić	HEP Toplinarstvo	Trg mladosti 6–9	2 500	800	890	480	5 286	4 699	588	natural gas
34	Zagreb	HEP Toplinarstvo	G. Prejca 4	1 800	500	440	130	2 436	2 257	179	natural gas
35	Zagreb	HEP Toplinarstvo	Koledinečka 4	3 000	800	720	270	3 774	3 471	302	natural gas
36	Zagreb	HEP Toplinarstvo	A. lipa 1a	2 600	700	850	240	4 661	4 369	292	natural gas
37	Zagreb	HEP Toplinarstvo	Dubrava 36	1 400	300	450	140	2 279	2 090	189	natural gas
38	Zagreb	HEP Toplinarstvo	Remetinečki gaj 27b	1 400	600	420	130	2 284	2 124	160	fuel oil
39	Zagreb	HEP Toplinarstvo	Ilica 509	900	400	330	60	1 480	1 337	143	natural gas
40	Osijek	HEP Toplinarstvo	Jug III + PTV V. Nazor	1 750	250	570	118	4 315	3 783	532	natural gas
41	Ogulin	SKG	Marinkovića 12					393	316	76	fuel oil
42	Ogulin	SKG	Lj. Gaja 3					466	236	230	fuel oil
43	Virovitica	Poslovni park	Slavonija					483	423	59	natural gas
44	Virovitica	Poslovni park	P+5					430	391	39	natural gas
45	Virovitica	Poslovni park	P+7					1 016	891	125	natural gas
46	Virovitica	Poslovni park	P+8					618	542	76	natural gas
47	Virovitica	Poslovni park	Obrtnik					824	742	82	natural gas
48	Varaždin	Vartop	Zagreb County					3 104	1 569	1 535	natural gas
49	Varaždin	Vartop	Trakošćanska					3 769	2 245	1 524	natural gas
50	Topusko	Terme	Trg bana J. Jelačića						3 833	–	geothermal

Table 0.20: Basic data on Croatia's DHS (steam) systems for 2019

City		Company	Site	Winter peak hours [t/h]	Summer peak hours [t/h]	Winter average load [t/h]	Summer average load [t/h]	Annual thermal energy generated [t/a]	Annual thermal energy delivered [t/a]	Annual network heat losses [t/a]
1	Zagreb	HEP Toplinarstvo	EL-TO	76	37	39	18	273 312	227 038	46 274
2	Zagreb	HEP Toplinarstvo	TE-TO	56	42	32	18	236 617	124 689	111 928
3	Osijek	HEP Toplinarstvo	TE-TO	32	12	12	6	82 161	63 521	18 640
4	Sisak	HEP Toplinarstvo	TE-TO	48	30	9	4	33 514	33 514	–

Table 0.21: Data on Vukovar and Karlovac heating systems for 2019

City		Vukovar						Karlovac	
Address of plant		Domovinskog rata 3	Olajnica 18a	Županijska 96	Dunavska 5	R. Perešina 3a	Trg Slavija 1	Tina Ujevića 7	Bašćinska cesta 41
Heating system type		DHS	DHS	CHS	CHS	CHS	SHS	DHS	CHS
Total installed thermal capacity of the installation	kW	18 200	15 600	1 570	1 280	990	350	87 000	1 628
Natural gas consumption	m^3	1 197 370	503 381	134 353		42 273	14 285	6 649 880	69 600
Fuel oil consumption	kg				4 304				
Other fuels – wood pellets	kg				159 755			226 940	0
Total primary fuel energy	kWh	11 565 184	4 860 601	1 297 839	785 110	408 259	137 911	65 481 383	659 488
Heat fed into heating system	kWh	11 770 150	4 764 800	1 255 440	713 030	419 600	112 790	61 552 500	619 919
Distribution network length	m	4 335	2 035	315	210	320	–	21 000	200
Number of heating substations	pcs	55	21	9	4	3	1	175	9
Number of heating substations with DHW	pcs	48	4	5	–	2	–		
Number of thermal energy meters	pcs	103	25	14	4	5	1	175	9
Number of end-use customers	–	2 222	869	281	144	143	49	7 717	131
Households	–	2 199	841	278	142	142	49	7 400	131
Industry and commercial consumers	–	23	28	3	2	1	–	317	
Total heated area		126 030	52 828	13 429	6 974	4 279	2 397	494 079	7 669
Households	m^2	121 143	41 713	13 181	5 628	4 044	2 397	391 812	7 669
Industry and commercial consumers	m^2	4 887	11 114	247	1 346	235	–	102 267	
Connected load		14 199	6 016	1 860	1 053	402	253	62 914	563
Households	kW	13 567	4 475	1 838	687	373	253	49 453	563
Industry and commercial consumers	kW	632	1 541	23	366	29	–	13 461	
Thermal energy delivered		9 764 340	4 123 947	1 137 540	622 660	262 248	114 146	49 407 536	480 930

City		Vukovar						Karlovac	
Address of plant		Domovinskog rata 3	Olajnica 18a	Županijska 96	Dunavska 5	R. Perešina 3a	Trg Slavija 1	Tina Ujevića 7	Bašćinska cesta 41
Households – heating	kWh	6 168 220	2 892 812	927 734	336 570	111 634	114 146	38 378 877	480 930
Households – DHW	kWh	2 878 928	149 682	205 291	–	122 668	–		
Industry and commercial consumers – heating	kWh	712 047	1 081 453	4 515	286 090	27 946	–	11 028 659	
Industry and commercial consumers – DHW	kWh	5 145	–	–	–	–	–		
Calculated efficiency									
Boiler room efficiency	–	1.02	0.98	0.97	0.91	1.03	0.82	0.94	0.94
Distribution losses	–	0.17	0.13	0.09	0.13	0.38	-0.01	0.20	0.22
Total heating system losses	–	0.16	0.15	0.12	0.21	0.36	0.17	0.25	0.27
Boiler room availability									
Available boiler room capacity	kW	4 001	9 584	-290	227	588	97	24 086	1 065
Available boiler room capacity	%	0.22	0.61	-0.18	0.18	0.59	0.28	0.28	0.65

Table 0.22: Data on Slavonski Brod heating systems for 2019

Name of the installation (address)		Slavonija 1	Mikrorajon	Kralj Tomislav	Hebrang 4 s	Hebrang 4 j	Hebrang 5 s	Hebrang 5 j	Hebrang 6	Hebrang 7 s	Hebrang 7 j
Heating system type		DHS	CHS	CHS	SHS	SHS	SHS	SHS	SHS	SHS	SHS
Total installed thermal capacity of the installation	kW	10 500	3 260	3 960	1 020	1 080	1 020	1 020	1 860	1 240	1 240
Natural gas consumption	m^3	1 547 729	333 309	269 563	118 207	109 389	128 397	124 812	275 574	111 636	124 044
Total primary fuel energy	kWh	14 950 415	3 219 241	2 602 931	1 141 811	1 056 378	1 240 109	1 205 462	2 661 756	1 078 243	1 198 029
Heat fed into heating system	kWh	13 197 500	2 882 800	2 329 100	979 660	1 163 330	1 130 110	1 107 600	2 620 850	1 049 290	1 171 810
Distribution network length	m	4 097	1 208	865	0	0	0	0	880	0	0
Number of heating substations	pcs	27	10	7	0	0	0	0	4	0	0
Number of heating substations with DHW	pcs	22	9	4	0	0	0	0	4	0	0
Number of thermal energy meters	pcs	29	10	7	1	1	1	1	1	1	1
Number of end-use customers		2 116	631	511	276	256	311	286	600	270	268
Households		1 054	332	315	137	126	153	138	290	127	134
Industry and commercial consumers		39	2	7	2	4	5	10	21	15	1
Number of end-use customers with DHW		1 023	297	189	137	126	153	138	289	128	133
Total (heated) area		71 081	12 272	15 478	7 124	6 869	8 015	7 856	15 504	6 835	7 850
Households	m^2	55 410	12 154	14 997	7 025	6 538	7 834	7 193	14 504	6 326	7 663
Industry and commercial consumers	m^2	15 671	118	481	99	331	181	663	1 000	509	187
Connected load		9 316	1 652	1 987	661	738	793	856	1 702	954	1 076
Households	kW	7 077	1 629	1 919	638	677	764	756	1 569	874	1 025

Name of the installation (address)		Slavonija 1	Mikrorajon	Kralj Tomislav	Hebrang 4 s	Hebrang 4 j	Hebrang 5 s	Hebrang 5 j	Hebrang 6	Hebrang 7 s	Hebrang 7 j
Industry and commercial consumers	kW	2 239	23	68	23	61	29	100	133	80	51
Thermal energy delivered		11 183 647	2 636 461	2 136 941	979 660	1 163 331	1 130 110	1 107 599	2 400 768	1 049 290	1 171 807
Households – heating	kWh	5 575 651	1 826 543	1 498 678	580 772	573 456	618 247	571 684	1 330 383	575 044	665 504
Households – DHW	kWh	3 556 355	796 411	574 900	378 361	525 061	494 570	482 490	929 319	411 348	485 510
Commercial consumers – heating	kWh	2 046 995	13 507	63 363	20 527	64 814	17 293	53 425	141 066	50 156	20 793
Commercial consumers – DHW	kWh	4 646	0	0	0	0	0	0	0	12 742	0
Calculated efficiency											
Boiler room efficiency		0.88	0.90	0.89	0.86	1.10	0.91	0.92	0.98	0.97	0.98
Distribution losses		0.15	0.09	0.08	0.00	0.00	0.00	0.00	0.08	0.00	0.00
Total heating system losses		0.25	0.18	0.18	0.14	-0.10	0.09	0.08	0.10	0.03	0.02
Boiler room availability											
Available boiler room capacity	kW	1 184	1 608	1 973	359	342	227	164	158	286	164
Available boiler room capacity	%	0.11	0.49	0.50	0.35	0.32	0.22	0.16	0.08	0.23	0.13

Table 0.23: Data on Slavonski Brod heating systems for 2019

Name of the installation (address)		Jelas	Centar 2	Centre 4	Centre 6	I.B.M	Cipelarski trg	Zrinska	Vatrenka	Lutvinka	Badalića 2
Heating system type		SHS	SHS	SHS	SHS	SHS	SHS	SHS	SHS	SHS	SHS
Total installed thermal capacity of the installation	kW	1 400	780	780	780	330	520	390	520	1 820	390
Natural gas consumption	m^3	103 518	76 014	82 063	72 615	31 850	35 181	25 839	59 251	123 477	23 963
Total primary fuel energy	kWh	999 240	734 358	792 848	701 408	307 363	339 498	249 365	572 103	1 191 255	231 271
Heat fed into heating system	kWh	968 770	578 500	585 590	533 510	254 730	273 920	210 560	425 240	1 014 690	178 440
Distribution network length	m	0	0	0	0	0	0	0	0	0	0
Number of heating substations	pcs	0	0	0	0	0	0	0	0	0	0
Number of heating substations with DHW	pcs	0	0	0	0	0	0	0	0	0	0
Number of thermal energy meters	pcs	4	1	1	1	2	2	1	3	2	1
Number of end-use customers		136	181	170	169	33	64	41	38	198	38
Households		135	89	83	84	29	56	34	33	191	38
Industry and commercial consumers		1	4	2	2	4	8	7	5	7	0
Number of end-use customers with DHW		0	88	85	83	0	0	0	0	0	0
Total (heated) area		6 439	3 913	3 678	3 696	1 937	2 908	1 630	2 204	9 106	1 520
Households	m^2	6 228	3 791	3 593	3 572	1 486	2 250	1 434	1 531	8 787	1 520
Industry and commercial consumers	m^2	211	122	85	124	451	658	196	673	319	0

Name of the installation (address)		Jelas	Centar 2	Centre 4	Centre 6	I.B.M	Cipelarski trg	Zrinska	Vatrenka	Lutvinka	Badalića 2
Connected load		879	505	473	481	254	359	219	325	1 198	204
Households	kW	842	488	462	459	184	289	185	203	1 142	204
Industry and commercial consumers	kW	37	17	11	22	70	70	34	122	56	0
Thermal energy delivered		968 770	578 500	585 590	533 510	254 730	273 920	210 560	425 240	1 014 690	178 440
Households – heating	kWh	932 923	341 437	334 232	303 731	227 442	205 247	191 757	262 180	961 954	178 440
Households – DHW	kWh	0	226 490	233 031	212 670	0	0	0	0	0	0
Commercial consumers – heating	kWh	35 847	10 573	15 808	17 109	27 288	68 673	18 803	163 060	52 736	0
Commercial consumers – DHW	kWh	0	0	2 519	0	0	0	0	0	0	0
Calculated efficiency											
Boiler room efficiency		0.97	0.79	0.74	0.76	0.83	0.81	0.84	0.74	0.85	0.77
Distribution losses		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total heating system losses		0.03	0.21	0.26	0.24	0.17	0.19	0.16	0.26	0.15	0.23
Boiler room availability											
Available boiler room capacity	kW	521	275	307	299	76	161	171	195	622	186
Available boiler room capacity	%	0.37	0.35	0.39	0.38	0.23	0.31	0.44	0.38	0.34	0.48

Table 0.24: Data on Rijeka heating systems for 2019

Name of the installation (address)		GORNJA VEŽICA	VOJAK	KRNJEVO	KOZALA	ŠKURINJE	PODMUR VICE	PO-48	V-44	ZAMET	MALONJI	SRDOČI
Heating system type		DHS		CHS								
Total installed thermal capacity of the installation	kW	18 450	14 490	10 620	9 340	9 200	4 150	9 400	2 530	9 260	3 680	6 100
Natural gas consumption	m³	1 692 802	557 201	268 040	540 340	840 433	219 242	905 299			245 082	418 410
Consumption of medium fuel oil	kg		697 280						88 325	559 000		
Consumption of extra light fuel oil	l	3 719		13 950	563	680		550		0		
Total primary fuel energy	kWh	15 902 642	12 965 954	2 652 134	5 069 863	7 883 711	2 054 857	8 490 152	980 408	6 204 900	2 296 975	3 921 764
Heat fed into heating system	kWh	14 218 316	11 674 549	2 309 321	4 410 544	7 280 034	1 715 800	7 230 890	751 548	5 074 330	1 939 230	3 422 132
Distribution network length	m	3 257	4 095	1 471	927	1 024	336	817	445	1 032	388	1 286
Number of heating substations	pcs	25	36	8	9	16	5	11	3	9	5	25
Number of heating substations with DHW	pcs	25	19	–	6	15	–	11	3	9	4	–
Number of thermal energy meters	pcs	41	39	8	12	26	5	26	3	16	7	25
Number of end-use customers		2 411	1 009	669	583	1 005	427	1 073	176	845	310	762
Households		2 401	996	669	582	1 002	427	1 071	175	845	310	762
Industry and commercial consumers		10	13	–	1	3	–	2	1	–	–	–
Number of end-use customers with DHW		2 382	980	–	382	1 001	–	1 052	–	728	237	–

Name of the installation (address)		GORNJA VEŽICA	VOJAK	KRNJEVO	KOZALA	ŠKURINJE	PODMUR VICE	PO-48	V-44	ZAMET	MALONJI	SRDOČI
Total heated area												
Households	m^2	129 699	55 541	36 185	38 515	63 594	23 493	59 625	8 549	44 200	19 132	40 241
Industry and commercial consumers	m^2	8 426	8 208	2 645	3 500	1 712	–	1 840	1 482	–	–	–
Connected load		13 966	7 201	4 866	4 522	8 082	2 809	7 812	923	4 758	2 140	5 246
Households	kW	12 852	6 134	4 522	4 522	7 928	2 809	7 573	730	4 758	2 140	5 246
Industry and commercial consumers	kW	1 114	1 067	344	–	153	–	239	193	–	–	–
Thermal energy delivered		10 753 029	10 187 664	1 587 350	3 943 144	6 347 527	1 426 090	6 404 000	549 370	4 119 783	1 650 035	2 612 845
Households – heating	kWh	5 465 170	3 875 421	1 587 350	2 349 450	3 651 138	1 426 090	3 456 220	412 320	2 519 900	1 184 600	2 612 845
Households – DHW	kWh	4 853 819	951 150	0	1 369 294	2 595 642	0	2 815 150	0	1 599 883	465 435	0
Industry and commercial consumers – heating	kWh	434 040	5 361 093	0	224 400	100 747	0	132 630	137 050	0	0	0
Calculated efficiency												
Boiler room efficiency	–	0.89	0.90	0.87	0.87	0.92	0.83	0.85	0.77	0.82	0.84	0.87
Distribution losses	–	0.24	0.13	0.31	0.11	0.13	0.17	0.11	0.27	0.19	0.15	0.24
Total heating system losses	–	0.32	0.21	0.40	0.22	0.19	0.31	0.25	0.44	0.34	0.28	0.33
Boiler room availability												
Available boiler room capacity	kW	4 484	7 289	5 754	4 818	1 118	1 341	1 588	1 607	4 502	1 540	854
Available boiler room capacity	%	0.24	0.50	0.54	0.52	0.12	0.32	0.17	0.64	0.49	0.42	0.14

Table 0.25: Data on Zagreb, Osijek and Sisak heating systems for 2019

City		ZAGREB			OSIJEK					SISAK	
Production unit's name (address)		TE-TO Zagreb	EL-TO Zagreb	KBC ZAGREB	TE-TO Osijek	BE-TO Osijek	Toplana – Cara Hadrijana	Kotlovnica V. Nazor	Kotlovnica Jug	TE Sisak	BE-TO Sisak
Heating system type		**DHS**			**DHS**				**CHS**	**DHS**	
Total installed boiler room capacity	kW	687 400	426 300	19 800	203 300	10 000	133 000	3 750	3 750	101 000	10 000
Natural gas consumption	m³	184 063 757		27 748	17 536 090		0	121 622	379 380	5 564 230	
Consumption of medium fuel oil [LU-S-I]	t				82		0				
Forest biomass consumption	t					23 107					13 841
Total fuel energy input	kWh	1 780 826 214		268 788	170 274 909	66 314 371	0	1 176 276	3 665 279	54 026 598	39 175 783
Heat fed into heating system	kWh	1 766 122 862		252 800	233 021 110		0	1 038 220	3 276 320	93 048 442	
Distribution network length	m	278 109			55 141			588	1 161	30 030	
Number of heating substations	pcs	2 664			713			11	20	172	
Number of heating substations with DHW	pcs	1 853						11	10	129	
Number of thermal energy meters		2 812			775			11	20	238	
Number of end-use customers		97 484			11 460			0	337	4 150	
Households		93 069			10 165				334	4 066	
Industry and commercial consumers (hot/warm water)		4 352			1 278				3	83	
Industry and commercial consumers (process steam)		51			13					0	
Number of end-use customers with DHW		82 531						433	334	3 359	
Predominantly for commercial use		12			4				0	1	
Total heated area		5 726 803			1 113 138				17 351	290 475	
Households	m²	5 115 630			592 129				17 125	230 258	
Industry and commercial consumers (hot/warm water)	m²	611 173			521 008				225	60 216	
Installed/leased capacity		1 126 901			177 750			3 543		39 978	
Households	kW	635 795			85 798			3 522		31 203	
Industry and commercial consumers (hot/warm water)	kW	335 858			73 147			20		8 776	

City		ZAGREB			OSIJEK					SISAK	
Production unit's name (address)		TE-TO Zagreb	EL-TO Zagreb	KBC ZAGREB	TE-TO Osijek	BE-TO Osijek	Toplana – Cara Hadrijana	Kotlovnica V. Nazor	Kotlovnica Jug	TE Sisak	BE-TO Sisak
Industry and commercial consumers (process steam)	kW	79 131			10 642			0		0	
Predominantly for commercial use*	kW	76 116			8 163			0		0	
Thermal energy delivered		1 374 435 105		252 800	212 333 430		0	3 782 652		75 395 740	
Households – heating	kWh	592 214 470			90 729 147		0	2 377 298		31 697 084	
Households – DHW	kWh	207 325 380						1 386 652		6 221 039	
Industry and commercial consumers – heating	kWh	321 619 603			68 691 498		0	18 702		9 526 209	
Industry and commercial consumers – DHW	kWh	1 248 511			0					34 246	
Industry and commercial consumers (process steam)	kWh	104 277 032			30 536 489		0	0		0	
Predominantly for commercial use*	kWh	147 750 110		252 800	22 376 296		0	0		27 917 162	
Calculated efficiency											
Boiler room efficiency		0.77		0.94	0.89				1.03	0.81	
Distribution losses		0.22		0.00	0.09				0.06	0.19	
Total heating system losses		0.23		0.06	0.09				0.23	0.19	

Table 0.26: Data on Zagreb heating systems for 2019

		ZAGREB – DUBRAVA											
Production unit's name (address)		M. GAVAZZIJA 3	ALEJA LIPA 1A	MIRKA DEANOVIĆA 15	DUBRAVA 37	KOLEDINEČKA 5	GJURE PREJCA 5	DUBRAVA 218	GRIŽANSKA 21	HRVATSKOG PROLJEĆA 28	HRVATSKOG PROLJEĆA 32	HRVATSKOG PROLJEĆA 36	HRVATSKOG PROLJEĆA 40
Heating system type		DHS	CHS	CHS	CHS	CHS	CHS	SHS	SHS	SHS	SHS	SHS	SHS
Total installed boiler room capacity	kW	13 296	4 530	2 908	3 000	3 000	3 141	3 141	1 200	3 688	3 688	3 688	3 200
Natural gas consumption	m^3	1 622 862	587 735	258 484	306 053	520 221	307 190	352 437	113 842	228 241	279 485	162 887	219 596
Extra light fuel oil consumption	l	0	0	0	0	0	0	0	0	0	0	0	0
Total fuel energy input	kWh	15 687 755	5 684 326	2 500 234	2 959 663	5 031 926	2 970 877	3 408 268	1 100 834	2 206 628	2 701 343	1 575 137	2 122 350
Heat fed into heating system	kWh	14 275 857	4 661 147	2 150 201	2 278 941	3 773 945	2 436 119	2 250 650	852 000	1 519 000	1 960 614	826 000	969 140
Distribution network length	m	3 505	145	80	95	200	175	0	0	0	0	0	0
Number of heating substations	pcs	44	2	1	4	4	1	1	1	1	1	1	1

		ZAGREB – DUBRAVA											
Production unit's name (address)		M. GAVAZZIJA 3	ALEJA LIPA 1A	MIRKA DEANOVIĆA 15	DUBRAVA 37	KOLEDINEČKA 5	GJURE PREJCA 5	DUBRAVA 218	GRIŽANSKA 21	HRVATSKOG PROLJEĆA 28	HRVATSKOG PROLJEĆA 32	HRVATSKOG PROLJEĆA 36	HRVATSKOG PROLJEĆA 40
Number of heating substations with DHW	pcs	0	2	1	3	3	1	1	1	1	1	1	1
Number of thermal energy meters		44	5	1	12	10	7	3	2	5	3	3	4
Number of end-use customers	–	1 952	399	374	182	422	252	298	87	132	122	128	138
Households	–	1 916	366	374	159	406	247	282	84	121	121	121	122
Industry and commercial consumers	–	36	33	0	23	16	5	16	3	11	1	7	16
Number of end-use customers with DHW	–		366	374	159	409	249	282	84	121	121	121	122
Total heated area		89 900	24 414	12 490	14 012	24 520	13 405	18 210	4 634	13 764	14 487	8 256	10 859
Households	m^2	82 320	21 346	12 490	9 095	22 786	13 061	16 959	4 415	7 342	7 391	7 348	7 413
Industry and commercial consumers	m^2	7 5780 [sic – likely editing error: 7 btw. 5 and 8]	3 068	0	4 917	1 734	344	1 251	219	6 422	7 095	908	3 446
Installed/leased capacity		13 634	3 046	1 853	1 751	3 514	2 119	1 903	664	1 662	2 048	1 172	1 461
Households	kW	11 850	2 622	1 853	1 107	3 266	2 065	1 772	632	1 001	1 044	1 029	965
Industry and commercial consumers	kW	1 784	424	0	644	248	54	131	31	661	1 004	143	496
Thermal energy delivered		13 305 731	4 369 000	2 064 000	2 090 110	3 471 450	2 256 965	2 250 650	852 000	1 519 000	1 960 614	826 000	969 140
Households – heating	kWh	10 645 141	2 266 000	1 409 336	1 054 072	2 081 218	1 417 607	1 470 955	610 528	530 000	630 000	393 000	298 554
Households – DHW	kWh	0	1 566 000	654 664	526 664	1 132 310	797 880	578 869	212 999	353 000	363 614	335 000	320 000
Industry and commercial consumers – heating	kWh	2 660 590	537 000	0	509 374	249 782	34 086	200 826	28 473	636 000	967 000	98 000	350 586
Industry and commercial consumers – DHW	kWh	0	0	0	0	8 140	7 392	0	0	0	0	0	0
Calculated efficiency													
Boiler room efficiency		0.85	0.77	0.83	0.71	0.69	0.76	0.66	0.77	0.69	0.73	0.52	0.46
Distribution losses		0.07	0.06	0.04	0.08	0.08	0.07	0.00	0.00	0.00	0.00	0.00	0.00
Total heating system losses		0.15	0.23	0.17	0.29	0.31	0.24	0.34	0.23	0.31	0.27	0.48	0.54
Boiler room availability													
Available boiler room capacity	kW	-338	1 484	1 055	1 249	-514	1 022	1 238	536	2 026	1 640	2 516	1 739
Available boiler room capacity	%	-0.03	0.33	0.36	0.42	-0.17	0.33	0.39	0.45	0.55	0.44	0.68	0.54

Table 0.27: Data on Zagreb heating systems for 2019

		ZAGREB – PREČKO		ZAGREB – SUSEDGRAD		ZAGREB – CENTAR		
Production unit's name (address)		REMETINEČKI GAJ 27B	REMETINEČKA C. 75	CRNOJEZERSKA 18	ILICA 510	BELOSTENČEVA 3	TRG BANA J.JELAČIĆA 3	VILKA ŠEFERA 10
Heating system type		CHS	SHS	SHS	CHS	SHS	SHS	SHS
Total installed boiler room capacity	kW	2 900	1 711	2 000	2 094	400	1 114	2 400
Natural gas consumption	m^3	107 608	160 128	0	218 621	39 658	0	163 766
Extra light fuel oil consumption	l	175 364	0	191 467	0	0	109 784	0
Total fuel energy input	kWh	2 687 031	1 548 357	1 791 372	2 113 631	383 318	1 027 143	1 583 671
Heat fed into heating system	kWh	2 283 976	1 386 410	1 652 000	1 479 542	328 400	840 081	1 308 000
Distribution network length	m	142	0	0	70	0	0	0
Number of heating substations	pcs	3	1	1	3	1	1	1
Number of heating substations with DHW	pcs	3	1	1	2	0	1	1
Number of thermal energy meters		4	1	2	7	1	5	1
Number of end-use customers	–	144	192	153	107	37	50	124
Households	–	135	146	138	100	36	39	111
Industry and commercial consumers	–	9	46	15	7	1	11	13
Number of end-use customers with DHW	–	136	146	152	100		41	111
Total heated area		8 160	9 083	9 762	6 145	1 837	6 156	9 321
Households	m^2	7 474	7 150	8 156	5 099	1 718	3 964	8 428
Industry and commercial consumers	m^2	687	1 933	1 606	1 046	119	2 192	894
Installed/leased capacity		1 734	1 425	1 192	1 023	292	839	1 527
Households	kW	1 028	1 122	996	739	274	543	1 383
Industry and commercial consumers	kW	706	303	196	283	18	296	144
Thermal energy delivered		2 123 570	1 386 410	1 652 000	1 337 000	328 400	840 081	1 308 000
Households – heating	kWh	924 333	926 101	1 095 650	847 000	307 917	468 341	863 401
Households – DHW	kWh	416 210	291 380	314 049	260 000	0	109 660	318 336
Industry and commercial consumers – heating	kWh	782 027	168 929	216 185	230 000	20 483	253 466	126 263
Industry and commercial consumers – DHW	kWh	1 000	0	26 116	0	0	8 614	0
Calculated efficiency								
Boiler room efficiency		0.79	0.90	0.92	0.63	0.86	0.82	0.83
Distribution losses		0.07	0.00	0.00	0.10	0.00	0.00	0.00
Total heating system losses		0.21	0.10	0.08	0.37	0.14	0.18	0.17
Boiler room availability								
Available boiler room capacity	kW	1 166	286	808	1 071	108	275	873
Available boiler room capacity	%	0.40	0.17	0.40	0.51	0.27	0.25	0.36

Table 0.28: Data on Samobor and Zaprešić heating systems for 2019

		SAMOBOR						ZAPREŠIĆ					
Production unit's name (address)		SLAVONSKA 6	MATOŠEVA 1A	LJUDEVITA GAJA 6	BASARIČEKOVA 9	DRAGE KODRMANA 13	FRANJE KRAJAČIĆA 1	TRG ŽR. FAŠIZMA 6	PAVLA LONČARA 6	MIHANOVIĆA 28	MOKRIČKA 61	TRG MLADOSTI 6	TRG MLADOSTI 10
Heating system type		DHS	CHS	SHS	SHS	CHS			SHS	CHS		CHS	
Total installed boiler room capacity	kW	11 800	4 800	930	1 220	1 200	1 700	1 500	1 330	4 530	4 400	3 300	2 400
Natural gas consumption	m³	1 050 037	402 367	0	4 157	0	251 602	0	0	489 001	535 079	145 272	488 762
Extra light fuel oil consumption	l	0	0	47 003	69 004	0	0	0	56 503	0	0	0	0
Total fuel energy input	kWh	10 117 797	3 875 354	439 762	685 935	0	2 441 225	0	528 644	4 746 265	5 182 521	1 410 248	4 736 810
Heat fed into heating system	kWh	8 600 127	3 177 790	190 000	523 524	1 977 392			474 000	8 042 317		5 286 470	
Distribution network length	m	2 134	1 220	0	0	385			0	593	915	475	
Number of heating substations	pcs	20	9	1	1	1	1	1	1	9	14	6	3
Number of heating substations with DHW	pcs	18	7	0	1	0	0	0	1	5	14	4	3
Number of thermal energy meters		21	9	1	4	1	2	3	2	10	14	7	4
Number of end-use customers	–	1 037	228	57	60	149	156	125	78	534	634	310	386
Households	–	1 022	220	56	58	149	137	121	78	528	626	295	347
Industry and commercial consumers	–	15	8	1	2	0	19	4	0	6	8	15	39
Number of end-use customers with DHW	–	962	157		58				78	284	626	295	347
Total heated area**		49 888	13 206	3 763	3 563	6 113	7 158	6 138	2 561	25 806	25 683	18 071	16 916
Households	m²	47 609	12 483	3 716	3 282	6 113	6 033	4 998	2 561	25 431	25 155	16 808	15 490
Industry and commercial consumers	m²	2 279	723	47	281	0	1 124	1 140	0.00	375	528	1 263	1 426
Installed/leased capacity		6 871	2 680	466	542	1 084	1 109	967	400	4 004	3 259	2 527	1 824
Households	kW	6 572	1 428	455	504	1 084	943	806	400	3 950	3 199	2 303	1 625
Industry and commercial consumers	kW	300	1 252	11	38	0	166	161	0	55	60	224	199
Thermal energy delivered		7 632 808	2 861 147	190 000	523 524	623 000	564 000	594 260	474 000	3 088 995	4 152 886	2 278 960	2 419 570
Households – heating	kWh	5 105 364	1 291 895	185 242	333 810	623 000	457 000	463 000	320 000	2 306 568	2 674 420	1 231 664	1 353 184
Households – DHW	kWh	2 267 914	395 906	0	166 520	0	0	0	154 000	738 008	1 451 733	976 296	884 913
Industry and commercial consumers – heating	kWh	259 530	1 165 865	4 758	23 194	0	107 000	131 260	0	44 419	26 733	71 000	181 473
Industry and commercial consumers – DHW	kWh	0	7 481	0	0	0	0	0	0	0	0	0	0
Calculated efficiency													

		SAMOBOR						ZAPREŠIĆ					
Production unit's name (address)		SLAVONSKA 6	MATOŠEVA 1A	LJUDEVITA GAJA 6	BASARIČEKOVA 9	DRAGE KODRMANA 13	FRANJE KRAJAČIĆA 1	TRG ŽR. FAŠIZMA 6	PAVLA LONČARA 6	MIHANOVIĆA 28	MOKRIČKA 61	TRG MLADOSTI 6	TRG MLADOSTI 10
Boiler room efficiency		0.75	0.74	0.43	0.76	0.73			0.90	0.73		0.76	
Distribution losses		0.11	0.10	0.00	0.00	0.10			0.00	0.10		0.11	
Total heating system losses		0.25	0.26	0.57	0.24	0.27			0.10	0.27		0.24	
Boiler room availability													
Available boiler room capacity	kW	4 929	2 120	464	678	1 241			930	1 667		1 350	
Available boiler room capacity	%	0.42	0.44	0.50	0.56	0.28			0.70	0.19		0.24	

Table 0.29: Data on Velika Gorica heating systems for 2019

Production unit's name (address)		ZAGREBAČKA 71	DR J. DOBRILE 40A	DR J. DOBRILE 8	CVJETNO NASELJE 18	VLADIMIRA VIDRIĆA 1	MAGDALENIĆEVA 3	KR. D. ZVONIMIRA 9	E. LASZOWSKOG 35	TRG KRALJA TOMISLAVA 34	D. DOMJANIĆA 3	ZAGREBAČKA 126	ŠIBENSKA
Heating system type		SHS	CHS	CHS	DHS				CHS	CHS	CHS	SHS	CHS
Total installed boiler room capacity	kW	1 000	4 359	2 727	5 232	19 779	18 498	8 326	1 200	2 268	2 200	2 000	1 628
Natural gas consumption	m^3	0	0	0	0	4 311 614	0	0	0	0	222 527	0	188 261
Extra light fuel oil consumption	l	43 016	471 343	158 170	8 000	0	531 653	0	59 000	143 970	8 000	117 508	0
Total fuel energy input	kWh	402 459	4 409 903	1 479 844	74 848	41 672 014	4 974 165	0	552 006	1 346 989	2 226 894	1 099 409	1 821 058
Heat fed into heating system	kWh	335 796	3 968 912	1 257 868	38 778 453				469 205	1 077 591	2 115 550	940 101	1 420 425
Distribution network length	m	0	1 260	50	470	3 973	3 380	520	150	50	120	0	248
Number of heating substations	pcs	1	10	3	10	26	37	10	5	2	3	1	6
Number of heating substations with DHW	pcs	1	6	2	9	25	21	10	1	1	3	1	6
Number of thermal energy meters	pcs	3	14	5	22	51	57	15	6	7	4	2	11
Number of end-use customers		45	500	184	323	1 840	1 925	466	38	68	220	149	144
Households	–	39	464	173	313	1 782	1 837	452	38	59	213	145	144
Industry and commercial consumers	–	6	36	11	10	58	88	14	0	9	7	4	0
Number of end-use customers with DHW	–	39	471	173	313	1 753	1 528	452	38	59	214	145	144
Total heated area		2 991	22 988	8 632	17 377	94 548	98 358	24 503	2 859	7 959	11 073	6 716	7 355
Households	m^2	2 494	21 783	8 114	16 745	91 029	87 426	24 057	2 859	3 102	10 675	6 382	7 355

Production unit's name (address)		ZAGREBAČK A 71	DR J. DOBRILE 40A	DR J. DOBRILE 8	CVJETNO NASELJE 18	VLADIMIRA VIDRIĆA 1	MAGDALENIĆEVA 3	KR. D. ZVONIMIRA 9	E. LASZOWSKOG 35	TRG KRALJA TOMISLAVA 34	D. DOMJANIĆA 3	ZAGREBAČKA 126	ŠIBENSKA
Industry and commercial consumers	m^2	497	1 205	518	631	3 519	10 932	446	0	4 857	398	334	0
Installed/leased capacity		372	2 520	1 526	2 230	13 935	15 549	4 457	376	1 192	1 744	738	1 366
Households	kW	308	2 316	1 453	2 107	12 674	12 001	3 331	376	434	1 676	702	1 366
Industry and commercial consumers	kW	64	204	73	124	1 261	3 548	1 126	0	758	68	37	0
Thermal energy delivered		335 796	3 657 847	1 171 736	2 473 312	13 658 842	14 762 716	4 699 253	419 351	986 877	1 948 616	940 101	1 244 000
Households – heating	kWh	156 000	2 092 790	633 368	1 501 726	6 878 328	6 670 973	1 694 719	219 001	189 290	1 348 081	529 958	821 336
Households – DHW	kWh	122 000	1 375 260	483 689	915 757	5 737 526	4 836 269	1 447 917	200 350	213 090	538 020	385 611	422 664
Industry and commercial consumers – heating	kWh	57 796	175 057	54 679	55 829	1 021 748	3 238 028	1 556 617	0	584 497	54 745	24 532	0
Industry and commercial consumers – DHW	kWh	0	14 740	0	0	21 240	17 446	0	0	0	7 770	0	0
Calculated efficiency													
Boiler room efficiency		0.83	0.83	0.79	0.76				0.76	0.73	0.88	0.86	0.68
Distribution losses		0.00	0.08	0.07	0.08				0.11	0.08	0.08	0.00	0.12
Total heating system losses		0.17	0.17	0.21	0.24				0.24	0.27	0.12	0.14	0.32
Boiler room availability													
Available boiler room capacity	kW	628	1 839	1 201	15 663				824	1 076	456	1 262	262
Available boiler room capacity	%	0.63	0.42	0.44	0.30				0.69	0.47	0.21	0.63	0.16

RESULTS OF THE SENSITIVITY ANALYSIS

Table 0.30: Results of the sensitivity analysis of a 20% increase in investment unit price for households, services and DHS, in absolute and relative terms

Investment unit price increase by 20%		**up to 2030**				**2031–2050**			
Measure code	Title of measure	**FNPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**	**FNPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
HOUSEHOLD SECTOR									
H_TB_1	Replacement of individual firewood stoves with central firewood boilers	-218.3	-35.4%	-193.9	-38.5%				
H_TB_2	Replacement of central firewood boilers with central modern biomass boilers	-1 176.8	-5.4%	-1 476.7	-4.0%	-952.1	-4.4%	-1 938.4	-3.3%
H_TB_3	Replacement of traditional biomass boilers with heat pumps					-339.9	-15.3%	-781.7	-9.7%
H_TB_4	Solar heating combined with heat pumps after H_TB_3 measure is implemented					-632.3	-68.9%	-589.4	-207.5%
H_ELLU1	Replacement of central fuel oil boilers with central modern biomass boilers	910.4	-6.1%	1 700.8	-3.2%				
H_ELLU2	Replacement of central fuel oil boilers with heat pumps	1 782.6	-3.6%	2 749.0	-2.2%				
H_ELLU3	Solar heating combined with heat pumps after ELLU2 measure is implemented	930.8	-28.8%	2 349.0	-13.1%				
H_UNP1	Replacement of central LPG boilers with central modern biomass boilers	1 370.4	-4.4%	2 204.2	-2.6%	1 931.1	-2.4%	4 845.0	-1.5%
H_UNP2	Replacement of central LPG boilers with heat pumps	2 297.1	-2.9%	3 318.0	-1.9%	2 643.9	-1.9%	6 191.7	-1.3%
H_UNP3	Solar heating combined with heat pumps after UNP2 measure is implemented	1 392.1	-22.3%	2 893.0	-11.6%	2 303.6	-11.5%	6 415.8	-6.7%
H_PP1	Replacement of standard natural gas boilers with condensing natural gas boilers	320.7	-14.8%	478.9	-9.9%	345.2	-10.5%	867.6	-6.7%
H_PP2	Natural gas micro-CHP	-1 207.3	-43.9%	-946.0	-58.1%	-471.1	-134.1%	-293.0	-337.7%
H_PP3	Solar heating combined with a condensing boiler after PP1 measure is implemented	-382.3	-1 810.6%	588.7	-39.4%	44.7	-87.2%	1 677.5	-21.8%
H_PP4	Replacement of natural gas boilers with heat pumps	533.5	-11.7%	1 018.9	-6.1%	389.1	-12,0%	1 450.9	-5.3%

Investment unit price increase by 20%		**up to 2030**				**2031–2050**			
Measure code	Title of measure	**FNPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**	**FNPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
H_PP_5	Replacement of natural gas boilers with modern biomass boilers					-332.1	-16.7%	88.3	-45.4%
H_EE_1	Increase in the share of heat pumps vs. electric resistance heating — heat pump installation	-270.9	-301.5%	150.6	-56.1%	1 676.2	-5.7%	4 148.6	-3.6%
H_TB_2_a	Replacement of traditional biomass boilers with modern biomass boilers	-512.2	-2.2%	-639.0	-1.7%	-591.8	-1.4%	-1 190.8	-1.1%
H_TB_4_a	Installation of solar collectors for DHW preparation					165.7	-24.6%	547.5	-13.2%
H_TB_3_a	Installation of heat pumps for DHW preparation					-381.9	-2.5%	-836.3	-1.8%
H_ELLU1_a	Replacement of fuel oil boilers with modern biomass boilers	1 116.9	-1.2%	1 953.1	-0.6%				
H_ELLU2_a	Replacement of fuel oil boilers with heat pumps	1 448.8	-1,0%	2 325.2	-0.6%				
H_ELLU3_a	Installation of solar collectors for DHW preparation	316.7	-52.7%	1 619.2	-17.1%				
H_UNP1_a	Replacement of LPG boilers with modern biomass boilers	1 722.9	-0.9%	2 629.6	-0.5%	2 204.5	-0.5%	5 377.3	-0.3%
H_UNP2_a	Replacement of LPG boilers with heat pumps	2 099.1	-0.8%	3 051.4	-0.5%	2 487.7	-0.5%	5 855.5	-0.3%
H_UNP3_a	Installation of solar collectors for DHW preparation	816.0	-32.9%	2 251.3	-14.4%	1 861.8	-13.9%	5 617.7	-7.6%
H_PP1_a	Replacement of standard boilers with condensing boilers	251.8	-5.1%	394.8	-3.1%				
H_PP2_a	Natural gas micro-CHP	601.5	-12.7%	886.0	-8.5%	839.5	-7.2%	1 854.1	-5.2%
H_PP3_a	Installation of solar collectors for DHW preparation	-970.3	-71.5%	-64.2	-120.2%	-406.1	-297,0%	865.7	-35.1%
H_PP4_a	Replacement of natural gas boilers with heat pumps	327.9	-5,0%	745.3	-2.1%	227.2	-5.4%	1 106.3	-1.8%
H_PP_5_a	Replacement of natural gas boilers with modern biomass boilers					-13.9	-412,0%	717.1	-2.3%
H_EE_1_a	Installation of heat pumps for DHW preparation					1 574.7	-2,0%	3 632.1	-1.3%

Investment unit price increase by 20%		up to 2030				2031–2050			
Measure code	Title of measure	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
H_EE_2_a	Replacement of electric boilers with solar collectors	1 533.8	-22,0%	3 157.5	-11.5%	0.0		0.0	
H_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	141.5	-32.6%	287.0	-18.4%	25.6	-67.7%	183.3	-31.1%
SERVICE SECTOR									
S_ELLU1	Replacement of fuel oil boilers with modern biomass boilers	717.8	-7.6%	1 459.7	-3.7%				
S_ELLU2	Replacement of fuel oil boilers with heat pumps	1 718.1	-3.7%	2 668.0	-2.3%				
S_ELLU3	Solar heating combined with heat pumps after ELLU2 measure is implemented	738.2	-33.8%	2 108.0	-14.4%				
S_UNP1	Replacement of LPG boilers with modern biomass boilers	1 370.4	-4.4%	2 204.2	-2.6%				
S_UNP2	Replacement of LPG boilers with heat pumps	2 433.3	-2.8%	3 488.1	-1.9%				
S_UNP3	Solar heating combined with heat pumps after UNP2 measure is implemented	1 392.1	-22.3%	2 893.0	-11.6%				
S_PP1	Replacement of standard boilers with condensing boilers	310.5	-15.2%	466.2	-10.1%	333.7	-10.9%	844.5	-6.9%
S_PP2	Natural gas micro-CHP	-1 367,8	-36.8%	-1 146,4	-43.5%	-586.9	-81.6%	-524.7	-344.7%
S_PP3	Solar heating combined with a condensing boiler after PP1 measure is implemented	-438.4	-1 197.2%	518.6	-42.4%	-11.6	-104,0%	1 564.3	-23.0%
S_PP4	Replacement of natural gas boilers with heat pumps	615.0	-10.3%	1 120.6	-5.6%	621.7	-7.1%	1 928.9	-3.7%
S_PP5	Replacement of natural gas boilers with modern biomass boilers					-320.4	-16.8%	112.0	-38.8%
S_PP6	Connecting user to DHS					802.1	-1,0%	1 117.3	-1.1%
S_EE_1	Increase in the share of heat pumps vs. electric resistance heating	71.7	-77.5%	309.5	-42.9%	1 200.7	-10.9%	2 792.1	-7.5%
S_ELLU1_a	Replacement of fuel oil boilers with modern biomass boilers	836.0	-1.7%	1 599.5	-0.8%				
S_ELLU2_a	Replacement of fuel oil boilers with heat pumps	1 318.2	-1.2%	2 156.5	-0.7%				
S_ELLU3_a	Installation of solar collectors for water heating	-17.6	-104.9%	1 243.4	-22.2%				
S_UNP1_a	Replacement of LPG boilers with modern biomass boilers	1 722.9	-0.9%	2 629.6	-0.5%				

Investment unit price increase by 20%		up to 2030				2031–2050			
Measure code	Title of measure	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
S_UNP2_a	Replacement of LPG boilers with heat pumps	2 235.3	-0.8%	3 221.4	-0.5%				
S_UNP3_a	Installation of solar collectors for water heating	816.0	-32.9%	2 251.3	-14.4%				
S_PP1_a	Replacement of standard boilers with condensing boilers	241.6	-5.3%	382.1	-3.2%	268.6	-3.5%	718.4	-2.1%
S_PP2_a	Natural gas micro-CHP	420.4	-17.5%	653.0	-11.4%	683.2	-8.6%	1 554.2	-6,0%
S_PP3_a	Solar heating combined with a condensing boiler after PP1 measure is implemented	-1 026.6	-65.1%	-134.4	-154.2%	-444.0	-209.9%	781.1	-37.3%
S_PP4_a	Replacement of natural gas boilers with heat pumps					428.1	-2.6%	1 532.2	-1.1%
S_PP5_a	Replacement of natural gas boilers with modern biomass boilers					-70.3	-18.9%	603.7	-2.8%
S_EE_1_a	Replacement of electric boilers with solar collectors	973.1	-30.8%	2 457.4	-14.3%	1 927.7	-14.4%	5 721.3	-8.1%
S_EE_2_a	Increase in the share of heat pumps vs. electric resistance warming	1 073.8	-4.3%	1 503.8	-2.9%	2 233.7	-1,0%	5 013.6	-0.7%
S_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	650.9	-10.3%	951.7	-6.9%	863.0	-5.9%	2 005.4	-4.0%
DHS									
01	Replacement of fuel oil boilers with biomass boilers	893.0	-6.7%	1 732.4	-4.7%				
02	Replacement of fuel oil boilers with water-to-water heat pumps	767.0	-7.8%	1 570.2	-5.2%				
03	Replacement of natural gas cogeneration with natural gas HEC	-3 326,1	-24.3%	-2 443,1	-54.6%	-29.2	-119,0%	1 511.9	-11.4%
04	Replacement of natural gas boilers with water-to-water compression heat pumps	-45.2	-262.5%	407.6	-19.2%	560.6	-3.7%	2 305.8	2.2%
05	Replacement of natural gas boilers with natural gas HEC					283.7	-61.1%	3 357.7	-15,0%
06	Replacement of natural gas boilers – industrial waste heat utilisation	-6 686.8	-24.7%	-8 406.6	-26.3%	-918.3	-433.2%	309.3	-79.6%
07	Replacement of natural gas boilers – waste heat utilisation	-3 440.6	-24.6%	-4 105.6	-28.1%	404.5	-33.2%	2 473.8	-8.2%
08	Replacement of natural gas boilers – solar energy harnessing	-2 883.6	-25.4%	-3 366.7	-29.9%	560.8	-23.6%	2 705.5	-6.2%

Investment unit price increase by 20%		up to 2030				2031–2050			
Measure code	Title of measure	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
09	Replacement of natural gas boilers with biomass HEC	-6 394.9	-24.8%	-8 010.3	-26.6%	1 427.7	-20.2%	5 166.1	-8.2%
10	Replacement of natural gas boilers with biomass boilers					1 194.3	-1.8%	3 544.7	1.4%
11	Replacement of natural gas boilers – geothermal energy exploitation	-9 594.0	-21.6%	-12 268.3	-22.6%	-1 423.8	-54.7%	-291.1	-175.1%

Table 0.31: Results of the sensitivity analysis of a 20% decrease in investment unit price for households, services and DHS, in absolute and relative terms

Investment unit price decrease by 20%		up to 2030				2031–2050			
Measure code	Title of measure	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
HOUSEHOLD SECTOR									
H_TB_1	Replacement of individual firewood stoves with central firewood boilers	-104.2	35.4%	-86.1	38.5%				
H_TB_2	Replacement of central firewood boilers with central modern biomass boilers	-1 056.5	5.4%	-1 363.1	4.0%	-871.4	4.4%	-1 813.8	3.3%
H_TB_3	Replacement of traditional biomass boilers with heat pumps					-249.9	15.3%	-642.9	9.7%
H_TB_4	Solar heating combined with heat pumps after H_TB_3 measure is implemented					-116.5	68.9%	206.1	207.5%
H_ELLU1	Replacement of central fuel oil boilers with central modern biomass boilers	1 028.3	6.1%	1 812.1	3.2%				
H_ELLU2	Replacement of central fuel oil boilers with heat pumps	1 914.0	3.6%	2 873.2	2.2%				
H_ELLU3	Solar heating combined with heat pumps after ELLU2 measure is implemented	1 683.6	28.8%	3 060.3	13.1%				
H_UNP1	Replacement of central LPG boilers with central modern biomass boilers	1 495.7	4.4%	2 322.6	2.6%	2 025.1	2.4%	4 990.0	1.5%
H_UNP2	Replacement of central LPG boilers with heat pumps	2 436.7	2.9%	3 449.9	1.9%	2 748.7	1.9%	6 353.4	1.3%
H_UNP3	Solar heating combined with heat pumps after UNP2 measure is implemented	2 192.0	22.3%	3 648.7	11.6%	2 904.1	11.5%	7 342.0	6.7%

Investment unit price decrease by 20%		up to 2030				2031–2050			
Measure code	Title of measure	**FNPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**	**FNPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
H_PP1	Replacement of standard natural gas boilers with condensing natural gas boilers	432.1	14.8%	584.2	9.9%	426.6	10.5%	993.1	6.7%
H_PP2	Natural gas micro-CHP	-471.2	43.9%	-250.6	58.1%	68.7	134.1%	539.5	337.7%
H_PP3	Solar heating combined with a condensing boiler after PP1 measure is implemented	427.0	1 810.6%	1 353.3	39.4%	652.3	87.2%	2 614.6	21.8%
H_PP4	Replacement of natural gas boilers with heat pumps	674.7	11.7%	1 152.3	6.1%	495.1	12.0%	1 614.5	5.3%
H_PP_5	Replacement of natural gas boilers with modern biomass boilers					-237.0	16.7%	235.1	45.4%
H_EE_1	Increase in the share of heat pumps vs. electric resistance heating — heat pump installation	136.0	301.5%	535.0	56.1%	1 877.1	5.7%	4 458.5	3.6%
H_TB_2_a	Replacement of traditional biomass boilers with modern biomass boilers	-489.6	2.2%	-617.7	1.7%	-574.9	1.4%	-1 164.7	1.1%
H_TB_4_a	Installation of solar collectors for DHW preparation					273.6	24.6%	714.0	13.2%
H_TB_3_a	Installation of heat pumps for DHW preparation					-363.1	2.5%	-807.2	1.8%
H_ELLU1_a	Replacement of fuel oil boilers with modern biomass boilers	1 143.7	1.2%	1 978.4	0.6%				
H_ELLU2_a	Replacement of fuel oil boilers with heat pumps	1 478.7	1.0%	2 353.4	0.6%				
H_ELLU3_a	Installation of solar collectors for DHW preparation	1 022.5	52.7%	2 286.0	17.1%				
H_UNP1_a	Replacement of LPG boilers with modern biomass boilers	1 753.3	0.9%	2 658.3	0.5%	2 227.4	0.5%	5 412.4	0.3%
H_UNP2_a	Replacement of LPG boilers with heat pumps	2 133.0	0.8%	3 083.4	0.5%	2 513.1	0.5%	5 894.7	0.3%
H_UNP3_a	Installation of solar collectors for DHW preparation	1 615.9	32.9%	3 007.0	14.4%	2 462.3	13.9%	6 543.9	7.6%
H_PP1_a	Replacement of standard boilers with condensing boilers	278.8	5.1%	420.4	3.1%				
H_PP2_a	Natural gas micro-CHP	775.8	12.7%	1 050.7	8.5%	970.4	7.2%	2 056.0	5.2%

Investment unit price decrease by 20%		up to 2030				2031–2050			
Measure code	Title of measure	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
H_PP3_a	Installation of solar collectors for DHW preparation	-161.0	71.5%	700.4	120.2%	201.5	297.0%	1 802.8	35.1%
H_PP4_a	Replacement of natural gas boilers with heat pumps	362.1	5.0%	777.7	2.1%	252.9	5.4%	1 146.0	1.8%
H_PP_5_a	Replacement of natural gas boilers with modern biomass boilers					8.5	412.0%	751.6	2.3%
H_EE_1_a	Installation of heat pumps for DHW preparation					1 637.4	2.0%	3 728.9	1.3%
H_EE_2_a	Replacement of electric boilers with solar collectors	2 399.6	22.0%	3 975.4	11.5%	0.0		0.0	
H_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	278.2	32.6%	416.1	18.4%	132.9	67.7%	348.9	31.1%
SERVICE SECTOR									
S_ELLU1	Replacement of fuel oil boilers with modern biomass boilers	835.7	7.6%	1 571.1	3.7%				
S_ELLU2	Replacement of fuel oil boilers with heat pumps	1 849.5	3.7%	2 792.1	2.3%				
S_ELLU3	Solar heating combined with heat pumps after ELLU2 measure is implemented	1 491.0	33.8%	2 819.2	14.4%				
S_UNP1	Replacement of LPG boilers with modern biomass boilers	1 495.7	4.4%	2 322.6	2.6%				
S_UNP2	Replacement of LPG boilers with heat pumps	2 572.9	2.8%	3 619.9	1.9%				
S_UNP3	Solar heating combined with heat pumps after UNP2 measure is implemented	2 192.0	22.3%	3 648.7	11.6%				
S_PP1	Replacement of standard boilers with condensing boilers	422.0	15.2%	571.5	10.1%	415.1	10.9%	970.0	6.9%
S_PP2	Natural gas micro-CHP	-631.8	36.8%	-451.1	43.5%	-59.4	81.6%	288.8	344.7%
S_PP3	Solar heating combined with a condensing boiler after PP1 measure is implemented	370.9	1 197.2%	1 283.2	42.4%	596.0	104.0%	2 501.3	23.0%
S_PP4	Replacement of natural gas boilers with heat pumps	756.2	10.3%	1 254.1	5.6%	716.9	7.1%	2 075.7	3.7%
S_PP5	Replacement of natural gas boilers with modern biomass boilers					-228.1	16.8%	254.3	38.8%
S_PP6	Connecting user to DHS					818.0	1.0%	1 141.7	1.1%

Investment unit price decrease by 20%		up to 2030				2031–2050			
Measure code	Title of measure	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
S_EE_1	Increase in the share of heat pumps vs. electric resistance heating	564.3	77.5%	774.9	42.9%	1 494.3	10.9%	3 245.0	7.5%
S_ELLU1_a	Replacement of fuel oil boilers with modern biomass boilers	864.5	1.7%	1 626.5	0.8%				
S_ELLU2_a	Replacement of fuel oil boilers with heat pumps	1 350.1	1.2%	2 186.6	0.7%				
S_ELLU3_a	Installation of solar collectors for water heating	735.3	104.9%	1 954.7	22.2%				
S_UNP1_a	Replacement of LPG boilers with modern biomass boilers	1 753.3	0.9%	2 658.3	0.5%				
S_UNP2_a	Replacement of LPG boilers with heat pumps	2 269.1	0.8%	3 253.4	0.5%				
S_UNP3_a	Installation of solar collectors for water heating	1 615.9	32.9%	3 007.0	14.4%				
S_PP1_a	Replacement of standard boilers with condensing boilers	268.6	5.3%	407.7	3.2%	288.3	3.5%	748.8	2.1%
S_PP2_a	Natural gas micro-CHP	598.9	17.5%	821.7	11.4%	811.1	8.6%	1 751.5	6.0%
S_PP3_a	Solar heating combined with a condensing boiler after PP1 measure is implemented	-217.3	65.1%	630.2	154.2%	157.5	209.9%	1 708.8	37.3%
S_PP4_a	Replacement of natural gas boilers with heat pumps					451.2	2.6%	1 567.8	1.1%
S_PP5_a	Replacement of natural gas boilers with modern biomass boilers					-47.9	18.9%	638.2	2.8%
S_EE_1_a	Replacement of electric boilers with solar collectors	1 838.9	30.8%	3 275.3	14.3%	2 577.7	14.4%	6 723.8	8.1%
S_EE_2_a	Increase in the share of heat pumps vs. electric resistance warming	1 170.2	4.3%	1 594.9	2.9%	2 280.1	1.0%	5 085.1	0.7%
S_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	800.6	10.3%	1 093.1	6.9%	971.5	5.9%	2 172.7	4.0%
DHS									
01	Replacement of fuel oil boilers with biomass boilers	1 020.8	6.7%	1 902.0	4.7%				
02	Replacement of fuel oil boilers with water-to-water heat pumps	895.9	7.8%	1 741.2	5.2%				
03	Replacement of natural gas cogeneration with natural gas HEC	-2 025.7	24.3%	-718.1	54.6%	337.5	119.0%	2 065.5	21.0%

Investment unit price decrease by 20%		up to 2030				2031–2050			
Measure code	Title of measure	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
04	Replacement of natural gas boilers with water-to-water compression heat pumps	100.9	262.5%	601.4	19.2%	603.8	3.7%	2 371.0	5.1%
05	Replacement of natural gas boilers with natural gas HEC					1 174.2	61.1%	4 702.4	19.1%
06	Replacement of natural gas boilers – industrial waste heat utilisation	-4 292.1	20.0%	-5 230.0	21.4%	-210.0	-22,0%	1 378.6	-9.1%
07	Replacement of natural gas boilers – waste heat utilisation	-2 083.9	24.6%	-2 306.0	28.1%	805.7	33.2%	3 079.6	14.3%
08	Replacement of natural gas boilers – solar energy harnessing	-1 714.1	25.4%	-1 815.4	29.9%	906.6	23.6%	3 227.7	11.9%
09	Replacement of natural gas boilers with biomass HEC	-3 856.1	24.8%	-4 642.5	26.6%	2 150.2	20.2%	6 257.0	11.1%
10	Replacement of natural gas boilers with biomass boilers					1 237.1	1.8%	3 609.4	3.3%
11	Replacement of natural gas boilers – geothermal energy exploitation	-6 187.8	21.6%	-7 749.8	22.6%	-416.4	54.7%	1 230.0	217.2%

Table 0.32: Results of the sensitivity analysis of higher energy product prices for households, services and DHS in absolute and relative amounts

Higher prices of energy products		up to 2030				2031–2050			
Measure code	Title of measure	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
HOUSEHOLD SECTOR									
H_TB_1	Replacement of individual firewood stoves with central firewood boilers	-148.0	8.2%	-123.0	12.1%				
H_TB_2	Replacement of central firewood boilers with central modern biomass boilers	-1 225.3	-9.7%	-1 558.6	-9.8%	-1 203.2	-32,0%	-2 479.2	-32.2%
H_TB_3	Replacement of traditional biomass boilers with heat pumps					-314.4	-6.6%	-752.4	-5.6%
H_TB_4	Solar heating combined with heat pumps after H_TB_3 measure is implemented					-235.8	37.0%	93.5	148.8%

Higher prices of energy products		up to 2030				2031–2050			
Measure code	Title of measure	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
H_ELLU1	Replacement of central fuel oil boilers with central modern biomass boilers	1 230.1	26.9%	2 089.4	19.0%				
H_ELLU2	Replacement of central fuel oil boilers with heat pumps	2 201.2	19.1%	3 261.7	16.0%				
H_ELLU3	Solar heating combined with heat pumps after ELLU2 measure is implemented	1 729.9	32.3%	3 244.4	20.0%				
H_UNP1	Replacement of central LPG boilers with central modern biomass boilers	1 611.7	12.5%	2 491.6	10.1%	2 005.6	1.4%	4 951.0	0.7%
H_UNP2	Replacement of central LPG boilers with heat pumps	2 643.5	11.7%	3 737.2	10.4%	3 040.6	12.8%	6 961.7	11.0%
H_UNP3	Solar heating combined with heat pumps after UNP2 measure is implemented	2 142.8	19.6%	3 718.8	13.7%	3 132.2	20.3%	7 946.8	15.5%
H_PP1	Replacement of standard natural gas boilers with condensing natural gas boilers	402.0	6.8%	564.2	6.1%	424.8	10.1%	1 008.5	8.4%
H_PP2	Natural gas micro-CHP	-754.5	10.1%	-490.0	18.1%	12.5	106.2%	563.0	356.7%
H_PP3	Solar heating combined with a condensing boiler after PP1 measure is implemented	163.7	632.3%	1 151.5	18.6%	539.3	54.8%	2 529.9	17.9%
H_PP4	Replacement of natural gas boilers with heat pumps	670.4	11.0%	1 170.2	7.8%	446.7	1.0%	1 533.4	0.0%
H_PP_5	Replacement of natural gas boilers with modern biomass boilers					-600.4	-111,0%	-501.0	-409.8%
H_EE_1	Increase in the share of heat pumps vs. electric resistance heating -– heat pump installation	21.7	132.2%	456.7	33.2%	2 181.7	22.8%	5 136.6	19.4%
H_TB_2_a	Replacement of traditional biomass boilers with modern biomass boilers	-571.9	-14.2%	-719.0	-14.4%	-815.9	-39.9%	-1 659.2	-40.9%
H_TB_4_a	Installation of solar collectors for DHW preparation					358.3	63.1%	915.9	45.2%
H_TB_3_a	Installation of heat pumps for DHW preparation					-370.3	0.6%	-817.3	0.5%
H_ELLU1_a	Replacement of fuel oil boilers with modern biomass boilers	1 401.1	24.0%	2 311.6	17.6%				
H_ELLU2_a	Replacement of fuel oil boilers with heat pumps	1 821.0	24.4%	2 795.5	19.5%				

Higher prices of energy products		up to 2030				2031–2050			
Measure code	Title of measure	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
H_ELLU3_a	Installation of solar collectors for DHW preparation	1 092.2	63.1%	2 492.3	27.6%				
H_UNP1_a	Replacement of LPG boilers with modern biomass boilers	1 916.7	10.3%	2 872.1	8.6%	2 243.4	1.2%	5 428.4	0.6%
H_UNP2_a	Replacement of LPG boilers with heat pumps	2 392.6	13.1%	3 420.6	11.5%	2 844.6	13.8%	6 564.3	11.7%
H_UNP3_a	Installation of solar collectors for DHW preparation	1 566.7	28.8%	3 077.0	17.0%	2 690.3	24.4%	7 148.6	17.6%
H_PP1_a	Replacement of standard boilers with condensing boilers	290.9	9.6%	440.2	8.0%				
H_PP2_a	Natural gas micro-CHP	774.8	12.5%	1 078.3	11.4%	1 118.7	23.6%	2 394.8	22.5%
H_PP3_a	Installation of solar collectors for DHW preparation	-424.4	25.0%	498.6	56.7%	88.6	186.6%	1 718.1	28.8%
H_PP4_a	Replacement of natural gas boilers with heat pumps	411.3	19.2%	846.2	11.1%	244.7	1.9%	1 126.8	0.1%
H_PP_5_a	Replacement of natural gas boilers with modern biomass boilers					-303.1	-11 063.7%	103.7	-85.9%
H_EE_1_a	Installation of heat pumps for DHW preparation					1 909.3	18.9%	4 304.2	16.9%
H_EE_2_a	Replacement of electric boilers with solar collectors	2 272.0	15.5%	3 956.3	10.9%	0.0		0.0	
H_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	237.6	13.2%	387.0	10.1%	116.4	46.9%	342.5	28.7%
SERVICE SECTOR									
S_ELLU1	Replacement of fuel oil boilers with modern biomass boilers	1 000.3	28.8%	1 800.9	18.8%				
S_ELLU2	Replacement of fuel oil boilers with heat pumps	2 109.1	18.2%	3 145.4	15.2%				
S_ELLU3	Solar heating combined with heat pumps after ELLU2 measure is implemented	1 500.1	34.6%	2 955.9	20.0%				
S_UNP1	Replacement of LPG boilers with modern biomass boilers	1 611.7	12.5%	2 491.6	10.1%				
S_UNP2	Replacement of LPG boilers with heat pumps	2 789.8	11.5%	3 920.2	10.3%				
S_UNP3	Solar heating combined with heat pumps after UNP2 measure is implemented	2 142.8	19.6%	3 718.8	13.7%				

Higher prices of energy products		up to 2030				2031–2050			
Measure code	Title of measure	**FNPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**	**FNPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
S_PP1	Replacement of standard boilers with condensing boilers	390.7	6.7%	550.1	6.0%	411.5	9.9%	982.0	8.2%
S_PP2	Natural gas micro-CHP	-926.9	7.3%	-705.7	11.7%	-138.7	57.1%	261.3	321.5%
S_PP3	Solar heating combined with a condensing boiler after PP1 measure is implemented	101.3	399.6%	1 073.4	19.1%	474.6	62.4%	2 399.6	18.0%
S_PP4	Replacement of natural gas boilers with heat pumps	755.9	10.3%	1 277.1	7.6%	707.4	5.7%	2 072.3	3.5%
S_PP5	Replacement of natural gas boilers with modern biomass boilers					-583.1	-112.6%	-464.5	-353.6%
S_PP6	Connecting user to DHS					845.0	4.3%	1 199.9	6.2%
S_EE_1	Increase in the share of heat pumps vs. electric resistance heating	355.6	11.8%	590.3	8.9%	1 556.5	15.5%	3 448.5	14.2%
S_ELLU1_a	Replacement of fuel oil boilers with modern biomass boilers	1 073.8	26.3%	1 898.5	17.7%				
S_ELLU2_a	Replacement of fuel oil boilers with heat pumps	1 659.4	24.4%	2 586.9	19.1%				
S_ELLU3_a	Installation of solar collectors for water heating	744.4	107.4%	2 091.4	30.8%				
S_UNP1_a	Replacement of LPG boilers with modern biomass boilers	1 916.7	10.3%	2 872.1	8.6%				
S_UNP2_a	Replacement of LPG boilers with heat pumps	2 538.9	12.7%	3 603.6	11.3%				
S_UNP3_a	Installation of solar collectors for water heating	1 566.7	28.8%	3 077.0	17.0%				
S_PP1_a	Replacement of standard boilers with condensing boilers	279.5	9.6%	426.1	7.9%	315.6	13.3%	808.3	10.2%
S_PP2_a	Natural gas micro-CHP	582.5	14.3%	830.4	12.6%	931.7	24.7%	2 032.1	22.9%
S_PP3_a	Solar heating combined with a condensing boiler after PP1 measure is implemented	-486.9	21.7%	420.3	69.6%	39.1	127.3%	1 611.7	29.5%
S_PP4_a	Replacement of natural gas boilers with heat pumps					477.8	8.7%	1 620.0	4.5%
S_PP5_a	Replacement of natural gas boilers with modern biomass boilers					-367.9	-522.5%	-26.7	-104.3%
S_EE_1_a	Replacement of electric boilers with solar collectors	1 669.6	18.7%	3 203.0	11.7%	2 907.1	29.0%	7 568.6	21.6%
S_EE_2_a	Increase in the share of heat pumps vs. electric resistance warming	1 203.3	7.2%	1 653.1	6.7%	2 621.2	16.1%	5 798.6	14.8%

Higher prices of energy products		up to 2030				2031–2050			
Measure code	Title of measure	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%	FNPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
S_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	781.2	7.6%	1 093.3	6.9%	1 073.1	17.0%	2 409.5	15.3%
DHS									
01	Replacement of fuel oil boilers with biomass boilers	1 240.4	29.6%	2 192.0	20.6%				
02	Replacement of fuel oil boilers with water-to-water heat pumps	1 108.7	33.3%	2 022.5	22.1%				
03	Replacement of natural gas cogeneration with natural gas HEC	-2 641.3	1.3%	-1 532.7	3.0%	225.4	46.2%	1 956.0	14.6%
04	Replacement of natural gas boilers with water-to-water compression heat pumps	84.3	203.0%	579.7	14.9%	654.4	12.4%	2 477.0	9.8%
05	Replacement of natural gas boilers with natural gas HEC					1 268.1	74.0%	5 189.8	31.4%
06	Replacement of natural gas boilers – industrial waste heat utilisation	-5 412.0	-0.9%	-6 716.1	-0.9%	-337.0	-95.7%	1 290.4	-14,9%
07	Replacement of natural gas boilers – waste heat utilisation	-2 684.9	2.8%	-3 103.6	3.2%	832.3	37.5%	3 223.2	19.6%
08	Replacement of natural gas boilers – solar energy harnessing	-2 221.5	3.4%	-2 488.8	3.9%	960.8	31.0%	3 413.0	18.3%
09	Replacement of natural gas boilers with biomass HEC	-5 000.0	2.4%	-6 158.4	2.7%	2 282.2	27.6%	6 729.7	19.5%
10	Replacement of natural gas boilers with biomass boilers					1 341.9	10.4%	3 823.1	9.4%
11	Replacement of natural gas boilers – geothermal energy exploitation	-7 813.5	1.0%	-9 906.8	1.0%	-693.0	24.7%	915.9	136.2%

Table 0.33: Results of the sensitivity analysis of higher CO_2 prices for households, services and DHS, in absolute and relative terms

Higher CO_2 prices		up to 2030		2031–2050	
Measure code	Title of measure	ENPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
HOUSEHOLD SECTOR					

Higher CO_2 prices		up to 2030		2031–2050	
Measure code	Title of measure	ENPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
H_TB_1	Replacement of individual firewood stoves with central firewood boilers	-134.1	4.2%		
H_TB_2	Replacement of central firewood boilers with central modern biomass boilers	-1 423.2	-0.2%	-1 877.0	-0.1%
H_TB_3	Replacement of traditional biomass boilers with heat pumps			-758.9	-6.5%
H_TB_4	Solar heating combined with heat pumps after H_TB_3 measure is implemented			-135.7	29.2%
H_ELLU1	Replacement of central fuel oil boilers with central modern biomass boilers	1 986.1	13.1%		
H_ELLU2	Replacement of central fuel oil boilers with heat pumps	3 022.4	7.5%		
H_ELLU3	Solar heating combined with heat pumps after ELLU2 measure is implemented	2 957.1	9.3%		
H_UNP1	Replacement of central LPG boilers with central modern biomass boilers	2 458.1	8.6%	5 448.6	10.8%
H_UNP2	Replacement of central LPG boilers with heat pumps	3 559.1	5.2%	6 750.5	7.6%
H_UNP3	Solar heating combined with heat pumps after UNP2 measure is implemented	3 489.8	6.7%	7 476.2	8.7%
H_PP1	Replacement of standard natural gas boilers with condensing natural gas boilers	565.8	6.4%	1 035.5	11.3%
H_PP2	Natural gas micro-CHP	-602.8	-0.8%	123.3	0.0%
H_PP3	Solar heating combined with a condensing boiler after PP1 measure is implemented	1 154.9	18.9%	2 647.9	23.4%
H_PP4	Replacement of natural gas boilers with heat pumps	1 225.2	12.9%	1 913.7	24.9%
H_PP_5	Replacement of natural gas boilers with modern biomass boilers			596.5	268.9%
H_EE_1	Increase in the share of heat pumps vs. electric resistance heating –– heat pump installation	401.7	17.2%	4 597.7	6.8%

Higher CO_2 prices		up to 2030		2031–2050	
Measure code	Title of measure	**ENPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
H_TB_2_a	Replacement of traditional biomass boilers with modern biomass boilers	-625.2	0.5%	-1 169.2	0.7%
H_TB_4_a	Installation of solar collectors for DHW preparation			688.3	9.1%
H_TB_3_a	Installation of heat pumps for DHW preparation			-852.7	-3.8%
H_ELLU1_a	Replacement of fuel oil boilers with modern biomass boilers	2 197.1	11.8%		
H_ELLU2_a	Replacement of fuel oil boilers with heat pumps	2 553.5	9.2%		
H_ELLU3_a	Installation of solar collectors for DHW preparation	2 205.4	12.9%		
H_UNP1_a	Replacement of LPG boilers with modern biomass boilers	2 838.6	7.4%	5 926.0	9.8%
H_UNP2_a	Replacement of LPG boilers with heat pumps	3 242.5	5.7%	6 353.0	8.1%
H_UNP3_a	Installation of solar collectors for DHW preparation	2 848.0	8.3%	6 678.1	9.8%
H_PP1_a	Replacement of standard boilers with condensing boilers	441.8	8.4%		
H_PP2_a	Natural gas micro-CHP	968.4	0.0%	1 955.1	0.0%
H_PP3_a	Installation of solar collectors for DHW preparation	502.0	57.8%	1 836.1	37.6%
H_PP4_a	Replacement of natural gas boilers with heat pumps	901.2	18.3%	1 507.1	33.8%
H_PP_5_a	Replacement of natural gas boilers with modern biomass boilers			1 171.7	59.5%
H_EE_1_a	Installation of heat pumps for DHW preparation			3 900.7	6.0%
H_EE_2_a	Replacement of electric boilers with solar collectors	3 762.5	5.5%		
H_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	369.9	5.2%	293.1	10.1%
SERVICE SECTOR					
S_ELLU1	Replacement of fuel oil boilers with modern biomass boilers	1 745.0	15.2%		

Higher CO_2 prices		up to 2030		2031–2050	
Measure code	Title of measure	**ENPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
S_ELLU2	Replacement of fuel oil boilers with heat pumps	2 941.3	7.7%		
S_ELLU3	Solar heating combined with heat pumps after ELLU2 measure is implemented	2 716.0	10.2%		
S_UNP1	Replacement of LPG boilers with modern biomass boilers	2 458.1	8.6%		
S_UNP2	Replacement of LPG boilers with heat pumps	3 729.1	4.9%		
S_UNP3	Solar heating combined with heat pumps after UNP2 measure is implemented	3 489.8	6.7%		
S_PP1	Replacement of standard boilers with condensing boilers	553.1	6.6%	1 012.4	11.6%
S_PP2	Natural gas micro-CHP	-803.3	-0.6%	-106.3	9.9%
S_PP3	Solar heating combined with a condensing boiler after PP1 measure is implemented	1 084.8	20.4%	2 534.6	24.7%
S_PP4	Replacement of natural gas boilers with heat pumps	1 327.0	11.8%	2 397.2	19.7%
S_PP5	Replacement of natural gas boilers with modern biomass boilers			620.5	238.7%
S_PP6	Connecting user to DHS			900.0	-20.3%
S_EE_1	Increase in the share of heat pumps vs. electric resistance heating	571.0	5.3%	3 194.4	5.8%
S_ELLU1_a	Replacement of fuel oil boilers with modern biomass boilers	1 842.7	14.2%		
S_ELLU2_a	Replacement of fuel oil boilers with heat pumps	2 382.8	9.7%		
S_ELLU3_a	Installation of solar collectors for water heating	1 851.5	15.8%		
S_UNP1_a	Replacement of LPG boilers with modern biomass boilers	2 838.6	7.4%		
S_UNP2_a	Replacement of LPG boilers with heat pumps	3 412.5	5.4%		
S_UNP3_a	Installation of solar collectors for water heating	2 848.0	8.3%		
S_PP1_a	Replacement of standard boilers with condensing boilers	429.1	8.7%	838.8	14.3%
S_PP2_a	Natural gas micro-CHP	732.8	-0.6%	1 664.6	0.7%
S_PP3_a	Solar heating combined with a condensing boiler after PP1 measure is implemented	431.8	74.2%	1 746.9	40.3%

Higher CO_2 prices		**up to 2030**		**2031–2050**	
Measure code	Title of measure	**ENPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
S_PP4_a	Replacement of natural gas boilers with heat pumps			1 944.9	25.5%
S_PP5_a	Replacement of natural gas boilers with modern biomass boilers			1 058.3	70.4%
S_EE_1_a	Replacement of electric boilers with solar collectors	3 062.4	6.8%	6 757.6	8.6%
S_EE_2_a	Increase in the share of heat pumps vs. electric resistance warming	1 611.5	4.0%	5 355.8	6.1%
S_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	1 064.9	4.2%	2 220.1	6.3%
DHS					
01	Replacement of fuel oil boilers with biomass boilers	1 982.7	9.1%		
02	Replacement of fuel oil boilers with water-to-water heat pumps	1 821.2	10.0%		
03	Replacement of natural gas cogeneration with natural gas HEC	-1 459.4	7.7%	2 460.5	44.1%
04	Replacement of natural gas boilers with water-to-water compression heat pumps	626.1	24.1%	3 012.0	33.5%
05	Replacement of natural gas boilers with natural gas HEC			4 698.0	19.0%
06	Replacement of natural gas boilers – industrial waste heat utilisation	-6 532.6	1.8%	2 273.3	49.9%
07	Replacement of natural gas boilers – waste heat utilisation	-3 084.1	3.8%	3 451.3	28.1%
08	Replacement of natural gas boilers – solar energy harnessing	-2 469.3	4.7%	3 641.1	26.2%
09	Replacement of natural gas boilers with biomass HEC	-6 204.8	1.9%	6 385.4	13.4%
10	Replacement of natural gas boilers with biomass boilers			4 251.2	21.6%
11	Replacement of natural gas boilers – geothermal energy exploitation	-9 887.3	1.2%	1 144.0	195.1%

Table 0.34: Results of the sensitivity analysis of a higher financial discount rate (7%) for households, services and DHS, in absolute and relative terms

Higher financial discount rate (7%)		**up to 2030**		**2031–2050**	
Measure code	Title of measure	**ENPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
HOUSEHOLD SECTOR					
H_TB_1	Replacement of individual firewood stoves with central firewood boilers	-162.0	-0.5%		
H_TB_2	Replacement of central firewood boilers with central modern biomass boilers	-961.4	13.9%	-576.2	36.8%
H_TB_3	Replacement of traditional biomass boilers with heat pumps			-180.6	38.7%
H_TB_4	Solar heating combined with heat pumps after H_TB_3 measure is implemented			-342.4	8.5%
H_ELLU1	Replacement of central fuel oil boilers with central modern biomass boilers	840.7	-13.3%		
H_ELLU2	Replacement of central fuel oil boilers with heat pumps	1 603.7	-13.2%		
H_ELLU3	Solar heating combined with heat pumps after ELLU2 measure is implemented	914.8	-30.0%		
H_UNP1	Replacement of central LPG boilers with central modern biomass boilers	1 238.2	-13.6%	1 262.9	-36.2%
H_UNP2	Replacement of central LPG boilers with heat pumps	2 048.9	-13.4%	1 723.5	-36.1%
H_UNP3	Solar heating combined with heat pumps after UNP2 measure is implemented	1 316.9	-26.5%	1 535.2	-41.0%
H_PP1	Replacement of standard natural gas boilers with condensing natural gas boilers	335.9	-10.8%	253.3	-34.4%
H_PP2	Natural gas micro-CHP	-942.6	-12.3%	-244.9	-21.7%
H_PP3	Solar heating combined with a condensing boiler after PP1 measure is implemented	-216.3	-1 067.6%	95.0	-72.7%
H_PP4	Replacement of natural gas boilers with heat pumps	524.4	-13.2%	285.6	-35.4%
H_PP_5	Replacement of natural gas boilers with modern biomass boilers			-180.4	36.6%

Higher financial discount rate (7%)		**up to 2030**		**2031–2050**	
Measure code	Title of measure	**ENPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
H_EE_1	Increase in the share of heat pumps vs. electric resistance heating — heat pump installation	-192.1	-184.8%	1 090.5	-38.6%
H_TB_2_a	Replacement of traditional biomass boilers with modern biomass boilers	-430.1	14.1%	-370.2	36.5%
H_TB_4_a	Installation of solar collectors for DHW preparation			121.1	-44.9%
H_TB_3_a	Installation of heat pumps for DHW preparation			-234.8	37.0%
H_ELLU1_a	Replacement of fuel oil boilers with modern biomass boilers	978.5	-13.4%		
H_ELLU2_a	Replacement of fuel oil boilers with heat pumps	1 269.1	-13.3%		
H_ELLU3_a	Installation of solar collectors for DHW preparation	340.9	-49.1%		
H_UNP1_a	Replacement of LPG boilers with modern biomass boilers	1 503.3	-13.5%	1 415.8	-36.1%
H_UNP2_a	Replacement of LPG boilers with heat pumps	1 832.6	-13.4%	1 598.5	-36.1%
H_UNP3_a	Installation of solar collectors for DHW preparation	780.7	-35.8%	1 231.8	-43.0%
H_PP1_a	Replacement of standard boilers with condensing boilers	232.6	-12.3%		
H_PP2_a	Natural gas micro-CHP	547.6	-20.5%	551.2	-39.1%
H_PP3_a	Installation of solar collectors for DHW preparation	-764.6	-35.2%	-215.1	-110.3%
H_PP4_a	Replacement of natural gas boilers with heat pumps	299.7	-13.1%	155.9	-35.0%
H_PP_5_a	Replacement of natural gas boilers with modern biomass boilers			0.1	103.7%
H_EE_1_a	Installation of heat pumps for DHW preparation			1 014.6	-36.8%
H_EE_2_a	Replacement of electric boilers with solar collectors	1 407.5	-28.4%		

Higher financial discount rate (7%)		up to 2030		2031–2050	
Measure code	Title of measure	ENPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
H_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	160.8	-23.4%	37.6	-52.6%
SERVICE SECTOR					
S_ELLU1	Replacement of fuel oil boilers with modern biomass boilers	673.7	-13.3%		
S_ELLU2	Replacement of fuel oil boilers with heat pumps	1 548.0	-13.2%		
S_ELLU3	Solar heating combined with heat pumps after ELLU2 measure is implemented	747.8	-32.9%		
S_UNP1	Replacement of LPG boilers with modern biomass boilers	1 238.2	-13.6%		
S_UNP2	Replacement of LPG boilers with heat pumps	2 167.1	-13.4%		
S_UNP3	Solar heating combined with heat pumps after UNP2 measure is implemented	1 316.9	-26.5%		
S_PP1	Replacement of standard boilers with condensing boilers	327.1	-10.7%	245.9	-34.3%
S_PP2	Natural gas micro-CHP	-1 082.0	-8.2%	-319.6	1.1%
S_PP3	Solar heating combined with a condensing boiler after PP1 measure is implemented	-265.0	-684.0%	58.9	-79.8%
S_PP4	Replacement of natural gas boilers with heat pumps	595.2	-13.2%	433.8	-35.2%
S_PP5	Replacement of natural gas boilers with modern biomass boilers			-173.0	36.9%
S_PP6	Connecting user to DHS			543.3	-32.9%
S_EE_1	Increase in the share of heat pumps vs. electric resistance heating	240.4	-24.4%	863.2	-35.9%
S_ELLU1_a	Replacement of fuel oil boilers with modern biomass boilers	734.9	-13.6%		
S_ELLU2_a	Replacement of fuel oil boilers with heat pumps	1 156.1	-13.3%		
S_ELLU3_a	Installation of solar collectors for water heating	54.8	-84.7%		
S_UNP1_a	Replacement of LPG boilers with modern biomass boilers	1 503.3	-13.5%		
S_UNP2_a	Replacement of LPG boilers with heat pumps	1 950.8	-13.4%		
S_UNP3_a	Installation of solar collectors for water heating	780.7	-35.8%		

Higher financial discount rate (7%)		up to 2030		2031–2050	
Measure code	Title of measure	ENPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
S_PP1_a	Replacement of standard boilers with condensing boilers	223.7	-12.3%	180.1	-35.3%
S_PP2_a	Natural gas micro-CHP	390.6	-23.4%	451.0	-39.6%
S_PP3_a	Solar heating combined with a condensing boiler after PP1 measure is implemented	-813.5	-30.8%	-239.8	-67.4%
S_PP4_a	Replacement of natural gas boilers with heat pumps			284.3	-35.3%
S_PP5_a	Replacement of natural gas boilers with modern biomass boilers			-36.1	38.9%
S_EE_1_a	Replacement of electric boilers with solar collectors	920.7	-34.5%	1 275.6	-43.4%
S_EE_2_a	Increase in the share of heat pumps vs. electric resistance warming	973.8	-13.2%	1 451.6	-35.7%
S_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	622.9	-14.2%	584.3	-36.3%
DHS					
01	Replacement of fuel oil boilers with biomass boilers	810.2	-15.3%		
02	Replacement of fuel oil boilers with water-to-water heat pumps	703.6	-15.4%		
03	Replacement of natural gas cogeneration with natural gas HEC	-2 169.4	18.9%	22.7	-85.3%
04	Replacement of natural gas boilers with water-to-water compression heat pumps	30.5	9.4%	372.1	-36.1%
05	Replacement of natural gas boilers with natural gas HEC			145.3	-80.1%
06	Replacement of natural gas boilers – industrial waste heat utilisation	-4 456.3	16.9%	-290.3	-68.5%
07	Replacement of natural gas boilers – waste heat utilisation	-2 290.2	17.1%	296.6	-51.0%
08	Replacement of natural gas boilers – solar energy harnessing	-1 904.2	17.2%	394.8	-46.2%
09	Replacement of natural gas boilers with biomass HEC	-4 265.7	16.8%	928.9	-48.1%

Higher financial discount rate (7%)		**up to 2030**		**2031–2050**	
Measure code	Title of measure	**ENPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
10	Replacement of natural gas boilers with biomass boilers			786.2	-35.3%
11	Replacement of natural gas boilers – geothermal energy exploitation	-6 563.2	16.8%	-855.9	7.0%

Table 0.35: Results of the sensitivity analysis of a lower financial discount rate (3%) for households, services and DHS, in absolute and relative terms

Lower financial discount rate (3%)		**up to 2030**		**2031–2050**	
Measure code	Title of measure	**ENPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
HOUSEHOLD SECTOR					
H_TB_1	Replacement of individual firewood stoves with central firewood boilers	-157.4	2.4%		
H_TB_2	Replacement of central firewood boilers with central modern biomass boilers	-1 304.0	-16.8%	-1 467.7	-61.0%
H_TB_3	Replacement of traditional biomass boilers with heat pumps			-488.6	-65.7%
H_TB_4	Solar heating combined with heat pumps after H_TB_3 measure is implemented			-347.4	7.2%
H_ELLU1	Replacement of central fuel oil boilers with central modern biomass boilers	1 123.6	15.9%		
H_ELLU2	Replacement of central fuel oil boilers with heat pumps	2 141.8	15.9%		
H_ELLU3	Solar heating combined with heat pumps after ELLU2 measure is implemented	1 807.0	38.2%		
H_UNP1	Replacement of central LPG boilers with central modern biomass boilers	1 667.3	16.3%	3 153.5	59.4%
H_UNP2	Replacement of central LPG boilers with heat pumps	2 749.1	16.1%	4 293.5	59.2%
H_UNP3	Solar heating combined with heat pumps after UNP2 measure is implemented	2 393.3	33.6%	4 458.0	71.2%
H_PP1	Replacement of standard natural gas boilers with condensing natural gas boilers	423.8	12.6%	598.4	55.1%
H_PP2	Natural gas micro-CHP	-687.1	18.1%	-39.8	80.2%
H_PP3	Solar heating combined with a condensing boiler after PP1 measure is implemented	339.7	1 420.0%	863.1	147.7%
H_PP4	Replacement of natural gas boilers with heat pumps	699.7	15.8%	696.8	57.6%
H_PP_5	Replacement of natural gas boilers with modern biomass boilers			-456.6	-60.5%

Lower financial discount rate (3%)		**up to 2030**		**2031–2050**	
Measure code	Title of measure	**ENPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
H_EE_1	Increase in the share of heat pumps vs. electric resistance heating — heat pump installation	99.7	247.7%	2 938.1	65.4%
H_TB_2_a	Replacement of traditional biomass boilers with modern biomass boilers	-586.4	-17.1%	-935.3	-60.3%
H_TB_4_a	Installation of solar collectors for DHW preparation			396.2	80.4%
H_TB_3_a	Installation of heat pumps for DHW preparation			-601.3	-61.4%
H_ELLU1_a	Replacement of fuel oil boilers with modern biomass boilers	1 312.6	16.1%		
H_ELLU2_a	Replacement of fuel oil boilers with heat pumps	1 697.5	16.0%		
H_ELLU3_a	Installation of solar collectors for DHW preparation	1 095.5	63.6%		
H_UNP1_a	Replacement of LPG boilers with modern biomass boilers	2 020.3	16.2%	3 530.2	59.3%
H_UNP2_a	Replacement of LPG boilers with heat pumps	2 456.5	16.1%	3 980.9	59.2%
H_UNP3_a	Installation of solar collectors for DHW preparation	1 774.3	45.9%	3 805.2	76.0%
H_PP1_a	Replacement of standard boilers with condensing boilers	304.2	14.7%		
H_PP2_a	Natural gas micro-CHP	864.5	25.5%	1 506.8	66.5%
H_PP3_a	Installation of solar collectors for DHW preparation	-290.9	48.6%	198.4	293.9%
H_PP4_a	Replacement of natural gas boilers with heat pumps	399.4	15.8%	376.2	56.7%
H_PP_5_a	Replacement of natural gas boilers with modern biomass boilers			-8.8	-222.7%
H_EE_1_a	Installation of heat pumps for DHW preparation			2 586.3	61.0%
H_EE_2_a	Replacement of electric boilers with solar collectors	2 677.0	36.1%		
H_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	271.5	29.4%	157.8	99.0%
SERVICE SECTOR					

Lower financial discount rate (3%)		up to 2030		2031–2050	
Measure code	Title of measure	**ENPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
S_ELLU1	Replacement of fuel oil boilers with modern biomass boilers	900.3	15.9%		
S_ELLU2	Replacement of fuel oil boilers with heat pumps	2 066.8	15.9%		
S_ELLU3	Solar heating combined with heat pumps after ELLU2 measure is implemented	1 583.6	42.1%		
S_UNP1	Replacement of LPG boilers with modern biomass boilers	1 667.3	16.3%		
S_UNP2	Replacement of LPG boilers with heat pumps	2 906.8	16.1%		
S_UNP3	Solar heating combined with heat pumps after UNP2 measure is implemented	2 393.3	33.6%		
S_PP1	Replacement of standard boilers with condensing boilers	412.0	12.5%	580.2	55.0%
S_PP2	Natural gas micro-CHP	-872.9	12.7%	-241.7	25.2%
S_PP3	Solar heating combined with a condensing boiler after PP1 measure is implemented	274.7	912.7%	773.8	164.9%
S_PP4	Replacement of natural gas boilers with heat pumps	794.1	15.8%	1 051.3	57.1%
S_PP5	Replacement of natural gas boilers with modern biomass boilers			-442.1	-61.2%
S_PP6	Connecting user to DHS			1 228.2	51.6%
S_EE_1	Increase in the share of heat pumps vs. electric resistance heating	415.7	30.7%	2 141.2	58.9%
S_ELLU1_a	Replacement of fuel oil boilers with modern biomass boilers	989.0	16.3%		
S_ELLU2_a	Replacement of fuel oil boilers with heat pumps	1 548.0	16.0%		
S_ELLU3_a	Installation of solar collectors for water heating	757.4	111.1%		
S_UNP1_a	Replacement of LPG boilers with modern biomass boilers	2 020.3	16.2%		
S_UNP2_a	Replacement of LPG boilers with heat pumps	2 614.2	16.1%		
S_UNP3_a	Installation of solar collectors for water heating	1 774.3	45.9%		
S_PP1_a	Replacement of standard boilers with condensing boilers	292.4	14.6%	438.3	57.4%
S_PP2_a	Natural gas micro-CHP	659.2	29.3%	1 253.9	67.8%

Lower financial discount rate (3%)		up to 2030		2031–2050	
Measure code	Title of measure	ENPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
S_PP3_a	Solar heating combined with a condensing boiler after PP1 measure is implemented	-356.0	42.8%	129.6	190.4%
S_PP4_a	Replacement of natural gas boilers with heat pumps			692.1	57.4%
S_PP5_a	Replacement of natural gas boilers with modern biomass boilers			-98.2	-66.1%
S_EE_1_a	Replacement of electric boilers with solar collectors	2 027.8	44.2%	3 983.9	76.8%
S_EE_2_a	Increase in the share of heat pumps vs. electric resistance warming	1 299.8	15.8%	3 572.2	58.3%
S_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	850.0	17.1%	1 465.4	59.8%
DHS					
01	Replacement of fuel oil boilers with biomass boilers	1 134.5	18.6%		
02	Replacement of fuel oil boilers with water-to-water heat pumps	986.3	18.6%		
03	Replacement of natural gas cogeneration with natural gas HEC	-3 315.0	-23.9%	417.1	170.6%
04	Replacement of natural gas boilers with water-to-water compression heat pumps	22.8	-18.2%	926.9	59.2%
05	Replacement of natural gas boilers with natural gas HEC			1 910.2	162.0%
06	Replacement of natural gas boilers – industrial waste heat utilisation	-6 482.3	-20.9%	144.8	184.1%
07	Replacement of natural gas boilers – waste heat utilisation	-3 347.4	-21.2%	1 172.2	93.7%
08	Replacement of natural gas boilers – solar energy harnessing	-2 788.6	-21.3%	1 339.4	82.6%
09	Replacement of natural gas boilers with biomass HEC	-6 188.2	-20.7%	3 346.5	87.1%
10	Replacement of natural gas boilers with biomass boilers			1 912.6	57.3%
11	Replacement of natural gas boilers – geothermal energy exploitation	-9 531.7	-20.8%	-841.4	8.6%

Table 0.36: Results of the sensitivity analysis of a higher economic discount rate (4%) for households, services and DHS, in absolute and relative terms

Higher economic discount rate (4%)		**up to 2030**		**2031–2050**	
Measure code	Title of measure	**ENPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
HOUSEHOLD SECTOR					
H_TB_1	Replacement of individual firewood stoves with central firewood boilers	-147.8	-5.6%		
H_TB_2	Replacement of central firewood boilers with central modern biomass boilers	-1 212.6	14.6%	-1 155.3	38.4%
H_TB_3	Replacement of traditional biomass boilers with heat pumps			-428.6	39.8%
H_TB_4	Solar heating combined with heat pumps after H_TB_3 measure is implemented			-312.6	-63.1%
H_ELLU1	Replacement of central fuel oil boilers with central modern biomass boilers	1 509.0	-14.1%		
H_ELLU2	Replacement of central fuel oil boilers with heat pumps	2 417.1	-14.0%		
H_ELLU3	Solar heating combined with heat pumps after ELLU2 measure is implemented	2 054.3	-24.0%		
H_UNP1	Replacement of central LPG boilers with central modern biomass boilers	1 939.7	-14.3%	3 058.5	-37.8%
H_UNP2	Replacement of central LPG boilers with heat pumps	2 904.6	-14.2%	3 904.6	-37.8%
H_UNP3	Solar heating combined with heat pumps after UNP2 measure is implemented	2 519.2	-23.0%	4 039.7	-41.3%
H_PP1	Replacement of standard natural gas boilers with condensing natural gas boilers	468.6	-11.8%	591.6	-36.4%
H_PP2	Natural gas micro-CHP	-779.3	-30.3%	-141.5	-214.8%
H_PP3	Solar heating combined with a condensing boiler after PP1 measure is implemented	543.0	-44.1%	1 096.8	-48.9%
H_PP4	Replacement of natural gas boilers with heat pumps	933.1	-14.0%	960.1	-37.4%
H_PP_5	Replacement of natural gas boilers with modern biomass boilers			104.0	-35.7%
H_EE_1	Increase in the share of heat pumps vs. electric resistance heating -– heat pump installation	129.6	-62.2%	2 594.1	-39.7%

Higher economic discount rate (4%)		up to 2030		2031–2050	
Measure code	Title of measure	ENPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
H_TB_2_a	Replacement of traditional biomass boilers with modern biomass boilers	-535.3	14.8%	-727.9	38.2%
H_TB_4_a	Installation of solar collectors for DHW preparation			356.5	-43.5%
H_TB_3_a	Installation of heat pumps for DHW preparation			-505.2	38.5%
H_ELLU1_a	Replacement of fuel oil boilers with modern biomass boilers	1 686.7	-14.2%		
H_ELLU2_a	Replacement of fuel oil boilers with heat pumps	2 009.9	-14.1%		
H_ELLU3_a	Installation of solar collectors for DHW preparation	1 381.7	-29.2%		
H_UNP1_a	Replacement of LPG boilers with modern biomass boilers	2 267.6	-14.2%	3 357.1	-37.8%
H_UNP2_a	Replacement of LPG boilers with heat pumps	2 633.9	-14.1%	3 657.6	-37.7%
H_UNP3_a	Installation of solar collectors for DHW preparation	1 922.0	-26.9%	3 503.6	-42.4%
H_PP1_a	Replacement of standard boilers with condensing boilers	353.4	-13.3%		
H_PP2_a	Natural gas micro-CHP	771.7	-20.3%	1 165.6	-40.4%
H_PP3_a	Installation of solar collectors for DHW preparation	-65.9	-120.7%	550.3	-58.8%
H_PP4_a	Replacement of natural gas boilers with heat pumps	654.3	-14.1%	706.1	-37.3%
H_PP_5_a	Replacement of natural gas boilers with modern biomass boilers			461.2	-37.2%
H_EE_1_a	Installation of heat pumps for DHW preparation			2 268.5	-38.4%
H_EE_2_a	Replacement of electric boilers with solar collectors	2 698.4	-24.3%		
H_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	276.1	-21.5%	141.1	-47.0%
SERVICE SECTOR					
S_ELLU1	Replacement of fuel oil boilers with modern biomass boilers	1 301.7	-14.1%		
S_ELLU2	Replacement of fuel oil boilers with heat pumps	2 347.6	-14.0%		

Higher economic discount rate (4%)		**up to 2030**		**2031–2050**	
Measure code	Title of measure	**ENPV [HRK/MWh]**	**%**	**ENPV [HRK/MWh]**	**%**
S_ELLU3	Solar heating combined with heat pumps after ELLU2 measure is implemented	1 847.0	-25.0%		
S_UNP1	Replacement of LPG boilers with modern biomass boilers	1 939.7	-14.3%		
S_UNP2	Replacement of LPG boilers with heat pumps	3 051.0	-14.2%		
S_UNP3	Solar heating combined with heat pumps after UNP2 measure is implemented	2 519.2	-23.0%		
S_PP1	Replacement of standard boilers with condensing boilers	457.7	-11.8%	577.2	-36.4%
S_PP2	Natural gas micro-CHP	-952.0	-19.2%	-285.6	-142.0%
S_PP3	Solar heating combined with a condensing boiler after PP1 measure is implemented	482.6	-46.4%	1 026.0	-49.5%
S_PP4	Replacement of natural gas boilers with heat pumps	1 020.7	-14.0%	1 258.0	-37.2%
S_PP5	Replacement of natural gas boilers with modern biomass boilers			118.9	-35.1%
S_PP6	Connecting user to DHS			750.5	-33.6%
S_EE_1	Increase in the share of heat pumps vs. electric resistance heating	422.5	-22.1%	1 882.3	-37.6%
S_ELLU1_a	Replacement of fuel oil boilers with modern biomass boilers	1 382.4	-14.3%		
S_ELLU2_a	Replacement of fuel oil boilers with heat pumps	1 864.9	-14.1%		
S_ELLU3_a	Installation of solar collectors for water heating	1 057.1	-33.9%		
S_UNP1_a	Replacement of LPG boilers with modern biomass boilers	2 267.6	-14.2%		
S_UNP2_a	Replacement of LPG boilers with heat pumps	2 780.3	-14.1%		
S_UNP3_a	Installation of solar collectors for water heating	1 922.0	-26.9%		
S_PP1_a	Replacement of standard boilers with condensing boilers	342.4	-13.3%	460.7	-37.2%
S_PP2_a	Natural gas micro-CHP	571.0	-22.6%	978.8	-40.8%
S_PP3_a	Solar heating combined with a condensing boiler after PP1 measure is implemented	-126.4	-151.0%	497.5	-60.0%
S_PP4_a	Replacement of natural gas boilers with heat pumps			971.5	-37.3%

Higher economic discount rate (4%)		up to 2030		2031–2050	
Measure code	Title of measure	ENPV [HRK/MWh]	%	ENPV [HRK/MWh]	%
S_PP5_a	Replacement of natural gas boilers with modern biomass boilers			390.3	-37.1%
S_EE_1_a	Replacement of electric boilers with solar collectors	2 095.6	-26.9%	3 565.1	-42.7%
S_EE_2_a	Increase in the share of heat pumps vs. electric resistance warming	1 333.0	-14.0%	3 159.8	-37.4%
S_EE_1_b	More efficient technology use (replacement of split systems with heat pumps: air-to-water, water-to-water, ground-to-water)	871.1	-14.8%	1 296.6	-37.9%
DHS					
01	Replacement of fuel oil boilers with biomass boilers	1 518.4	-16.4%		
02	Replacement of fuel oil boilers with water-to-water heat pumps	1 382.0	-16.5%		
03	Replacement of natural gas cogeneration with natural gas HEC	-1 262.1	20.2%	996.3	-41.6%
04	Replacement of natural gas boilers with water-to-water compression heat pumps	424.0	-16.0%	1 467.5	-35.0%
05	Replacement of natural gas boilers with natural gas HEC			1 947.4	-50.7%
06	Replacement of natural gas boilers – industrial waste heat utilisation	-5 493.4	17.4%	687.4	-54.7%
07	Replacement of natural gas boilers – waste heat utilisation	-2 640.3	17.6%	1 581.6	-41.3%
08	Replacement of natural gas boilers – solar energy harnessing	-2 131.7	17.7%	1 728.4	-40.1%
09	Replacement of natural gas boilers with biomass HEC	-5 230.0	17.3%	3 187.8	-43.4%
10	Replacement of natural gas boilers with biomass boilers			2 256.7	-35.4%
11	Replacement of natural gas boilers – geothermal energy exploitation	-8 268.8	17.4%	-172.0	-144.4%

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