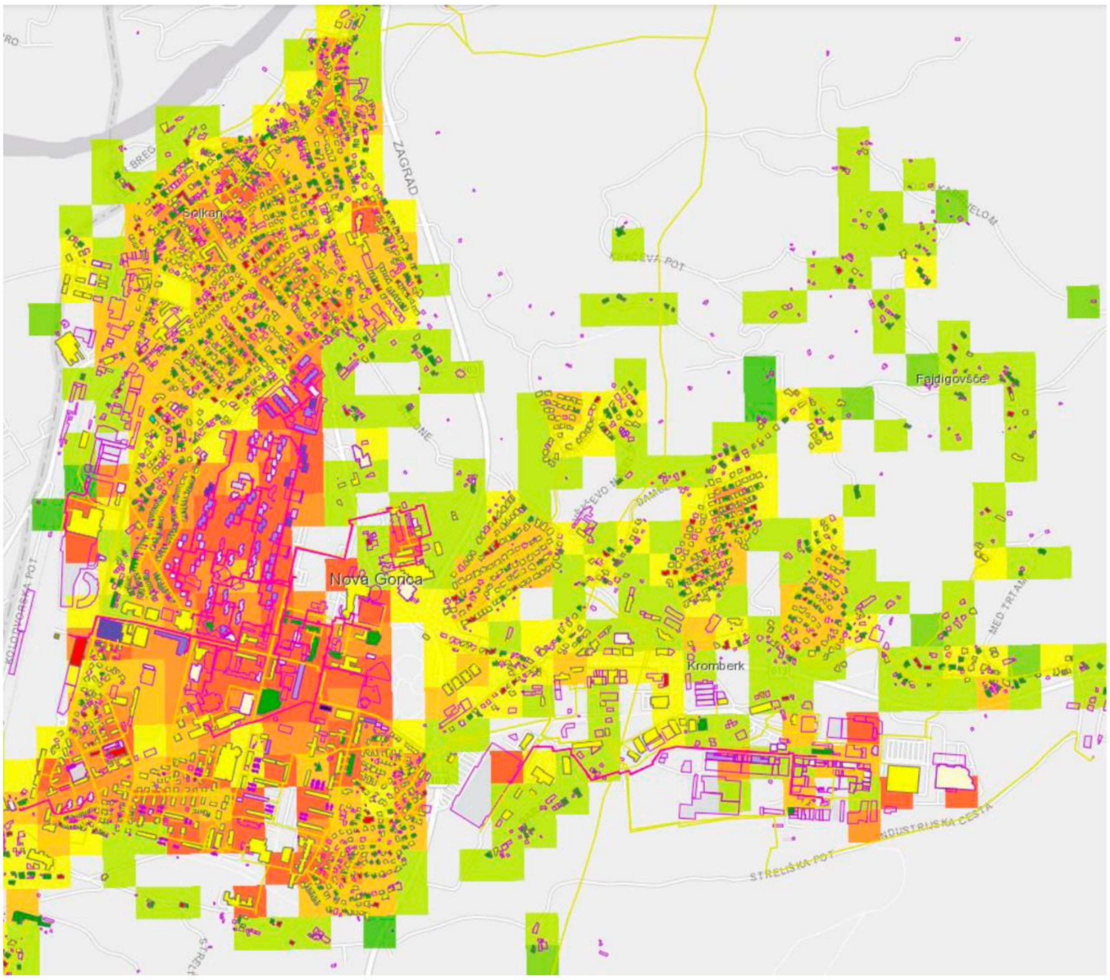
REPUBLIC OF SLOVENIA
MINISTRY OF INFRASTRUCTURE



COMPREHENSIVE ASSESSMENT OF THE POTENTIAL FOR EFFICIENT HEATING AND COOLING IN SLOVENIA

Ljubljana, August 2021

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LIST OF ABBREVIATIONS

ALT	Alternative scenario
ARSO	Slovenian Environment Agency
AzE	Energy Agency
WBB	Wood biomass boiler
COP	Coefficient of performance
DC	District cooling
DH	District heating
DHC	District heating and cooling
DSEPS 2050	Long-Term Strategy for the Energy Renovation of Buildings by 2050
DHE	District heat
AMA	Ambitious NECP scenario with additional measures
STH	Single- and two-family house
Eco Fund	Eco Fund (Slovenian Public Environmental Fund)
ELE	Electricity
ELHO	Extra-light heating oil
EC	Energy contracting
EEX	Even expansion
EU	European Union
EU ETS	EU Emissions Trading System
EXT	Industrial waste heat – transmission to an external network
E-PRTR	European Pollutant Release and Transfer Register
GEO	Geothermal energy
GIS	Geographical Information System
DPA	Densely populated area
GURS	Surveying and Mapping Authority of the Republic of Slovenia
BASE	Baseline scenario
HRE4	Heat Roadmap Europe No 4
INT	Industrial waste heat – internal use
WB	Wood biomass
LCC	Life-cycle costing
NEK	Nuklearna elektrarna Krško (Krško nuclear power plant)
NECP	National Energy and Climate Plan
HC	Heating and cooling
ORC	Organic Rankine Cycle
WH	Waste heat
TWTP	Thermal waste treatment plant
EM	Scenario with existing measures
RES	Renewable energy sources
GI	Generation installation
CA	Connected areas
SPA	Sparsely populated area
DCS	District cooling system
DHS	District heating system
SPP	Solar power plant
SECAP	Sustainable Energy and Climate Action Plan
SEER	Seasonal Energy Efficiency Ratio
NZEB	Nearly zero-energy building
SOL	Solar energy
CHP	High-efficiency cogeneration of heat and power
SEC	Solar energy collector
DHW	Domestic hot water
SURS	Statistical Office of the Republic of Slovenia
HP	Heat pump
TE-TOL	Termoelektrarna Toplarna Ljubljana (Ljubljana thermal electricity generation installation)
TEŠ	Termoelektrarna Šoštanj (Šoštanj thermal electricity generation installation)
GHG	Greenhouse gases
HM	Heat map
LPG	Liquefied petroleum gas
EE	Energy efficiency
MFH	Multi-family house
ZOVE	Renewable Energy Sources Act
NG	Natural gas
ZURE	Energy Efficiency Act

INTRODUCTION

Pursuant to Article 14 of the Energy Efficiency Directive (2012/27/EU) and Commission Delegated Regulation (EU) 2019/826 amending Annexes VIII and IX to Directive 2012/27/EU, Slovenia is required to draw up a **comprehensive assessment of the potential for efficient heating and cooling** (hereinafter: comprehensive assessment). The content of the document is laid down in detail in Annex VIII. The document shall include:

I. **an overview of the situation regarding heating and cooling (HC),** to include an assessment of heating and cooling demand in terms of assessed useful energy on a sector-by-sector basis, an assessment of the current supply of heat and cold, an identification of installations that generate waste heat (WH) and cold, a heat map (HM) containing the locations of the use and supply of heat and cold in Slovenia, and a forecast of HC demand for 10 and 30 years;
II. **a description of the objectives, strategies and measures** in the area of HC, in accordance with the Regulation on the Governance of the Energy Union and the National Energy and Climate Plan (NECP) for Slovenia;
III. **an analysis of the economic potential of efficient heating and cooling** using a cost-benefit analysis that pays due regard to sustainable technologies (waste heat and cold, thermal waste treatment, the high-efficiency cogeneration of heat and power (CHP), and renewable energy sources (RES) not used in CHP, such as geothermal energy (GEO), solar energy (SOL), biomass), heat pumps (HP), and reductions in losses from district networks, etc.).
IV. **any new strategies and measures** for exploiting the defined economic potential.

Pursuant to the Directive on the promotion of the use of energy from renewable sources (2018/2001), a comprehensive assessment shall also include an assessment of the potential for the use of RES, WH and cold in the HC sector.

Increasing the efficiency of HC is a key condition for the long-term decarbonisation of these two sectors on the path to climate neutrality. In the face of rapid changes and the development of new technologies, this hugely demanding process requires good planning if the ambitious targets are to be met at the lowest possible cost. It also requires close cooperation between all sectors. A good knowledge of current and future HC needs, supported by spatial analysis and assessments of the economic potential of different sustainable carbon-free heating sources, is the first step towards the preparation of a support environment and high-quality local planning in what is a long-term process.

This comprehensive assessment relies on the results of past analyses, the statistical data available and new analyses, and is in line with the expert groundwork produced for the NECP.

1 SUMMARY AND CONCLUSIONS

At 22 TWh, heating and cooling accounts for almost 40% of energy end-use in Slovenia and more than 30% of primary energy supply.[1] It therefore has a very significant effect on the achievement of national targets in all five dimensions of the Energy Union: energy security, the internal energy market, energy efficiency, decarbonisation, and research, innovation and competitiveness.

Reducing heat and cold demand is one of the priorities of the NECP and has the greatest potential as a source for efficient HC – one that makes vital contributions to achieving the objectives of the other dimensions of the Energy Union. Total consumption of useful energy for HC should therefore fall by 11% (2.2 TWh) by 2030 and by 13% (2.6 TWh) by 2050. Consequently, and because of the introduction of efficient energy-supply technologies, energy end-use will fall by 23% (5.1 TWh) by 2030 and by 28% (6.4 TWh) by 2050. **The reduction of 5.1 TWh in final energy for HC by 2030 relative to 2017 represents almost 9% of total energy end-use in 2017. As it accounts for just over half the target reduction, it makes a vital contribution to achieving the energy efficiency objective for 2030.[2]**

Owing to the increase in energy efficiency and the high baseline share taken by RES in HC, the quantity of heat from RES under the 2030 NECP scenario is expected to fall from almost 29 TWh in 2017 to just over 25 TWh in 2030, thereafter increasing to 27 TWh by 2050. **Despite the reduction in the quantity of RES resulting from greater efficiency, and because of the reduction in the final consumption of heat, the share of RES in HC, which has fallen slightly from 35% since 2017, will exceed 40% by 2030 and 50% by 2050, which is in line with the more ambitious RES targets for the period leading up to 2030.**

The estimated economic potential of RES for HC is in excess of 7 TWh of useful heat and 0.8 TWh of electricity from CHP. Wood biomass (WB) remains the biggest source (3.5 TWh), followed by shallow geothermal and ambient energy heat pumps (2.4 TWh). While the estimated economic potentials for efficient heating may provide all the required heat in buildings by 2050 (6.4 TWh), supplying industry with heat presents a greater challenge (its heat demand amounts to 9 TWh).

Wood biomass: By 2050, final consumption of WB in households will fall by almost 70% to 1.8 TWh (from the 2017 figure of 5.4 TWh); this is mainly due to an increase in the efficiency of buildings and wood biomass boilers (WBB). Nevertheless, WB maintains a one-third share of useful heat demand in households, and remains, along with district heating (DH) and heat pumps (HP), an important domestic RES for balanced heat supply over the long term. Mainly because of an increase in the number of CHP generation installations (GI) that use WB and the development of gasification technology, the potential for the use of WB in industry is estimated to be 1.9 TWh by 2050, which is more than double the current use of WB in industry (0.8 TWh in 2017). The total current potential supply of heat from WB in existing and new district heating systems (DHS) in areas with an annual heat demand density of more than 350 MWh/ha is estimated to be between 1 000 and 1 200 GWh. In light of the planned reduction in useful heat demand in buildings of almost 40% by 2050 as a result of an increase in building efficiency, the potential of heat from WB in DHS in 2050 is estimated to be 0.6 TWh under the alternative scenario (ALT),[3] which is double the 2017 figure.

Deep geothermal energy: According to NECP estimates, the deep geothermal energy (GEO) potential by 2050 is at least 300 GWh of heat in buildings, services and agriculture. The potential generation of geothermal electricity could substantially increase this figure through the efficient cascade use of geothermal energy. Activities to remove obstacles and provide a supportive environment must be continued if a more detailed assessment is to be made and the feasibility of the economic potential of deep GEO is to be accelerated.

Heat pumps: Heat pumps (HP) will, over the long term, become the largest source of heat supply in buildings, accounting for at least 30% (or 2 TWh of useful heat) by 2050. According to NECP estimates, the economic

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[1] Taking the primary electricity conversion factor into account.

[2] In line with the EU target of a 32.5% reduction in energy consumption, Slovenia should reduce energy end-use by 2.5 TWh by 2030 relative to 2020.

[3] The analysis looked at two scenarios: the baseline scenario, which addresses existing measures, and the alternative scenario, which addresses additional measures as part of the ambitious NECP scenario. These scenarios were drawn up in the course of the preparation of expert groundwork for the NECP and the Long-Term Climate Strategy of Slovenia.

potential of heat generation using shallow GEO HP is at least 750 GWh of heat in buildings and at least 300 GWh in district heating systems (DHS) by 2050. The economic potential of HP for the recovery of ambient heat in buildings will more than double by 2030 to an estimated 1.1 TWh. According to the two NECP scenarios, this will increase to almost 1.2 TWh (or to almost 20% of all useful heat demand in buildings) by 2050. Owing to the fact that they are more efficient for HC purposes and are almost wholly independent of meteorological conditions, shallow GEO HP have an important qualitative advantage over air-to-water HP. It therefore makes sense to introduce these heat pumps mainly in larger buildings in order to increase efficiency and relieve pressure on the electricity grid. In industry, HP could, by harnessing WH, meet the majority of demand for low-temperature heat for technology and heating (300 GWh) and, together with the direct use of WH, at least 125 GWh of district heat (DHE) in district heating systems.

Waste heat in industry: The total estimated WH potential is in excess of 650 GWh (more than 60% at the 200-500°C temperature level, 25% at the 100-200°C temperature level and 10% at the temperature level of over 500°C). Companies could use just over 160 GWh of the WH potential for their own (internal) needs, with almost 500 GWh being sold to other users. The potential exceeds current the needs of existing district heating systems in the vicinity of the companies in question. As many industrial locations do not have a DHS in the vicinity, a more detailed assessment of the potential for WH use and of its economic potential requires a case-by-case approach and local planning for each individual industrial location and DHS. The economic potential for the sale of WH in industry is estimated at around 110 GWh (145 GWh of heat transmitted into DHS through heating provided by heat pumps).

Thermal waste treatment: In 2018 the calorific value of all municipal waste in Slovenia was more than 1 TWh. Of this figure, only 10% is currently being utilised in the country's sole thermal waste treatment plant (TWTP), which is located in Celje and generates around 35 GWh of heat and 7 GWh of electricity per year. In light of current plans for TWTP being drawn up by the two largest urban municipalities, thermal waste treatment has an estimated total economic potential of more than 520 GWh of calorific value, or the generation of almost 320 GWh of heat and 70 GWh of electricity. The year-round operation of the planned thermal waste treatment plants, with a thermal output of approximately 50 MW, provides a potential for the generation of around 70 GWh of cold and district cooling (DC) in the summer months.

High-efficiency cogeneration of heat and power: The cogeneration of heat and power (CHP) remains the key technology for achieving high efficiency in the use of RES (WB, biogases, GEO, etc.) and e-fuels in all sectors (and mostly in DHS and industry), and could make an important contribution to increasing self-sufficiency and reliability in electricity supply, particularly in the winter months. As fossil fuels are phased out, the accessibility and competitiveness of e-fuels will be a key factor in the future development of CHP in Slovenia. The economic potential of CHP in the period leading up to 2050 is estimated at around 430 MWe, which means only a small increase on current capacities, while the replacement of technologies will lead to an 80% increase in electricity generation to 2.3 TWh and an increase in the useful consumption potential of 3 TWh of heat.

District heating and cooling: The estimated additional current potential for the expansion of existing DHS with the inclusion of larger buildings in particular is 150 GWh in areas with an annual heat demand density exceeding 350 MWh/ha and 500 GWh in areas with a density exceeding 200 MWh/ha (areas more suitable for low-temperature fourth-generation systems in particular). The expansion of existing DHS enables an increase of between 12 and 40% on today's sale of heat for the heating of buildings (excluding domestic hot water, or DHW), i.e. to a total of between 1.4 and 1.8 TWh. The estimated current economic potential of the establishment of new smaller DHS is between 200 and 400 GWh (areas with a density exceeding 350 MWh/ha). For new low-temperature micro DHS that only connect a few buildings in areas with a greater density of consumption, this potential is between 400 and 600 GWh. The total current estimated economic potential of the supply of heat for the heating of buildings from district heating systems is between 2 and 2.8 TWh per year (excluding DHW), or between 23 and 31% of current useful heat demand in buildings (excluding DHW). This estimate will have to be updated by more detailed analyses and planning at the local level. Given the planned reduction in useful heat demand in buildings of almost 40% by 2050 as a result of an increase in building efficiency, and in line with the NECP scenario, the total potential heat supply for the heating of buildings from DHS is estimated to be 1.4 TWh (under the ALT scenario), or 1.6 TWh if DHW is included. A more detailed analysis should be drawn up, and linked with waste heat projections for the summer months, if an assessment of the economic potential of district cooling is to be made.

Reduction of losses in existing district heating systems: Heat losses can be significantly reduced by making systematic investments in the renovation and optimisation of DHS networks and, above all, by reducing temperature operating regimes. According to NECP projections, the estimated potential reduction in losses in DHS is at least 125 GWh by 2050.

Costs and benefits of the baseline (BASE) and alternative (ALT) scenarios: A comparative analysis of the two scenarios has shown that, despite the greater volume of investment in building renovation (21% higher) and the replacement of systems for heating and for the production of domestic hot water (3% higher), the more ambitious alternative scenario (ALT) leads to 5% lower energy-use costs and 9% lower indirect external emission costs after 2030 (and cumulatively throughout the entire period), resulting in 4% lower total costs by 2050. The estimated total costs of ALT for the 2021-2050 period therefore amount to EUR 44.5 billion, which is EUR 1.7 billion less than the total costs estimated under the baseline (BASE) scenario.

Direct GHG emissions from heating and cooling totalled 2.8 $MtCO_2$ equivalent in 2017 (16% of all GHG emissions in Slovenia). Despite this comparatively low percentage, this sector has contributed most to reducing emissions in Slovenia in the last few years. In the period between 2005 and 2017, emissions from HC fell by more than 40%, or by 1.9 $MtCO_2$ equivalent. Households contributed most to this reduction, and buildings overall by just over 1.2 $MtCO_2$ equivalent. According to NECP projections, GHG emissions for HC in the period leading up to 2030 will fall by 42% relative to 2017, or by 1.2 $MtCO_2$ equivalent, with reductions in buildings twice as high as those in industry. In the period leading up to 2050, emissions will remain minimal at 0.1 $MtCO_2$ equivalent. **By 2030, emissions will fall by just over 66% in HC, more than 80% in buildings and more than 60% in industry relative to 2005. An absolute reduction in emissions in HC by 3.1 $MtCO_2$ equivalent by 2030 relative to 2005 means a reduction in total emissions of just over 26%. This makes an extremely important contribution to achieving the new, more ambitious 2030 emission reduction target and accounts for almost half the target reduction.**[4]

The increase in efficiency and the balanced decarbonisation of HC using all available domestic renewable energy sources (wood biomass, geothermal energy, solar energy, etc.) and district heat envisaged in the NECP would make an important contribution to reducing reliance on imports and exposure to risks in emergency situations, particularly in winter months with extremely low temperatures.

The planned concept increases the role district heating systems play as important infrastructure for integrating energy sectors effectively and providing support to the electricity grid (flexible cogeneration of electricity in the winter months, storage of energy surpluses, provision of system services, etc.). There is a great emphasis on energy efficiency, which also makes an important contribution to reducing the risk of fuel poverty.

Increasing the volume of research and innovation will be key to the successful exploitation of the potential for efficient HC and increasing the use of renewable energy sources, particularly in industry (where the challenges are greatest), while successful solutions can significantly improve industrial competitiveness. Finding alternatives to natural gas for heating in industry is a key technological development challenge. Any effective and efficient solution will have a positive impact on all other sectors.

Slovenia has already adopted most of the measures for achieving the potential for efficient HC in the NECP. Prior to adopting the new measures, it first had to ensure that they could be implemented effectively and to the planned extent.

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[4] Slovenia's total GHG emissions in 2005 were practically the same as emissions in the reference year of 1990 (1986 for Slovenia). It is therefore immaterial whether the target comparison of total emissions is made with 2005 or 1990. The large increase in emissions from traffic (by 1.1 $MtCO_2$ equivalent since 2005) reduces the effect of the reduction in emissions from heating. In order to achieve the target of a 55% reduction by 2030, a larger reduction must therefore be achieved in all sectors.

2 OVERVIEW OF HEATING AND COOLING

Total energy end-use for heating and cooling in households, services and industry was a little over 22 TWh in 2017, which accounted for just under 39% of total energy end-use in Slovenia (Figure 1). Households account for the largest share of HC (48%, or 18% of total final energy), followed by industry (38%, or 15% of total final energy), and services (14%, or 5% of total final energy). Energy consumption for HC in buildings accounts for almost a quarter of final energy consumption in Slovenia.

Total direct GHG emissions from heating[5] amounted to 2.8 MtCO₂ equivalent in 2017, which accounted for only 16% of all GHG emissions in Slovenia. Industry was responsible for 57%, households for 30% and services for 12% of emissions (Figure 2).

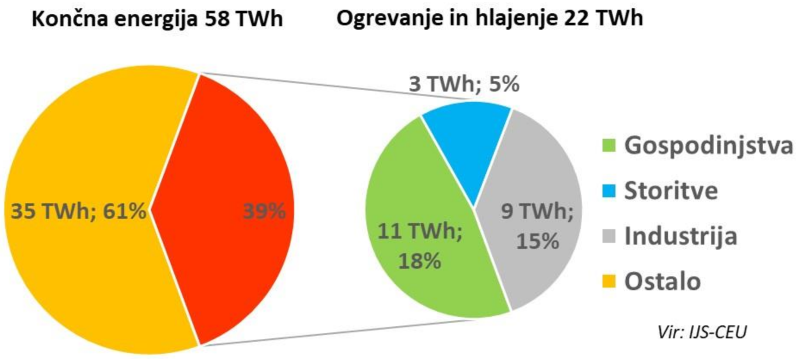

Figure 1: Energy end-use for heating and cooling in Slovenia in 2017

	Final energy 58 TWh
	Heating and cooling 22 TWh
	Households
	Services
	Industry
	Other
	Source: IJS-CEU

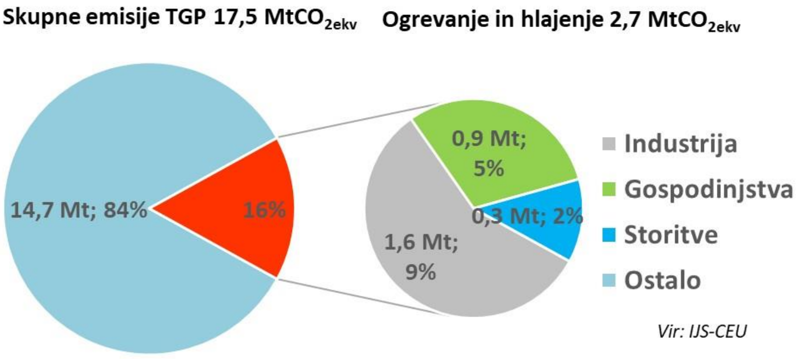

Figure 2: Total direct greenhouse gas emissions from heating in Slovenia in 2017

	Total GHG emissions 17.5 MtCO₂ equivalent
	Heating and cooling 2.7 MtCO₂ equivalent
	Industry
	Households

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[5] Indirect emissions resulting from the use of electricity for HC and the generation of district heat (DHE) are not included.

	Services
	Other
	Source: IJS-CEU

2.1 Heating demand

2.1.1 Households

Households required 7.9 TWh of useful energy for heating and hot water in 2017 (hot water 1.6 TWh or 22%, heating 6.2 TWh). Single-family houses[6] accounted for just over 75% (5.9 TWh) of the total energy required for heating and domestic hot water (DHW). This figure was 2 TWh for multi-family houses (MFH). From the point of view of the preparation of the required heat, the division into central and local systems used by households for heating and the production of DHW is an another potentially attractive development.

The structure is shown in the graph below. The shares shown are calculated for MFH and STH separately. The heat required for heating and the production of DHW is mainly provided by central systems (89% in single-family houses and 88% in MFH) (Figure 3).

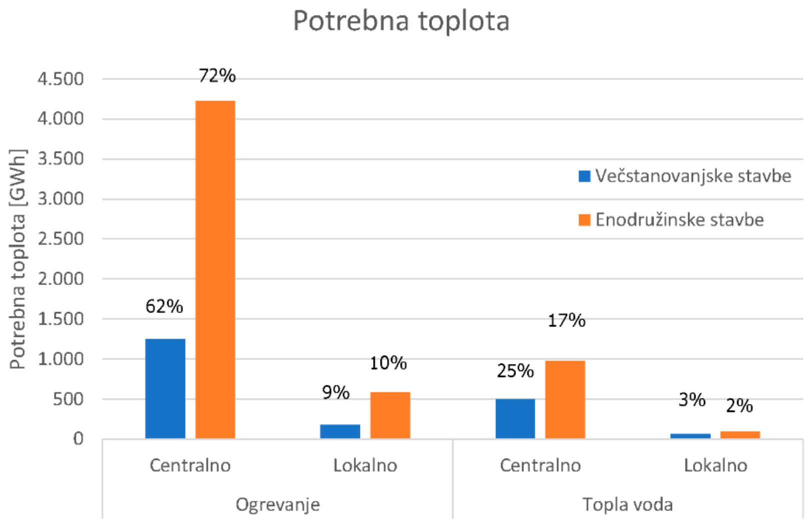

Figure 3: Distribution of heat demand in households in relation to building type, method of generation and consumption

	Heat demand
	Heat demand [GWh]
	Multi-family houses
	Single-family houses
	Central
	Local
	Heating
	Central
	Local
	Hot water

The distribution of heat demand in terms of the fuel used for the production of heat is as follows: for all buildings, wood biomass (WB) predominates, followed by natural gas (NG), extra-light heating oil (ELHO), district heat/heating (DHE/DH), ambient energy recovered by heat pumps (HP), electricity (ELE), liquefied petroleum gas (LPG) and solar energy (SOL) (Figure 4, left). As expected, the structure for MFH differs significantly from the structure for single-family houses (Figure 4, right). DH predominates in MFH (43%), followed by NG (24%), ELE (13%, particularly for the production of DHW using electric heaters), ELHO (9%), wood (5%), LPG (4%) and HP

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[6] This category includes single- and two-family houses (STH).

(2%). Solar energy accounts for a negligible proportion. In single-family houses, wood accounts for 50%, ELHO and NG for 14% each, HP for 11%, ELE and LPG for 3% each, and DH and SOL for 2% each.

In light of the potential replacement of energy products, fuels that will have to be replaced by low-carbon alternatives account for a higher share in MFH, as fossil fuels (ELHO, NG and LPG) account for 37% (31% in single-family houses). However, it should be noted that, because of the negative impact on air quality, a high proportion of wood biomass use in single-family houses must be redirected towards more efficient generation installations, and more intensive efforts made towards raising awareness regarding the correct way to heat buildings.

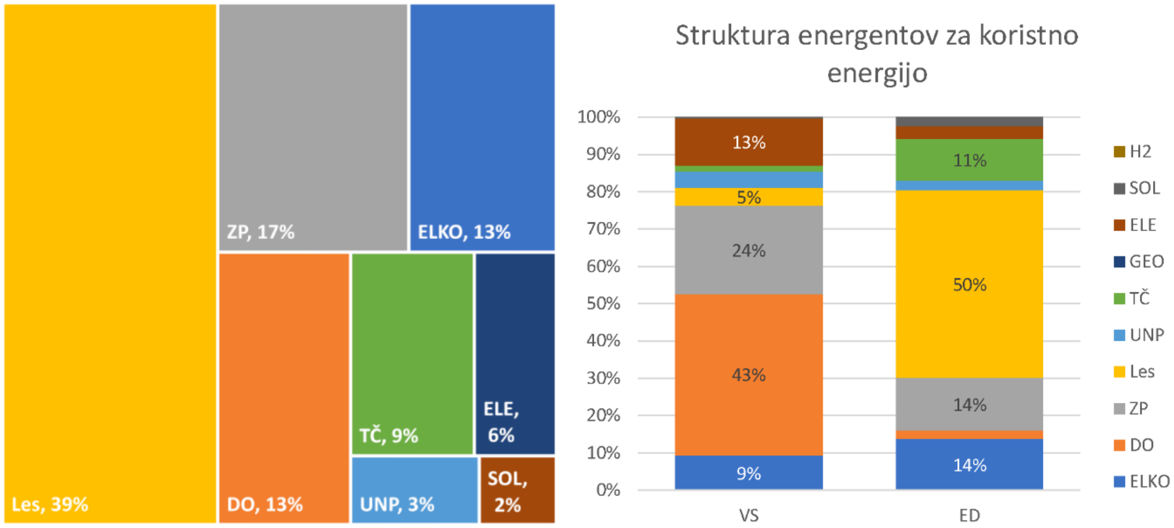

Figure 4: Distribution of useful heat demand for heating and domestic hot water in households, by energy product for all buildings (left), and separately for multi-family houses and single- and two-family houses (right).

	Wood, 39%
	NG, 17%
	ELHO, 13%
	DH, 13%
	HP, 9%
	ELE, 6%
	LPG, 3%
	SOL, 2%
	Structure of energy products for useful energy
	MFH
	SFH
	H2
	SOL
	ELE
	GEO
	HP
	LPG
	WB
	NG
	DH
	ELHO

Slovenia is characterised by considerable dispersal of settlement, with more densely populated areas having grown up mainly in areas of greater economic development. For the purpose of producing spatial analyses of annual heat demand for heating, seven classes of density of heat demand for heating have been defined, classified into two settlement density types: sparsely populated areas (SPA) and densely populated areas (DPA), as shown in Table 1.

Table 1: Classes of density of heat demand for heating

Population density type	Sparsely populated areas (SPA)			Densely populated areas (DPA)			
Class	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Annual heat demand density [MWh/ha]	< 20	20-50	50-100	100-200	200-350	250-600	> 600

The structure of useful heat for heating and the production of DHW in households relative to population density and energy product consumed in 2017 is shown in Figure 5.

Dispersed settlement is not typical only of smaller municipalities, as the largest municipalities can also be made up of a number of sparsely populated areas. Figure 6 shows the structure of annual heat demand by density class for the 16 biggest Slovenian municipalities in which estimated demand exceeds 100 GWh per year. As expected, Ljubljana and Maribor have the lowest proportions of SPA (10% and 18%, respectively). In all other municipalities, the proportion is higher than 20% and, in two municipalities, even higher than 60%.

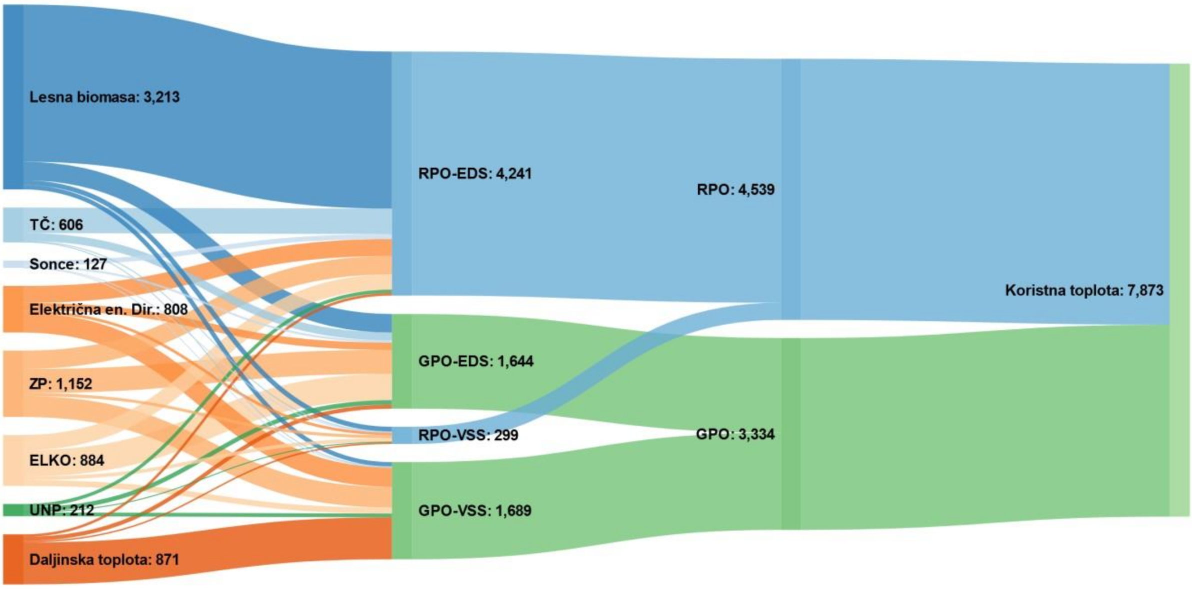

Figure 5: Structure of the supply and consumption of useful heat for heating and the production of domestic hot water in GWh (2017)

	Wood biomass: 3.213
	HP: 606
	Solar: 127
	Electricity direct: 808
	NG: 1.152
	ELHO: 884
	LPG: 212
	District heating: 871
	SPA–STH: 4.241
	SPA: 4.539
	DPA–STH: 1.644
	SPA–MFH 299
	DPA: 3.334
	DPA–MFH: 1.689
	Useful heat: 7.873

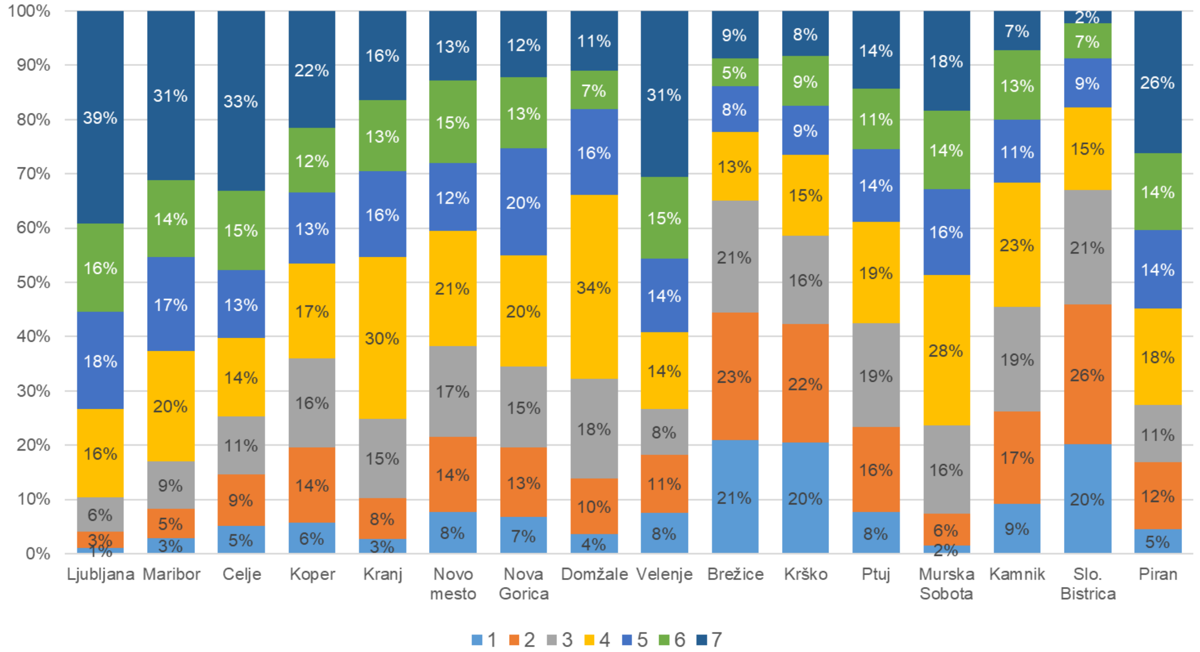

Figure 6: Share of annual heat demand in relation to consumption density class

2.1.2 Services

The demand for energy for heating and the production of DHW in the service sector was 2.6 TWh in 2017: 1.1 TWh (44%) in the public-service sector and 1.4 TWh (56%) in the private-service sector. Structure is shown by energy product in Figure 7 below. ELHO and DH are the predominating energy products, followed by NG, WB, ambient energy (HP), LPG, GEO and ELE. Solar energy has a 0.1% share.

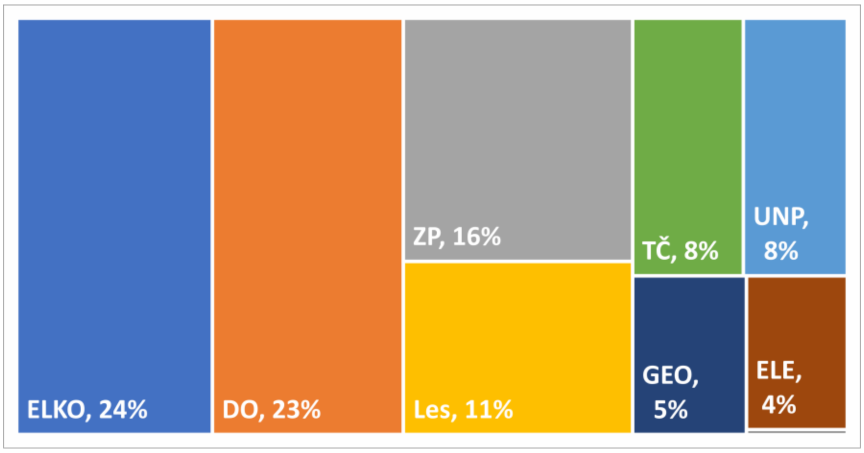

Figure 7: Distribution of heat demand for the service sector, by energy product (2017)

	ELHO, 24%
	DH, 23%
	NG, 16%
	WB, 11%
	HP, 8%
	GEO, 5%
	LPG, 8%
	ELE, 4%

Dispersal of settlement

The results of an analysis of the dispersal of 'bottom-up' useful heat demand for the heating of buildings (households and services), where the demand, broken down by municipality for different groups of buildings classified into annual demand classes, are shown in Table 2 and the maps and graph below (Figure 8 – Figure 11).

Table 2: Classes of useful heat demand for the heating of buildings

Class	Single-family houses		Multi-family houses		Service-sector buildings	
	Lower limit [GWh/year]	Upper limit [GWh/year]	Lower limit [GWh/year]	Upper limit [GWh/year]	Lower limit [GWh/year]	Upper limit [GWh/year]
1	0	25	0	5	0	10
2	25	50	5	10	10	20
3	50	100	10	15	20	30
4	100	150	15	30	30	50
5	150	300	30	50	50	100
6	300		50		100	

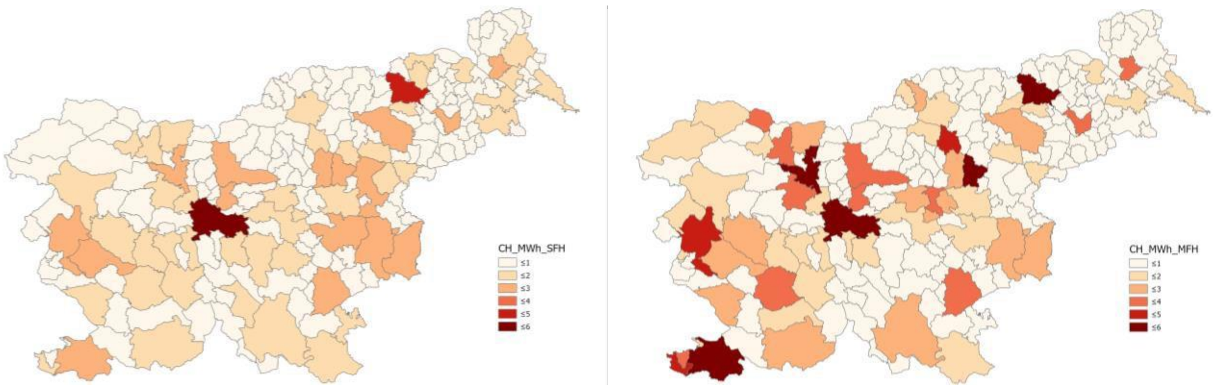

Figure 8: Heat demand for the heating of single-family houses (left) and multi-family houses (right), by individual municipality, in relation to the classes of useful heat demand for heating

	CH_MWh_SFH
	CH_MWh_MFH

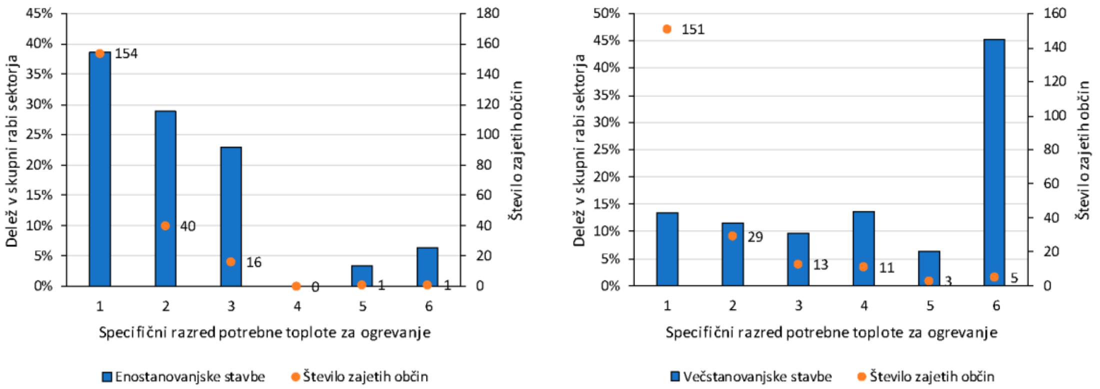

Figure 9: Share of heat demand for the heating of single-family houses (left) and multi-family houses (right), and the number of municipalities by class of useful heat demand for heating

	Sectoral shares of total consumption
	Number of municipalities included

	Specific class of useful heat demand for heating
	Single-family houses
	Multi-family houses

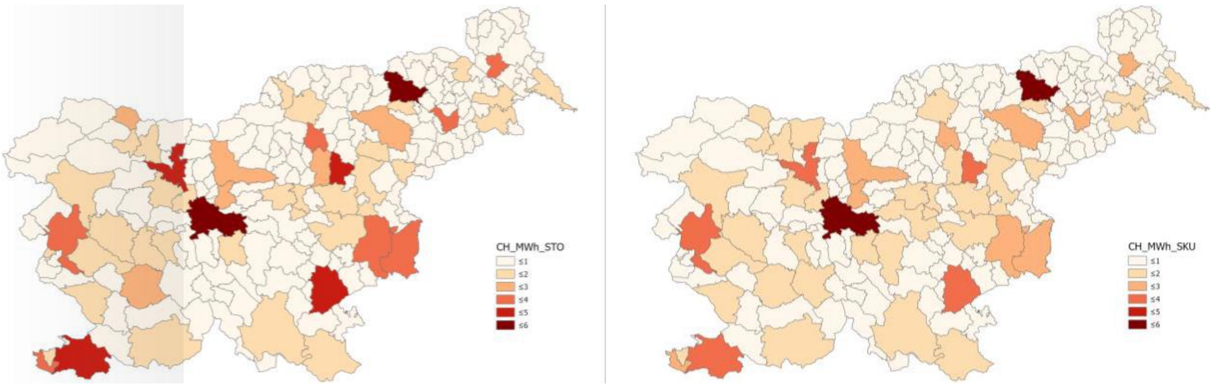

Figure 10: Heat demand for the heating of service buildings (left) and all buildings (right), by individual municipality, in relation to the class of useful heat demand for heating

	CH_MWh_SERVICES
	CH_MWh_TOTAL

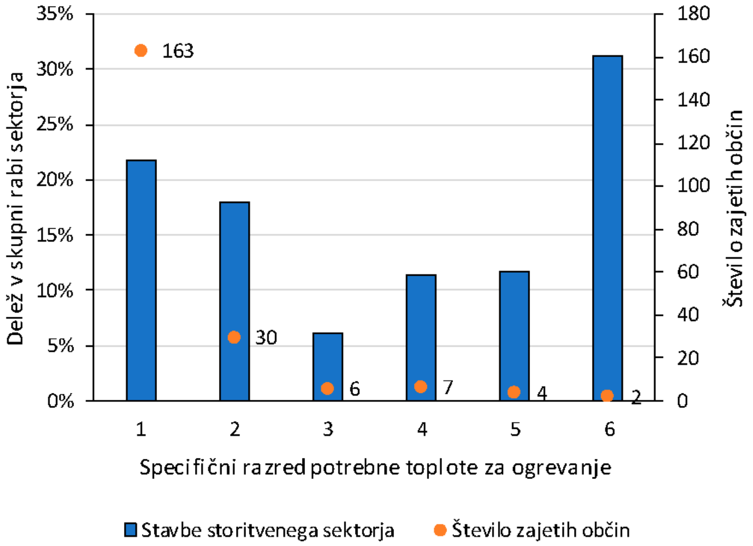

Figure 11: Share of heat demand for the heating of service-sector buildings and the number of municipalities, by class of useful heat demand for heating

	Sectoral shares of total consumption
	Number of municipalities included
	Specific class of useful heat demand for heating
	Service-sector buildings

2.1.3 Industry

The manufacturing sector accounted for around a quarter of all final energy consumption in Slovenia in 2017. The key energy products in that sector are electricity and natural gas, which accounted for just over 77% of the final energy consumed in industry in 2017 (ELE 45%, NG 36%). They were followed by RES at 6% (WB, biogas, ambient energy, solar energy), petroleum products, also at 6%, DHE at 4% and solid fuels at 3%.

A total of 8.6 TWh of final energy was consumed for thermal processes and heating in industry in 2017. An overview of the useful heat consumption is given below by industrial branch. Energy-intensive branches (C17 – Manufacture of paper and paper products, C20 – Manufacture of chemicals and chemical products, C23 – Manufacture of other non-metallic mineral products, C24 – Manufacture of basic metals) are addressed separately from other branches.

Estimated useful heat demand in industry was 8.2 TWh in 2017, which accounted for 44% of total useful heat demand in Slovenia. Energy-intensive branches account for almost 70% of all useful heat demand. The largest single share (almost a quarter, 23%) of all useful heat demand in industry comes from C23 (Manufacture of other non-metallic mineral products), which also includes cement production. This is followed by C24 (Manufacture of basic metals, 20% of useful heat demand), C17 (Manufacture of paper and paper products, 14%) and C20 (Manufacture of chemicals and chemical products, 10%). Other branches account for 33% of all useful heat demand (Figure 12).

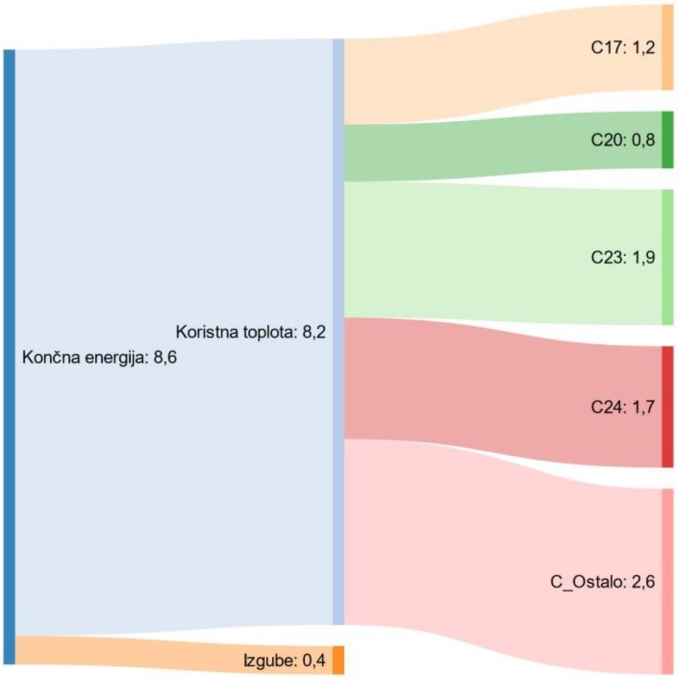

Figure 12: Energy flows and useful heat demand, by branch (TWh, 2017)[7]

	Final energy: 8.6
	Useful heat: 8.2
	Losses: 0.4
	C17: 1.2
	C20: 0.8
	C23: 1.9
	C24: 1.7
	C_Other: 2.6

The structure of useful heat demand in industry in 2017 is shown by purpose of use in Figure 13. Direct heat consumption in processes, i.e. process use, accounts for the highest single share, almost two-thirds, of the total estimated heat demand of 8.2 TWh, followed by the production of high-temperature heat (steam) at 30%. According to estimates, low-temperature heat accounted for around 4% of useful heat demand in 2017.

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[7] Owing to the large number of different technologies and methods of consumption, assessing useful heat for process use is an extremely complex task and one that requires a more detailed examination of technologies at the level of the individual process or individual industrial company. This analysis presupposes that final energy is converted into useful heat with efficiency 1.

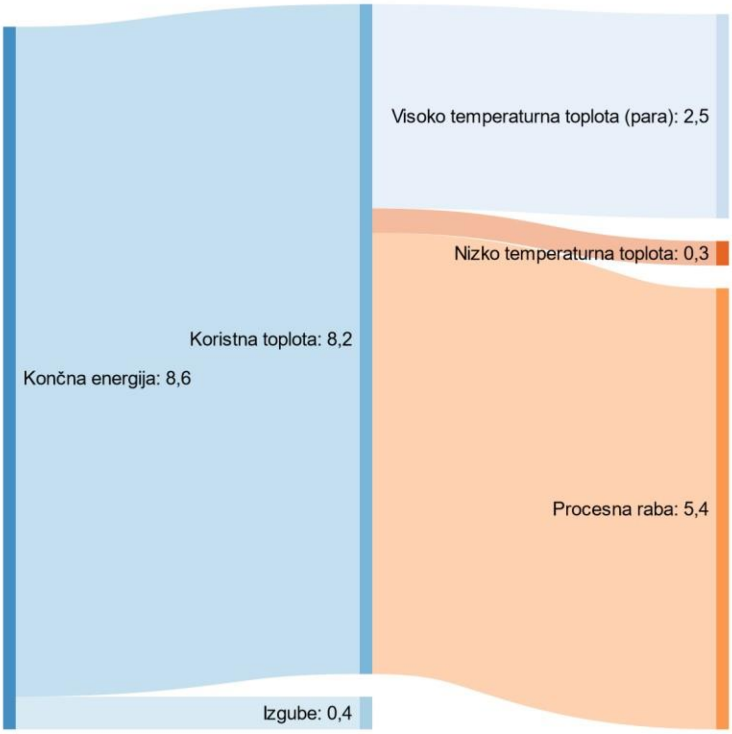

Figure 13: Energy flows and useful heat demand, by purpose of use in industry (TWh, 2017)

	Final energy: 8.6
	Useful heat: 8.2
	Losses: 0.4
	High-temperature heat (steam): 2.5
	Low-temperature heat: 0.3
	Process use: 5.4

It is possible to conclude on the basis of figures on the use of heat in industry, broken down by municipality, that use is highest in large urban municipalities and municipalities in which energy-intensive industries are located. Table 3 shows the estimated useful heat demand in industry (including process use) in 2017 for the ten municipalities with the highest heat demand. The estimated useful heat in those ten municipalities accounts for more than half (53%) of the total beneficial heat use in industry.

Table 3: Estimated useful heat in industry for the ten municipalities with the highest heat use (2017)

Municipality	Useful heat with process use [GWh]
Ljubljana	720
Kanal ob Soči	471
Jesenice	384
Ravne na Koroškem	375
Škofja Loka	354
Celje	353
Kidričevo	352
Domžale	345
Krško	319
Novo Mesto	297

Figure 14 shows the geographical distribution of useful heat (with process use) in industry, by municipality, in 2017.

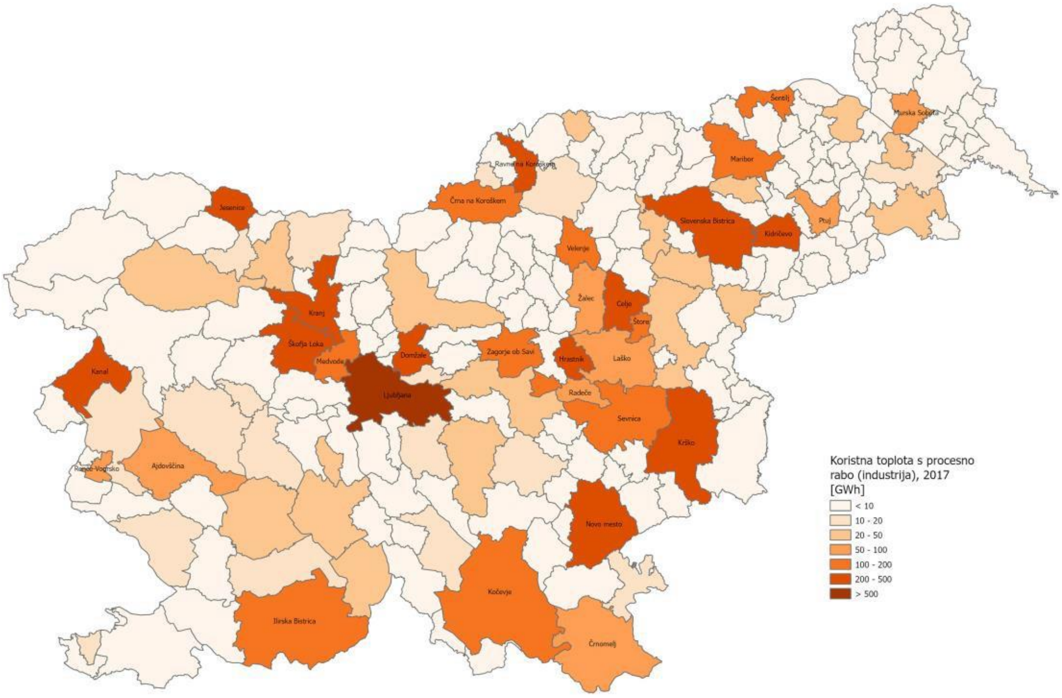

Figure 14: Useful heat with process use in industry, by municipality (2017)

	Useful heat with process use (industry), 2017 [GWh]

2.2 Cooling demand

2.2.1 Households and services

In 2017, cooling demand in households was estimated to be 332 GWh. This estimate was calculated on the basis of an assumed average annual cooling demand of 35 kWh/m^2, where it is presupposed that only half the useful area of an apartment is cooled, that the temperature excess is 170 (which is 37% higher than the multi-year average used to calculate the factor), and that 25% of households are fitted with air-conditioning equipment.

The growth in the use of air-conditioning equipment in particular is having an impact on the growth in demand for cooling, as is global warming, although there is considerable variability, as is evident from Figure 15 below, which shows the trend in the percentage of households with air-conditioning and the temperature excess for the period between 2010 and 2019. In 2017 the average Seasonal Energy Efficiency Ratio (SEER) was 3.7 and the estimated consumption of electricity for cooling in households was 90.5 GWh.

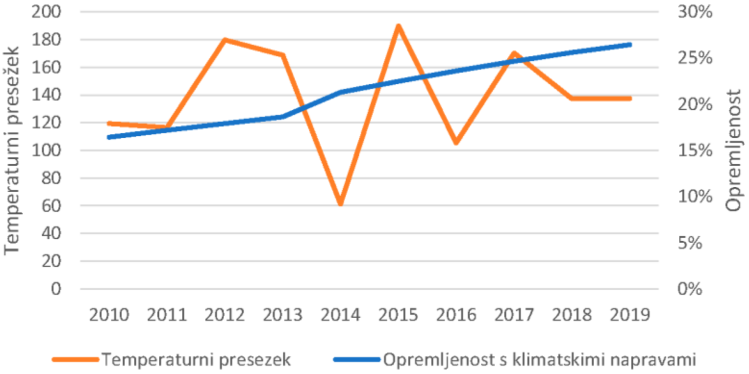

Figure 15: Temperature excess and percentage of households with air-conditioning equipment (source: ARSO and IJS-CEU)

	Temperature excess

	Percentage
	Percentage of households with air-conditioning equipment

The need for cooling is greater in the service sector, although the assessment is less precise because there is less data available on the situation in this sector. Cooling demand is estimated to be 515 GWh. The assessment is based on a calculation using the 'bottom-up' method. In services, the default factor for the energy efficiency of cooling appliances is 3, which is slightly lower than in households. The factor is expected to increase considerably by 2050. The consumption of electricity for cooling in the service sector is estimated to be 172 GWh.

Table 4: Classes of useful cold demand for the cooling of buildings

Class	Lower limit [GWh/year]	Upper limit [GWh/year]
1	0	5
2	5	10
3	10	15
4	15	30
5	30	50
6	50	

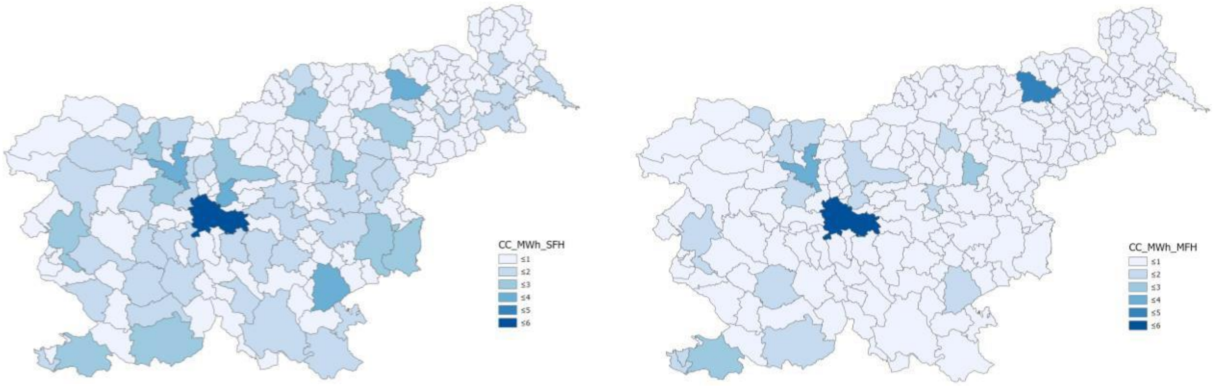

Figure 16: Cold required for cooling single-family houses (left) and multi-family houses (right), by individual municipality and in relation to the specific cooling demand class

	CH_MWh_SFH
	CH_MWh_MFH

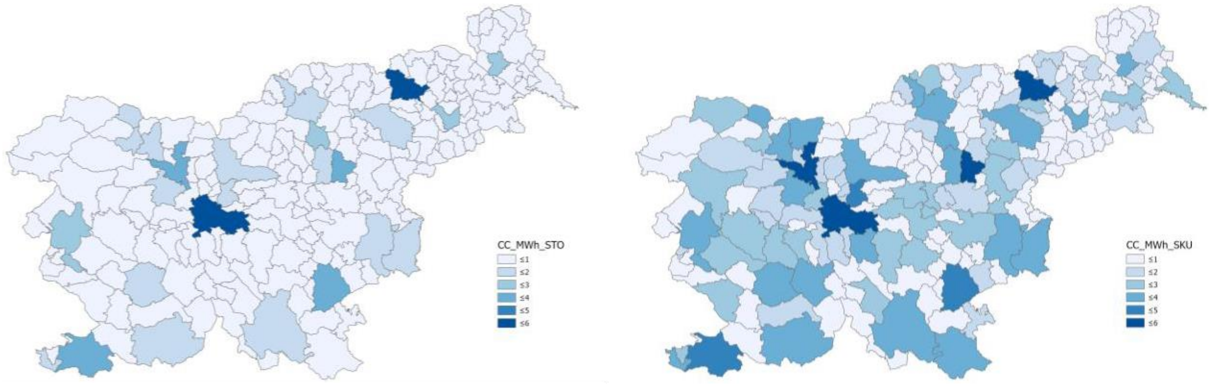

Figure 17: Cold required for cooling service buildings (left) and all buildings (right), by individual municipality and in relation to the specific cooling demand class

	CH_MWh_SERVICES
	CH_MWh_TOTAL

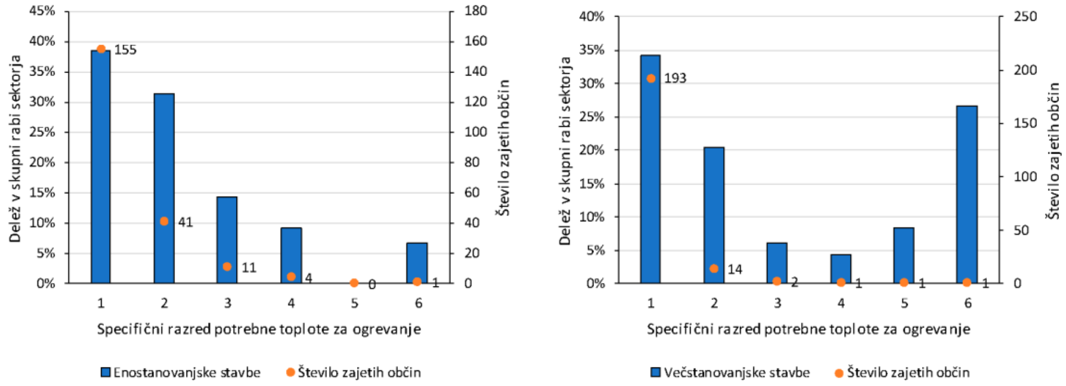

Figure 18: Share of demand for the cooling of single-family houses (left) and multi-family houses (right), and the number of municipalities, by cooling demand class

	Sectoral shares of total consumption
	Number of municipalities included
	Specific class of useful heat demand for heating
	Single-family houses
	Multi-family houses

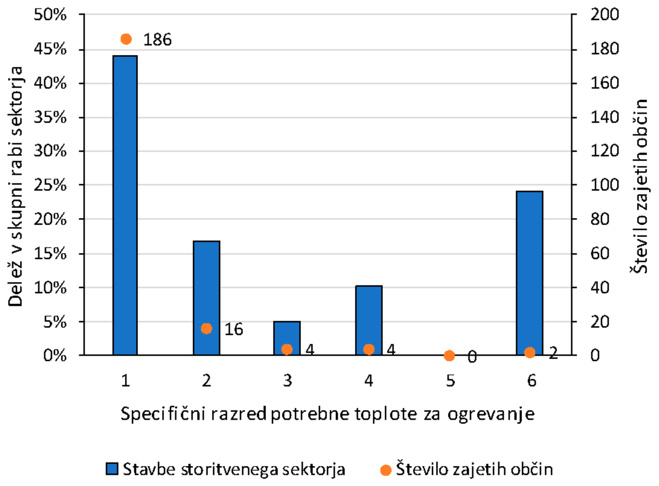

Figure 19: Share of demand for the cooling of service-sector buildings and the number of municipalities, by cooling demand class

	Sectoral shares of total consumption
	Number of municipalities included
	Specific class of useful heat demand for heating
	Service-sector buildings

2.2.2 Industry

The estimate of current cooling demand in industry has been determined on the basis of the assessment of the energy required for cooling in energy-intensive branches and the food industry produced by SURS for 2018. Total cooling demand is therefore estimated at a little less than 100 GWh and final consumption of electricity for cooling at slightly less than 30 GWh (a COP factor of 3.5 is used to estimate final energy consumption).

The cooling demand in municipalities is evaluated on the basis of the intensity of energy use for cooling in a specific branch, and the presence of a specific branch in the municipality (Figure 20). As expected, those municipalities in which food manufacturers are located have the highest energy-use intensity.

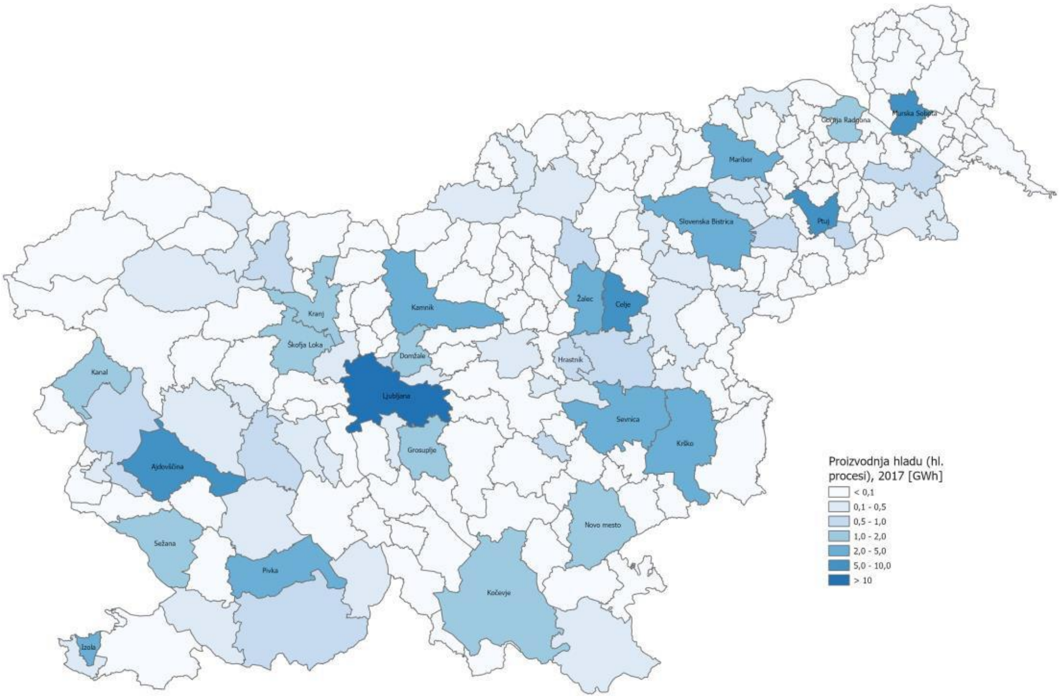

Figure 20: Production of cold in industrial cooling processes (2017)

	Production of cold (cooling processes), 2017 [GWh]

2.3 Total heating and cooling demand

Total HC demand at the useful energy level in 2017 was estimated to be almost 20 TWh, 95% of which (18.6 TWh) was heating and 1 TWh was cooling, as shown in Figure 21. Sectoral industry and households account for almost the same share (42%, just over 8 TWh), while the total share of demand for HC in buildings accounts for 58% of the share of total demand (or 11.4 TWh).

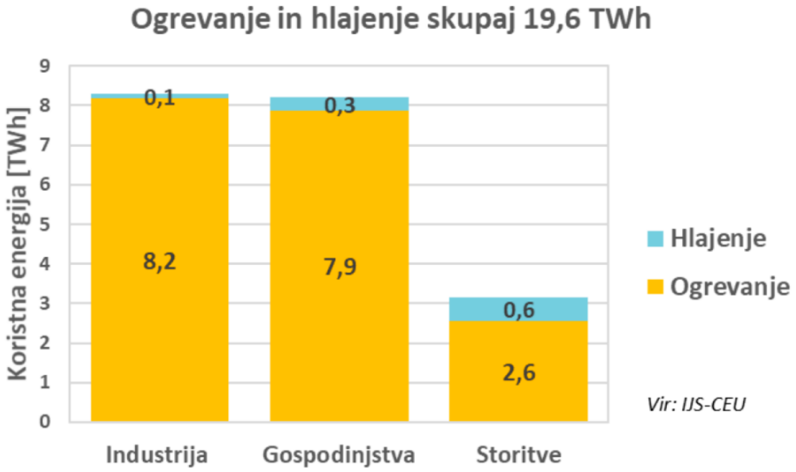

Figure 21: Total heating and cooling demand (useful energy) in 2017, by sector

	Heating and cooling together 19.6 TWh
	Useful energy [TWh]
	Industry

	Households
	Services
	Cooling
	Heating
	Source: IJS-CEU

2.4 Supply of heat

2.4.1 Buildings – households and services

Boilers are responsible for by far the biggest share of useful heat in residential buildings. In 2017 boilers supplied 5.5 TWh (69% of useful heat or 78% of useful heat supplied on-site). A total of 3.2 TWh (59%) was supplied using RES and the remainder using fossil fuels. As Figure 3 shows, this mostly comprised natural gas (NG), with extra-light heating oil (ELHO) still accounting for a significant share. The remainder of useful heat produced at the location at which it is consumed is generated using heat pumps (HP), although some is also generated by solar energy collectors (SEC), which are categorised in Table 5 as 'RES – Other technologies'. Eighty-nine per cent of useful heat is supplied on-site. Electricity used for generating useful heat for heating and domestic hot water on-site is included under 'Fossil fuels – Other technologies' and accounts for 0.8 TWh, or 10% of the energy required for heating. Energy from elsewhere is supplied in the form of district heat and amounts to 0.9 TWh. The energy required for cooling is added to HP and amounts to 0.3 TWh in the housing sector.

Seventy-seven per cent less useful heat is generated on-site in the service sector than in the housing sector; boilers are also responsible for generating a lower share of useful heat on-site (68%). Heat is also supplied on-site by HP (11%), CHP (8%, mostly using fossil fuels) and other RES technologies, which include the direct use of geothermal as well as solar energy. District heating systems (DHS) supply 23% of useful heat. In 2017, 0.5 TWh of energy was required for cooling via air-conditioning equipment. This energy was therefore placed in the HP category. In 2017, 0.5 TWh of the required energy was supplied via district heating (DH).

DHE is energy supplied from elsewhere. In 2017, 2.1 TWh of DHE heat was sold to final customers. Just over 77% of heat produced was generated using fossil fuels (65% in CHP, 12% in boilers and 0.3% from waste heat), while the remainder (23%) came from heat generated from RES (15% in CHP, 7% in WBB and 0.2% from GEO). The total proportion of heat generated in CHP is therefore just over 80%. Reducing the share of fossil fuels is therefore the main challenge for the future.

2.4.2 Industry

In 2017, 2.9 TWh of energy was consumed for the production of high-temperature heat (steam). This figure was 0.3 TWh for the production of low-temperature heat. The greatest share of energy required for heat was consumed in production processes themselves as process heat (mostly in a wide range of furnaces). The figure was 5.4 TWh (this includes the consumption of electricity for thermal processes, and excludes electric arc furnaces and electrolysis). Heat-producing boilers consumed 1.9 TWh of energy in industry in 2017. This figure was 1.1 TWh for CHP, 0.6 TWh for DHS and 5 TWh for process use. The structure of heat supply for specific branches is shown in Figure 22 and Figure 23.

The estimated heat demand for the manufacture of paper and paper products (C17) was 1.2 TWh in 2017. C17 is the branch with the highest proportion of heat generated in CHP (0.8 TWh, or 68%, in 2017). Some 0.3 TWh of heat was generated in boilers (25% of demand), while direct process use accounted for 6% (0.1 TWh) and DH use for 1%.

Heat demand for the manufacture of chemicals and chemical products (C20) was 0.8 TWh in 2017. The manufacture of chemicals and chemical products (C20) is a branch in which heat from DHS plays an important role. In 2017 a total of 0.3 TWh of heat (35%) was generated in boilers, 0.1 TWh (13%) in CHP, 0.3 TWh (33%) in DHE, and 0.2 TWh (19%) in the direct process use of heat.

The estimated heat demand for the manufacture of other non-metallic mineral products (C23) was 1.92 TWh in 2017. The manufacture of other non-metallic mineral products (C23) is the branch with the highest demand for the process use of heat (1.87 TWh, or 97% of the demand for heat within the branch). Two per cent of the demand for heat is supplied in boilers (0.04 TWh) and 0.6% of the heat is generated in CHP (0.01 TWh).

A total of 1.66 TWh of heat was consumed in the manufacture of basic metals. As with the C23 branch, the manufacture of basic metals (C24) is the branch with a high demand for the process use of heat (1.5 TWh, or 92% of the demand for heat within the branch). Six per cent of the demand for heat is supplied in boilers and the rest comes from DHS (1.4%) and CHP (0.3%).

Other branches had a heat demand of 2.6 TWh in 2017. Direct use in processes accounts for a significant portion of the demand for heat (51%). Thirty-five per cent of heat demand is covered by boilers, 11% by DHS and 3% by CHP.

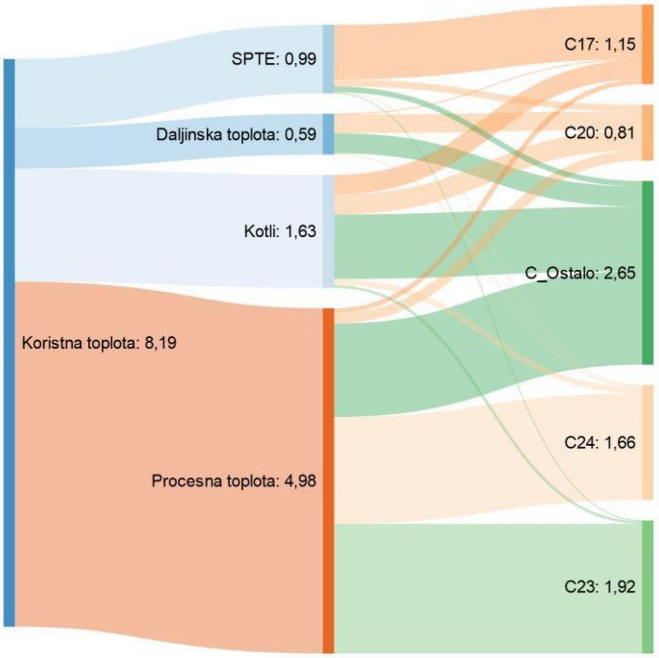

Figure 22: Structure of useful heat supply, by branch (TWh, 2017)

	CHP: 0.99
	District heating: 0.59
	Boilers: 1.63
	Useful heat: 8.19
	Process heat: 4.98
	C17: 1.15
	C20: 0.81
	C_Other: 2.65
	C24: 1.66
	C23: 1.92

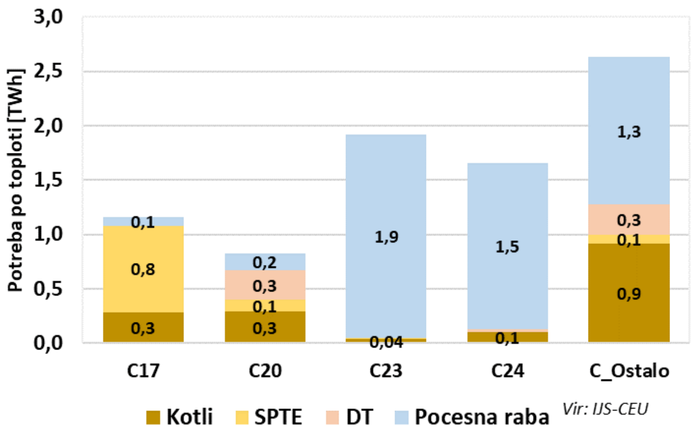

Figure 23: Heat supply in industry, by source and branch (2017)

	Heat demand [TWh]
	C17
	C20
	C23
	C24
	C_Other
	Boilers
	CHP
	DHE
	Process use
	Source: IJS-CEU

In 2017, 8.6 TWh of final energy was consumed for heating purposes, with fossil fuels accounting for 71%, RES for 9% and heat from DHS for 7%. The remaining share (13%) was taken by waste and by the use of electricity for thermal processes. The structure of energy end-use is shown by technology and fuel in Figure 24.

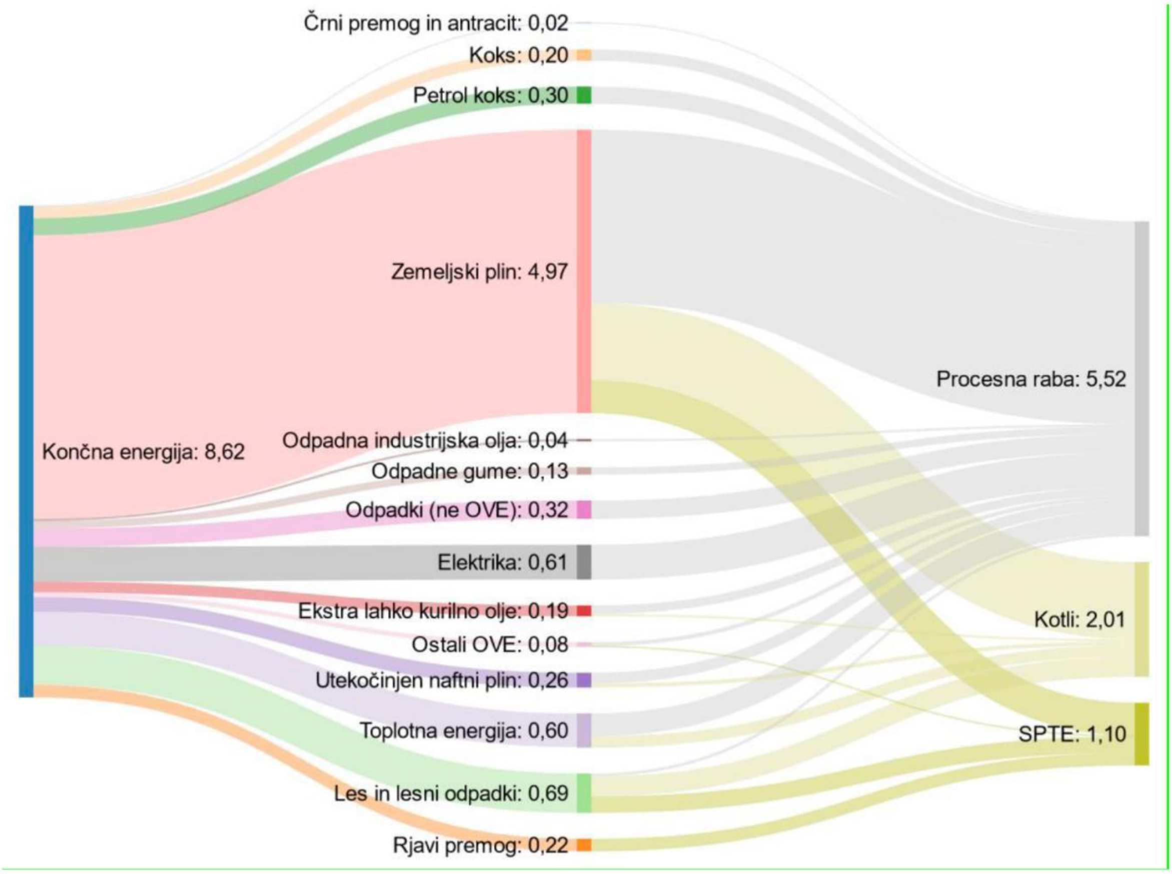

Figure 24: Final energy consumption for heat purposes in industry, by technology and fuel (TWh, 2017)

	Black coal and anthracite: 0.02
	Coke: 0.20
	Petroleum coke: 0.30
	Natural gas: 4.97
	Final energy: 8.62
	Waste industrial oils: 0.04
	Waste tyres: 0.13
	Waste (non-RES): 0.32
	Electricity: 0.61
	Extra-light heating oil: 0.19
	Other RES: 0.08
	Liquefied petroleum gas: 0.26
	Thermal energy: 0.60
	Wood and wood waste: 0.69
	Brown coal: 0.22
	Process use: 5.52
	Boilers: 2.01
	CHP: 1.10

The structure of energy end-use for heat is shown, by energy product (excluding electricity[8]) used for the production of useful heat in industry, in Figure 25. The largest share of energy required for heat in industry is

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[8] The use of electricity for thermal processes in industry is estimated to be 0.61 TWh, which was around 7% of the energy required for thermal processes in industry in 2017. This is mainly for use in various electrical furnaces, for example in glassmaking, the production of insulating materials and similar thermal processes that we ascribe to process use. This estimate does not include thermal processes in electric arc furnaces and aluminium electrolysis.

provided by NG (61%), followed by liquid fuels (10% – ELHO, LPG, heating oils), WB (9%), heat from DHS (7%), non-RES waste (6%), solid fuels (5%) and other RES (1%).

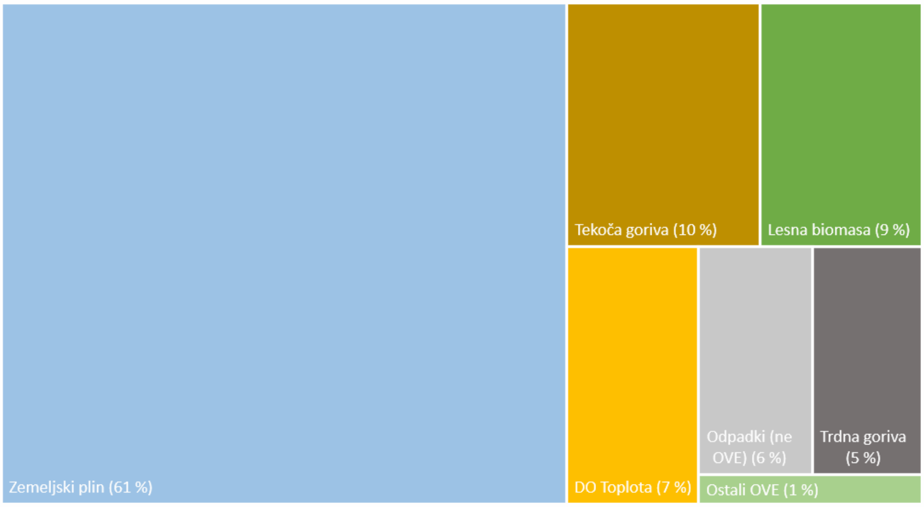

Figure 25: Structure of energy consumption for heat purposes in industry in 2017 (excluding electricity)

	Natural gas (61%)
	Liquid fuels (10%)
	Wood biomass (9%)
	DH heat (7%)
	Waste (non-RES) (6%)
	Solid fuels (5%)
	Other RES (1%)

The C24 branch (Manufacture of basic metals) consumes the largest amount of natural gas (28% of all NG consumed for thermal purposes in industry), followed by C17 (Manufacture of paper and paper products, 18%), C23 (Manufacture of other non-metallic mineral products, 17%), C20 (Manufacture of chemicals and chemical products, 6%) and other (less energy-intensive) branches (31%).

The structure of energy use for thermal purposes is shown below by individual branch for 2017, separately for energy-intensive and other branches (Figure 26). It is clear that the predominating energy product is NG, followed by liquid fuels, WB, DHE, waste, solid fuels and other RES:

- **In the manufacture of paper and paper products (C17),** NG accounted for 73% of the energy consumed for thermal purposes in 2017, followed by solid fuels (19%), WB (6%), and other energy products (DHE and liquid fuels, 1%). This branch has a high proportion of high-temperature heat (steam), which accounts for just over 93% of heat demand. Low-temperature heat accounts for 6%. Process use (the direct use of energy in manufacturing processes) accounts for around 1%.
- **In the manufacture of chemicals and chemical products (C20),** NG accounted for 33% of the energy consumed for thermal purposes in 2017, followed by DHE (32%), WB (30%) and liquid fuels (5%). High-temperature heat (steam) accounted for 65% of heat demand and low-temperature heat for 9%. Process use (the direct use of energy in manufacturing processes) accounts for 26%.
- **In the manufacture of other non-metallic mineral products (C23),** NG accounted for 46% of the energy consumed for thermal purposes in 2017, followed by waste (24%), liquid fuels (18%), solid fuels (7%) and other RES (5%). The C23 branch has an exceptionally high share of direct energy use for thermal purposes (97%). Different energy products are used directly mainly in furnaces (manufacture of glass, cement and insulating materials). The share taken by high-temperature heat (steam) is low in this branch, at around 1%, while low-temperature heat accounts for 2%.
- **In the manufacture of basic metals (C24),** NG accounted for 87% of the energy consumed for thermal purposes in 2017, which was the highest figure of all energy-intensive branches. Liquid fuels account for 7%, solid fuels for 5% and heat from DHS for 1%. Similarly to the manufacture of other non-metallic

mineral products, the C24 branch has an exceptionally high share of direct energy use for thermal purposes (92%). Different energy products are used directly mainly in furnaces (manufacture of high-quality steel, thermal treatment and aluminium processing). The share taken by high-temperature heat (steam) in this branch is around 6%, while low-temperature heat accounts for 2%.

- **In other (less energy-intensive) branches,** NG accounted for 61% of the energy consumed for thermal purposes in 2017, followed by WB (14%), liquid fuels (13%), heat (11%) and other fuels (1%). The production of high-temperature heat (steam) accounts for 41% and low-temperature heat for 5% of the energy consumed for heat. Direct use in processes accounts for 55% of the energy required for heat.

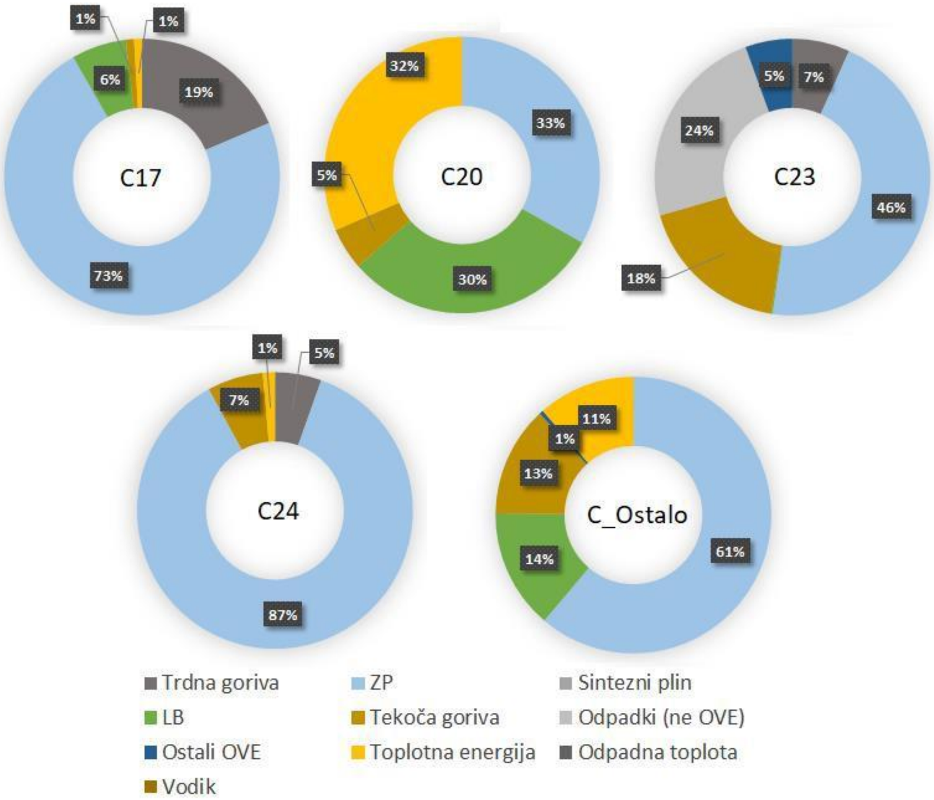

Figure 26: Structure of energy consumption for heat purposes, by industrial branch (2017)

	C17
	C20
	C23
	C24
	C_Other
	Solid fuels
	WB
	Other RES
	Hydrogen
	NG
	Liquid fuels
	Thermal energy
	Syngas
	Waste (non-RES)
	Waste heat

2.4.3 District heating

According to AzE figures, 93 distribution district heating systems (DHS) operated in 64 municipalities in Slovenia in 2017. The total volume of production and purchase of DHE was 2.4 TWh, with more than 80% of heat being generated in CHP, which also generated 0.8 TWh of electricity, Figure 27. Despite the high efficiency rate in the production of DHE, the main future development challenge will be the replacement of fossil fuels, which today account for more than 87% of DHE supply, and particularly coal (almost 60%). Renewable energy sources account for a mere 13% (mainly WB and, to a lesser extent, GEO and biodegradable waste), while the share of WH from industry is only 0.2%. Fossil fuel boilers generate 14% and wood biomass boilers 5% of heat, as shown in detail in Figure 28. The total volume of sales of DHE was 2 TWh, with households accounting for the largest single share (45%), followed by services (36%) and industry (18%).

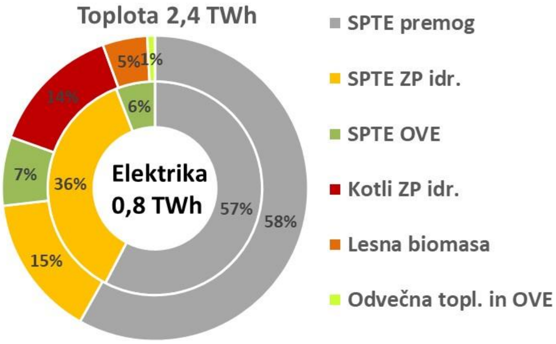

Figure 27: Structure of production of district heat and electricity in district heating systems (2017)

	Heat 2.4 TWh
	Electricity 0.8 TWh
	CHP coal
	CHP NG etc.
	CHP RES
	NG boilers, etc.
	Wood biomass
	Waste heat and RES

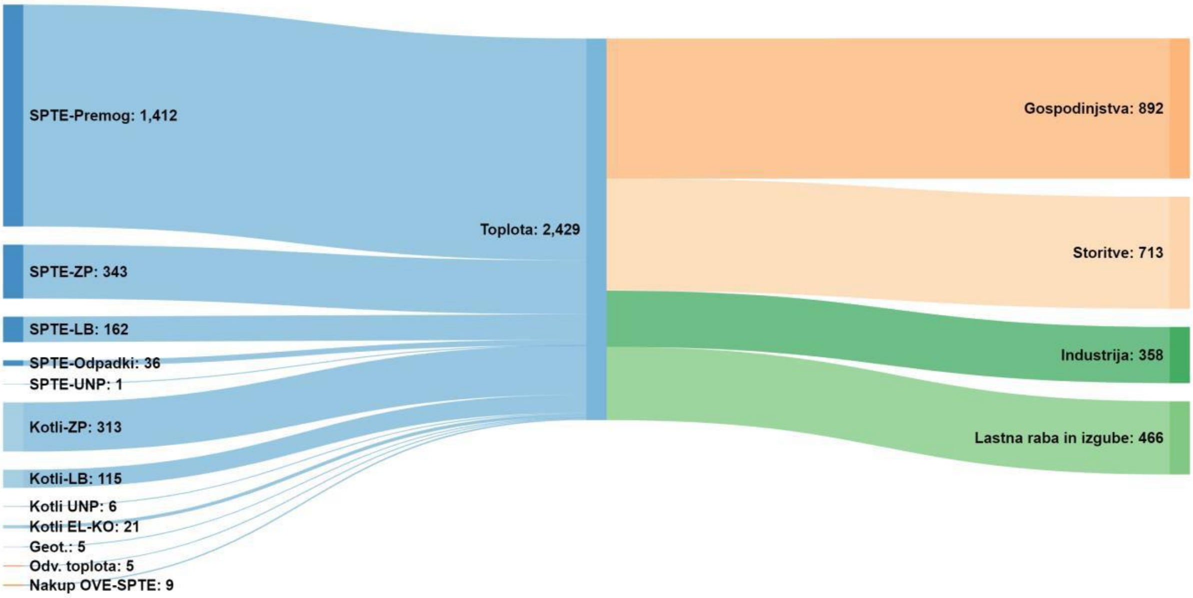

Figure 28: Structure of supply and sale of district heat in GWh (2017)

	CHP (coal): 1.412
	Heat: 2.429
	CHP (NG) 343
	CHP (WB) 162
	CHP (waste): 36

	CHP (LPG): 1
	Boilers (NG) 313
	Boilers (WB) 115
	Boilers (LPG): 6
	Boilers (ELHO): 21
	Geothermal: 5
	Waste heat: 5
	Purchase of RES (CHP): 9
	Households: 892
	Services: 713
	Industry: 358
	Own use and losses: 466

2.5 Cold supply

In households, cold is supplied almost exclusively via air-conditioning (split systems). Air-conditioning appliances can be categorised as heat pumps as their method of operation is the same. As mentioned in the previous chapter, 25% of all buildings had air-conditioning equipment in 2017 (the figure is 30% higher for MFH than for STH, 21% of which are equipped with air-conditioning).

In services, by far the highest proportion of cold is produced by air-conditioning appliances, with larger cooling systems being used in addition to split systems. A few absorption chillers have also been installed for the beneficial use of CHP heat in the summer months (tri-generation), along with a number of cold-storage systems (ice banks). In addition to classic air-conditioning appliances that correspond to air-to-air heat pumps, water-to-water systems are also used, particularly in newer buildings with reversible HP for the recovery of shallow GEO.

Large compressor cooling systems predominate in industry. These are mainly connected to technological processes. To a lesser extent there are also cooling (split) systems for the cooling of buildings and installations in the summer months.

Slovenia has only two district cooling systems (DCS): Velenje DCS (1 MW of nominal cooling power) and the Iskra Labore commercial zone DCS (3.6 MW of cooling power).[9]

2.6 Summary of heat and cold supply

Table 5 gives overall information on the supply sources and technologies for useful energy supply for heating and cooling in Slovenia in 2017. Almost 90% of supply is provided at the HC site, as energy supplied from elsewhere (from heat and cold distribution systems) currently accounts for only just over 10%. RES accounts for almost one-third (or 6.4 TWh) of the supply of around 20 TWh of useful heat and cold (Figure 29). The share of RES in the supply of useful heat in buildings is almost half (53% in households, 39% in services), but a mere 10% in industry, making this the biggest development challenge to the decarbonisation of HC, particularly when it comes to process heat (other technologies), which accounts for almost 60% of all demand in industry (Figure 30). Boilers still account for the largest share of supply (total 43%, in buildings 60%), while the share of supply using heat pumps and the cogeneration of heat and power is less than 15% (although it is a more encouraging 23% if the 80% share of CHP in district heating systems is taken into account).

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[9] Energy-efficient heat and cold distribution systems in 2019 (AzE)

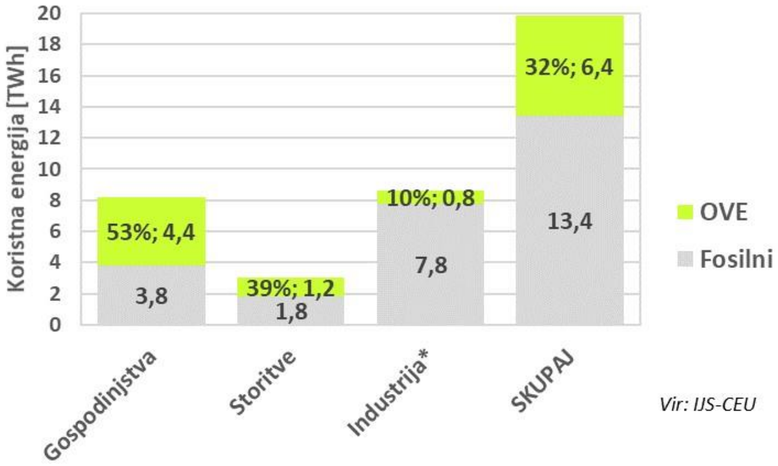

Figure 29: Structure of supply of useful energy for heating and cooling by sector – share of RES

	Useful energy [TWh]
	Households
	Services
	Industry*
	TOTAL
	RES
	Fossil
	Source: IJS-CEU

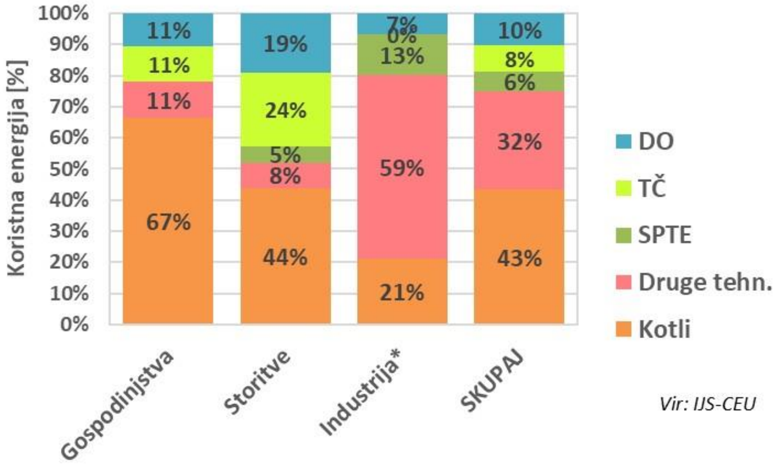

Figure 30: Structure of supply of useful energy for heating and cooling, by sector – shares of technologies

	Useful energy [%]
	Households
	Services
	Industry*
	TOTAL
	DH
	HP
	CHP
	Other technologies
	Boilers

	Source: IJS-CEU

Table 5: Supply of useful energy for heating, by technology, in 2017

Sector	Source	Technology	Useful energy [GWh]		
Supply of energy provided on-site					**17 859**
Housing sector	Fossil fuels	Boilers that generate heat only	2 248	**3 055**	**7 334**
		Other technologies	807		
		CHP	0		
	RES	Boilers that generate heat only	3 213	**4 279**	
		CHP	0		
		HP	939		
		Other technologies	127		
Service sector	Fossil fuels	Boilers that generate heat only	1 056	**1 330**	**2 485**
		Other technologies	115		
		CHP	159		
	RES	Boilers that generate heat only	292	**1 155**	
		CHP	0		
		HP	728		
		Other technologies	136		
Industrial sector+	Fossil fuels	Boilers that generate heat only	1 463	**7 265**	**8 040**
		Other technologies	4 998		
		CHP	803		
	RES	Boilers that generate heat only	348	**775**	
		CHP	301		
		HP	0		
		Other technologies	127		
Energy supply from elsewhere – DHS[10]					**2 053**
Housing sector	Fossil fuels	WH	2	**761**	**871**
		CHP	637		
		Other technologies	122		
	RES	WH	0	**110**	
		CHP	67		
		Other technologies	43		
Service sector	Fossil fuels	WH	1	**514**	**588**
		CHP	430		
		Other technologies	82		
	RES	WH	0	**74**	
		CHP	45		
		Other technologies	29		
Industrial sector*	Fossil fuels	WH	1	**519**	**593**
		CHP	434		
		Other technologies	83		
	RES	WH	0	**75**	
		CHP	46		
		Other technologies	29		
Supply TOTAL					**19 912**

**The figures for industry are for final energy.*

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[10] The structure of district heat (DHE) supply was determined at the level of the entire production of DHE, and is distributed between the sectors in equal shares.

2.7 Waste heat and cold

In accordance with Annex VIII of the Energy Efficiency Directive (EED), this chapter describes the current situation regarding installations that generate waste heat (WH) or cold, and their still-unutilised potential for the supply of heating or cooling, divided into the following groups:

- **thermal electricity generation installations** capable of generating HC with a total thermal input exceeding 50 MW, or of being retrofitted to do so;
- **installations for the cogeneration of heat and power** with a total thermal input exceeding 20 MW;
- **thermal waste treatment plants;**
- **installations for the generation of energy from RES** with a total thermal input exceeding 20 MW that generate heat or cold by using energy from RES (excluding thermal electricity generation installations and CHP);
- **industrial installations** with a total thermal input exceeding 20 MW and capable of providing WH.

The total estimated current available WH potential in the **larger installations analysed exceeds 8 TWh (Table 6), although the real scope of possible utilisation for the supply of heat and cooling is significantly lower.**

Table 6: Assessment of available waste heat in larger installations

Plants	Thermal input (net) [MW]	Unutilised WH [GWh/a]
Thermal electricity generation installations	50	8 000
CHP	20	50
Thermal waste treatment –		
Generation of energy from RES	20	
Industry[11]	20	300

2.7.1 Thermal electricity generation installations

Five larger thermal electricity generation installations currently operate on the transmission network in Slovenia.

- **Termoelektrarna Šoštanj (TEŠ):** coal blocks 5 and 6 and two gas turbines with a total thermal input of 2 400 MW and a net electrical power of 930 MW in a cogeneration regime produce around 330 GWh a year for the supply of a large district heating system (DHS) for the heating of towns and smaller settlements in the surrounding area (Velenje, Šoštanj, Topolšica, etc.). An alternative sustainable source for the DHS will have to be provided in the long term given the planned transition from coal.
- **Termoelektrarna Toplarna Ljubljana (TE-TOL):** three coal blocks – one with co-incineration of wood biomass with a total thermal power of 660 MW and net electrical power of 119 MW operates as CHP and is the main source of heat for the largest DHS in Ljubljana. The potential for the additional utilisation of low-temperature WH for the condenser coolant is limited at the site.
- **Krško nuclear power plant:** thermal power of the reactor 1 994 MW, net electrical power 696 MW – 8 TWh of low-temperature WH a year (approximately 33°C) is currently discharged into the Sava river and surrounding area. At least two studies have been produced[12] analysing the potential for operating as cogeneration with the removal of steam from the turbine and utilising low-temperature WH with an HP for Brežice and Krško distribution network, and for the supply of the Vrbina industrial zone with steam (only cogeneration is suitable for steam supply). Owing to the large distance to larger cities (Ljubljana is more than 100 km away, Zagreb 33 km), the utilisation of a larger quantity of available WH is currently not cost-effective.
- **Termoelektrarna Brestanica:** with seven gas turbines with a total thermal input of 1 475 MW and net

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[11] Companies included in the GHG emissions trading system (EU ETS) for the 2021-2025 period, source: https://www.gov.si/assets/ministrstva/MOP/Dokumenti/Podnebne-spremembe/seznam_naprav_126a_clen.docx

[12] Izvedljivostna študija možnosti koriščenja toplote (Feasibility study for the potential for utilising heat), Sipro inženiring, Krško, March 2013, Revised by IBE, d.d., Ljubljana, October 2013.

electrical power of 430 MW, the installation provides system services of tertiary regulation; it therefore operates only in a very limited and unpredictable time frame, and is not a suitable source for the utilisation of WH (moreover, there are no larger settlements or heat users in the vicinity of the installation).

- **Termoelektrarna Trbovlje:** with two gas turbines with a total thermal input of 362 MW and net electrical power of 58 MW, the installation provides system services of tertiary regulation; it therefore operates only in a very limited and unpredictable time frame and is not a suitable source for the utilisation of WH.

The unutilised WH potential of thermal electricity generation installations in Slovenia is specific: both coal-fired installations are already operating as CHP[13] and supply larger DHS with heat. However, because of the gradual phasing-out of coal at both sites, the potential for the additional utilisation of low-temperature WH is limited by time. Due regard must be given to this fact when developing alternative generation installations at these sites (this potential is stated under CHP in the summary table). Owing to their extremely limited and unpredictable operation, the two thermal electricity generation installations are not a suitable stable source of WH for HC. Krško nuclear power plant (NEK) has a large and unutilised low-temperature WH potential estimated at 8 TWh. There is currently no larger DHS in operation in the vicinity of NEK, and the entire immediate area is gasified.

2.7.2 High-efficiency cogeneration of heat and power

More than 475 CHP generation installations with a total net electrical power of around 400 MW and annual generation of more than 1.2 TWh of electricity and more than 3 TWh of useful heat were in operation in Slovenia in 2017. A spatial presentation of CHP units in relation to their rated electrical power and the energy product is given in Figure 31 and Figure 32.

As regards energy product used, coal continues to account for the biggest single share of electricity generated (39%), followed by NG (38%), WB (11%) and biogas (10%). The shares taken by other energy products are considerably lower, as Table 7 shows.

Table 7: CHP units in Slovenia and generation in 2017

	Electrical power – net [MW]	Number of units	Electricity generated [GWh]	Heat generated [GWh]
TOTAL	**416**	**475**	**1 236**	**3 046**
Coal	219	7	482	1 649
Natural gas	134	348	471	973
Wood biomass	27	41	139	310
Biogas	28	27	119	62
Waste	2	1	7	36
LPG	1.4	37.0	4.9	8.9
Landfill gas	3.0	2.0	5.9	2.3
Biofuels	0.9	1.0	5.0	3.5
Biogas TP	0.5	2.0	2.2	1.2
ELHO	0.1	9	0.2	0.4
Units with a thermal input of > 20 MW	**287**	**14**	**689**	**2 380**

Fourteen CHP generation installations with a thermal input exceeding 20 MW were in operation in Slovenia in 2017. This represented almost 70% of the total installed power of CHP units and 56% of the total electricity generated in CHP. They included five larger coal-fired units (TE-TOL and TEŠ), three older steam turbines at paper mills, a steam turbine in the wood industry, three larger gas engine units in DHS, and the largest biogas plant. As these are CHP units, from the point of view of the WH potential for the additional supply of heat and cold they primarily constitute possible technical solutions for the additional utilisation of available low-temperature waste

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[13] In accordance with the definition of Directive 2018/2001, useful heat in CHP is not classified as WH.

heat. **Under the assumption that this constitutes 2% of the total heat generated, this would mean a potential of around 50 GWh of WH in larger CHP units.**

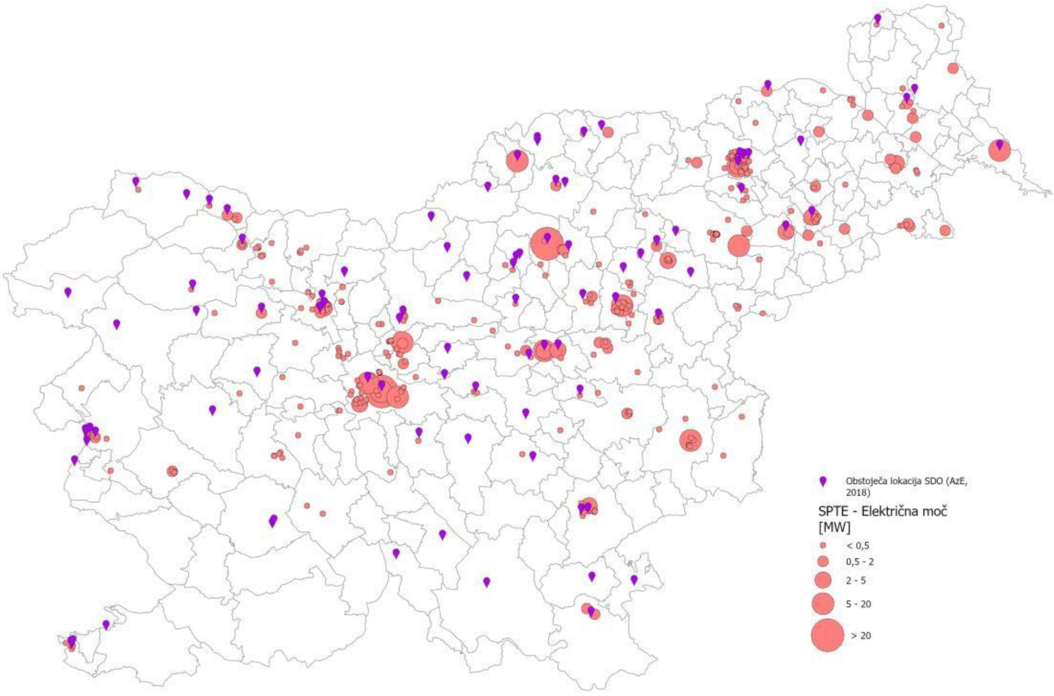

Figure 31: CHP units relative to nominal electrical power (2017)

	Existing DHS location (AzE, 2018)
	CHP – Electrical power [MW]

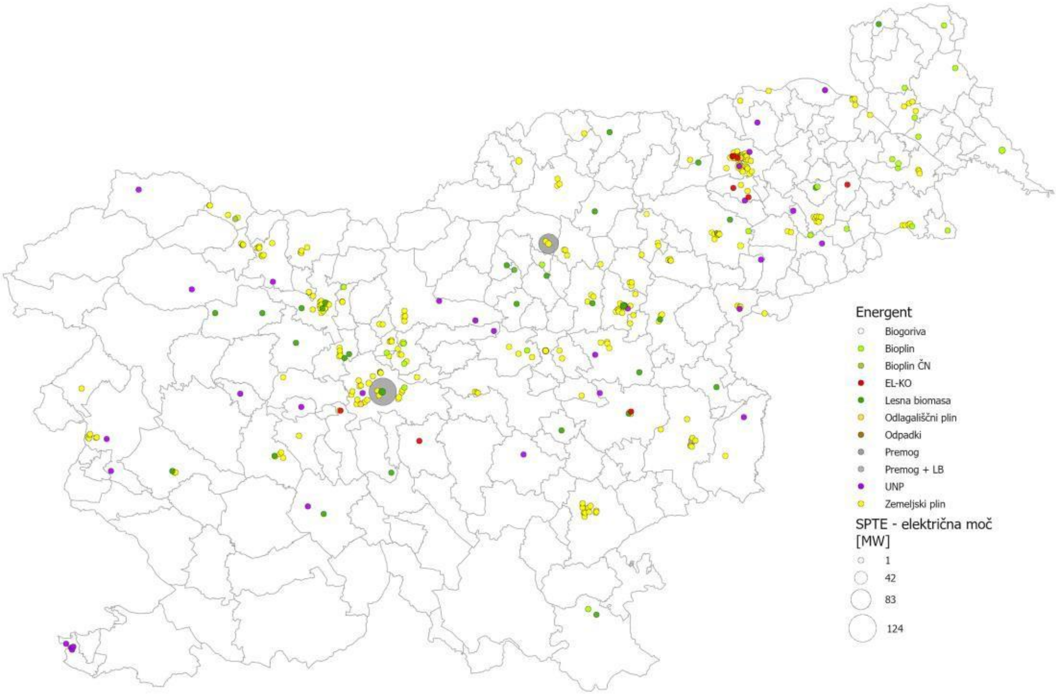

Figure 32: Predominant energy products for the generation of electricity and heat in CHP units (2017)

	Energy product
	Biofuels

	Biogas
	Biogas TP
	ELHO
	Wood biomass
	Landfill gas
	Waste
	Coal
	Coal + WB
	LPG
	Natural gas
	CHP – Electrical power [MW]

2.7.3 Thermal waste treatment

Slovenia has only one TWTP (Celje). The heat generated in the CHP generation installation is used to generate electricity (2 GWh a year). The remaining heat is used to supply district heating systems (36 GWh a year). The current total efficiency of this CHP generation installation is less than 50%, which indicates the potential for the additional beneficial use of available heat from the thermal treatment of waste, particularly in the summer months, as district heating systems do not ensure domestic hot water supply. The construction of an additional condensing steam turbine is at the planning stage. This will increase electricity generation and, with the installation of a heat tank, will also increase the quantity of useful heat in the winter. Taking into account the annual amount of energy from waste treatment (96 GWh), it is possible to increase the amount of useful heat by more than 10 GWh, which takes priority over the utilisation of available low-temperature WH (air steam condenser, etc.).

2.7.4 Installations for the generation of energy from renewable sources

Slovenia currently has no installations for generating electricity from RES with a total thermal input exceeding 20 MW, except for CHP generation installations using WB and biogas (which have already been included under CHP installations).

2.7.5 Industry

Waste heat (WH) generated in industrial and commercial processes can be an excellent sustainable source of energy in companies as well as in district heating systems, as it is heat that arises from processes whose primary purpose is not the generation of energy (i.e. it would otherwise not be put to use).

As only a small amount of data is available for an analysis of the use of WH in industry, only a few examples of best practice are given below, with an analysis of the potential for WH use being addressed in more detail in Chapter 4.3.. This chapter therefore presents the integration of industry (SIJ Metal Ravne, Lek Ljubljana) with local DHS (Petrol, Energetika Ljubljana) and of industry (Aquafil Ljubljana) with the service sector (Atlantis aquatic park):

- *At the SIJ Metal Ravne plant, the WH generated by the cooling of the electric arc furnace is transmitted to the Ravne na Koroškem DHS and the entire commercial area surrounding the Ravne ironworks. WH accounts for around 40%*[14] *of all heat demand for the heating of the town. The company predicts that the quantity of WH transmitted will reach 10 GWh a year, i.e. an additional 40% utilisation of flue gas waste heat from the metallurgical furnace,*[15] *which will be sufficient to cover around half of all the town's heating needs. SIJ Metal Ravne is also an example of best practice from the point of view of the integration of key stakeholders and cooperation with the local community.*
- *The connection between the pharmaceutical industry and district energy in Ljubljana (Lek and Energetika Ljubljana), which works on the circular economy principle, enables 3 GWh of energy and 50 000* m^3 *of softened cooling water to be saved. Use is made of steam condenser waste heat from drug production processes.*

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[14] More than 8 GWh of heat generated in the electric arc furnace cooling process was transmitted to the local energy supplier to heat the town of Ravne na Koroškem in 2018.

[15] As part of the ETEKINA (H2020) project, a heat pipe was installed to enable the WH to be used to heat the town and industrial plant, and to pre-heat the air in the metallurgical furnace.

- *The integration of the chemical industry and the aquatic park in Ljubljana is another good example of the integration of stakeholders. The Aquafil company supplies Atlantis aquatic park with WH generated in the process of manufacturing of polyamide filaments and granules. It does so by rerouting it to the swimming pool complex. The aquatic park's heat demand is met entirely by WH. As the partners are located very close to each other, cooperation brings considerable economic and environmental benefits (a reduction in CO_2 emissions of more than 2 000 tonnes a year).*

The estimated current potential of available WH in industrial plants given in the summary table (Table 6) represents the potential of companies included in the GHG emissions trading system 2021-2025 (EU ETS).[16] **For the companies mentioned, the estimated available WH amounts to 300 GWh a year.** The WH potential is also given by temperature level, i.e. it is estimated that a WH temperature level of between 100 and 200°C constitutes 17% of the estimated potential, a temperature level of between 200 and 500°C constitutes 62% of the potential, and the highest temperature level (over 500°C) constitutes 21% of the estimated potential of the available WH.

2.8 Share of renewable energy sources and waste heat or cold in district heating and cooling systems

The amount of heat generated from renewable energy sources[17] gradually increased between 2015 and 2019,[18] reaching 466 GWh in 2019, when almost 90% of the total came from wood biomass and the remainder from biogas and geothermal energy, Figure 33[19]. With minimal changes to the total net district heat generated, the share of heat generated from RES also increased in 2019 (that share amounted to 20%).

The utilisation of waste heat from industry in district heating systems is still greatly limited in scope, although the available figures suggest that it is gradually increasing and approaching 10 GWh a year, which is 0.4% of the total quantity of district heat generated.

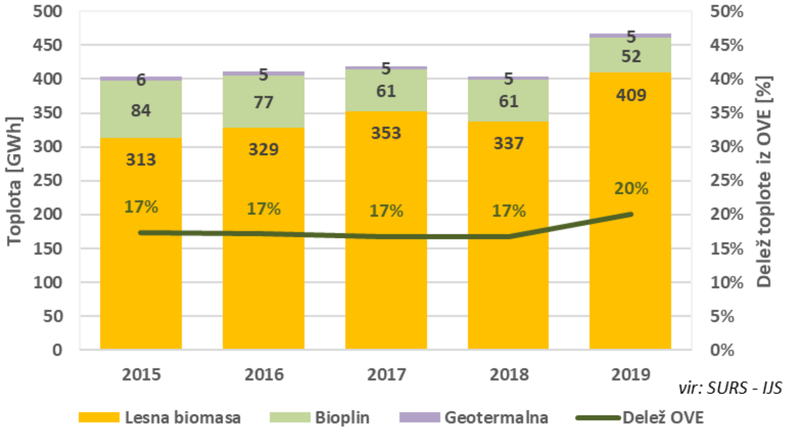

Figure 33: Volume and share of district heat generated from renewable energy sources

	Heat [GWh]
	Share of heat from RES [%]
	Source: SURS-IJS
	Wood biomass
	Biogas
	Geothermal
	Share of RES

2.9 Heat map

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[16] Source: List of installations and operators in accordance with Article 126a of the ZVO-1.

[17] SURS – Shares Tool 2019 for Slovenia

[18] Reporting in accordance with Directive (EU) 2018/2001.

[19] The official statistics do not yet contain figures on the heat generated from renewable municipal waste (estimated at around 15 GWh).

A heat map (HM) is recognised as an effective aid that helps us define the potentials for the use and supply of heat in spatially interdependent or connected areas/users and sources. An HM brings together different information in a visual form and in a way that enables a clearer and more comprehensive understanding of the issue, facilitates the formulation of more comprehensive and integrated development solutions, and can be used as part of the process of involving stakeholders. An HM is a spatial presentation of the available heat/cold and of potential sources, of the localised density of use of heat/cold, and connecting networks and other infrastructure. All these aspects are important input information for strategic planning, including the formulation of policies and areas for the priority use of energy products for the heating and cooling of buildings, the production of domestic hot water, and other generation of heat/cold for final customers.

When we are compiling heat maps, an analytical approach to the use of geographical information systems (GIS) enables a multi-layered analysis to be conducted and the conditions and spatially-dependent conditions and potentials to be assessed. This in turn enables the objective bases for the objective decision-making related to the planning of energy use and investments in infrastructure to be designed so as to ensure that the requirements are adequately met and the infrastructure deployed in a rational way. By using GIS analyses, an HM can be assessed more accurately and objectively, and the potential for reducing energy consumption localised. Combining data on energy use with other maps or data sets enables us to identify those areas in which the greatest benefits can be accrued from energy efficiency measures, or help us to achieve other policy objectives, such as environmental protection, emission reduction, the identification of areas with elevated fuel poverty rates, or the preparation of groundwork for the sustainable planning of measures.

The quality of the results of heat mapping depends to a large extent on the input data used to develop the HM. The availability and quality of this data is therefore crucially important. An HM is a collection of several data layers, with the emphasis mainly on maps of (i) the use or potential for removal of heat and cold, (ii) the heat supply potential (sources) and (iii) the localisation of existing infrastructure, sources and expansion potentials, with an emphasis on district heating. The formulation of an individual data layer includes the acquisition, verification and preparation of input data and the creation of connections between them (integration of several different data sources), in accordance with the modelling and evaluation requirements. The potentials for heat supply (heating of buildings and domestic hot water) were addressed at the individual building level, using GIS tools among others. All buildings in the household and service sectors were included in the analysis for the preparation of the HM. An analysis was performed for industry from the point of view of process heat, while the potential for the heating of buildings and the production of DHW in this sector was not included in the HM. At the level of municipalities, the potential for heating using WH from industry was mapped. The locations and potential for the 20 highest rated potential sources are also shown.

The calculations of annual heat demand in an individual building are model-based, with all publicly available data on building performance or their renovations being used. The data was available at various 'spatial' and quality levels. Some data was available for individual buildings and locations (e.g. ...), others for areas (generally municipalities), e.g. the use of NG broken down by CDK group. The baseline input data for the mapping of the use of heat for the heating of buildings is spatial and cadastral data on buildings (GURS) and data on renovations carried out with the help of Eco Fund resources. In the mapping of sources and infrastructure for the supply of heat to buildings or energy for heating and the production of DHW, the emphasis was on DH networks, the gas supply network, locations of potential WH sources (in industry) and CHP. The mapping of this infrastructure provides an insight into the topography of these systems, their interconnection and the way they complement each other, and their potential interoperability. Regarding installations that generate heating, data on CHP generation installations contained in Energy Agency (AzE), Borzen and SURS databases have been included.

The heat map was prepared for the entire territory of Slovenia, and for heating (Figure 35) as well as cooling (Figure 36). Heat/cold demand for buildings are aggregated in the HM on a 100 x 100 m grid (one cell in the grid corresponds to one hectare), with the results for all buildings whose centroids (data from the GURS database) are located in the same cell being combined into that individual cell. The HM enables a high degree of definition (e.g. Figure 37, Figure 38, Figure 39), and the identification, localisation and evaluation of areas with different heat/cold consumption densities or energy intensity, in accordance with the criteria described in more detail below. The methodological approach employed enables the potentials to be addressed both quantitatively and qualitatively using a combination of various criteria. For example, it enables areas with existing infrastructure for DH or gas supply and those in which such infrastructure is planned or has technical, economic or market potential to be addressed separately. The cells in the HM are coloured in accordance with the density of annual heat and cold demand, which enables a swifter insight into areas with greater density that are economically attractive from the point of view of the development of the district supply of heat and cold. They are placed into classes under the criteria set out in Table 1, with those areas in which the density of annual demand for heat exceeds 200 MWh/ha (200 GWh/km^2) being dealt with in the analysis as areas potentially attractive for DH supply.

One of the decisive facts for the selection of this criterion was that the majority of DH systems in Slovenia are second-generation and partly third-generation systems with a typical operating regime that utilises input temperatures of between 100 and 130°C or 80 and 110°C, with heat losses in distribution amounting to an average of around 15%. This is a relatively conservative estimate of the potential, which could, if supply temperatures into the network at the level of fourth-generation DH systems (approximately 45-60°C) were to fall, further increase to a significant degree.

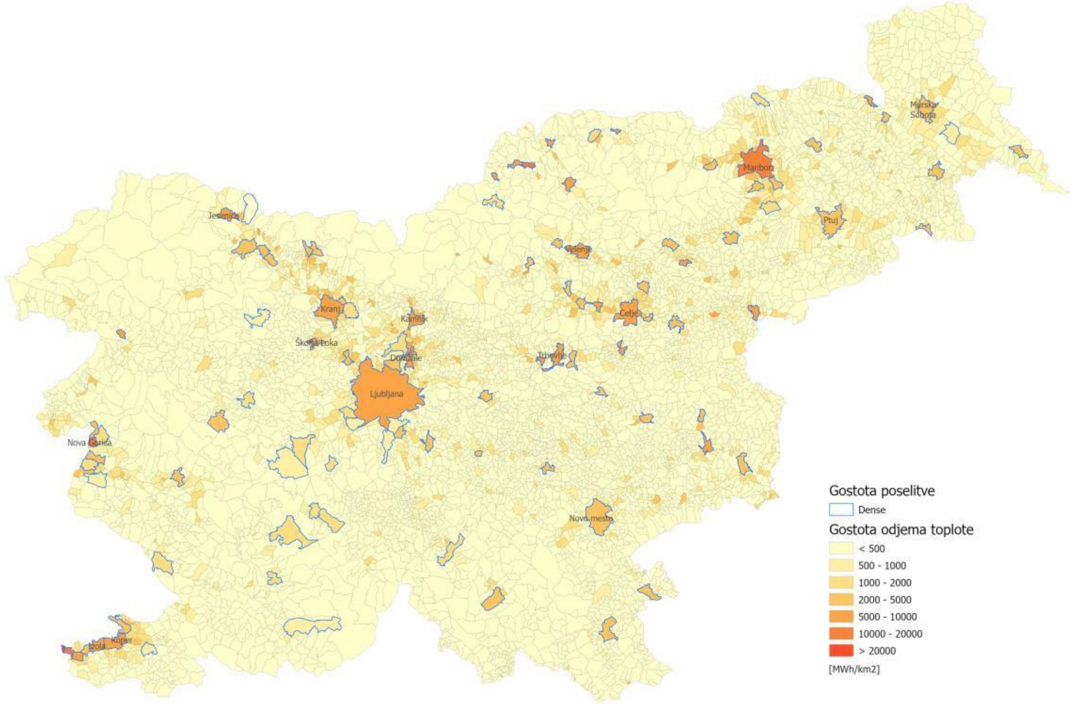

Figure 34: Density of annual heat demand relative to population density in settlements in Slovenia

	Population density
	Dense
	Density of heat consumption
	[MWh/km2]

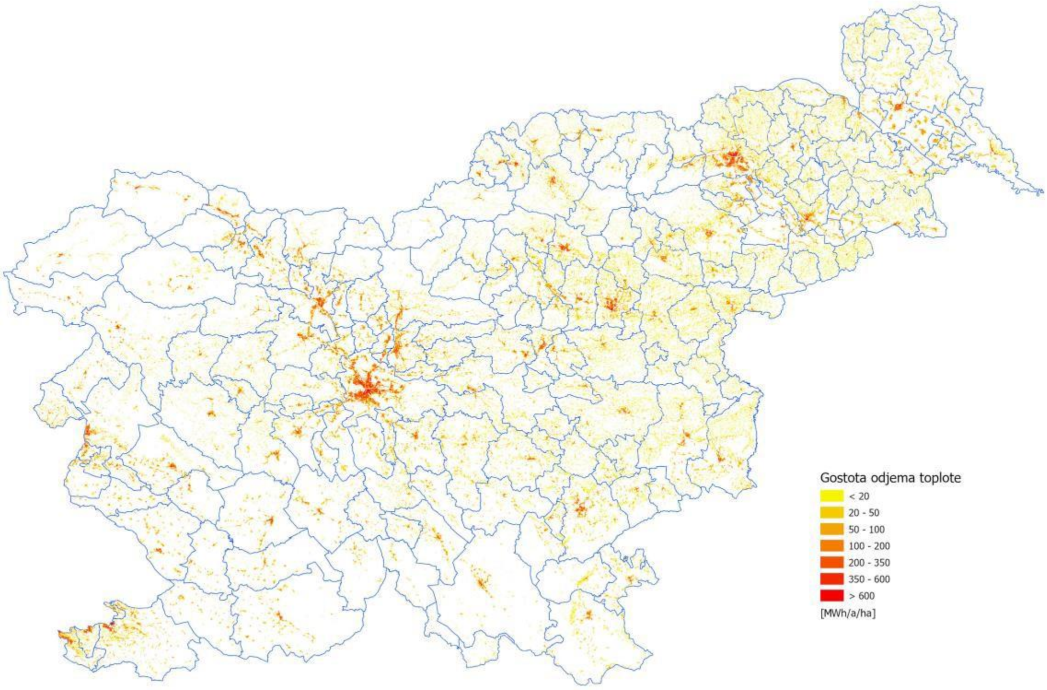

Figure 35: Slovenia heat map – demand for the heating of buildings, households and services (2017)

	Density of heat consumption
	[MWh/a/ha]

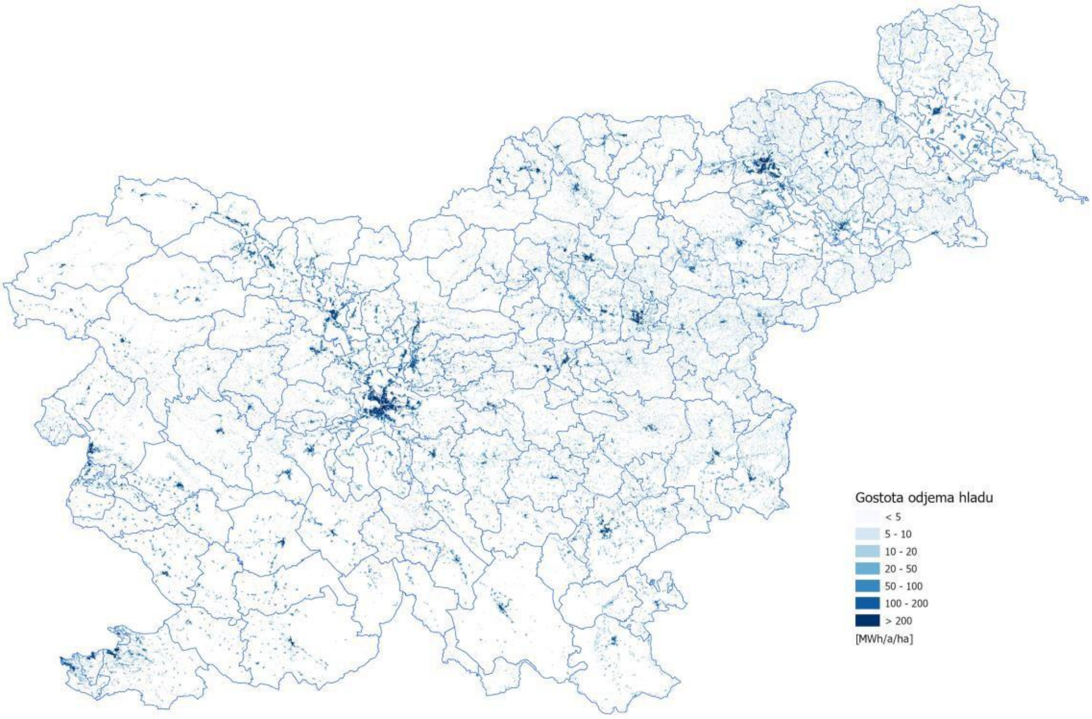

Figure 36: Slovenia heat map – demand for the cooling of buildings, households and services (2017)

	Density of consumption of cold
	[MWh/a/ha]

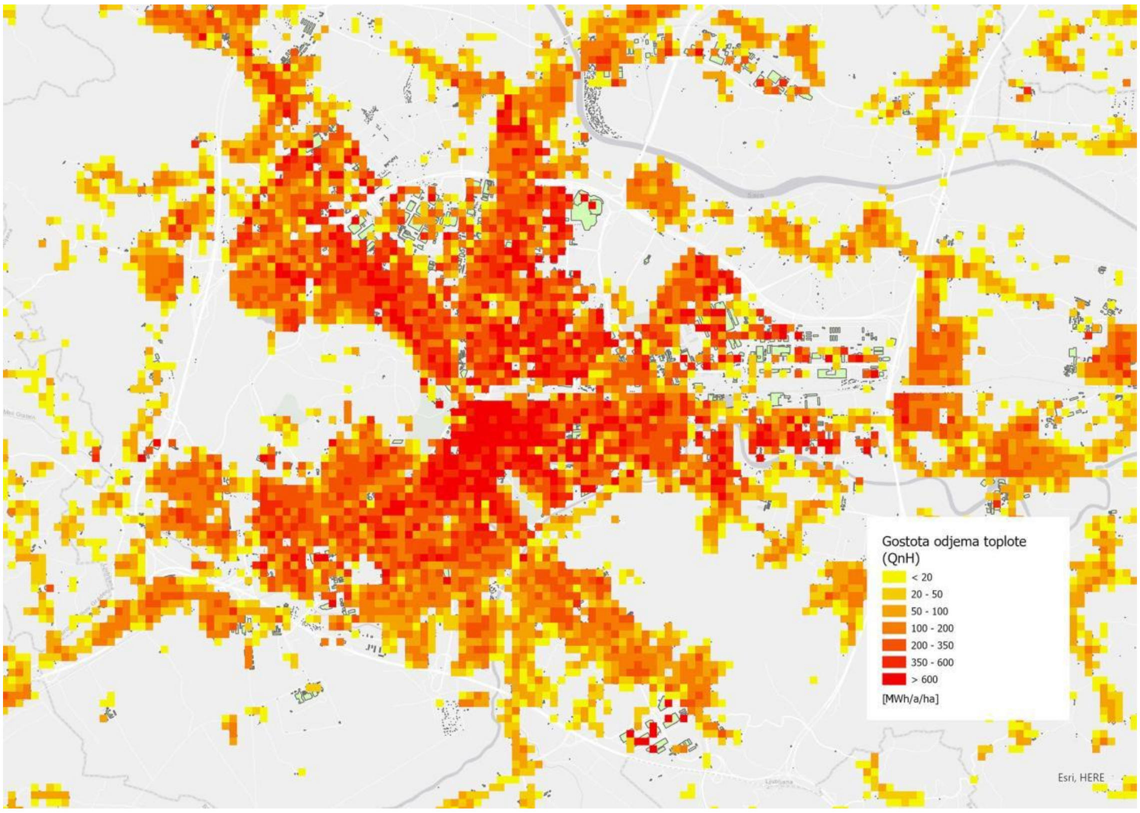

Figure 37: Ljubljana heat map – demand for the heating of buildings, households and services (2017)

	Density of heat consumption (QnH)
	[MWh/a/ha]

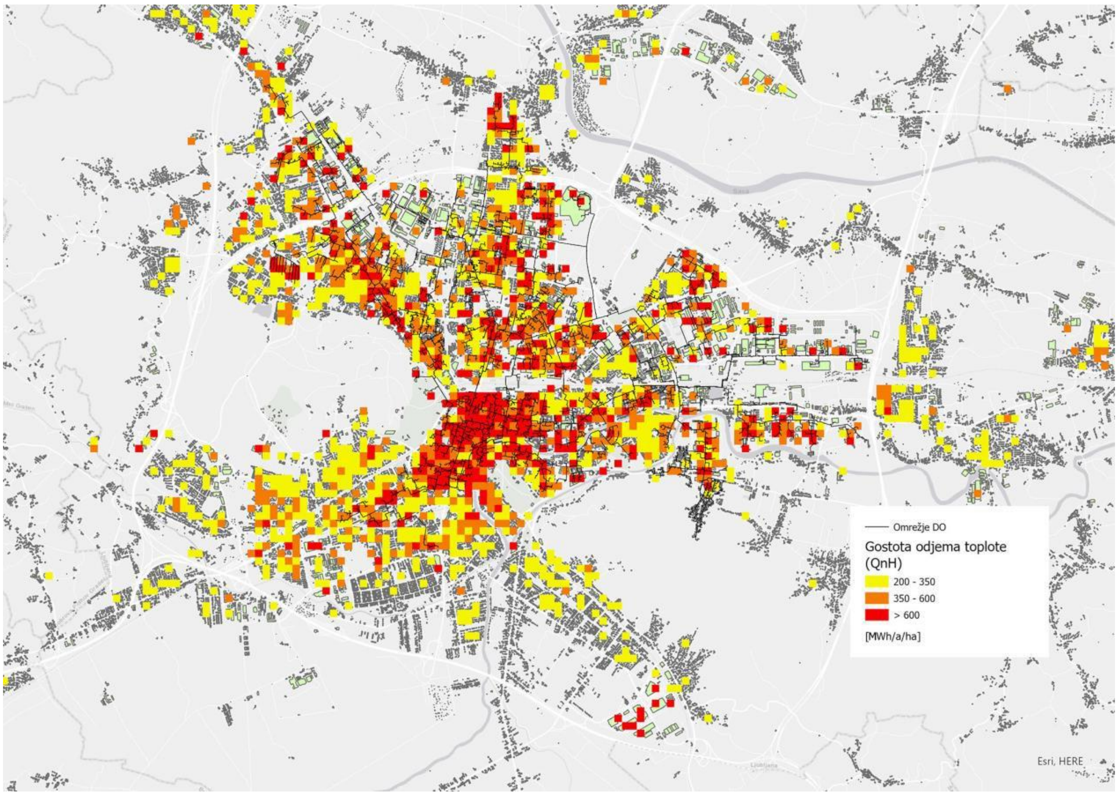

Figure 38: Areas of Ljubljana with a density of annual heat demand exceeding 200 GWh/ha in households and services (2017)

	DH network
	Density of heat consumption (QnH)
	[MWh/a/ha]

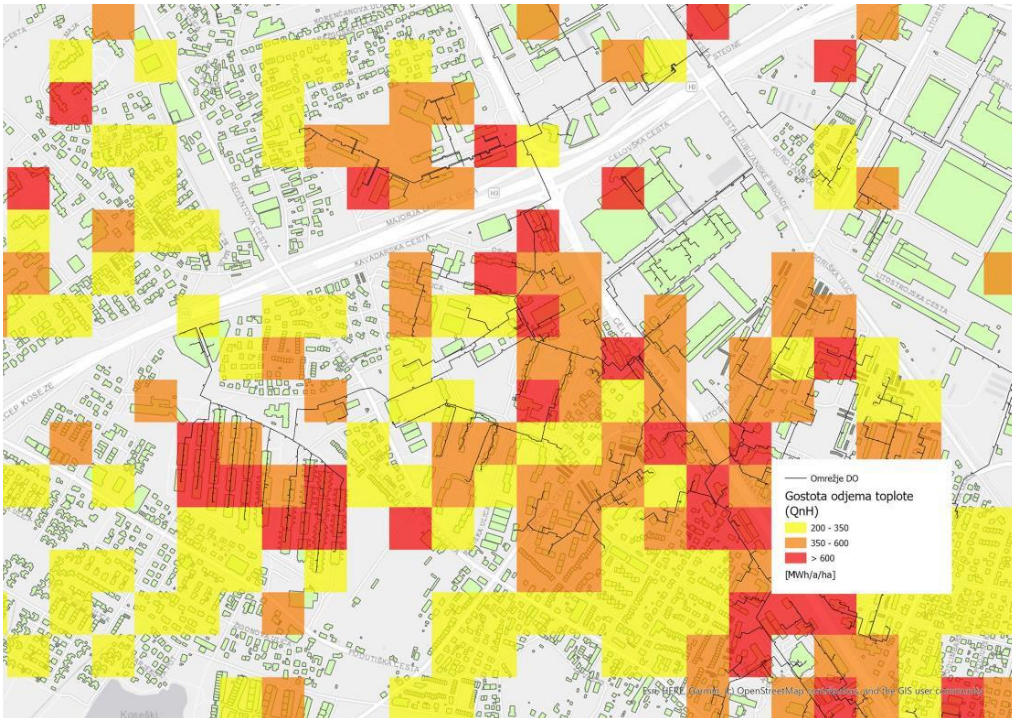

Figure 39: Extract from the Ljubljana heat map – cells with an annual heat demand density exceeding 200 GWh/ha in households and services (2017)

	DH network
	Density of heat consumption (QnH)
	[MWh/a/ha]

When the potential areas for DHS are being determined, due consideration is also given to the size and integrity of zones with high densities of annual heat demand, a factor that makes the establishment or expansion of a DH network in that area more feasible.

2.10 Forecast heating and cooling demand

The total estimate of HC demand at the level of useful and final energy in 2017 and projections for 2050[20] is shown in Table 8.

Total future heating demand (useful heat) will, according to the projection for 2050, fall from 18.6 TWh to 15.3 TWh (a fall of 3.4 TWh, or almost 20%) (Figure 40). Industry is maintaining and increasing its majority share, as the expected heating demand relative to the projected growth in the physical product of energy-intensive activities (up to 21%) and added value of industry (40-50%) will grow slightly and constitute almost 60% of all heating demand in 2050. Heating demand will fall most by 2050 in households (by more than 45%) or by 3.6 TWh, as a moderate increase in floor area (7%) and intensive investments in building renovation are expected. Projections for services envisage a 40% increase in the floor area of buildings by 2050, with intensive renovations leading to a reduction in heat demand by 15% relative to 2017. The share of buildings in heating demand will therefore fall from today’s 56% to just over 42%.

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[20] Projections of useful and final energy have been produced on the basis of the NECP scenario.

Owing to the limited figures, the assessment of future cooling demand is less reliable and the estimated total cooling demand will increase by at least 80% by 2050 (Figure 41) because of the growth in air-conditioning appliances in buildings as well as climate change. According to Slovenian Environment Agency (ARSO) projections for 2050, the temperature excess will rise by 58% relative to 2017 (which was a very warm year). The expected growth is highest in households, where it is expected to more than double to 760 GWh, mainly as a result in the increase in cooling appliances and the expected increase in the temperature excess. It is expected to increase by around 60% in services. Although assessments for industry are less reliable, buildings will account for more than 90% of future cooling demand. Owing to the increase in the efficiency of cooling appliances, the growth in energy end-use will be considerably less than the growth in useful energy.

Table 8: Current and future heating and cooling demand

[GWh/year]		Sector	2017	2020	2025	2030	2035	2040	2045	2050
Useful energy	**Heating**	Households	7 873	7 261	6 304	5 594	5 000	4 606	4 437	4 283
		Services	2 558	2 516	2 353	2 246	2 115	2 086	2 123	2 167
		Industry	8 192	8 213	8 345	8 401	8 429	8 444	8 702	8 817
		TOTAL	**18 623**	**17 990**	**17 002**	**16 241**	**15 544**	**15 136**	**15 262**	**15 267**
	Cooling	Households	332	302	374	449	583	688	702	763
		Services	515	542	565	591	743	848	816	810
		Industry	98	98	99	100	101	101	103	105
		TOTAL	**945**	**942**	**1 038**	**1 140**	**1 427**	**1 637**	**1 621**	**1 678**

Final energy	**Heating**	Households	10 566	9 417	7 715	6 489	5 614	5 110	4 939	4 813
		Services	2 958	2 872	2 643	2 455	2 294	2 257	2 286	2 324
		Industry	8 633	8 579	8 442	8 298	8 418	8 363	8 534	8 532
		TOTAL	**22 157**	**20 652**	**18 566**	**17 051**	**16 222**	**15 723**	**15 790**	**15 748**
	Cooling	Households	90	77	88	96	115	125	118	120
		Services	172	173	168	164	195	210	191	180
		Industry	28	28	28	29	29	29	29	30
		TOTAL	**290**	**278**	**284**	**289**	**339**	**364**	**338**	**330**

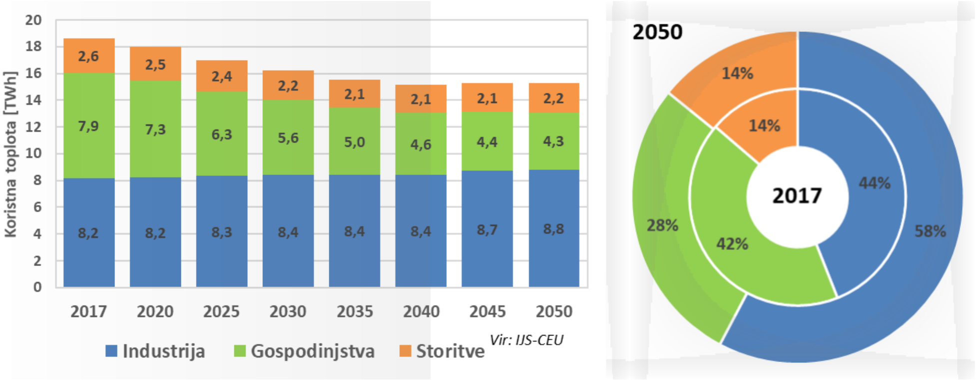

Figure 40: Projection of heating demand (useful energy) up to 2050, by sector

	Useful heat [TWh]
	Industry
	Households
	Services
	Source: IJS-CEU

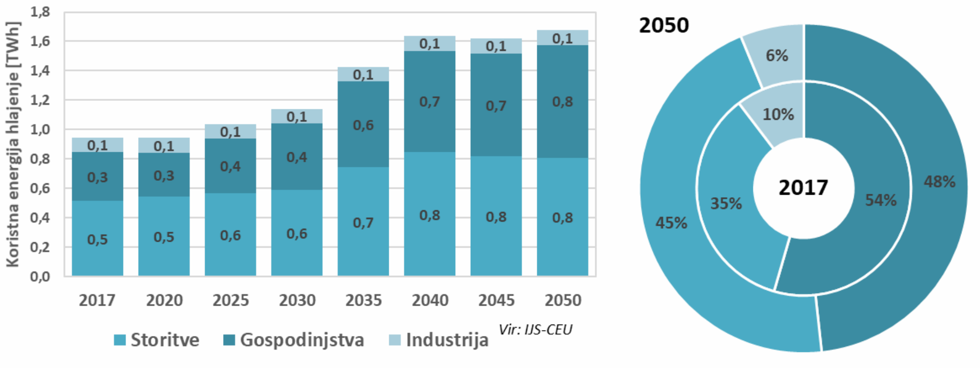

Figure 41: Projection of cooling demand (useful energy) up to 2050, by sector

	Useful cooling energy [TWh]
	Services
	Households
	Industry
	Source: IJS-CEU

3 OBJECTIVES, STRATEGIES AND POLITICAL MEASURES

3.1 Contribution to national targets

At 22 TWh, heating and cooling accounts for almost 40% of energy end-use and more than 30% of primary energy supply.[21] It therefore has a very significant effect on the achievement of national targets in all five dimensions of the Energy Union.

1. Energy efficiency

Reducing needs for heat and cold is one of the priorities of the NECP and makes vital contributions to achieving the objectives of the other dimensions of the Energy Union. Total consumption of useful energy for HC should therefore fall by 11% (2.2 TWh) by 2030 and by 13% (2.6 TWh) by 2050. Consequently, and because of the introduction of efficient supply technologies, energy end-use will fall by 23% (5.1 TWh) by 2030 and by 28% (6.4 TWh) by 2050. **The 5.1 TWh reduction in final energy for HC by 2030 relative to 2017 constitutes almost 9% of total energy end-use in 2017, and make a crucial contribution to achieving the energy efficiency objective for 2030, as it accounts for just over half the target reduction.[22]**

2. Decarbonisation – increase in share of RES

Owing to the increase in efficiency and the high baseline share taken by RES in HC, the quantity of heat from RES under the 2030 NECP scenario is expected to fall to just over 25 TWh by 2030 from the 2017 figure of almost 29 TWh, increasing to 27 TWh by 2050. **Despite the reduction in the quantity of RES resulting from greater efficiency, and because of the reduction in the final consumption of heat, the share of RES in HC, which has fallen slightly from 35% since 2017, will exceed 40% by 2030 and 50% by 2050 (Figure 42), which is in line with the more ambitious RES targets for the period leading up to 2030.**

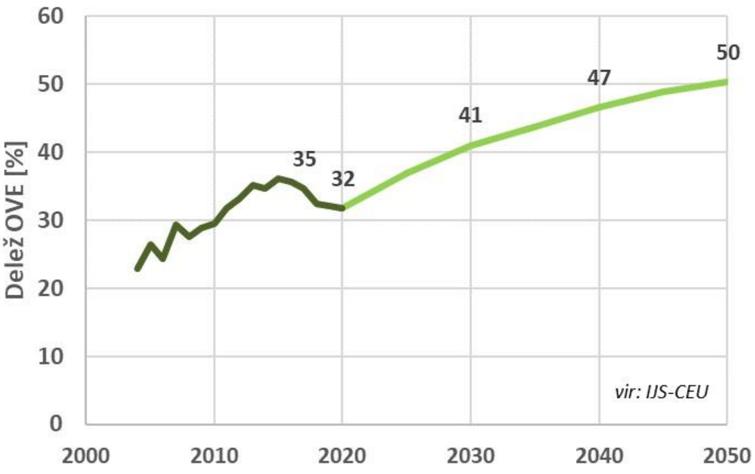

Figure 42: Share of RES in heating and cooling

	Share of RES [%]
	Source: IJS-CEU

3. Decarbonisation – reduction in GHG emissions

Direct GHG emissions from heating and cooling were 2.8 $MtCO_2$ equivalent in 2017, which accounted for 16% of all GHG emissions in Slovenia. Despite this comparatively low percentage, this sector has contributed most to reducing emissions in Slovenia in the last few years. In the period between 2005 and 2017, emissions from HC fell by more than 40%, or by 1.9 $MtCO_2$ equivalent. Households contributed most to this reduction, and buildings overall by just over 1.2 $MtCO_2$ equivalent (Figure 43).

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[21] Taking the primary electricity conversion factor into account.

[22] In line with the EU target of a 32.5% reduction, Slovenia will have to reduce energy end-use by 2.5 TWh by 2030 relative to 2020.

According to NECP projections, GHG emissions for HC in the period up to 2030 will fall by 42% relative to 2017, or again by 1.2 $MtCO_2$ equivalent, with reductions in buildings twice as high as those in industry, with only minimal amounts (0.1 $MtCO_2$ equivalent) still being produced by 2050.

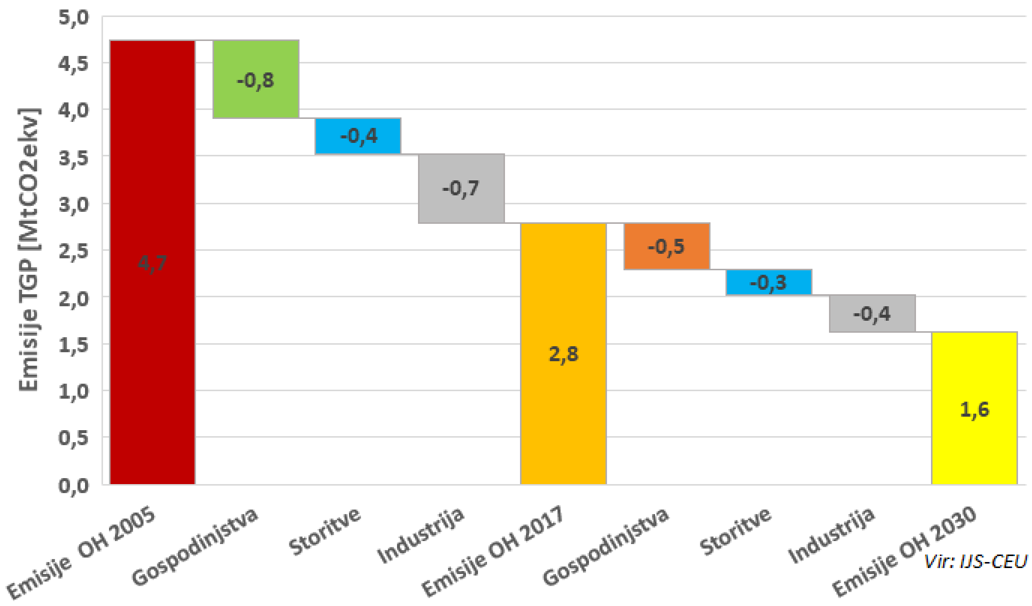

Figure 43: Reduction in GHG emissions in heating and cooling

	GHG emissions [$MtCO_2$ equivalent]
	HC emissions 2005
	Households
	Services
	Industry
	HC emissions 2017
	HC emissions 2030
	Source: IJS-CEU

By 2030, emissions will therefore have fallen by just over 66% in HC, by more than 80% in buildings and by more than 60% in industry relative to 2005. An absolute reduction in emissions in HC by 3.1 $MtCO_2$ equivalent by 2030 relative to 2005 means a reduction in total emissions by just over 26%, which is an extremely important contribution to achieving the new more ambitious 2030 emission reduction target and accounts for almost half the target reduction.[23]

4. Energy security and the internal energy market

The increase in efficiency and the balanced decarbonisation of HC using all available domestic renewable energy sources (WB, GEO, solar energy, etc.) and DHE envisaged in the NECP would make an important contribution to reducing reliance on imports and exposure to risks in emergency situations, particularly in winter months with extremely low temperatures. The planned concept increases the role district heating systems play as important infrastructure for integrating energy sectors effectively and providing support to the electricity grid (flexible cogeneration of electricity in the winter months, storage of energy surpluses, provision of system services, etc.). There is a great emphasis on energy efficiency, which also makes an important contribution to reducing the risk of fuel poverty.

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[23] Slovenia's total GHG emissions in 2005 were practically the same as emissions in the reference year of 1990 (1986 for Slovenia). It is therefore immaterial whether the target comparison of total emissions is made with 2005 or 1990. The large increase in emissions from traffic (by 1.1 $MtCO_2$ equivalent since 2005) reduces the effect of the reduction in emissions from heating. Therefore, in order to achieve the target of a 55% reduction by 2030, a larger reduction must be achieved in all sectors.

5. Research, innovation and competitiveness

Increasing the volume of research and innovation will be key to the successful exploitation of the potential for efficient HC and increasing the use of renewable energy sources, particularly in industry (where the challenges are greatest), while successful solutions can significantly improve the industrial competitiveness. Finding alternatives to natural gas for heating in industry is a key technological development challenge. Any effective and efficient solution will have a positive impact on all other sectors.

3.2 Overview of existing policies and measures

The NECP defined the existing and additional policies and measures important for efficient heating and cooling. The main measures are summarised in brief in Table 9. The measures are targeted towards all sectors and all five dimensions of the NECP, as this is a multi-sectoral issue that requires a coordinated approach in all sectors and at all levels of action, including the development of the necessary energy infrastructure. The priority measures for establishing energy efficiency are therefore being linked to measures to increase the use of RES and reduce GHG emissions, as well as other horizontal measures, including training, awareness-raising and an increase in the volume of research and innovation.

The Energy Efficiency Act (ZURE) was adopted after the NECP. The act established several additional measures in the area of HC, and a number of other sectoral laws are being prepared (Promotion of the Use of Renewable Energy Sources Act [ZOVE], Electricity Supply Act, etc.).

Table 9: Existing and additional measures for efficient heating and cooling – NECP

Dimension	Measure	Name of instrument	Type of instrument
I	Existing	**GHG emissions trading (EU-ETS)**	economic
I	Additional	**Non-repayable financial incentives for measures to reduce GHG emissions in industry with circular** economy measures (measure aimed at the ETS and non-ETS sector [2020-2030].)	economic (financial incentives) and support activities
I	Existing	**Environmental tax for pollution of the air with carbon dioxide emissions**	tax policy
I	Existing	**Promotion of energy efficiency in the utilisation of renewable energy sources as part of other taxes on energy products**	tax policy, incentives
I	Existing	**Gradual reduction in and discontinuation of fossil fuel incentives**	tax policy, economic, regulations
I	Existing	**Expansion and upgrading of the green public procurement system (ZeJN), including the introduction of green innovation procurement**	regulations
I	Existing	**Support scheme for the promotion of electricity generated from RES and in the high-efficiency cogeneration of heat and power**	economic (financial incentives)
I	Existing	**Investment incentives for the promotion of electricity generated from RES**	economic (financial incentives)
I	Existing	**Self-sufficiency in electricity from RES**	group of instruments (regulation, financial incentives)
I	Existing	**Technical criteria, procedures and tariffs for the connection of RES units to the network**	technical regulation
I	Additional	**Incentives for the improved network integration of RES generation installations and demand response**	regulations
I	Additional	**Promotion of local energy communities**	economic
I	Additional	**Incentives for the more rapid development of the RES community**	group of instruments (regulations, financing, publicity)

Dimension	Measure	Name of instrument	Type of instrument
I	Additional	Promotion of investments and technologies for the conversion of surpluses of electricity from RES and the integration of networks for energy storage demand	economic
I	Additional	Promoting the multi-purpose use of geothermal energy	economic (financial incentives), regulations
I	Existing	Efficient district heating systems – mandatory share of RES, CHP and waste heat in district heating systems	regulations
I	Existing	Promotion of the development of DH systems using RES within the context of the OP ECP	economic (financial incentives)
II	Existing	Financial incentives in the form of repayable funds for industry	economic (financial incentives) and support activities
II	Existing	Non-repayable financial incentives for the use of EE and RES in industry	economic (financial incentives) and support activities
II	Existing	Incentives for EE and RES for SME	economic (financial incentives)
II	Existing	Incentives for introducing energy management systems	economic (financial incentives) and support activities
II	Existing	Amendments to regulations on the energy efficiency of buildings	regulation
II	Existing	Renovation of cultural heritage buildings and other special building categories	group of instruments
II	Existing	Energy performance contracting (EPC)	economic
II	Existing	Production of sustainable criteria for buildings	planning
II	Existing	Aid scheme for energy efficiency in households for vulnerable population groups	economic (financial incentives) and support activities
II	Existing	Financial incentives for the energy efficiency and the use of RES in residential buildings	economic (financial incentives)
II	Existing	Instruments for financing renovation in buildings with multiple owners	economic, regulations
II	Existing	Mandatory division and billing of heating costs in multi-family houses	regulation
II	Existing	Energy advice network for citizens – ENSVET	information/publicity
II	Existing	Grant schemes for energy efficiency in households: Eco Fund loans and incentives to other providers of green loans for the housing sector	economic
II	Existing	Distribution of incentives among owners and tenants in multi-family houses	regulation, incentives
II	Existing	Establishment of a guarantee scheme	economic (financial incentives)
II	Existing	Energy management in the public sector	other (monitoring, reporting and support activities)
II	Existing	Repayable fund schemes for energy efficiency in the public sector	economic
II	Existing	Financial incentive investment grants for the energy renovation of buildings in the public sector targeted at increasing the share of projects carried out using energy performance contracting	economic (financial incentives)
II	Existing	Quality assurance of projects for the energy renovation of buildings in the public sector	group of instruments
II	Existing	Project office for the energy renovation of public buildings	other (organisational measure)
II	Additional	Limiting the use of fossil fuels for heating in buildings	regulations

Dimension	Measure	Name of instrument	Type of instrument
II	Additional	**Drafting of a plan for the financing of sustainable building renovation**	planning
II	Additional	**Establishment of an energy performance of buildings portal**	other (information platform)
II	Existing	**Assessment of the efficient heating and cooling potentials**	planning
II	Existing	**Heating and cooling strategy, action plan for district heating and cooling, heat map**	planning
II	Existing	**Obligations of energy suppliers to achieve savings in energy end-use among final customers**	other (energy services)
II	Existing	**Eco Fund loans with a subsidised interest rate for environmental investments**	economic
II	Existing	**Regulations in the field of air quality protection and the use of the best available technologies**	regulations
II	Existing	**Spatial planning instruments for the transition to a climate-neutral society**	planning, policy, regulations
II	Existing	**Energy and environmental labelling and minimum standards for products and appliances**	regulations
II	Existing	**Information and publicity for target publics**	information, publicity
	Existing	**Follow-up monitoring of measures and policies**	monitoring and reporting
IV	Additional	**Provision of conditions for the further integration of markets and the construction of the necessary infrastructure**	economic, legislative
IV	Additional	**Development incentives for decarbonisation of the gas supply**	legislative, economic
IV	Additional	**Support environment for the alleviation of fuel poverty**	legislation, action plan
V	Existing	**Promotion of research and innovation for transition to a climate-neutral society**	economic (financial incentives), demonstration
V	Existing	**Financial incentives for demonstration projects**	economic (financial incentives)
V	Existing	**Encouraging training and staff recruitment**	training
V	Existing	**Planning and development of training for transition to a climate-neutral society**	education, training
V	Existing	**Inclusion of climate content in the wider development of schooling and education**	education, training
V	Additional	**Increase in funds for research and development as support to the transition to a low-carbon society** (RES and EE technologies and other low-carbon technologies, energy storage, smart networks, recycling, materials efficiency, etc.)	economic (funding, investments, tax policy)

4 ANALYSIS OF THE ECONOMIC POTENTIAL OF EFFICIENT HEATING AND COOLING

An analysis of the economic potential for various heating and cooling technologies for the entire country was produced for the following technologies:

- energy efficiency in buildings;
- energy efficiency in industry;
- waste heat in industry;
- thermal waste treatment;
- high-efficiency cogeneration of heat and power;
- renewable energy sources;
    - wood biomass;
    - solar energy;
    - deep geothermal energy;
    - heat pumps;
- district heating and cooling systems;
- reduction in losses from existing district heating systems.

4.1 Potential for energy efficiency in buildings

The Long-Term Strategy for the Energy Renovation of Buildings by 2050 (DSEPS 2050) incorporates the key targets of the NECP in the area of buildings by 2030.

DSEPS 2050 targets by 2030

- **Reduction of GHG emissions in buildings by at least 70% by 2030 relative to 2005.**
- **RES* to account for at least two-thirds of energy use in buildings by 2030.**
  (*share of use of RES in energy end-use excluding electricity and district heat).

pursues the principle of 'energy efficiency in first place', defines the approaches and policies towards the decarbonisation of the national building stock by 2050, and defines the necessary measures, **as the targets will only be achieved by reducing energy demand and increasing the efficiency of heating systems.**

DSEPS 2050 target by 2050

- **To move towards net-zero emissions in the building sector by preserving the large volume of energy renovation of buildings with low-carbon and renewable materials, and a focus on heating using RES technologies and centralised heating systems using RES.**
- **The redirecting of new building construction and energy renovation towards the achievement of almost zero emissions throughout the entire life cycle. The promotion of wider building renovation so as to provide users with safety, health, well-being and productivity. The construction and renovation of buildings will be a priority for the transition to a low-carbon circular economy.**

To achieve the targets and positive economic effects outlined, DSEPS 2050 plans a high level of energy renovation of buildings (more than 75% of today's buildings will still be in use in 2050), an increase in the use of RES in buildings for heating and the production of domestic hot water, and an increase in the number of connections to district heating systems and a considerable growth in the number of DHS in areas where this is economically feasible.

In accordance with the NECP, DSEPS 2050 also includes a gradual ban on the purchase of new heating appliances using fossil fuels[24] and in SPA focuses the generation of heat for heating and the production of DHW on individual

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[24] A ban on the use of heating oil in new buildings from 2021 and a ban on the sale and installation of new heating oil boilers by 2023

technologies, particularly HP and efficient wood biomass boilers, since WB remains an important low-carbon resource in Slovenia. It gives priority to centralised heat supply and the continued development of district heating systems in areas with a greater density of heat demand and areas in which district heating systems are already located. The sectoral 2030 targets of the DSEPS are shown in Table 10, while the planned reduction in useful heat demand by individual building type of more than 35% by 2050 is shown in Figure 44[25].

Table 10: DSEPS 2050 targets by 2030

Sector	Objectives
Households	➢ Reduction in energy demand by 1.7 TWh, energy end-use by 25% and CO_2 emissions by 45% ➢ The energy renovation of 16.1 million m^2 of single-family houses and 7.3 million m^2 of multi-family houses – focus on comprehensive energy renovation, nearly-zero-energy buildings (NZEB) will account for at least 36% of all buildings
Public buildings	➢ Reduction in energy demand by 20% or 0.2 TWh, in energy end-use by 7%, and CO_2 emissions by 57% ➢ Energy renovation of 2.3 million m^2 of public buildings and at least 26% of public buildings to be NZEB
Private service sector	➢ Reduction in energy demand by 16% or 1 TWh and CO_2 emissions by 51% ➢ Energy renovation of 4.1 million m^2 of buildings and at least 24% of buildings to be NZEB

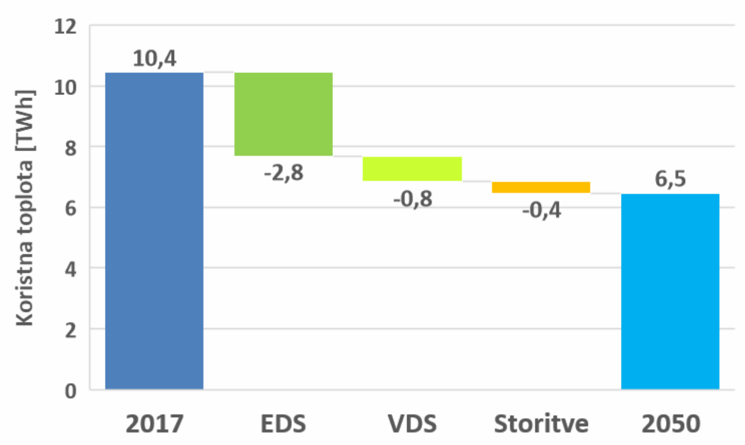

Figure 44: Planned reduction in useful heat demand by type of building 2020-2050 in DSEPS 2050.

	Useful heat [TWh]
	STH
	MFH
	Services

Better energy management in buildings (targeted monitoring of energy use, better regulation and advanced management of systems, regular maintenance of appliances, measurements, awareness-raising among users and managers, etc.) constitutes an additional energy efficiency potential of at least 5 to 10% of energy end-use for heating and cooling in buildings, which today represents a potential of around 1 TWh of savings in final energy in buildings.

4.2 Energy efficiency potential in industry

The following horizontal measures for the energy efficiency of thermal processes in industry can be highlighted:

- use (recovery) of waste heat (the utilisation of WH, both high- and low-temperature, is envisaged – as a matter of priority, within industrial processes and for the supply of heat users in the vicinity);

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[25] Owing to the expected increase in building floor area of more than 40%, the reduction is lowest in the service sector.

- reduction in the specific use of energy because of the occupancy of appliances;
- the optimisation of generation, technological modernisation, replacement and modernisation of process machinery and devices, and digital transformation;
- transition from natural gas to electricity in thermal processes, e.g. in glassworking and the metals manufacturing, and the increased use of other alternative fuels (wood biomass, biogas, waste, hydrogen, etc.)
- organisational measures, such as active energy management (energy management systems, energy accounting and targeted energy use monitoring, introduction of ISO 50.001 standards, etc.).

Current environmental and economic conditions favour an increase in the use of RES for thermal purposes. This will be based in particular on WB and CHP systems, the use of low-temperature heat from geothermal energy, and the use of RES from waste (increase in the share of biogenic waste). The use of syngas and/or hydrogen is also envisaged. Various technologies are employed for thermal purposes in industry: boilers, CHP, DHE, furnaces, etc. Measures to increase savings and to replace industrial boilers are being carried out. Newer CHP with gas turbines and engines, and new technologies (ORC, fuel cells, etc.) are replacing old, less efficient steam installations.

Only electric arc furnaces in which various technological measures have been introduced to reduce the intensity of fuel consumption are used in steel production: modernisation of the furnace, incorporation of ‘oxy fuel’ burners, oxygen injection, use of natural gas for the initial flame melting of the furnace charge, preheating of the furnace charge, injection of carbon materials for the foaming of the furnace slag, etc. CHP units are an important source of thermal energy in the manufacture of paper and paper products. The thermal processes in this branch may be significantly improved by WH recuperation, technological modernisation and the modernisation of paper machines.

Aluminium production has a significant impact on heat demand in industry and, with the anticipated gradual increase in the use of secondary aluminium, heat demand (excluding electricity) will gradually increase. In this branch as well, the use of WH is an important measure. The replacement of gas furnaces for thermal treatment in steelmaking and glassmaking with electric induction furnaces is expected. It is estimated that electric furnaces are capable of providing a third of the heat required for thermal treatment processes.

4.3 Waste heat potential in industry

The basic energy management principle in Slovenia remains prioritising energy efficiency measures. The same applies to industry. Energy efficiency measures enable more efficient energy management and consequently also reduce energy end-use. At this point we should highlight the use of energy from WH that is generated in thermal processes and that can, through various technologies, be captured and re-used or placed in district heating systems. The use of WH energy is envisaged for the whole of industry and, to a greater extent, in energy-intensive industrial branches, particularly the manufacture of metals, paper, cement and chemicals.

One important developmental direction to be taken involves the integration of industrial concerns with district heating systems, which can use WH from industry to provide heat to other final customers (households, service sector). Branches with a pronounced demand for heat (paper and chemicals industries) or cold (food industry) may, alongside the generation of heat via CHP technologies or tri-generation (generation of cold), also generate electricity for their own needs or for transmission to the network. Along with the use of wood biomass or biogas, this could additionally reduce GHG emissions.

Various sources[26] () have been used for an analysis of the energy potential of WH. Projections for the use of WH are also given in the NECP. The Sustainable Energy Atlas GIS portal contains information on available WH, the calculation of which is based on data from the ARSO environmental database. The database for the sEEnergies and HoTMAPS projects comprises various sources. An important role is played by the databases of companies and installations involved in emissions trading (EU ETS[27]) and by data from the European Pollutant Release and

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[26] Sources: Sustainable Energy Atlas (Borzen), H2020 Projects sEEnergies and HoTMAPS

[27] European Environment Agency: European Union Emissions Trading System (EU ETS) data from EUTL (EU Transaction Log). Available at (25 February 2020) www.eea.europa.eu/ds_resolveuid/DAT-21-en

Transfer Register (E-PRTR),[28] which have been linked together in an attempt to assess the WH potential for 15 energy-intensive companies in Slovenia. The study assessed WH potential in relation to the temperature level of the selected district heating generation (current status, fourth and fifth generations).

As part of the preparation of the NECP, the potentials for the use of WH in energy-intensive industrial branches are analysed and the total WH potential in the industrial sector up to 2050 is also outlined.

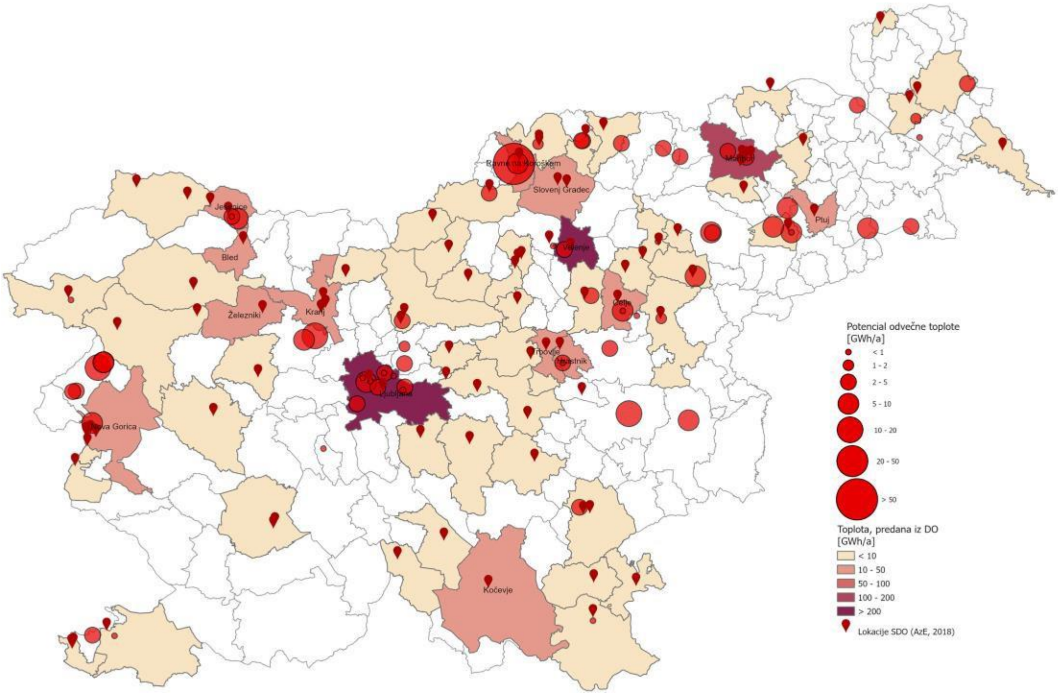

Figure 45: Locations of industrial installations with waste heat energy potential for reference year 2017 (source: Sustainable Energy Atlas)

	Waste heat potential [GWh/a]
	Heat transmitted from DH [GWh/a]
	DHS locations (AzE, 2018)

Projections were drawn up for the NECP that examined the potential for WH in energy-intensive and other branches, with the different shares of the potential being taken into account for individual industrial branches. The same approach is employed at the local level, with an estimate made of the potential at the level of the individual company. The estimated total energy potential of WH under the NECP methodology is therefore 658 GWh for 2030. According to current projections of economic activity, this figure could rise to more than 1 TWh by 2050, although the considerable uncertainty regarding the structure of the branches and the new technologies means that this estimate is less reliable.

The 20 companies with the highest estimated WH energy potential account for around 50% of the total potential. Table 11 gives an estimate of heat demand, the energy potential of WH and the share of WH in energy demand for 2030. An estimate is made of the potential of high- and low-temperature WH (steam, flue gases). The NECP predicts that industrial companies will gradually replace the consumption of heat from district heating systems with their own WH (Figure 47, Waste heat INT). Based on this assumption, an estimate has been made of the total cumulative potential that companies could place in district heating systems (Figure 47, Waste heat EXT).

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[28] European Environment Agency: European Pollutant Release and Transfer Register (EPRTR), Member States reporting under Article 7 of Regulation (EC) No 166/2006, available at www.eea.europa.eu/ds_resolveuid/DAT-21-en

Table 11: Energy demand for 2030 and energy potential of waste heat for industrial enterprises according to the NECP scenario[29]

Company	Municipality	Branch	Heat demand 2030 [GWh]	Temperature level 100-200°C	Temperature level 200-500°C	Temperature level > 500°C	WH potential 2030 [GWh]
Acroni	Jesenice	C24	397	0	35	21	56
Metal Ravne	Ravne na Koroškem	C24	385	0	35	20	55
Salonit	Kanal	C23	476	0	50	0	50
Talum	Kidričevo	C24	219	0	19	12	31
Knauf Insulation	Škofja Loka	C23	276	0	29	0	29
MPI-RECIKLAŽA	Črna na Koroškem	C24	187	0	27	0	27
Steklarna	Hrastnik	C23	200	0	21	0	21
Cinkarna Celje	Celje	C20	217	18	0	0	18
Železarna	Štore	C24	121	0	11	6	17
SILKEM	Kidričevo	C23	144	15	0	0	15
Impol	Slovenska Bistrica	C24	101	0	9	5	14
Tanin	Sevnica	C20	150	13	0	0	13
Aquafil	Ljubljana	C20	130	11	0	0	11
Lek	Ljubljana	C21	176	11	0	0	11
Krka	Novo Mesto	C21	154	9	0	0	9
Goodyear Sava	Kranj	C22	133	8	0	0	8
Količevo Karton	Domžale	C17	270	8	0	0	8
Vipap Videm Krško	Krško	C17	258	8	0	0	8
Lesonit	Ilirska Bistrica	C16	125	8	0	0	8
Melamin	Kočevje	C20	90	8	0	0	8
Top 20			**4 208**	**117**	**235**	**65**	**418**
Other companies			**4 193**	**48**	**186**	**8**	**240**
Total			**8 401**	**165**	**421**	**72**	**658**

The geographical distribution of WH potential is shown by municipality and company in Figure 46. It shows that the municipalities with the most available WH are: Jesenice, Ravne na Koroškem, Kanal, Kidričevo, Škofja Loka, Črna na Koroškem, Hrastnik, Celje, Štore, Slovenska Bistrica, Sevnica, Ljubljana and Novo Mesto. The feasibility of the utilisation of the potential must be addressed in more detail in the future in studies and in local planning for each individual municipality and identified industrial location.

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[29] Enterprises in the EU ETS (for 2021-2025) are labelled as green, Source: List in accordance with Article 126a of the ZVO-1.

Waste heat potential in industry up to 2030

- **The total estimated WH potential is greater than 650 GWh. Of this figure, 60% is at the 200-500°C temperature level, 25% at the 100-200°C temperature level and 10% at a temperature level over 500 °C.**
- **Companies could utilise just over 160 GWh internally for their own needs and almost 500 GWh for sale to other users. The potential exceeds the current demand from existing DHS in the vicinity of the identified companies, while many industrial locations do not have a district heating system in the vicinity. A more detailed assessment of usability and economic potential therefore requires a case-by-case approach and local planning for each individual industrial location and DHS. The economic potential for the sale of WH in industry is indicatively estimated at around 110 GWh (145 GWh of heat transmitted into DHS through heating by means of heat pumps).**

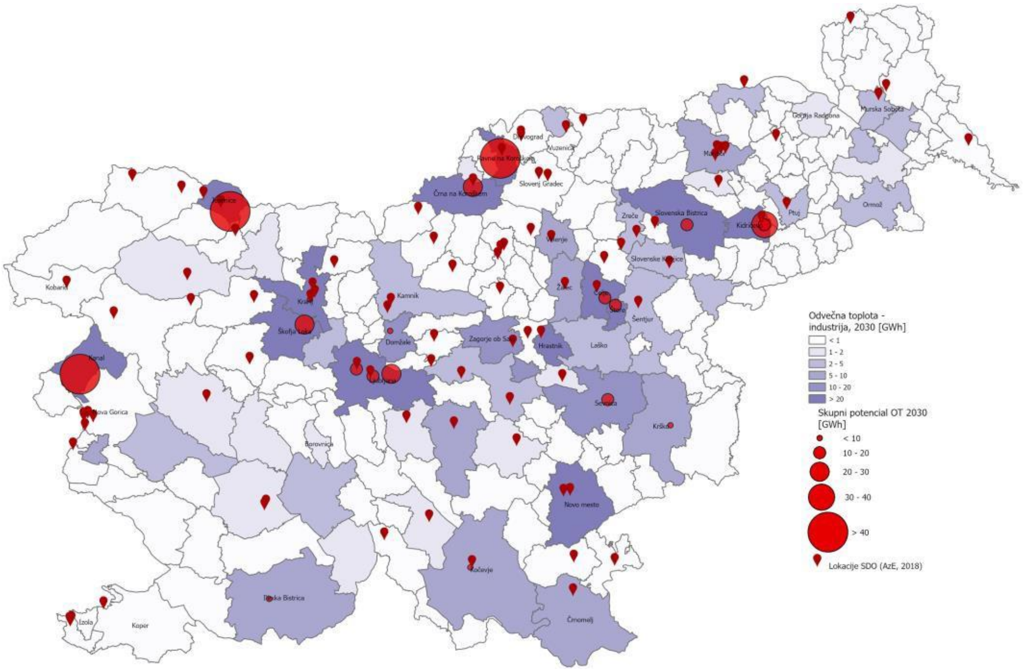

Figure 46: Geographical distribution of the energy potentials of waste heat for reference year 2030 (source: IJS-CEU)

	Waste heat – industry, 2030 [GWh]
	Total WH potential 2030 [GWh]
	DHS locations (AzE, 2018)

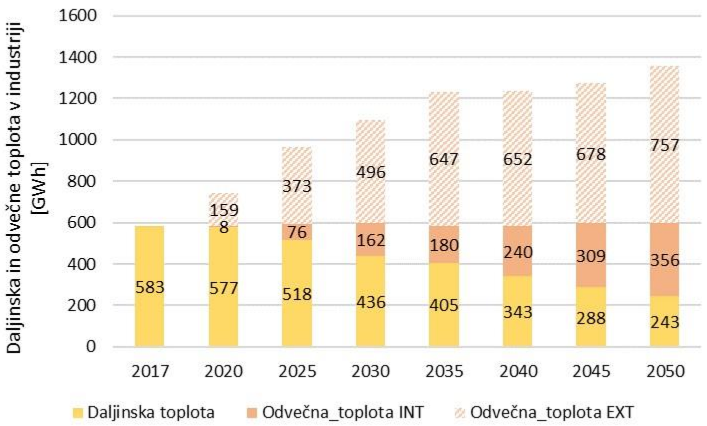

Figure 47: District and waste heat in industry for own use (INT) and transmission to external systems (EXT)

	District and waste heat in industry [GWh]
	District heat
	Waste heat INT
	Waste heat EXT

4.4 Thermal waste treatment potential

In the Slovenian Waste Management and Prevention Programme of 2016, the average available thermal power of the energy recovery of combustible municipal waste was estimated at around 90 MW between 2014 and 2030. This energy potential is only partly utilised, specifically at Celje heating plant (Toplarna Celje), which is the only Slovenian thermal municipal waste treatment plant (TWTP). A steam boiler with a thermal output of 15 MWt and a steam turbine with an electrical power of 2 MWt have been installed at the heating plant for the cogeneration of heat for DH and electricity. Energy is recovered from up to 30 000 tonnes of pre-treated municipal waste from municipalities in the Savinjska region every year; this waste comprises light fractions and sludge from the City of Celje's central municipal waste water treatment plant. The thermal power plant operates without interruption, 24 hours a day, seven days a week.

Slovenia is therefore dependent on TWTPs abroad for the processing and disposal of waste with thermal treatment. In 2018 it exported over 210 000 tonnes of fuel from waste and residues from the mechanical processing of municipal waste. The energy value of waste was more than 1 TWh and thermal power around 170 MW in 2018.

As the Environmental Protection Act (ZVO-1) defines the processing ('incineration') of municipal waste as a compulsory national public environmental protection utility service, the Ministry of the Environment and Spatial Planning has taken steps to regulate the legislative framework and produced a draft Decree on provision of the compulsory national public utility service of municipal waste incineration. This decree should enable and accelerate the construction of adequate TWTPs for the incineration of combustible municipal waste suitable for use as energy in Slovenia. This will also enable the country to become self-sufficient and flexible in the area of waste management. The draft decree is also a concession deed. The decree lays down the conditions that a concessionaire is required to meet, including requirements for the thermal treatment of waste and utilisation of the combustion heat recovered, the nominal capacity of the TWTP (which may not fall below three tonnes of waste an hour) and the achievement of at least 65% energy efficiency in the incineration of combustible municipal waste. The concession may be awarded for a single area, several areas or the entire country, with a minimum quantity of 26 000 tonnes of combustible municipal waste per area. Several municipalities responded to the changes to the regulatory framework and showed a readiness to establish a TWTP: Ljubljana, Maribor, Ptuj, Jesenice and Kočevje. The two biggest urban municipalities, Ljubljana and Maribor, are actively engaged in preparing TWTP investments. Table 12 sets out the basic parameters for two potential TWTPs for supplying heat to district heating systems to a total of 284 GWh a year.

Table 12: Potential thermal municipal waste treatment plants in Ljubljana and Maribor

Energetika Ljubljana TWTP	
Thermal input (thermal input of waste from Ljubljana regional waste management centre)	39 $\mathrm{MW_t}$
Thermal output (DH)	25 $\mathrm{MW_t}$
Heat generated	203 $\mathrm{GWh_t}$/year
Gross electrical power;	5.4 $\mathrm{MW_e}$
Net electrical power	3.4 $\mathrm{MW_e}$
Electricity generated	27.5 $\mathrm{GWh_e}$/year
Total efficiency	74%
Existing thermal power plant	
Heat transmitted to DHS in 2018	1 064 $\mathrm{GWh_t}$
Heat supply Maribor	
Thermal input	25 $\mathrm{MW_t}$
Thermal output (DH)	17.5 $\mathrm{MW_t}$
Heat generated	81 $\mathrm{GWh_t}$/year
Gross electrical power;	5.7 $\mathrm{MW_e}$
Net electrical power	4.9 $\mathrm{MW_e}$
Electricity generated	35 $\mathrm{GWh_e}$/year
Total efficiency	88-90%
Fuel consumption (mixture of waste substances: 24 MJ/kg > LHV > 8 MJ/kg)	50 000-55 000 t/year
Planned start of operation	September 2024
Existing thermal power plant	
Heat transmitted to DHS in 2018	113 $\mathrm{GWh_t}$
TOTAL heat generated	**284 GWh**

Given that the year-round peak load operation is a total thermal output exceeding 50 $\mathrm{MW_t}$, the TWTP provides a considerable heat surplus in the summer months in comparison with other sustainable sources of heat in DHS (WH, SOL, etc.) and is an important heat potential for DC. With the use of absorption cooling, this would mean a potential to generate around 70 GWh of district cold, which is around 10% of the expected cooling demand in the service sector in Slovenia after 2030.

Thermal waste treatment potential

- **In 2018 the energy value of all municipal waste in Slovenia was more than 1 TWh. Of this figure, only 10% is currently being utilised in the country's only thermal waste treatment plant, which is located in Celje and generates around 35 GWh of heat and 7 GWh of electricity per year.**
- **In light of current plans drawn up by the two largest city municipalities for the establishment of TWTPs, the total economic potential represented by thermal waste treatment is estimated at more than 520 GWh or the generation of almost 320 GWh of heat and 70 GWh of electricity.**
- **The year-round operation of the planned TWTPs with a thermal output of approximately 50 MW provides a potential for the generation of around 70 GWh of cold and district cooling in the summer months.**

4.5 Potential for the high-efficiency cogeneration of heat and power

The total use of more than 3 TWh of useful heat generated in CHP generation installations in 2017 constitutes 17% of total useful heat for heating in Slovenia. Almost two-thirds of this heat (2 TWh) is generated by CHP generation installations in district heating systems, the remainder (1.2 TWh) is generated by CHP generation installations in end-use sectors (1 TWh in industry and 0.2 TWh in services), while generation in households is minimal (Figure 48).

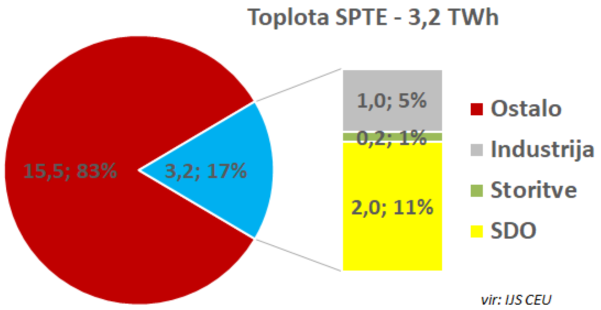

Figure 48: Supply of heat from high-efficiency cogeneration – share of total useful heat

	CHP heat – 3.2 TWh
	Other
	Industry
	Services
	DHS
	Source: IJS-CEU

The share of heat from own CHP generation installations is highest in industry and accounts for 12% of useful heat in industry. In services, own CHP generation installations provide 6% of heat demand. Useful heat from CHP generation installations in DHS accounts for just over 96% of all district heat (DHE) sold[30] and, taking this heat into account as well, the share of useful CHP heat is highest in services (just over 28% of all heating demand in 2017) and industry (just over 19%). As expected, it is lower in households (a mere 11%), as Figure 49 shows in more detail.

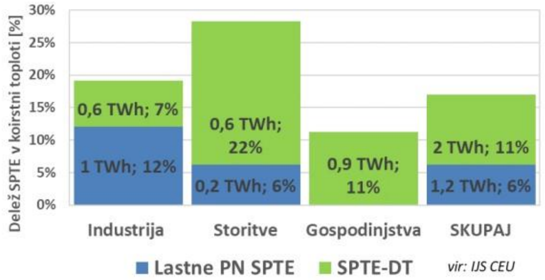

Figure 49: Volume of CHP heat from own units and from the purchase of district heat and its share of useful heat in 2017

	CHP share of useful heat [%]
	Industry
	Services
	Households
	TOTAL
	Own CHP generation installations
	CHP-DHE
	Source: IJS-CEU

Given the low CHP shares of useful heat in all sectors, there is already potential to increase the volume of CHP generation. The key factors in future development are presented below.

4.5.1 Main factors for the future development of CHP

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[30] Losses from the network are not taken into account in the share; otherwise, useful heat from CHP accounts for just over 80% of all district heat generated.

The following factors in particular will have an important impact on the future development of CHP as the technology with the highest level of efficiency in electricity generation in Slovenia.

Increase and provision of high efficiency in the use of (combustible) RES: particularly WB, biogas, waste (RES and other fractions), deep geothermal energy (cascade use), etc.

Electricity supply in the winter months: with the phasing-out of the use of coal in thermal power generation installations, new additional generating capacities will have to be provided for the generation of electricity in the winter months, when demand for heating is greater and there are, at the same time, significantly fewer available renewable energy sources (solar energy, hydroelectric power in very cold periods, limited wind potential, etc.). Regardless of the energy source used for additional generation, it makes sense to connect it as far as possible with the use of heat. The use of CHP technologies is therefore a priority.

Availability and competitiveness of e-fuels: today's predominant use of coal and natural gas in CHP generation installations will have to be replaced in future by carbon-free energy products. In addition to the use of RES, the accessibility and price of new e-fuels (hydrogen, synthetic methane, ammonia, methanol, etc. produced mainly from electricity from RES and other low-carbon sources) will be crucial to the further development of CHP. Regardless of the price, it is logical and necessary to use high-efficiency CHP technologies in all sectors if e-fuels are used to generate electricity or process heat (steam in industry and district heating systems). The volume of CHP will depend significantly on the available quantity of e-fuels in the EU and Slovenia (particularly if it is lower than current supply with NG) and its accessibility, i.e. whether these fuels will only be available to larger consumers (separate transmission network) or more widely through the current distribution networks. The key factor will, of course, be the price of e-fuel. The higher it is, the less competitive CHP will be in supplying low-temperature heat, for which other sustainable technologies (particularly in buildings) are available. CHP will then focus on generating process heat and the necessary additional electricity during the winter months, and providing system services to the network.

The future development and competitiveness of CHP technologies: in addition to a reduction in the costs of technologies (fuel cells, etc. and, in established technologies, the costs of smaller units in particular), further increases in efficiency (mainly electrical efficiency) and improvements in the ability of CHP generation installations to adapt and operate flexibly will be important factors. They will be an essential requirement if the technologies are to be competitive on the increasingly dynamic electricity market (including system services). The currently predominant steam turbines will be replaced by a gas steam process, gas turbines, internal combustion engines and fuel cells with a significantly higher ratio between electricity and heat generated. This will, as a result, increase the quantity of electricity generated even if heat demand is lower as a result of greater efficiency.

These factors will also be key to achieving economic efficiency in the future development of CHP. The estimated economic potential is presented below, broken down by main sector.

District heating systems

The future development of CHP will depend primarily on an expansion of existing and new DHS, and on the necessary additional generation of electricity in the winter months. Current estimates point towards a reduction in the amount of heat generated (from the current 2 TWh to 1.4 TWh by 2050) and in the share of CHP in the generation of district heat (currently over 80%) as a result of the increase in the utilisation of WH and GEO and the simultaneous increase in electricity generation from the current 0.8 TWh to 1.1 TWh as a result of the replacement of technology.[31] The main developments in relation to this will be:

- **Replacement of coal as the main fuel used in CHP:** a gas steam unit using NG with a power of 142 MWe is currently under construction in Ljubljana and will replace the two oldest coal blocks. According to the NECP, the third coal block (co-incineration of WB) should be replaced by a WB unit or thermal waste treatment by 2030. The future of heat supply in district heating systems in Velenje and Šoštanj has not yet been analysed in detail. Nevertheless, in line with the coal exit strategy, the supply of heat from

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[31] Given the demand for the additional generation of electricity in the winter months and the accessibility and competitiveness of e-fuels, the volume of generation could be even greater.

lignite-fired CHP will, as a matter of priority, have to be replaced by WH and RES.[32]

- **Gradual reduction in the use of NG** with a transition to WH, CHP using wood biomass (gasification and ORC turbines) and other RES, and the gradual introduction of e-fuels in gas engine and fuel cell units.

Industry

Given the considerably outmoded and obsolete nature of the predominant gas turbines, the introduction of modern gas turbines, generation installations using WB (gasification and ORC turbines) and fuel cells, would, with the same volume of useful heat recovery (1 TWh), double current capacity by 2050 to more than 100 MWe and electricity generation from the current 0.2 TWh to almost 0.7 TWh. The main factors in future development will, in addition to the competitiveness of WB technologies, be the accessibility and competitiveness of e-fuels. Future development will focus mainly on useful heat for process purposes (high-temperature heat), along with the utilisation, as a matter of priority, of all other WH at an industrial location (primarily for low-temperature purposes).

Services and households

We estimate that the future development of CHP is most uncertain in relation to buildings and is dependent to the greatest extent on the accessibility and competitiveness of e-fuels in the NG distribution network and of fuel cell technologies (including micro technologies), which could gradually replace and also increase current CHP capacities (25 MWe, gas engines). Those capacities could, given favourable development, be increased to at least 45 MWe and electricity generation to around 135 GWh.

Biogas in agriculture and treatment plants

The results of the analysis confirm that existing capacities (around 30 MWe) could increase to more than 40 MWe by 2050 and, in light of the current difficulties in this sector, that electricity generation could more than double to 0.3 TWh. The estimated biogas potential of around 0.9 TWh must be utilised with the highest possible efficiency on-site or with the injection of biogas into the gas network and the use in CHP at another site at which greater beneficial use of available heat from CHP is possible. Additional research must be carried out into the WB gasification potential and the potential for injecting it into the gas network,[33] which could primarily ensure the necessary supply of gas for industrial processes (where there is no alternative) and domestic RES for electricity generation in CHP (particularly in the winter months).

4.5.2 Assessment of the economic potential of CHP

An assessment of the economic potential of CHP is based on the following key targets of Slovenia's energy and climate policy for transition to climate neutrality in accordance with the NECP and the draft Resolution on the Long-Term Climate Strategy:

- **Energy efficiency in first place** – including in the supply and transformation of RES (WB, biogas, GEO, e-fuels, etc.);
- **Increase in the volume of RES in HC and electricity generation** to replace fossil fuels, reduction of dependence on imports and an increase in the reliability of energy supply;
- **Achievement of the greatest possible degree of self-sufficiency in electricity supply.**

CHP technologies using RES and e-fuels make a vital contribution to achieving the targets set and, with lower costs and lower energy use than separate generation, enable domestic electricity generation to be increased following the gradual phasing-out of coal and other fossil fuels for electricity generation. They also provide important support to other, less stable electricity generation from RES (e.g. solar and wind energy).

An assessment of the economic potential of CHP has been drawn up on the basis of NECP projections and additional analyses in this study. It envisages minimal growth in CHP capacities in the period leading up to 2050 (around 430 MWe) and, owing to the replacement of technologies, an increase in electricity generation by 80% to 2.3 TWh, alongside a smaller reduction in heat supply (to 3 TWh), as Table 13 and the figures below show.

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[32] Depending on how the attractive energy location is used in the future, WH could be utilised to produce hydrogen or gasify wood biomass, or use could be made of the heat from mine water and the nearby lakes, the geothermal heat in Topolšica, and so on.

[33] Reducing the use of WB in buildings represents additional potential for efficient energy use using gasification, particularly if it could be linked to a strengthened wood processing chain.

In the event of the more intensive development and expansion of DHS and greater access to competitive e-fuels,[34] the estimated potential could be considerably greater, as CHP will account for a share of around 17% of the total estimated useful heat demand by 2050.

Table 13: Assessment of economic potential of CHP up to 2050

CHP	2017	2020	2025	2030	2035	2040	2045	2050
TOTAL [MW_e]	**397**	**393**	**471**	**473**	**483**	**421**	**427**	**431**
DHS	290	277	340	316	311	240	237	235
Industry	51	58	65	85	91	97	104	108
Services	25	25	25	25	29	29	30	35
Households	0	1	8	13	14	14	13	10
Biogas	31	31	33	34	37	41	42	43
TOTAL [GWh_e]	**1 250**	**1 235**	**1 764**	**1 935**	**2 153**	**2 095**	**2 166**	**2 246**
DHS	806	747	1 208	1 214	1 234	1 101	1 097	1 106
Industry	201	238	286	431	585	629	674	698
Services	116	116	116	116	124	116	113	131
Households	0.0	0.3	3	5	6	6	5	4
Biogas	127	135	151	169	204	244	276	307
TOTAL [GWh_e]	**3 296**	**3 200**	**3 083**	**3 060**	**2 898**	**2 724**	**2 835**	**2 959**
DHS	2 018	1 857	1 677	1 624	1 643	1 389	1 397	1 414
Industry	992	1 050	1 091	1 100	857	897	960	1 005
Services	159	159	159	159	186	188	196	229
Households	0	1	5	7	7	7	6	4
Biogas[35]	127	135	151	169	204	244	276	307

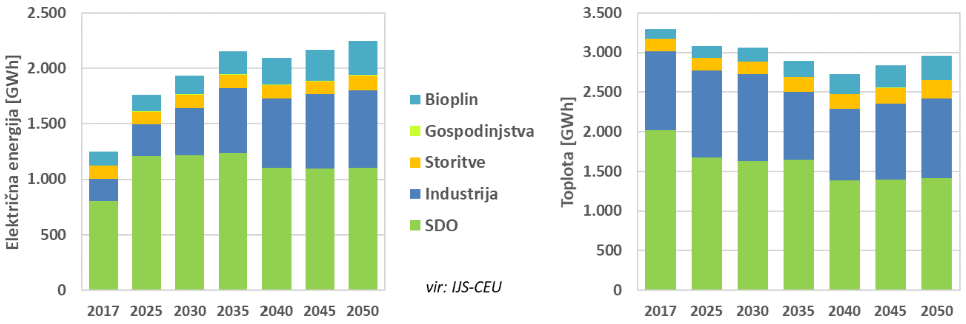

Figure 50: Assessment of economic potential of CHP up to 2050 – projection for electricity and heat production

	Electricity [GWh]
	Biogas
	Households
	Services
	Industry
	DHS
	Source: IJS-CEU
	Heat [GWh]

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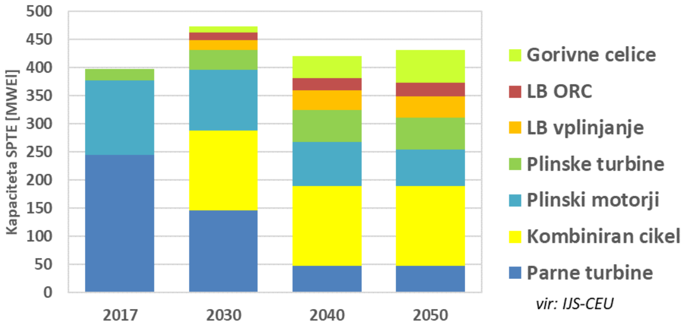
[34] The assessment takes account of the gradual replacement of NG with substitute (carbon-neutral) gases in line with the indicative target in the NECP of a 10% share of such gases by 2030, rising to 25% in 2040 and 100% by 2050.

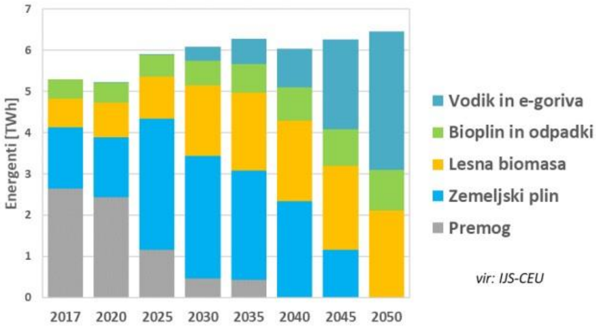
[35] The estimate of the total beneficial use of heat also includes heat from biogas plants, where only small amounts of heat are currently recovered (mainly for the production of biogas), but should be increased in the future (mainly in agriculture).



vir: IJS-CEU

Figure 51: Assessment of economic potential of CHP up to 2050 – CHP technologies

	CHP capacities [MWei]
	Fuel cells
	WB ORC
	WB gasification
	Gas turbines
	Gas engines
	Combined cycle
	Steam turbines
	Source: IJS-CEU



vir: IJS-CEU

Figure 52: Assessment of economic potential of CHP up to 2050 – structure of energy products

	Energy products [TWh]
	Hydrogen and e-fuels
	Biogas and waste
	Wood biomass
	Natural gas
	Coal
	Source: IJS-CEU

Potential for the high-efficiency cogeneration of heat and power

- **CHP is the key technology for achieving high efficiency in the use of RES (wood biomass, biogases, geothermal energy, etc.) and e-fuels in all sectors (and mostly in DHS and industry), and could make an important contribution to increasing self-sufficiency and reliability in electricity supply, particularly in the winter months.**
- **As fossil fuels are phased out, the accessibility and competitiveness of e-fuels will be a key factor in the future development of CHP in Slovenia.**
- **The economic potential of CHP in the period leading up to 2050 is estimated at around 430 MWe, which constitutes only a small increase on current capacities,**

while the replacement of technologies will lead to an 80% increase in electricity production, i.e. to 2.3 TWh and the potential use of 3 TWh of useful heat.

4.6 Heating potential of wood biomass

Baseline situation

With trees covering 59% of its territory, Slovenia is one of the most forested countries in Europe. Wood biomass is Slovenia's most important renewable energy source (Figure 53). WB is a source of energy[36] mainly for heating and the production of domestic hot water in households (5.4 TWh, 41% of useful heat) and services (0.4 TWh, 11% of useful heat), followed by the generation of process heat and heat for heating in industry (0.7 TWh, 8% of useful heat) and the generation of heat in district heating systems (0.5 TWh, 12% of useful heat). In 2017, 144 GWh (net) of electricity was generated from WB, or a mere 1.2% of all electricity generated.[37] Slovenia uses more than 2 million tonnes of WB for energy purposes annually. According to figures from SURS, households accounted for almost 1.6 million tonnes in 2017.

The consumption of WB in households grew slightly between 2009, when a new methodology was used to calculate consumption, and 2013 (Figure 54). Consumption dropped considerably in 2014 because of the exceptionally mild winter, but then rose again, albeit to a level 5% below that recorded prior to 2014. Between 2017 and 2019, there was a pronounced downward trend in WB consumption, chiefly as a result of improvements to the energy efficiency of buildings and the replacement of energy products.

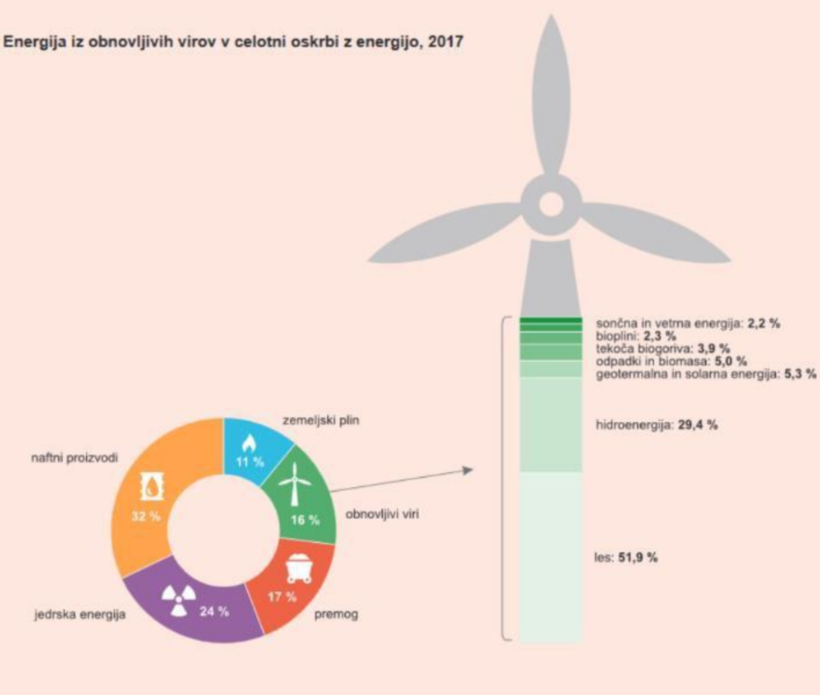


Figure 53: Share of wood biomass in Slovenian supply using renewable energy sources (2017; source: SURS)

	Energy from renewable energy sources as a proportion of overall energy supply, 2017
	petroleum products
	natural gas
	renewable sources
	coal
	nuclear energy

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[36] The figures are for 2017.

[37] Including the 50% of electricity generated at NEK.

	solar and wind energy: **2.2%**
	biogases: **2.3%**
	Bioliquids: **3.9%**
	waste and biomass: **5%**
	geothermal and solar energy: **5.3%**
	hydro: **29.4%**
	wood: **51.9%**

There has been a continual increase in the consumption of WB for district heating in Slovenia since 2004, when only three wood biomass district heating systems operated in Slovenia (and only one of these was fully operational). By 2017 there were already 42 district heating systems operational in Slovenia that used WB as fuel (Figure 55). These systems generated 1 571 GWh of heat, including 272 GWh (17.3%) from WB, in 2017. Most (30) of these systems use WB only. These are mainly smaller systems, which transmitted 79 GWh of heat to DH systems in 2017. By far the greatest amount of heat for DH from WB is generated at TE-TOL Ljubljana, which co-incinerates coal and wood chips: 142 GWh in 2017, or more than half (52%) of all district heat generated from WB.

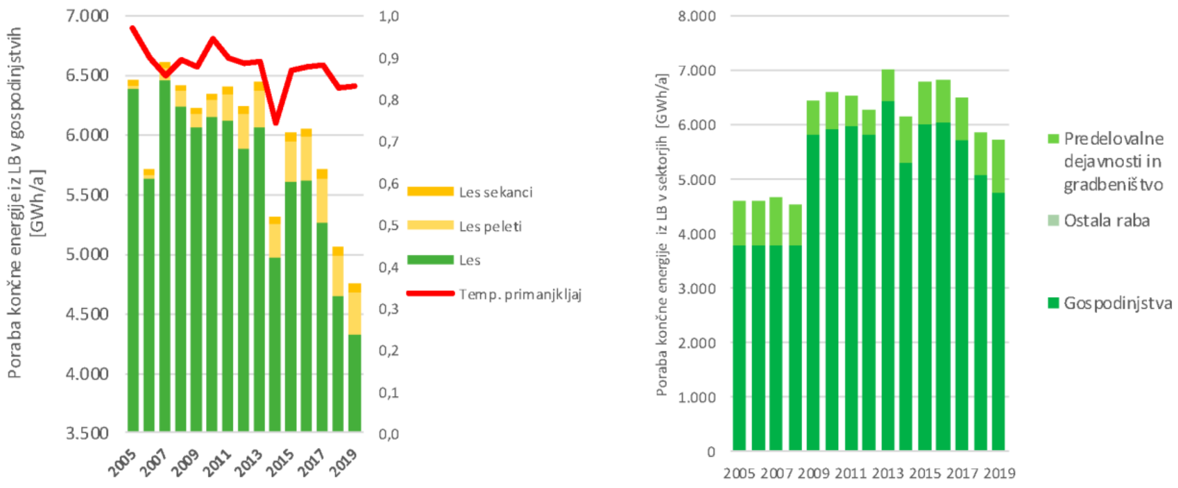

Figure 54: Structure of consumption of wood biomass in households (left) and energy end-use from wood biomass by sector (right), 2005-2019[38]

	Energy end-use from WB in households [GWh/a]
	Wood chips
	Wood pellets
	WB
	Temperature deficit
	Energy end-use from WB in sectors [GWh/a]
	Manufacturing and construction
	Other use
	Households

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[38] Owing to the change in the methodology in 2009, the data for the period before this year deviates from the figures in the graph on the left-hand side, where the data under the new methodology was determined for the entire period.

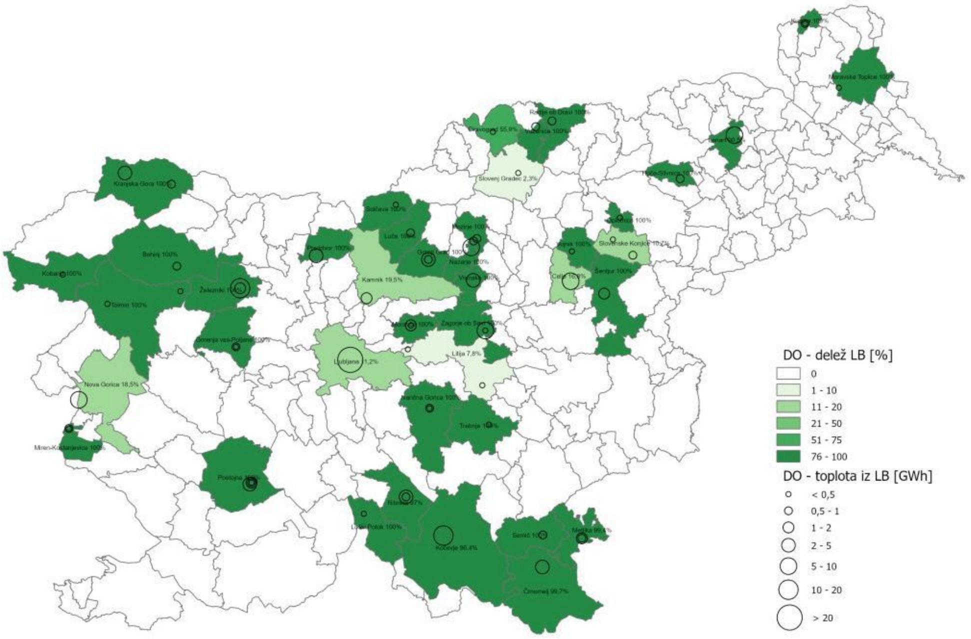

Figure 55: Heat generated and the share of heat from wood biomass in district heating systems (2017)

	DH – share of WB [%]
	DH – heat from WB [GWh]

Potential of wood biomass as an energy product

It is estimated[39] that the total quantity of poorer-quality wood that entered the market between 2009 and 2013 was 470 000 tonnes of dry matter, or approximately 830 000 m^3 (2.7 TWh). This wood constitutes an actual market potential as an input material for the cellulose and chemical industry, manufacturers of timber boards, manufacturers of wood fuels, and energy companies that manufacture and market heat and/or electricity. The theoretical annual quantity of poorer-quality wood that could be extracted from forests and could enter the market is estimated at 1 578 000 tonnes of dry matter, or approximately 2 560 000 m^3.[40] The energy value of this wood is approximately 8.4 TWh, and the total annual energy use of WB in 2017 was 7.3 TWh.

Further development of the use of wood biomass for energy purposes

There are several key aspects to the assessment of the further development of WB use for heating, i.e. the consumption of WB in households and industry – including in connection with the development of WB gasification technologies and the further development of wood biomass district heating systems, including CHP.

Households

The analysis of the consumption of WB in households up to 2050 has been drawn up with reference to the ambitious NECP scenario with additional measures (AMA). Figure 56 shows the useful (required) and final energy from WB for heating and the production of domestic hot water in households in the 2020-2050 period (AMA scenario).

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[39] Estimated in accordance with the methodology of the Forestry Institute of Slovenia in the draft **Strategy for the Rational Use of Wood for Energy Purposes, 2020**.

[40] Estimated in accordance with the WISDOM (Wood Fuels Integrated Supply/Demand Overview Mapping) methodology of the Slovenian Forest Service in the draft **Strategy for the Rational Use of Wood for Energy Purposes, 2020**.

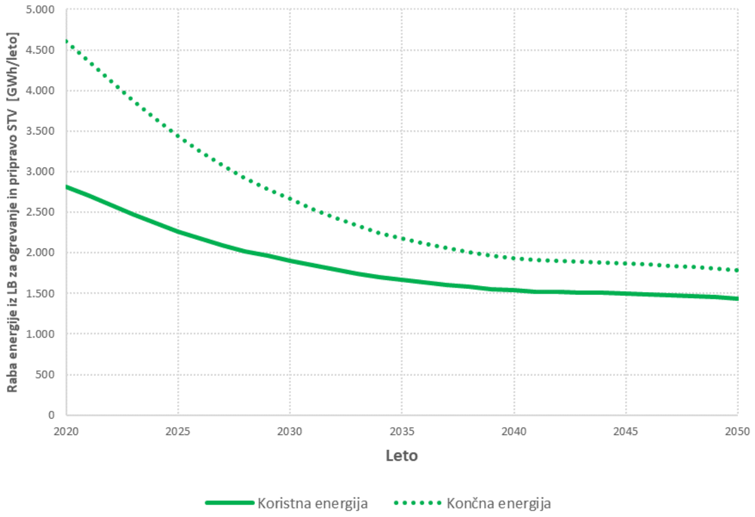

Figure 56: Required final and useful energy from WB for heating and the production of DHW in households 2020-2050

	Use of energy from WB for heating and the production of DHW [GWh/year]
	Year
	Useful energy
	Final energy

The AMA scenario shows that the use of WB for heating and the production of DHW in households will fall sharply until 2030. This fall will then slow until 2040 and will continue, but to a smaller extent, in the subsequent years leading up to 2050. The required useful energy for heating will fall across the entire period from 2 817 GWh in 2020 to 1 434 GWh in 2050 (a fall of 49%). This significant fall in WB use in households is primarily the result of ambitious plans to improve the energy efficiency of housing and replace old wood biomass boilers with new ones, in accordance with the ‘energy efficiency in first place’ principle. In addition to this, measures to improve air quality will continue, which means that wood biomass boilers will be replaced by heat pumps in critical areas.

A spatial analysis of the use of heat for heating in buildings in Slovenia shows that, owing to the considerably dispersed nature of settlement in the country, almost 30% of total heating demand, or 2.6 TWh of useful heat, is in areas with a density of annual heat demand of less than 50 MWh per hectare. There are almost 270 000 buildings in these areas, which is just over 48% of all buildings. Of this number, one-third (more than 135 000 buildings) are located in areas with a density of less than 20 MWh per hectare.[41] Such areas are found in larger urban municipalities (Figure 6) and, to a marked degree, in smaller municipalities (Figure 57). In these areas, the introduction of efficient wood biomass boilers would be logical and environmentally acceptable.

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[41] A density of between 20 and 50 MWh/ha means the presence of between two and three buildings per hectare, which is very sparse settlement.

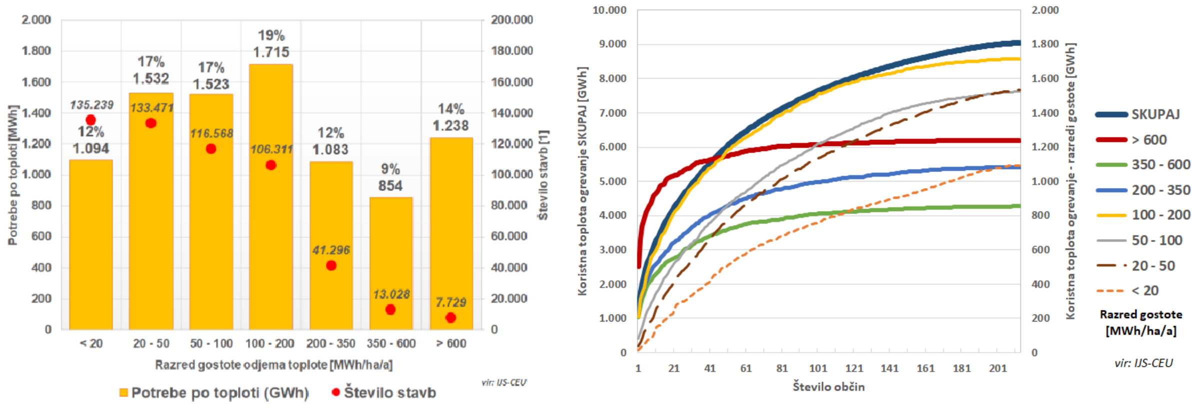

Figure 57: Spatial analysis of the density of annual heat demand for the heating of buildings by class, the number of buildings per class and a cumulative presentation by class for all municipalities (arranged from the municipality with the highest to the municipality with the lowest heat demand)

	Heat demand [MWh]
	Number of buildings [1]
	Heat consumption density class [MWh/ha/a]
	Heat demand [GWh]
	Number of buildings
	Source: IJS-CEU
	TOTAL useful heat for heating [GWh]
	Useful heat for heating – density classes [GWh]
	Number of municipalities
	Density class [MWh/ha/a]

Industry

Owing to the gradual phasing-out of fossil fuels, we are expecting an increase in WB use in the years up to 2050 in industry as well (Figure 58). According to the AMA NECP, current use (a little less than 850 GWh) will increase to almost 1 900 GWh by 2050, mainly as a result of increased CHP using wood biomass. Given the rapid development of WB gasification technologies, use of WB directly in the process industry is also possible.

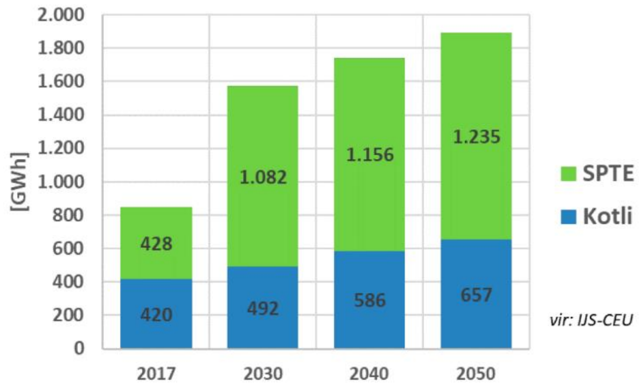

Figure 58: Use of wood biomass in CHP units and boilers in industry 2017-2050 (NECP projection)

	[GWh]
	CHP
	Boilers
	Source: IJS-CEU

District heating

The evaluation of the potential use of WB in district heating systems also takes into account the role of WB in replacing fossil fuels by RES in existing DHS and in the further sustainable development of the entire DH sector with an increase in areas supplied with district heat from existing and new DHS.

In line with these objectives, the NECP (AMA scenario) sets out plans to more than double the use of WB in existing DHS. The use of WB to generate heat and electricity in these systems should therefore increase from 429 GWh in 2020 to 1 040 GWh in 2050, or by 611 GWh (115 000 tonnes of dry matter).

The additional potential for the generation of heat from WB in DHS is based on an analysis of the technical and economic potential of the development of existing DHS (concentration of consumption within existing DHS areas, expansion to new areas) and the construction of new DHS. The assessment of this potential takes into account the methodological approaches presented in Chapter 4.10. The technical potential of useful energy for heating in existing DHS, taking into account only a minimum annual heat demand density of 350 MWh/ha, therefore amounts to between 1 650 and 1 870 GWh/a. The development of existing DHS with the concentration of consumption and expansion to new areas also enables the energy use of WB to be increased in these systems. Taking the conservative estimate into account (i.e. that one third of this potential in existing DHS will be realised through supply from new DHS using WB), the economic potential of useful energy from WB for heating in existing DHS amounts to between 550 and 620 GWh/a[42] (Table 14).

Table 14 : Technical and economic potential of an increase in the use of useful energy from wood biomass generated in district heating systems

Annual heat demand density > 350 MWh/a		**Approach**	
		Connected areas	Even expansion
Existing DHS			
Technical potential	[GWh/a]	1 652	1 870
Economic potential from WB	**[GWh/a]**	**551**	**623**
New DHS and micro DHS			
Economic potential – new DHS	[GWh/a]	417	542
Economic potential – micro DHS	[GWh/a]	476	671
Economic potential (new + micro)	[GWh/a]	893	1 213
Economic potential from WB (new + micro)	**[GWh/a]**	**447**	**607**
Existing, new and micro DHS			
Total economic potential from WB	**[GWh/a]**	**998**	**1 230**

The economic potential of the supply of final energy from new DHS, (including micro DHS) assessed using the two methodological approaches amounts to between 890 and 1 210 GWh/a. Assuming that at least half of the new DHS will be designed as wood biomass district heating systems with CHP, the economic potential of the supply of useful heat from these systems is between 440 and 600 GWh/a. **The total potential of useful energy for heating generated from WB in DHS, i.e. only in areas with a density of annual heat demand of more than 350 MWh/ha, is estimated to be between 1 000 and 1 200 GWh.** In the case of cogeneration of heat (410-540 GWh/a) and electricity only in new wood biomass district heating systems (which are expected to be smaller), electricity generation would amount to between 240 and 290 GWh/a and WB use to between 1 470 and 1 770 GWh/a, or between 277 000 and 333 000 tonnes of dry matter.[43]

Economic potential of wood biomass

- **Final consumption of WB in households will fall by almost 70% to 1.8 TWh by 2050 (from the 2017 figure of 5.4 TWh); this is mainly due to an increase in the efficiency of buildings and boilers. Nevertheless, WB maintains a one-third share of useful heat demand in households and therefore, along with DH and HP, remains an important domestic RES for balanced heat supply over the long term.**
- **Mainly because of an increase in CHP using WB and the development of gasification technology, the potential for consumption of WB in industry is estimated to be**

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[42] The NECP envisages the establishment of new generation installations using woodchips following the abolition of the co-incineration of coal and WB. These installations will generate 390 GWh of DHE and 153 GWh of electricity.
[43] Taking the technical characteristics of ORC CHP generation installations using WB into account.

1.9 TWh by 2050, which is more than double the current consumption of WB in industry (0.8 TWh in 2017).

- **The total current potential supply of heat from WB in existing and new DHS in areas with a density of heat consumption of more than 350 MWh/ha is estimated to be between 1 000 and 1 200 GWh. In light of the planned reduction in useful heat demand in buildings of almost 40% by 2050 as a result of an increase in building efficiency, the potential of heat from WB in DHS in 2050 is estimated to be 0.6 TWh under the NECP alternative scenario, which is double the 2017 figure.**

4.7 Heating and cooling potential of solar energy

The rapid development and reduction in the costs of solar power plants (SPP) means that the generation of electricity from solar power has already overtaken the generation of heat using solar energy collectors (SEC) in Slovenia in recent years. SPP are already achieving lower costs per unit of electricity generated. At the same time, that electricity can be used for a variety of purposes, i.e. not only for heating or the production of domestic hot water. For this reason, future development will focus on SPP as a matter of priority. Nevertheless, it would make sense to continue to use SEC, as they do not place a strain on the electricity network and, at the same time, it is much easier and cheaper to store the heat generated.[44] They therefore complement generation by SPP, particularly in areas served by a weaker network. The analysis therefore focused as a matter of priority on an assessment of the potential of SPP in heating using heat pumps. An assessment is also made of the potential for the development of SEC.

4.7.1 Solar power plants

This chapter presents the main results of the analysis of the suitability of utilising solar energy on the rooftops of existing buildings for the heating and cooling of Slovenia's housing stock (940 000 buildings). The analysis has been drawn up for 2020 and 2050, and also takes account of the expected changes in solar radiation resulting from climate change and of improvements in the technologies over that 30-year period. The energy demand for heating and cooling is taken into account for each building separately at the annual level. It is then broken down by month, with due regard to the temperature deficit/excess of the region in which the building is located. The figures are based on a typical meteorological year. The monthly generation of electricity using rooftop SPP has also been estimated using a similar method. The estimate of the needs for the cooling of buildings takes into account night time passive cooling and ventilation, which further reduces energy demand. The analysis is based on publicly accessible databases (property register, energy performance certificates, Eco Fund) and data resulting from the use of established methods (e.g. calculation of the heat required for heating) and original data. For the purpose of the analysis, the buildings were divided into three groups in terms of their purpose: residential buildings (single- and multi-family houses), public buildings (e.g. healthcare, administration) and private buildings (e.g. restaurants, hotels).

Climate modelling

Slovenia has 23 meteorological stations for which a typical meteorological modelling year exists.[45] It therefore makes sense to use the statistics already established on a region-by-region basis. Using data for typical meteorological years for individual regions makes it possible to produce an accurate calculation of the temperature deficit/excess for each building relative to its location (Figure 59).

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[44] The aspect of storage is a current one in classic heat storage tanks in buildings, particularly in the case of seasonal storage for large buildings with low-temperature heating and district heating systems.

[45] National meteorological service. meteo.si. National meteorological service. [Electronic] Slovenian Environment Agency, 2017. http://meteo.arso.gov.si/met/sl/climate/.

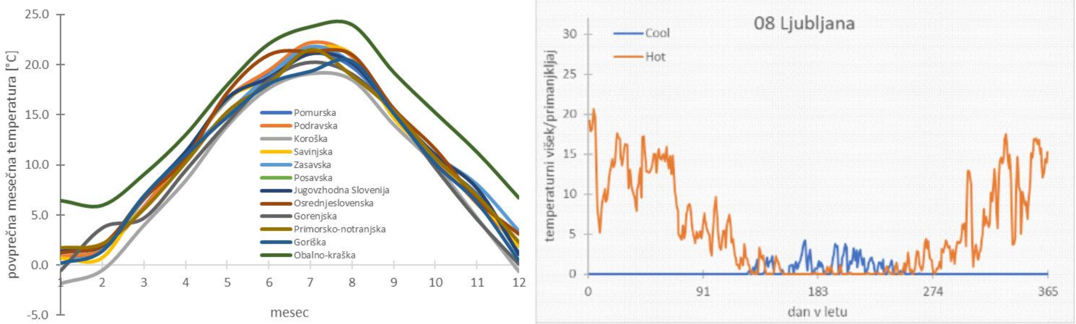

Figure 59: Average monthly temperature by region (left) and temperature deficit/excess in the Central Slovenia (Osrednjeslovenska) statistical region (right)

	Average monthly temperature [°C]
	Pomurska
	Podravska
	Koroška
	Savinjska
	Zasavska
	Posavska
	South-Eastern Slovenia (Jugovzhodna Slovenija)
	Central Slovenia (Osrednjeslovenska)
	Gorenjska
	Primorsko-Notranjska
	Goriška
	Obalno-Kraška (Coastal-Karst)
	month
	temperature excess/deficit
	day in year

Heat and cold demand

The heat or cold demand of each property[46] is divided into individual months, where the monthly temperature deficit was considered in the form of the weighting function J, and the Coefficient of Performance is also taken into account (assumed value of 2-4):

$$E^{heating}(region, month) = E^{heating}_{annual} \cdot \beta_{heating}(month, region)$$

$$E^{cooling}(region, month) = E^{cooling}_{annual} \cdot \beta_{cooling}(month, region)$$

Figure 60 presents the weighted function G for heating (left) and cooling (right), by region and month.

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[46] The required heat and cold for HC is calculated for each building in Slovenia on the basis of the building typology originally drawn up as part of the IEE TABULA project, as most recently updated and upgraded as part of the LIFE ClimatePath2050 project. Based on the typology, a building is ascribed an indicator of the required heat for heating in relation to the age of the components of its thermal envelope (external walls, roof, windows) and year of construction.

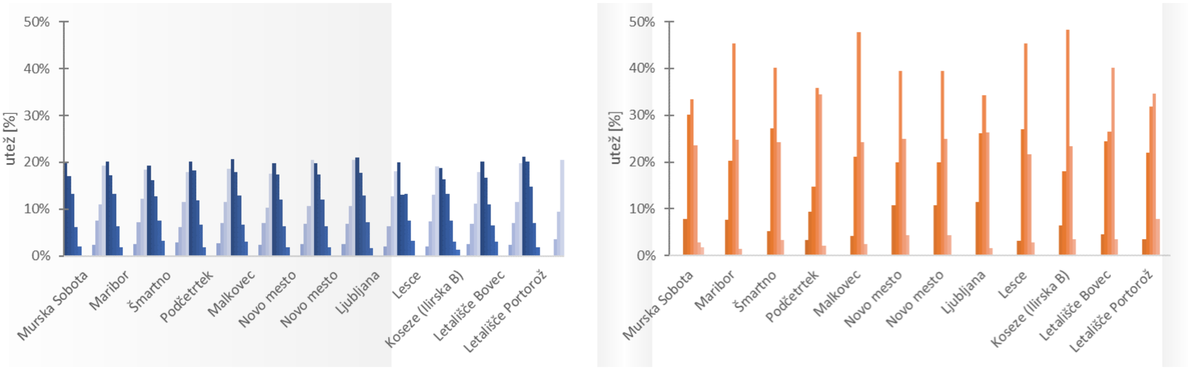


Figure 60: Weighted function for heating (left) and cooling (right), by month and region

	weighting [%]
	Bovec airport
	Portorož airport

Assessment of electricity generation by solar power plants

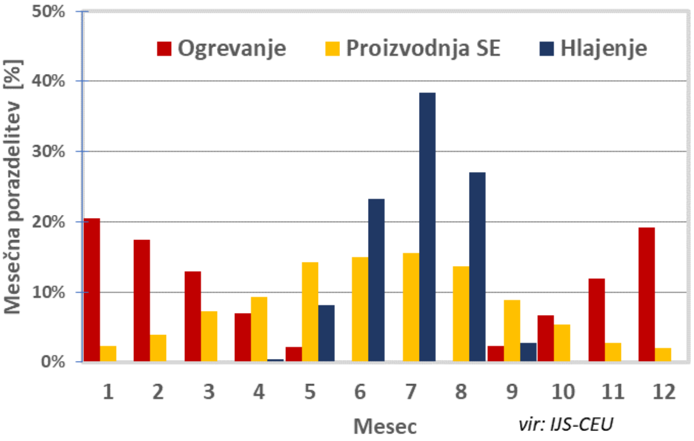
The electricity generated by solar power plants installed on the rooftops of existing buildings was taken into account as a source for covering needs for the heating and cooling of buildings. The energy must suffice for monthly total consumption of:

$$\forall month\colon E_{gen} \geq E^{heating}(region, month) + E^{cooling}(region, month)$$

The following statistical approach has been used to calculate electricity generation from solar energy:[47]

$$E(A) = A_{rooftops} \cdot \varepsilon_{rooftops} \cdot E_{region}(\gamma) \cdot \varepsilon_{PV}(\gamma) \cdot COP(T)$$

Where A_{roof} is the surface area of the roof, $\mathcal{E}_{roof}$ is the percentage of the roof that can be utilised, E_{region} is the average solar radiation received by the roof (in the region) and $\mathcal{E}_{PV}$ is the efficiency of the PV panel (together with the other parts of the solar power plant). Between 40 and 42% of a rooftop can be utilised, and Slovenia's average annual solar radiation in 2015 was 1 240 kWh/m^2. This is increasing because of climate change. The projection for 2050 also takes into account improvements to efficiency $\mathcal{E}_{PV}$ relative to the NREL data (from 16 to 25%[48]). Figure 61 shows the average monthly distribution of annual heating and cooling demand and the generation of electricity by solar power plants.



vir: IJS-CEU

Figure 61: Monthly distribution of annual heating and cooling demand and the generation of electricity by solar power plants

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[47] Marko Kovač, Andreja Urbančič, Damir Staničič. Deliverable C1.1: Climate Mitigation 2050 Potentials and Mid-term Challenges Part 5B: Photovoltaic Rooftop Potential in Slovenia by 2050. IJS-DP-12619, Version 1.0 Ljubljana: Institut Jožef Stefan, June 2018.

[48] Photovoltaic Research. National Renewable Energy Laboratory. [Electronic] NREL, 2017. https://www.nrel.gov/pv/.

	Monthly distribution [%]
	Heating
	SPP generation
	Cooling
	Month
	Source: IJS-CEU

SPP development scenarios in line with the NECP

The levels of theoretical energy potential from rooftop SPP have so far been estimated as extremely high (in excess of 25 TWh of electricity annually).[47] Actual market developments and the realistic possibility of gradual SPP construction should be taken into account when estimating market potential. This was analysed in detail in the expert groundwork produced for the preparation of the NECP, with three scenarios for the development of rooftop SPP in Slovenia being drawn up in relation to the intensity of support:

- with existing measures (EM);
- with additional measures (AM); and
- additional measures, ambitious (AMA) – **NECP scenario.**

Figure 62 shows the envisaged installed power and annual output of rooftop solar power plants 2020-2050 for all three scenarios.

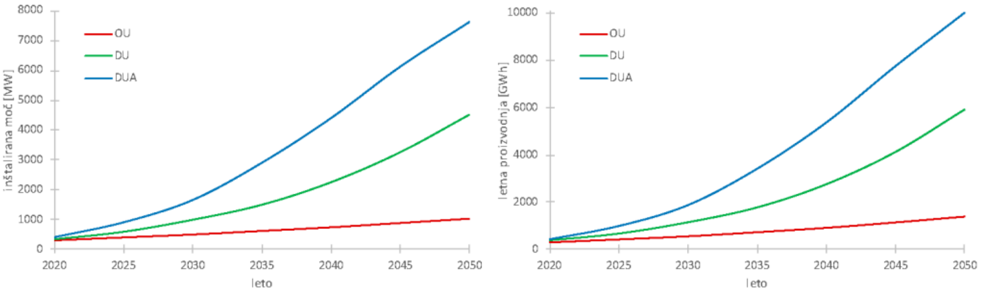

Figure 62: Envisaged installed power and annual output of rooftop solar power plants 2020-2050

	installed power [MW]
	EM
	AM
	AMA
	annual output [GWh]
	year

Potential and balances

In the analysis of the potential of SPP located on the roofs of heating and cooling facilities, the following were considered in relation to the three scenarios (EM, AM and AMA-NEPN) produced as part of the expert groundwork for NECP:

- **scenarios of HC demand** in buildings (in relation to intensity of renovation);
- **SPP development scenario** up to 2050.

The months of December, January and February, which together account for over 60% of annual demand, are the stand-out months as far as the heating of buildings is concerned (there is considerably less heating in the other months of the year). Cooling demand is concentrated (to an even more marked extent) in the months of June, July and August.[49] Owing to the intensity of the introduction of energy efficiency measures in all three scenarios, the differences between HC needs are comparatively small, while the differences between the

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[49] The actual amount of cooling of buildings and, consequently, the final energy required for cooling depends on whether apartments are equipped with cooling appliances. According to the projection produced, the number of apartments with cooling devices will rise from 18 to 30% between 2020 and 2050.

scenarios for the generation of electricity using SPP are significantly greater. Figure 63 shows the absolute deficit of heat generated using heat pumps compared to electricity generated by rooftop SPP in relation to monthly demand for heating (left) and cooling (right) in 2020 (top graph), 2030 (second graph), 2040 (third graph) and 2050 (bottom graph) for all three scenarios. The results show that only under the most ambitious NECP scenario (AMA) would the energy obtained from solar power plants suffice for heating using heat pumps by 2050, although for the cooling of buildings this would happen by 2030. Cooling is slightly less problematic, as it requires less energy and, because the output levels of SPP are highest during the cooling season, there is less need to store the energy. Buildings would therefore be able to achieve self-sufficiency very quickly.

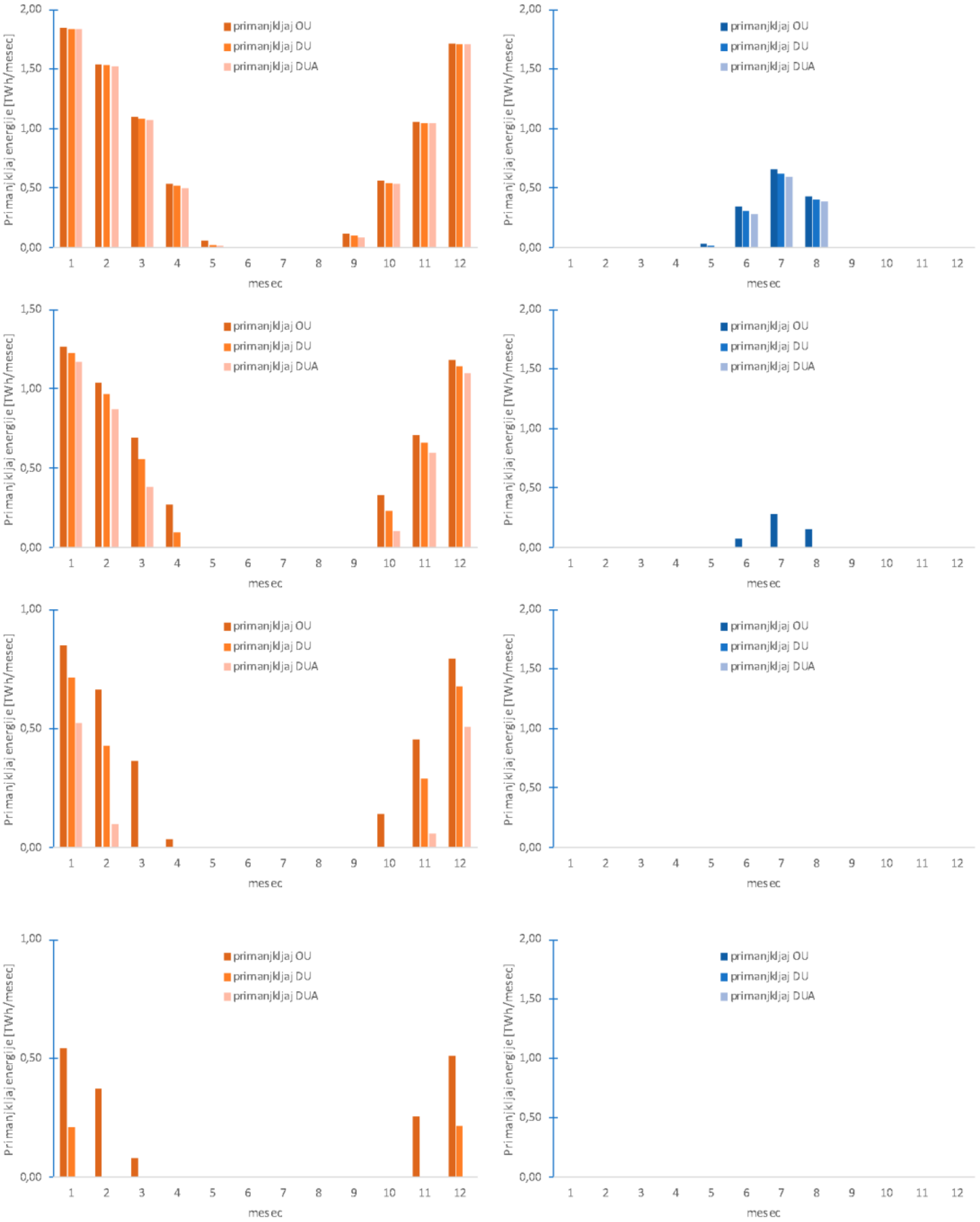

Figure 63: Deficit of energy from solar power plants on the roofs of facilities, by month for heating (left) and cooling (right) for 2020, 2030, 2040 and 2050 (in sequence downwards)

	Energy deficit [TWh/month]
	EM deficit
	AM deficit
	AMA deficit

	month

The results show that the electricity output from rooftop SPP does not yet suffice to meet all building heating and cooling needs using heat pumps. The biggest energy deficit is, as expected, in the months of December to February (for heating, with an increase in SPP capacity of approximately 800% required) and from July to August (for the cooling of buildings, with an increase in SPP capacity of 150%).[50]

Table 15 presents the deficit of heat generated using heat pumps with electricity from rooftop SPP set against annual demand under the three scenarios (EM, AM and AMA) between 2020 and 2050. It should also be pointed out that the analysis has been produced with reference to monthly balances. For greater precision in the coverage of demand, daily balances would also have to be taken into account, showing the need for the use of electricity and heat storage facilities, as well as additional investments in the network for the predominant use of HP for heating.

Table 15: Deficit of generated heat with rooftop electricity installations set against monthly demand

		Heating [TWh]				Cooling [TWh]				Total [TWh]	
Year	Scenario	Heating demand	Heat generated with electricity SPP	Deficit/Surplus	Solar contribution	Cooling demand	Cold generated with electricity SPP	Deficit/Surplus	Solar contribution	Heat and cold generated	Electricity generated SPP
2020	**EM**	9.1	0.5	-8.6	5%	2.1	0.5	-1.6	24%	**1.0**	**0.3**
2030	**EM**	6.4	0.9	-5.5	14%	1.5	0.9	-0.6	63%	**1.8**	**0.6**
	AM	6.4	1.8	-4.6	28%	1.5	1.9	0.4	100%	**3.7**	**1.1**
	AMA	6.4	3.0	-3.4	47%	1.5	3.1	1.6	100%	**6.1**	**1.9**
2040	**EM**	4.5	1.4	-3.0	32%	1.0	1.5	0.5	100%	**2.9**	**0.9**
	AM	4.5	4.4	-0.1	98%	1.0	4.6	3.6	100%	**9.0**	**2.7**
	AMA	4.5	8.5	4.1	100%	1.0	9.0	7.9	100%	**17.5**	**5.4**
2050	**EM**	3.1	2.2	-0.9	70%	0.7	2.3	1.9	100%	**4.5**	**1.4**
	AM	3.1	9.4	6.3	100%	0.7	9.9	9.5	100%	**19.3**	**5.9**
	AMA	3.1	15.9	12.8	100%	0.7	16.7	16.4	100%	**32.6**	**10.0**

The analysis confirms that solar energy has great potential. With the increase in the installed power of solar power plants, there will also be a gradual increase in the amount of electricity generated in the winter and transitional months. According to the NECP scenario, SPP will already be capable of generating almost 50% of the required electricity in the three most critical winter months by 2030 (and more than is required in the transitional months), and all the electricity required for efficient heating using HP in 30% of buildings in the winter months by 2040 (Table 16). As SPP generate almost 45% of electricity in the three summer months, according to the NECP scenario they will already be capable of also providing the electricity required for cooling during the summer by 2025 (Table 16).

Table 16: Distribution of annual electricity for heating and cooling and the generation of electricity by solar power plants, by period – current situation and the NECP scenario

HP – annual demand for electricity for HC SPP – annual electricity output			2017			2030			2040		
			EL-HP	EL-SPP	Share of SPP	EL-HP	EL-SPP	Share of SPP	EL-HP	EL-SPP	Share of SPP
	HP share	**SPP share**	**290**	**284**		**573**	**1 866**		**641**	**5 361**	
Winter months (Dec-Feb)	**57%**	**8%**	166	23	**14%**	327	151	**46%**	366	434	**119%**
Transitional period 1 (Mar, Oct, Nov)	**32%**	**15%**	92	44	**48%**	181	286	**158%**	202	822	**406%**
Transitional period 2 (Apr, May, Sept)	**11%**	**32%**	33	92	**281%**	65	606	**935%**	72	1 740	**2 401%**
Summer (Jun, Jul, Aug)	**100%**	**44%**	**262**	**125**	**48%**	**260**	**823**	**317%**	**335**	**2 364**	**706%**

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[50] In addition to the increase in SPP capacity and in the efficiency of HC appliances, the expected considerable reduction in specific energy demand for heating per apartment will make a considerable contribution to reducing the deficit (to only around half of today's demand, owing to technological improvements and climate change).

In assessing the economic potential of SPP from the point of view of heating, we are looking for the most optimal mixture of district heat supply (economics of the utilisation of waste heat and RES) and other RES (mainly wood biomass) relative to the required investments and the limitations imposed by the electricity grid. The analysis produced confirms that SPP generation will be unable for some time to provide sufficient electricity for fully electric heating in the winter months (the electricity distribution grid is a further hindrance in this regard). Provision will therefore have to be made for the balanced development of a wider range of sustainable technologies (particularly DHS in more densely populated areas and efficient WB appliances in more sparsely populated areas). This will enable us to achieve our objectives more quickly and at lower cost. As far as their planned development is concerned, SPP will, alongside the introduction of all types of storage facility, provide important support to the accelerated introduction of efficient HP for heating. By 2040 the plants will be capable of providing around one third of all required heat supply in buildings.

Economic potential of solar power plants for district heating and cooling

- **According to NECP projections, the amount of electricity generated by SPP in the most critical heating months (December, January and February) will have increased to almost 150 GWh by 2030, to more than 430 GWh by 2040 and to more than 800 GWh of electricity by 2050. Output in transitional periods (March, October and November) will almost double. This means that, with the gradual introduction of different storage facilities for the daily balancing of electricity, at least 30% of heat demand in buildings during the winter months may be covered by electricity from SPP and HP by 2040.**
- **Generation using SPP already covers 50% of the estimated electricity demand for the cooling of buildings in the summer months and will, according to NECP projections, be capable of providing all the required electricity for the efficient cooling of buildings in Slovenia already by 2025.**

4.7.2 Solar energy collectors (SEC)

Despite the advantages of SPP over SEC referred to above, the latter remain a sustainable technology for heating and the production of DHW in all sectors because they are already well-established, More than 95% of the estimated installed capacity of almost 250 000 m^2 is in households. However, since the breakthrough of solar energy after 2010, installation has fallen from 20 000 m^2 a year to less than 1 500 m^2 a year.[51] Solar power plants contribute a total of around 130 GWh of heat a year. Despite the uncertainty regarding their future development, this figure should more than double by 2050 according to NECP projections (to almost 290 GWh or 555 000 m^2)[52] with the more rapid growth in the service sector and low-temperature DHS in particular.

Given the economics of SEC in comparison with SPP and the rapid growth in the efficiencies of compressor cooling systems, the use of absorption and adsorption solar cooling systems is less promising than SPP, which remain an attractive solution mainly where other waste heat sources are available for cooling.

4.8 Deep geothermal energy potential

More than 160 GWh of heat was obtained through the direct use of deep geothermal energy (GEO) in Slovenia in 2017 (the capacity of installations at 31 locations is 62 MWt). Eighty per cent of this was in services (particularly health tourism, and the remainder in agriculture, where use has increased rapidly in recent years), and around 3% in DHS.

Deep GEO has particularly significant potential in the north- and south-east parts of the country, where temperatures at a depth of 1 km below ground are more than 50°C (Figure 64). A 90°C isotherm is located at a depth of around 1 500 m, utilisation of which is extremely promising from an economic point of view (Figure 65).

An indicative estimate was also made of the future development of deep GEO for the heating of buildings and in agriculture as part of the expert groundwork produced for the NECP. Use of this energy could already increase

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[51] Only SEC subsidised by the Eco Fund are included in the assessment.

[52] Even if circumstances dictate that solar energy collectors do not come into use because they are replaced by SPP, the estimated potential of the use of solar energy for heating, particularly domestic hot water, is realistic and feasible.

by more than 70% by 2030, with at least 300 GWh of heat being produced by 2050. The estimate did not include the potential generation of electricity, which could significantly increase the volume of use of this resource through the efficient cascade use of GEO.

The estimated demand for useful heat for the heating of buildings in the Pomurska region, which has the highest GEO potential, is currently a little less than 600 GWh: 110 GWh in areas with an annual heat demand density of more than 200 MWh/ha, which already provides the conditions for the cost-effective introduction of district heating, and almost 70 GWh in areas with a density of more than 350 MWh/ha. Heating demand in the Podravska region, which has the next highest GEO potential, is almost three times greater. The estimated useful heat for the heating of buildings in areas with a density of more than 350 MWh/ha is almost 300 GWh.

In a bid to remove certain obstacles and accelerate the use of GEO, the government adopted a resolution in April 2021 ordering the competent ministries to carry out a variety of measures for the efficient and multi-purpose use of GEO in Slovenia, at the same time preserving the quantitative and qualitative status of groundwater (deep and shallow aquifers).[53]

Economic potential of deep geothermal energy

- **According to NECP estimates, the deep geothermal energy potential by 2050 is at least 300 GWh of heat in buildings, services and agriculture. The potential for electricity to be generated could further substantially increase this amount through the efficient cascade use of GEO.**
- **Activities to remove obstacles and provide a supportive environment must be continued if a more detailed assessment is to be made and the feasibility of the economic potential of deep GEO is to be accelerated.**

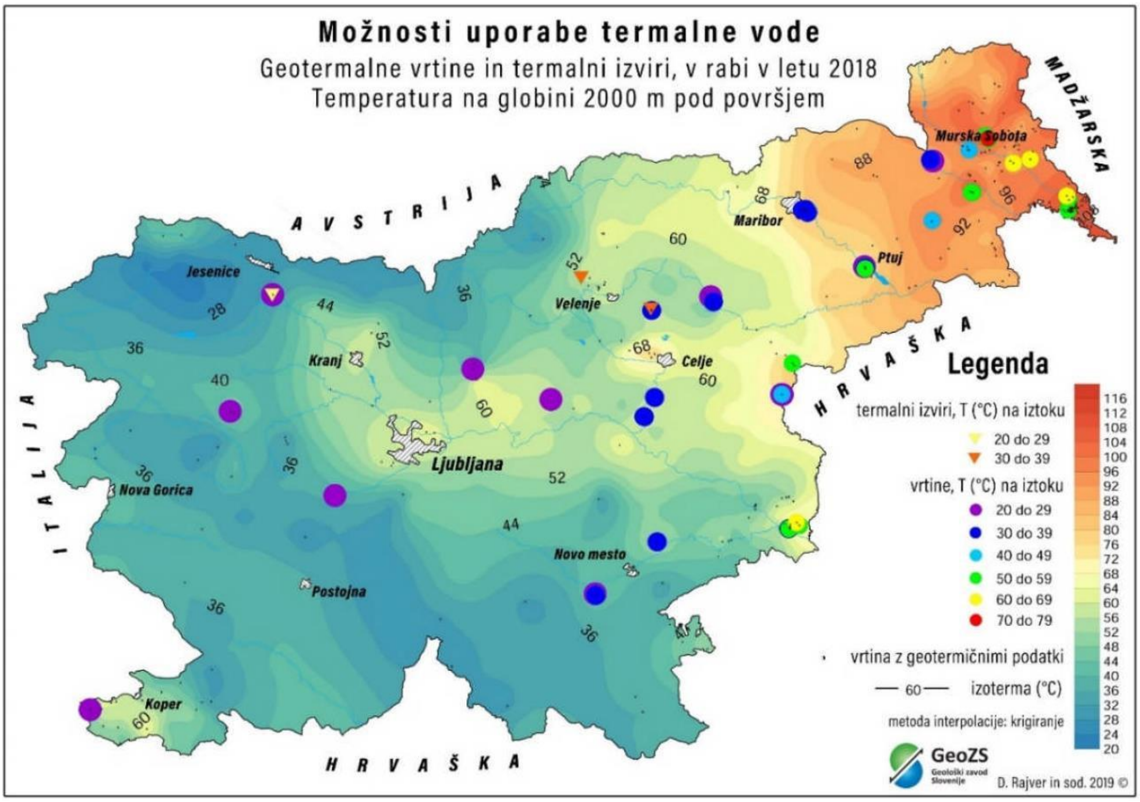

Figure 64: Deep geothermal energy potential in Slovenia – geothermal boreholes and thermal springs in use in 2018 (source: Geological Survey of Slovenia).

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[53] Appointment of a coordinator and the creation of an interdepartmental group to ensure that information is publicly available, draft guidelines, technical requirements and the bases for the installation of a geothermal economic power plant for demonstration purposes, upgrade the monitoring process, etc.

	Potentials for using thermal water
	Geothermal boreholes and thermal springs in operation in 2018
	Temperature at a depth of 2 000 m below ground
	HUNGARY
	AUSTRIA
	ITALY
	CROATIA
	Key
	thermal springs, T (°C) at the outlet
	20 to 29
	30 to 39
	boreholes, T (°C) at the outlet
	20 to 29
	30 to 39
	40 to 49
	50 to 59
	60 to 69
	70 to 79
	borehole with geothermal data
	isotherm (°C)
	method of interpolation: kriging
	Geological Survey of Slovenia
	D. Rajver et al. 2019 ©

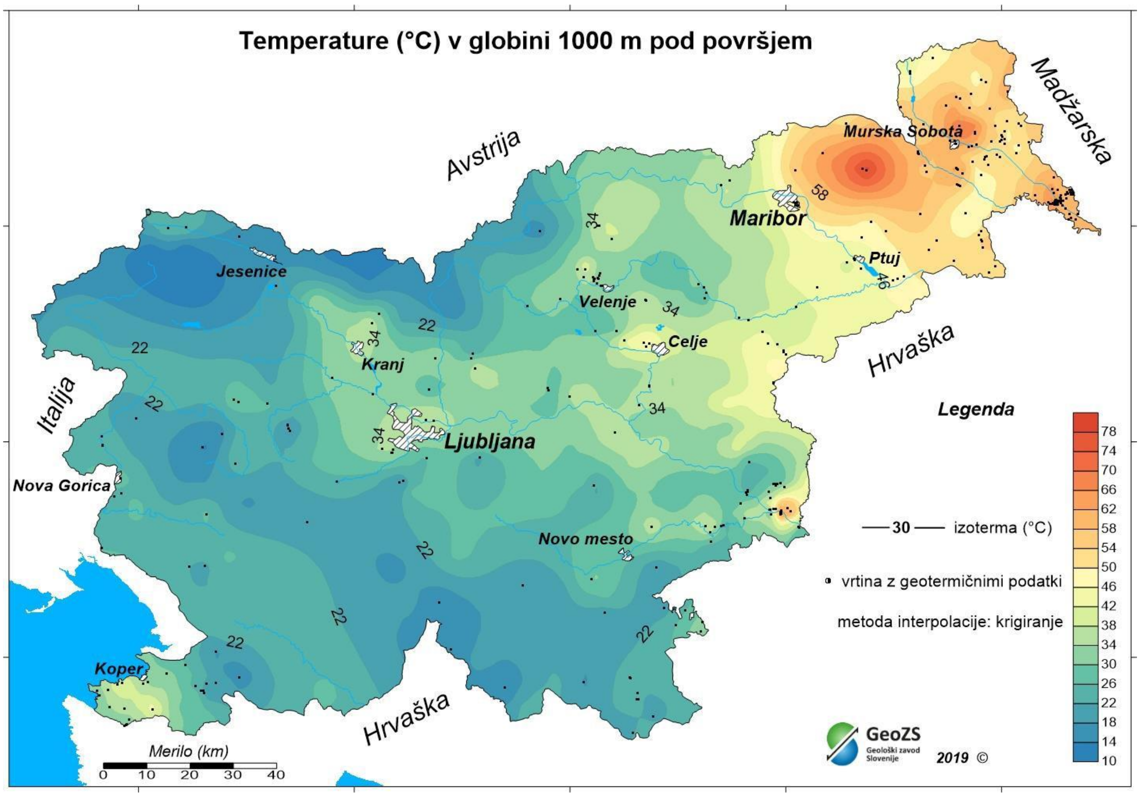

Figure 65: Deep geothermal energy potential in Slovenia – temperatures at a depth of 1 km below ground (source: Geological Survey of Slovenia)

	Temperature (°C) at a depth of 1 000 m below ground
	Austria
	Hungary

	Italy
	Croatia
	Key
	isotherm (°C)
	borehole with geothermal data
	method of interpolation: kriging
	Scale (km)
	Geological Survey of Slovenia
	2019 ©

4.9 Heat pump potential

An analysis of the economic potential of heat pumps is divided, according to the resource used, into geothermal HP, HP that recover heat from the ambient air, and HP for the recovery of waste heat.

4.9.1 Geothermal heat pumps

The potential for utilising shallow GEO is present across almost the entire territory of Slovenia. Given the geological structure of the ground, closed-loop systems (vertical geoprobes to a depth of 100-150 m and horizontal collectors and baskets at a depth of around 1.5 m[54]) and open-loop systems for the utilisation of groundwater (water protection zones must be avoided) are suitable, as shown in Figure 66.

The high efficiency levels resulting from the higher ground temperatures, which are practically independent of the ambient air temperature, are the main advantage of geothermal HP. Even in the coldest periods, they operate at a high level of efficiency, which is particularly important from the point of view of the peak load of the electricity grid when temperatures are at their lowest. Owing to the higher investment costs (costs of boreholes and earthworks) in comparison with HP that recover heat from the ambient air, geothermal HP are attractive from an economic point of view mainly in larger buildings in areas without DHS and at locations with higher heat demand (industry, supply of heat from DHS, agriculture, cultural heritage buildings on which energy renovation cannot be performed, etc.).[55] As part of the LIFE ClimatePath2050 project, a detailed analysis was carried out of shallow GEO potential that took into consideration the exclusion zones for different types of HP and building types, with modelling in all densely populated areas in which there are interactions and limitations resulting from the operation of several geothermal heat pumps in close proximity to each other. The results are shown in Figure 67. They confirm that there are no major limitations in utilisation, particularly in the case of the supply of larger energy-efficient buildings.[56] Geothermal HP also demonstrate considerable potential when it comes to efficient cooling in the summer months through the use of low-temperature RES. A more stable temperature status is maintained for aquifers and soil with cooling and heat recovery in the summer months. This increases the potential for heating in the winter months.

We estimate that geothermal HP in buildings (water-to-water and ground-to-water) generated more than 300 TWh of heat in 2017, almost 60% of this in the service sector. The amount of heat generated could double to at least 750 GWh by 2050 according to the NECP scenarios.

The economic potential of geothermal heat pumps was also estimated for district heating systems, where they could generate at least 300 GWh of DHE by 2050, mainly through the use of water-to-water HP (larger aquifers, mine water, rivers, lakes, etc.)

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[54] Built structures, such as building foundations, tunnels, mine shafts, etc. may also be used as the heat exchangers.

[55] This is also confirmed by data from the Eco Fund, which shows that the power of geothermal HP is greater and is continuing to increase: in 2020, 230 water/water HP were installed with an average power of more than 21 kW_t (in households 17 kW_t, in companies 126 kW_t).

[56] There would be limitations only in the event of a larger number of smaller buildings using geoprobes.

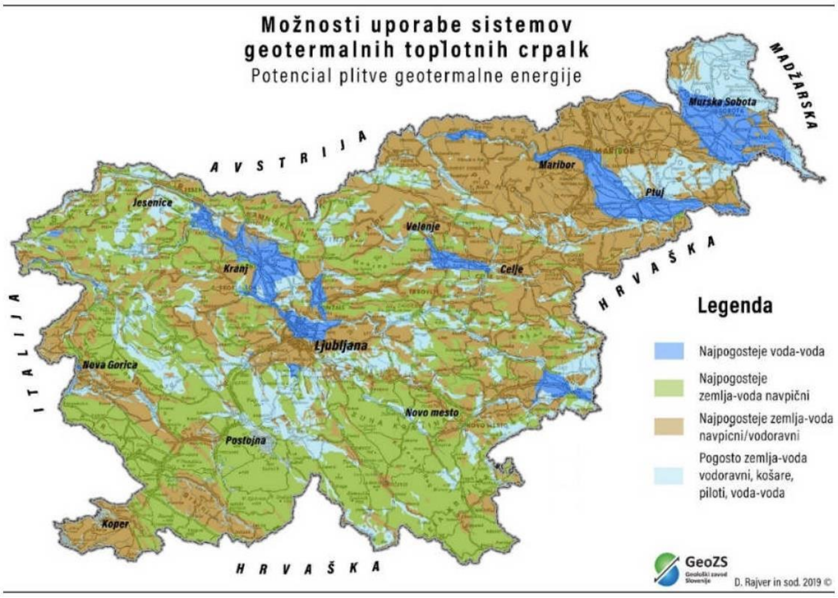

Figure 66: Shallow geothermal energy potential in Slovenia (source: Geological Survey of Slovenia)[57]

	Potential for the use of geothermal heat pump systems
	Shallow geothermal energy potential
	AUSTRIA
	HUNGARY
	ITALY
	CROATIA
	Key
	Most commonly water-to-water
	Most commonly earth-to-water vertical
	Most commonly earth-to-water vertical/horizontal
	Frequently horizontal ground-to-water, baskets, pilot, water-to-water
	Geological Survey of Slovenia
	D. Rajver et al. 2019 ©

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[57] Report of the working group tasked with dealing with the issue of efficient and multi-purpose use of geothermal energy, draft government decision, 12 April 2021.

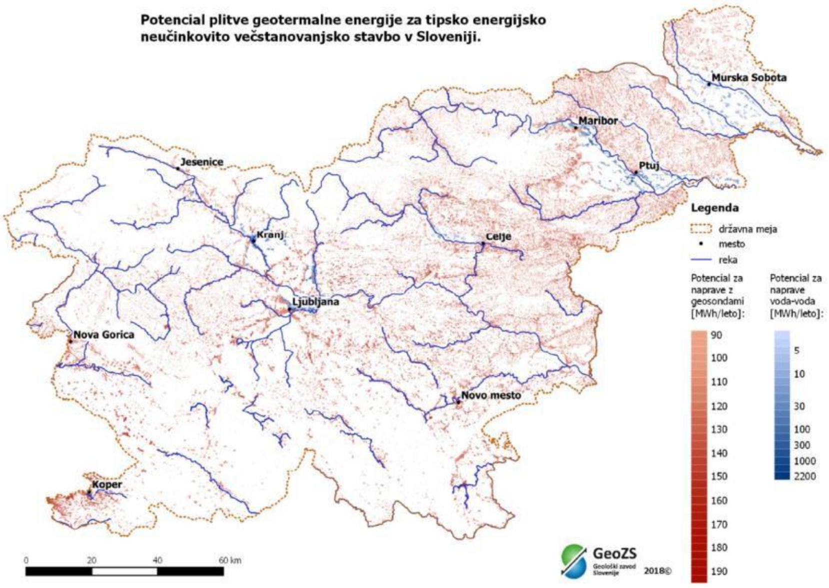

Figure 67: Shallow geothermal energy potential in Slovenia for multi-family houses (source: Geological Survey of Slovenia)[58]

	Shallow geothermal energy potential for standard energy-inefficient multi-family houses in Slovenia.
	Key
	national border
	town
	river
	Potential for geoprobe appliances [MWh/year]:
	Potential for water-to-water appliances [MWh/year]:
	Geological Survey of Slovenia
	2018 ©

4.9.2 Heat pumps for the recovery of heat from the ambient air

In the last few years, rapid technological development has reduced investment costs and increased the efficiency of heat pumps that recover heat from the ambient air. This has greatly increased their competitiveness (and consequently their numbers) in recent years. In terms of numbers and total power, they account for around 90% of all newly installed HP in Slovenia.[59]

We estimate that HP that recover heat from the ambient air in buildings generated more than 500 TWh of heat in 2017, mostly in households. The amount of heat generated could double by 2030 and, according to the NECP scenarios, increase to at least 1.2 TWh (or to almost 20% of all useful heat demand in buildings) by 2050.

From a technical point of view, the potential for using HP to recover heat from the ambient air in smaller buildings in more sparsely populated areas is practically unlimited, although the weak electricity distribution grid could present an obstacle (it is currently not yet dimensioned for the supply of such large amounts of power to all customers). A further challenge is presented by electricity supply in the winter months after the phasing-out of fossil fuels at thermal electricity generation installations, which could increase the price of electricity considerably during the heating season, thereby reducing the cost-effectiveness of HP. From this point of view, it would make sense to engage in the concerted and balanced installation of HP that recover heat from the ambient air at the same time as wood biomass boilers are replaced and new clean and efficient boilers capable of competing with HP in terms of cost are installed. This coordinated development will keep heat-supply costs at the lowest level. These heat pumps for district heat are the first priority for smaller buildings in more densely

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[58] Analysis of the shallow geothermal energy potential in Slovenia up to 2050, LIFE ClimatePath2050 project, Geological Survey of Slovenia, 2018.

[59] Eco Fund data for 2017-2020. In 2019 and 2020, around 5 600 heat pumps of this type were installed with the help of Eco Fund subsidies in both years, the majority in households (average power 10 kW_t).

populated areas, as the levels of noise produced by new HP models have fallen considerably, thus enabling them to be used in areas of dense construction as well.

An overall presentation of the economic potential of HP in buildings is given in Figure 68. Rapid development by 2030 goes hand in hand with the intensive renovation of buildings in this period, after which the growth trend will slow slightly. As the situation develops, total volumes could even be higher. From the point of view of efficiency, development should be focused on geothermal HP in all areas where this is economically feasible (particularly in larger buildings).

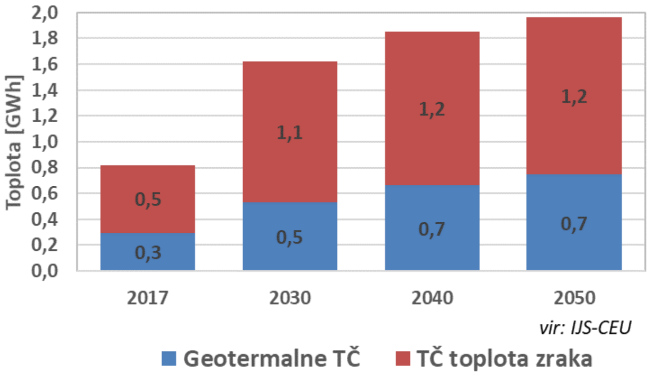

Figure 68: Assessment of economic potential of heat generation up to 2050 with heat pumps in buildings

	Heat [GWh]
	Source: IJS-CEU
	Geothermal HP
	Ambient air HP

Most of the heat pumps that recover heat from the ambient air are of the reversible type, which means that they can also be used for cooling in the summer months. As regards the dimensioning of HP to match the greater heating demand (particularly in residential buildings), their use for cooling usually requires additional adjustments to be made (installation of cold storage facilities, additional equipment and pipes for the cooling of rooms, etc.). These adjustments are currently considerably more expensive than the cooling of individual rooms using separate air-conditioning appliances (air-to-air HP using a split system). With the increase in cooling demand, greater use of heat storage for greater flexibility of HP operation and the development of solutions for central cooling, we expect an increase in their use for the cooling of smaller (residential) buildings as well.

The increasing efficiencies of split system air-to-air heat pumps and their ability to also operate at lower temperatures provide an important potential for efficient local heating, as an alternative to direct electric heating (electric radiators, IR panels, etc.), and the possibility of efficient heating in the transitional period in the event of their priority use for the cooling of rooms.

4.9.3 Heat pumps that recover waste heat

From the point of view of energy efficiency, the utilisation of WH in all sectors is a priority. However, this area has not yet been researched or developed in detail in Slovenia, which means that greater attention needs to be paid to it in the coming years.

We estimate that by using heat pumps that recover WH in industry and services, we could meet most of the demand for industrial low-temperature heat (300 GWh in industry) and the heating of buildings in companies with WH potential. HP will also play an important role in exploiting the assessed WH potential in district heating systems. They could, by 2050, provide at least 125 GWh of district heat (directly and with the use of high-temperature HP – particularly in district heating systems, which require a higher temperature regime for operation).

Economic potential of heat pumps

- **Heat pumps will, over the long term, become the largest source of heat supply in**

buildings, accounting for at least 30% (or 2 TWh of useful heat) by 2050.

- **According to NECP estimates, the economic potential of heat generation using shallow GEO HP is at least 750 GWh of heat in buildings and at least 300 GWh in DHS by 2050.**
- **The economic potential of HP for the recovery of ambient heat in buildings will more than double by 2030 to an estimated 1.1 TWh. According to the NECP scenarios, this will increase to almost 1.2 TWh (or to almost 20% of all useful heat demand in buildings) by 2050.**
- **Owing to the greater efficiency for heating and cooling purposes, and the fact that they are almost wholly independent of meteorological conditions, shallow GEO HP have an important qualitative advantage over air-to-water HP. It therefore makes sense to introduce these heat pumps mainly in larger buildings in order to increase efficiency and relieve pressure on the electricity network.**
- **In industry, heat pumps could, by harnessing WH, provide the majority of demand for low-temperature heat for technology and heating (300 GWh) and, together with the direct use of WH, at least 125 GWh of district heat in district heating systems.**

4.10 District heating and cooling potential

Despite the considerable dispersal of settlement in Slovenia and the fact that the country has almost 100 district heating systems, selling around 2 TWh of district heat annually, we estimate that there is still unutilised economic potential for expanding existing systems and constructing new smaller (micro) DHS. The volume of district heat sold for the heating of buildings and for domestic hot water in households and services fluctuates between 1.5 and 1.6 TWh,[60] which currently represents 14% of the total estimated heat demand for heating and the production of DHW in buildings, or 11% in households and 26% in services.

With the help of the Slovenia heat map, the estimate of the economic potential of DHS was produced across four steps and using various economic efficiency criteria. An indicative estimate for the development of district cooling was then given in the fifth step.

1. Annual heat demand density of all buildings in 100 x 100 m cells

An analysis of the density of annual heat demand using a heat map and calculation with 100 x 100 m (1 ha) cells for the whole of Slovenia for 2017,[61] with the cells being divided into seven density classes and the total heat demand calculated for each class (Table 17), shows that:

- more than 50% of the heat demand in buildings or 5 TWh in cells with a density of more than 100 MWh/ha;
- more than 35% (or 3.2 TWh) in cells with a density of more than 200 MWh/ha.

These are areas that are economically attractive for DHS.

Annual heat demand in the cells with the greatest annual heat demand density stands at 2.1 TWh (over 350 MWh/ha) or 1.2 TWh (over 600 MWh/ha). Most of this is found in urban municipalities that already have DHS (1.4 TWh or a 61% share of areas with a density exceeding 350 MWh/ha, and 0.9 TWh or a 75% share of areas with a density exceeding 600 MWh/ha). The remaining demand is divided almost equally between municipalities with DHS and municipalities without DHS. The total heat demand in the two classes with the highest density (over 350 MWh/ha) is just over 1.7 TWh in municipalities with DHS. This figure exceeds the current volume of sale of district heat in buildings, which is 1.3 TWh (DHW excluded), while municipalities without DHS achieve only a fifth of this figure (0.34 TWh). For areas in which district heating systems already

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[60] The SURS and AzE figures differ slightly. According to the data available, heat for the production of DHW accounts for more than 200 GWh.
[61] All household and service buildings in Slovenia have been included in the analysis, although DHW needs do not feature in the heat demand.

exist, the technical heat potential as estimated by spatial analysis is 2.3 TWh. The total area covered by these areas is 97 km^2.

Table 17: Structure of annual heat demand for the heating of buildings, by class for 2017

Class	1	2	3	4	5	6	7	TOTAL
Annual heat demand density [MWh/ha]	< 20	20-50	50-100	100-200	200-350	350-600	> 600	
Heat demand [GWh]								
All buildings	**1 101**	**1 528**	**1 527**	**1 702**	**1 103**	**845**	**1 239**	**9 045**
Urban municipalities with DHS	118	229	329	596	527	470	935	**3 203**
Other municipalities with DHS	324	444	413	409	250	181	155	**2 176**
Municipalities without DHS	660	855	785	696	326	195	149	**3 666**
Shares of class [%]								
All buildings	**12.2**	**16.9**	**16.9**	**18.8**	**12.2**	**9.3**	**13.7**	**100**
Urban municipalities with DHS	1.3	2.5	3.6	6.6	5.8	5.2	10.3	**35**
Other municipalities with DHS	3.6	4.9	4.6	4.5	2.8	2.0	1.7	**24**
Municipalities without DHS	7.3	9.5	8.7	7.7	3.6	2.2	1.6	**41**

2. Annual heat demand density of all buildings in 100 x 100 m cells (buildings larger than 400 m^2)

As larger buildings are considerably more attractive from the point of view of the cost-efficiency of connection to DHS, an analysis was carried out in the next step to establish the annual heat demand exclusively for buildings with a useful floor area of more than 400 m^2. As expected, the total heat demand for larger buildings is substantially lower, accounting for only one third of the total demand of all buildings (2.9 TWh), with just over 90% of this demand (or 2.6 TWh) in cells with a density exceeding 100 MWh/ha and more than 75% (or 2.2 TWh) in areas with a density exceeding 200 MWh/ha (Table 18).

The current volume of sale of district heat to buildings in municipalities with DHS (1.2 TWh excluding DHW) is 15% lower than the estimated total demand of these municipalities in cells with a density greater than 350 MWh/ha (1.4 TWh). In municipalities without DHS, this demand exceeds 250 GWh. Total heat demand in cells with a density of between 200 and 350 MWh/ha exceeds 530 GWh. In areas with a density of between 100 and 200 MWh/ha, this figure is an additional 420 GWh.

Table 18: Structure of annual heat demand for the heating of buildings larger than 400 m^2, by density class

Class	1	2	3	4	5	6	7	TOTAL
Annual heat demand density [MWh/ha]	< 20	20-50	50-100	100-200	200-350	350-600	> 600	
Heat demand [GWh]								
All buildings	**3**	**90**	**202**	**420**	**535**	**619**	**1 075**	**2 945**
Urban municipalities with DHS	1	27	65	164	250	367	840	**1 714**
Other municipalities with DHS	1	25	56	103	136	121	114	**557**
Municipalities without DHS	1	39	81	152	148	131	122	**675**
Share of class [%]	**0.1%**	**3.1%**	**6.9%**	**14.3%**	**18.2%**	**21%**	**36.5%**	**100%**

The proximity or interconnection of cells with the greatest annual heat demand density must be taken into account in any more detailed analysis of potential (and was included in the analysis in the subsequent steps).

3. Assessment of economic potential in existing district heating systems

The spatial analysis of heat demand for the heating of buildings in households and the service sector, which was carried out at the individual building level, showed that, alongside areas in which district heating systems have already been established, there is a larger number of more densely populated areas with a high annual heat demand density (over 200 MWh/ha) that can be classified as potential areas for the development of district heating systems. Two methodological approaches were employed for the assessment of the potential for the expansion of existing DHS:

1. **Even expansion (EEX) approach:** An analysis was carried out of the heat demand of all buildings in areas located up to 250 m from current DHS networks, i.e. regardless of building size and consumption density, as Figure 69 shows (for comparative purposes).

Figure 69: Analysis of the potential expansion of existing DHS using the even expansion approach

The total potential supply of heat by way of the even expansion of existing DHS was estimated at almost 1.9 TWh (Table 19), which is 45% (or 580 GWh) more than the current sale of district heat for the heating of buildings (1.2 TWh, DHW excluded). The estimated potential is comparable with the estimated consumption of heat in buildings of over 400 m^2 in areas with a density exceeding 200 MWh/ha in municipalities with existing DHS (12% lower than the total demand of buildings of over 400 m^2 in areas with a density exceeding 100 MWh/ha). This approach does not include possible larger expansions of DHS networks to potentially promising areas located more than 250 m from a current network. These areas are, however, included in the analysis of the potential for new DHS.

Table 19: Results of the analysis of the potential expansion of existing DHS using the even expansion approach

[GWh]	Areas [MWh/ha]	
	> 100	> 200
All buildings in municipalities with DHS	3 523	2 517
Buildings > 400 m^2 in municipalities with DHS	2 096	1 828
Sale of DHE 2017 buildings heating	1 290	
Even expansion	**1 870**	
Additional potential	**580**	

2. **Connected areas (CA) approach:** Using the heat map, an analysis was conducted of the potential expansion of areas served by existing DHS, taking into account the criteria of minimum consumption density (> 350 MWh/ha, > 200 MWh/ha and > 100 MWh/ha) and the size of the area concerned, which should measure at least 9 ha (Figure 70).

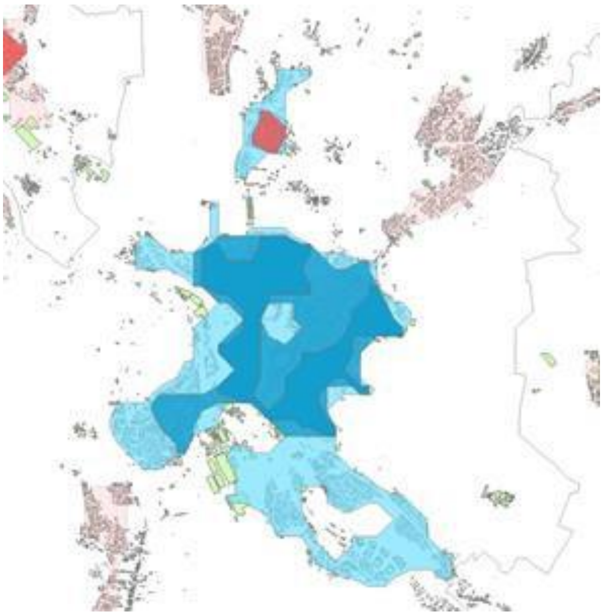

Figure 70: Analysis of the potential for the expansion of existing DHS using the connected areas approach

The total potential heat supply in areas with existing DHS and a density exceeding 350 MWh/ha was estimated to be 1.6 TWh (28% or 360 GWh more than the current sale of DHE to buildings, with heat for DHW not included). This figure was 2.6 TWh for areas with a density greater than 200 MWh/ha and 3.3 TWh in areas with a density greater than 100 MWh/ha (Table 20).

Table 20: Results of analysis of the potential for the expansion of existing DHS using the connected areas approach

[GWh]	Areas [MWh/ha]		
	> 100	> 200	>350
All buildings in municipalities with DHS	3 523	2 517	1 740
Buildings > 400 m^2 in municipalities with DHS	**2 096**	**1 828**	**1 442**
Sale of DHE 2017 buildings heating		1 290	
Expansion under the connected areas approach	**3 300**	**2 560**	**1 652**
Additional potential	**2 010**	**1 270**	**362**

Taking the criterion of annual heat demand density into account as the measure of economic potential, along with the expansion of existing DHS primarily with the inclusion of larger buildings, we estimate the economic potential for the expansion of existing DHS as between 150 GWh in areas with a density exceeding 350 MWh/ha and 500 GWh in areas with a density exceeding 200 MWh/ha (areas more suitable for low-temperature fourth-generation systems in particular). Although this is a conservative estimate of economic potential, it does represent an increase of between 12 and 40% on the current sale of heat for the heating of buildings (DHW excluded). The accuracy of this estimate of the potential is also confirmed by figures on the current consumption of natural gas in municipalities with DHS: 174 GWh in large household boilers and more than 500 GWh in services.[62]

4. Assessment of the economic potential of new district heating systems

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[62] The estimate takes account of the consumption of NG in CDK consumption groups 6-13 for households and CDK services1-8 for non-household consumption (even higher if even larger consumers are included), converted to the lower calorific value.

Alongside the expansion of existing DHS, there is also considerable potential for new smaller and micro DHS in Slovenia. Their potential has been studied by means of spatial analysis, with due regard to several criteria. The lower limit of annual heat demand density was chosen as 200 MWh/ha. The criteria for determining connected areas included the distance of the cells (100 x 100 m), which could not exceed 200 m, and a minimum size of area of at least 9 ha (the shape of the area was unimportant). Figure 71 shows areas of existing DHS in Ljubljana and the surrounding area (including expansions of the network within existing DHS areas) and the potential new areas for DHS. It shows the district heating network, with the blue area denoting where a district heating system already exists and the green area denoting zones of considerable potential for heat supply from DHS.

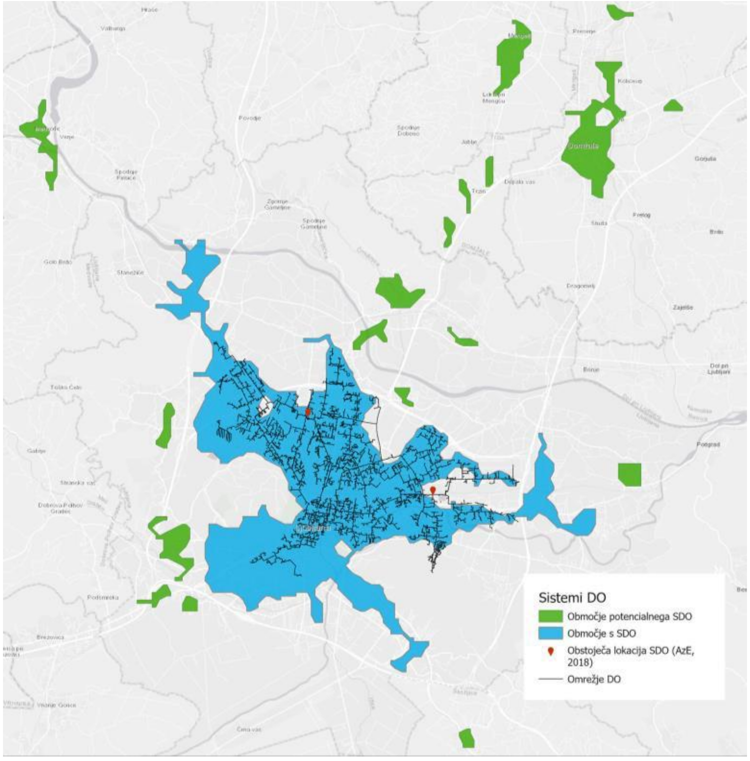

Figure 71: Existing and potential district heating system areas – Ljubljana and surrounding area

	DH systems
	Area of potential DHS
	Area with DHS
	Existing DHS location (AzE, 2018)
	DH network

Under this methodology, 95 new potential areas were identified covering a total of 32 km^2 (an average of 34 ha). The estimated total annual potential heat demand in these areas is 540 GWh, while the cooling potential in these buildings is estimated at 138 GWh.

Figure 72 shows the locations of existing DHS and the areas identified, by means of a spatial analysis of annual heat demand density, as those areas with considerable potential for supply by DHS.

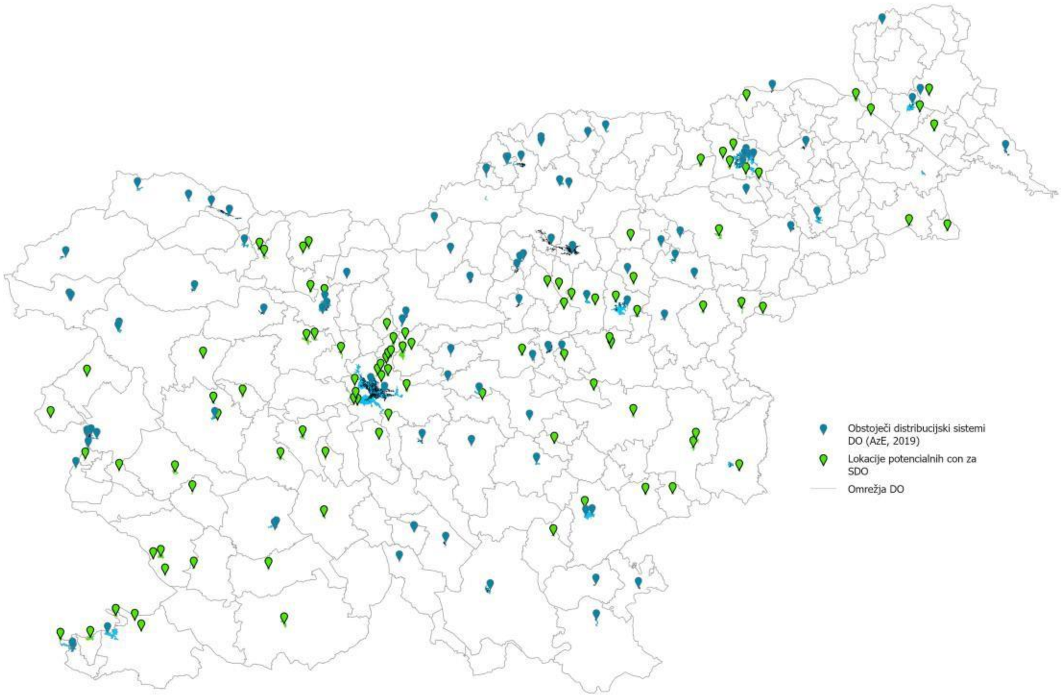

Figure 72: Overview of locations of existing district heating distribution systems and potential areas for their establishment

	Existing DH distribution systems (AzE, 2019)
	Location of potential zones for DHS
	DH networks

The HRE4[63] methodology was used to assess the economic potential of the construction of new DHS. It was upgraded and tested for Slovenia.[64] The methodology is based on a calculation of the costs of supplying heat from DHS:

1. **Heat generation** – the costs of energy, investments in the systems, maintenance and operation over a 30-year period are taken into account;
2. **Heat distribution** – the cost of constructing a network in line with local heating needs (impact on the dimensions and length of pipes) is taken into account;
3. **Heat transmission** – the cost of transmitting energy to the final customer is taken into account,

which results in the price of district heat from a new DHS for a final customer in the area observed. Using the LCC (Life Cycle Costs) method, the investment in a necessary SDO station or in an air-to-water heat pump (the reference technology for buildings in densely populated areas) is calculated and compared for individual buildings. If investment in a heating station for a final customer is shown to be economically feasible, i.e. that the net current value is lower than the investment in the HP, the building is connected to the DHS and this is included in the assessment of the economic potential of the construction of the new DHS. Areas of varying size were analysed using various minimum density criteria.[65] Because both approaches (even expansion and connected areas) are taken into account in the assessment of the potential of existing DHS, the results of the analysis of the economic potential of new DHS are shown separately for the two approaches for new smaller and micro DHS (Figure 73).

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[63] https://heatroadmap.eu/wp-content/uploads/2018/11/D2.3 Revised-version 180928.pdf

[64] Stegnar, G., Staničič, D., Česen, M., Čižman, J., Pestotnik, S., Prestor, J., Urbančič, A., Merše, S. A framework for assessing the technical and economic potential of shallow geothermal energy in individual and district heating systems: A case study of Slovenia. Energy, ISSN 0360-5442, 2019, Vol. 180, pp. 405-420, DOI: 10.1016/j.energy.2019.05.121.

[65] The density criterion was taken into account when defining the central cell for a potential new DHS area. Then, after the economic criteria were met, buildings from neighbouring cells were included regardless of density of consumption.

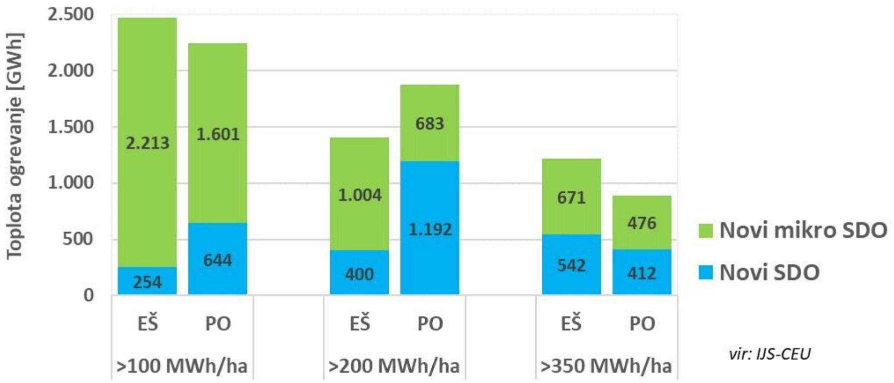

Figure 73: Economic potential in new DHS areas (small and micro DHS) under the even expansion and connected areas approach

	Heat heating [GWh]
	New micro DHS
	New DHS
	EEX
	CA
	>100 MWh/ha
	>200 MWh/ha
	>350 MWh/ha
	Source: IJS-CEU

Taking all the results presented into account, we estimate the economic potential for new smaller DHS at between 200 and 400 GWh (areas with a density greater than 350 MWh/ha). The economic potential for new low-temperature micro DHS that only interconnect a few buildings in areas with a greater density of consumption is estimated to be between 400 and 600 GWh, and depends on the cost-effectiveness of their installation in areas with a high concentration of residential housing.

5. Assessment of economic potential of district cooling

Using the model, an estimate was also produced of the technical potential for the cooling of buildings in areas of existing DHS, which amounts to more than 760 GWh (almost 90% of the current estimated demand for cooling in buildings, although only a small percentage of residential buildings are currently cooled) and constitutes a baseline potential for the development of district cooling systems. A more detailed analysis will have to be produced to estimate the economic potential of district heating, including in relation to the waste heat potential in the summer months (70 GWh from the planned thermal waste treatment), as there is currently too little data available for the production of such an estimate.

Economic potential of district heating and cooling

- **The additional current potential for the expansion of existing DHS with the inclusion of larger buildings above all is estimated at 150 GWh in areas with a density exceeding 350 MWh/ha and 500 GWh in areas with a density exceeding 200 MWh/ha (more suitable for low-temperature fourth-generation systems in particular), and represents an increase in the current sale of heat for the heating of buildings (excluding domestic hot water) of between 12 and 40% to a total of between 1.4 and 1.8 TWh.**
- **The estimated current economic potential for new smaller DHS is between 200 and 400 GWh (areas with a density greater than 350 MWh/ha). For new low-temperature micro DHS that only interconnect a few buildings in areas with a greater density of consumption, this potential is between 400 and 600 GWh.**
- **The total current estimated economic potential of the supply of heat for the heating**

of buildings from district heating systems is between 2 and 2.8 TWh per year (excluding DHW), or between 23 and 31% of current useful heat demand in buildings (excluding DHW). This estimate will have to be updated by more detailed analyses and planning at the local level.

- **Given the planned reduction in useful heat demand in buildings of almost 40% by 2050 as a result of an increase in building efficiency, and in line with the NECP scenario, the total potential heat supply for the heating of buildings from DHS is estimated to be 1.4 TWh (under the ALT scenario), or 1.6 TWh if DHW is included.**
- **A more detailed analysis should be drawn up, and linked with waste heat projections for the summer months, if an assessment of the economic potential of district cooling is to be made.**

4.11 Potential for a reduction in heat losses in existing district heating systems

An analysis of the baseline status of heat losses in existing DHS is based on information from the forms for the transmission of data to the AzE (technical and economic data), specifically for the 18 DHS that distributed 88% of district heat in Slovenia in 2018, as well as SURS data for all DHS. The table below (Table 21) gives the quantities of heat transmitted to the distribution network of 16 sample district hot and warm water systems, and the heat transmitted to final customers. Losses of 304 GWh (on average, 17.4% of the heat transmitted to DHS) occurred in the distribution of heat. The largest individual established heat losses amount to 27.1%, or 22.6%. They are from district heating systems with long distribution network interconnectors and high preflow temperatures, and connected to the age of the DHS. Most DHS can be classified as second-generation DHS, with some systems being third-generation. According to SURS figures for 2018, heat losses in heat distribution amounted to 370 GWh (or 14.8%) in all DHS (warm-water, hot-water, steam-supply).

Table 21: Heat transmitted to the distribution network and final customers, and the share of heat losses in 2018

	Heat transmitted to the distribution network [GWh]	Heat transmitted to final customers [GWh]	Heat losses in heat distribution [GWh]	Heat losses in heat distribution [%]
16 DHS	1 731.7	1 427.9	303.8	17.5
SURS	2 501.5	2 131.9	369.6	14.8

The assessment of the potential for a reduction in heat losses in district heating systems has been drawn up on the basis of projections for the generation and sale of DHS heat up to 2050, taking the ambitious NECP scenario with additional measures (AMA) into account (Figure 74). In the period leading up to 2050, a reduction in heat losses of 125 GWh is planned (from the 14.5% figure for 2020 to 11% by 2050).

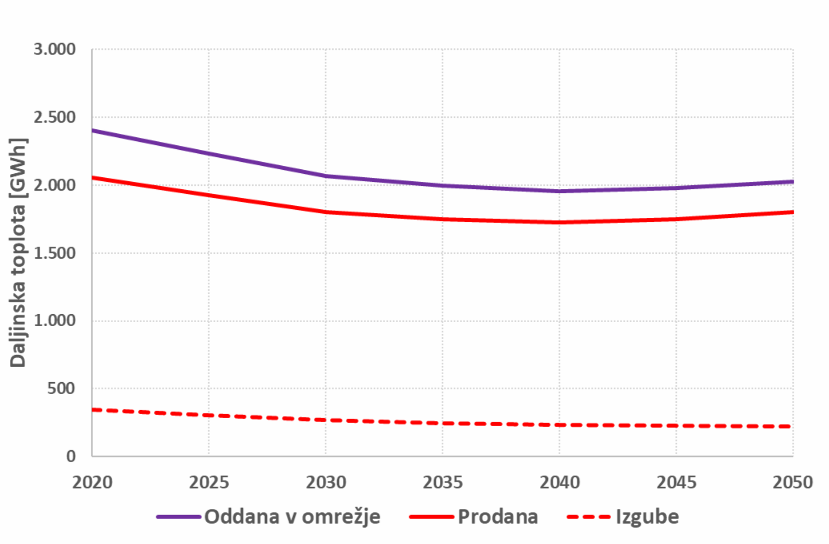

Figure 74: District heat transmitted to the network, heat sold and losses in the network (2020-2050)

	District heat [GWh]
	Transmitted to network
	Sold
	Losses

Economic potential for reducing losses from existing DHS

- ➢ **Heat losses can be significantly reduced by making systematic investments in the renovation and optimisation of DHS networks and, above all, by reducing temperature operating regimes.**
- ➢ **According to NECP projections, the estimated potential reduction in losses in DHS is at least 125 GWh by 2050.**

4.12 Overall assessment of economic potential

An overall assessment of the economic potential of HC in line with the prescribed form of reporting is given in Table 22. The results show that the 15.3 TWh of useful heat required for heating in 2050 could be provided as follows:[66]

- **At least 50% from RES, WH and thermal waste treatment;**
    - **7 TWh (or 45%) from RES, and a further 0.8 TWh of electricity from RES;**
    - 0.5 TWh GWh [sic] or 3% with WH recovery in industry (350 GWh internal, 145 GWh in DHS);
    - 0.3 TWh (or 2%) and 70 GWh of electricity from thermal waste treatment;
- **3 TWh (or almost 20%) and 2.3 TWh of electricity from CHP** (RES and e-fuels);
- **At least 2.4 TWh or 16% with HP;**
- **1.8 TWh or 12% from DHS.**

While the estimated annual potentials may provide all the required heat in buildings by 2050 (6.4 TWh), supplying industry with heat represents a greater challenge (its demand totals 9 TWh).

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[66] Because the economic potential overlaps by source and technology, the results must be interpreted carefully.

Table 22: Total assessment of economic potential of efficient heating and cooling technologies in 2050

	TOTAL heat	**TOTAL electricity**	**TOTAL source**	Households*	Services*	Industry*	DHS*	Notes
	GWh per year	**GWh per year**	**GWh per year**	GWh per year	GWh per year	GWh per year	GWh per year	
Industrial waste heat – DHS	**145**		**109**			109		Only waste heat transmitted into DHS – total heat transmitted (direct and using HP is 145 GWh). Internal use in industry is estimated at an additional 350 GWh.
Industrial waste cold								Data not available
Thermal waste treatment	**319**	**70**	**522**				522.1543155	Assessment for three large plants in Ljubljana, Maribor and Celje
High-efficiency cogeneration	**2 959**	**2 246**	**2 959**	4	536	1 005	1 414	Estimate of useful consumption of heat in CHP by sector.
Renewable energy sources –								
Deep geothermal energy	**300**		**300**		290		10	Deep geothermal energy, excluding electricity use required
Shallow geothermal energy	**1 066**		**798**	186	370		243	Shallow geothermal energy (not generated heat).
Ambient energy	**1 215**		**1 350**	888	462			Ambient energy (heat not generated).
Biomass	**3 526**	**499**	**4 291**	1 780	311	1 235	965	Use of wood biomass for heating, including in CHP.
Solar thermal energy	**288**		**288**	256	20		12	Solar thermal energy – high likelihood that part of the potential will be utilised in solar power plants.
Other renewable energy sources – CHP biogas	**445**	**307**	**889**		877	12		Biogas.
Heat pumps – total heat	**2 426**		**2 426**	1 346	616		465	Total estimated generation of heat with HP by sector (RES and waste heat, no assessment for industry).
Reduction in heat losses in existing networks for DHC	**125**		**125**					Estimate of reduction of losses relative to current situation
District heating systems	**1 789**	**1 106**	**1 789**	758	788	243		Estimated potential for heat supply from DHS.

4.13 Design of scenarios

The analysis included two scenarios drawn up as part of the preparation of expert groundwork for the NECP and the Long-Term Climate Strategy of Slovenia (these scenarios are described in detail in the joint expert groundwork[67]).

BASELINE scenario (BASE) Existing measures (EM)	ALTERNATIVE scenario (ALT) Additional measures, ambitious NECP scenario (AMA)
With existing measures – all measures carried out by the end of 2018 and being carried out until 2050 are taken into account.	**Ambitious scenario with additional measures** – assumed ambitious and intensive implementation of additional measures in all areas to ensure that Slovenia achieves net-zero emissions by 2050 – **selected NECP scenario.**

The main assumptions, measures and focuses of both scenarios are set out in Table 23, while Figure 75 illustrates the ALT scenario at the level of the structure and volume of supply of useful heat in buildings.

Table 23: Main measures and policies of scenarios

Measures and policies	BASELINE scenario	ALTERNATIVE scenario
Intensity of energy renovation of buildings	**STH:** ~2% annually **MFH:** ~ 3% by 2040 followed by ~ 2% **Public sector:** 2.6% annually **Private sector:** 2.3% annually	**STH:** 2.5-3% by 2040 followed by 1% **MFH:** 3.5-4% by 2040 followed by 0.8% **Public sector:** 3.5% annually **Private sector:** 3.3% annually Building renovation is more focused on comprehensive energy renovation supported by various financial instruments and funding sources (advanced forms of energy contracting, including for MFH).
Replacement of heating systems and energy products	Gradual replacement of old appliances with new	Quicker replacement of old inefficient installations with new ones and quicker transition to RES • **Densely populated areas:** priority connection to DHS and HP (shallow GEO, air/water, split systems), WH in services • **Sparsely populated areas:** efficient wood biomass boilers and heat pumps • **Cascade use of deep GEO** in DHS, services and agriculture
Phasing-out of fossil fuels	**NG:** existing network preserved, without expansion **Liquid fuels:** transition to DH, NG and RES **Coal:** phasing-out by 2050	**NG:** • **Buildings:** STH – gradual transition to HP; MFH and services – DHS and e-gases/CHP • **Industry:** process use – e-gases, process heat – e-gases and WB CHP, heat – WH, DHS, WB and HP **Liquid fuels:** no new installations after 2025, transition to DHS and RES (HP and WB) **Coal:** phasing-out by 2030/2033 in DHS
DHS	Current timetable for the expansion of existing and the construction of new networks.	• **Expansion and new DHS where the criterion of density of annual demand for heat and cold is met** (taking additional benefits into account) • **Use of WH and RES** (shallow and deep GEO, CHP using WB, SOL, RES waste) • **Focus on low-temperature networks and the integration of energy systems** (heat storage facilities, flexibility of various heat sources, WH from the production of e-fuels, etc.) • **Introduction of district cooling**

Figure 75 shows the main focuses of the ALT scenario in relation to the heating of buildings – market shares of technologies or sources of heat at the level of required useful heat for heating and the production of DHW:

- **Households:** the major share of heating taken by WB (41%) to gradually fall and account for a third of useful heat in 2050, with a simultaneous increase in the share of heat produced by HP, which will

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[67] Summary of the analysis of scenarios for deciding on Slovenia's Long-Term Climate Strategy to 2050, LIFE ClimatePath2050, 2020. Available at: https://www.energetika-portal.si/dokumenti/strateski-razvojni-dokumenti/nacionalni-energetski-in-podnebni-nacrt/dokumenti/

account for the next third of heating by 2050. In 2050 the remaining third will comprise DHE (17%), ELE (12%) and SOL (5%).

- **Services:** DHE will become the main source of heating by 2050 (36%), followed by HP (28%). The share of GEO will also increase (11%), while the share of WB will remain at today's level (12%). CHP units using hydrogen or e-fuel account for a 9% share.
- **Buildings total:** Heat pumps will account for a 30% share of heating and be the largest source of heat in buildings by 2050, followed by WB (26%), DHE (23%) and ELE (8%). The shares taken by other energy products (GEO, solar and H2 or e-fuels) are considerably lower, at 3 or 4%.

The structure of the heating of buildings presented in the ALT scenario points the way towards the balanced and effective replacement of fossil fuels for the heating of buildings by using technologies available today. The shares achieved are not absolute targets and will have to be adjusted to future technological and social development in order to achieve the greatest possible positive multiplier effects.

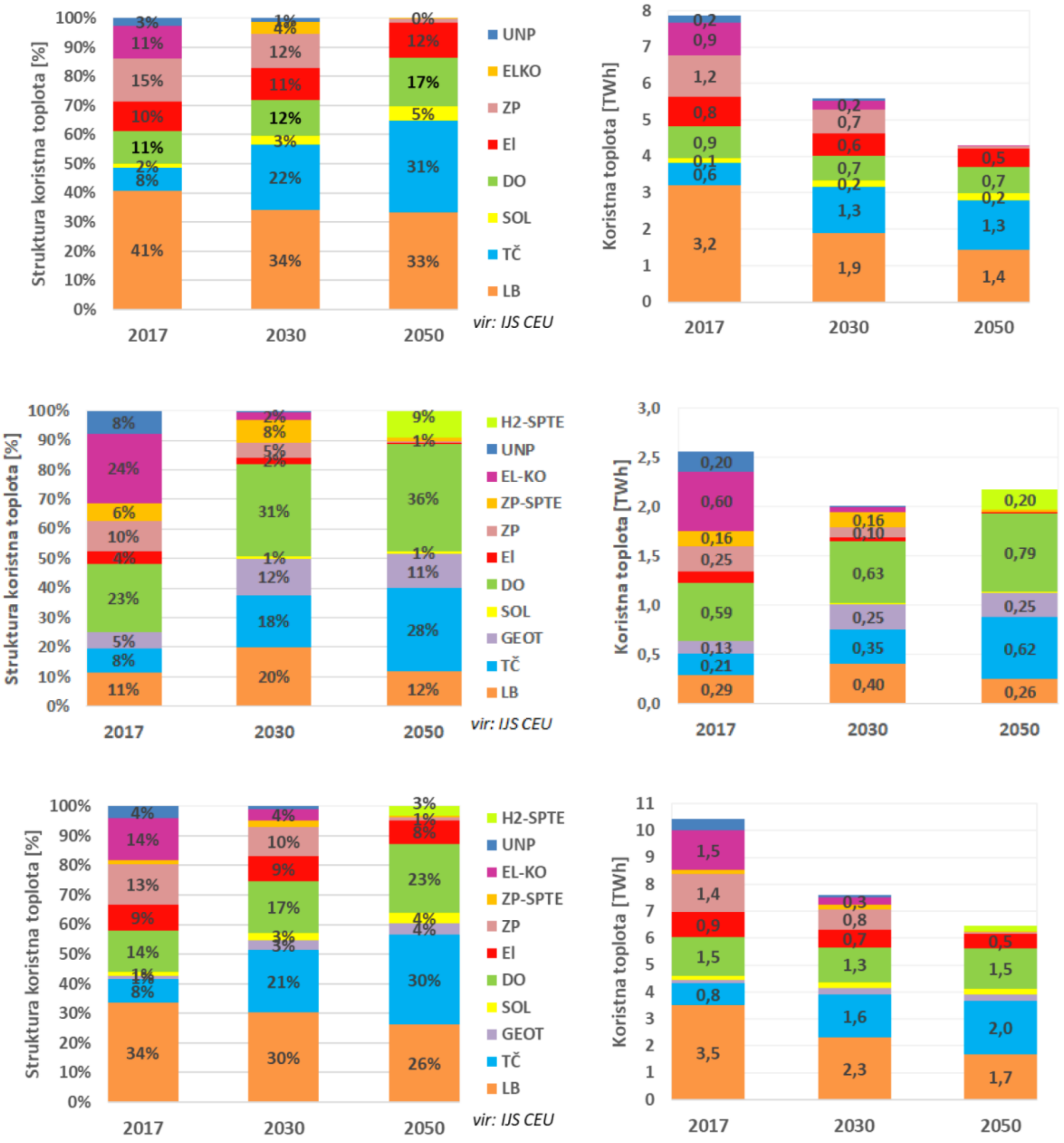
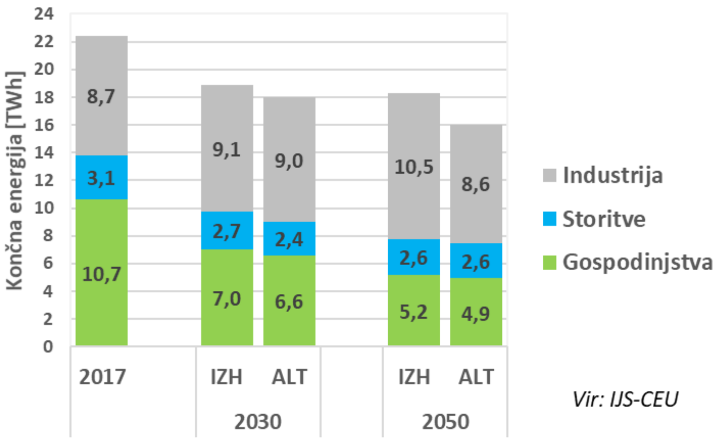


Figure 75: Structure and volume of supply of useful heat in buildings in the ALT scenario for households, services and in total

	Structure of useful heat [%]
	LPG
	ELHO
	NG
	EL
	DH
	SOL
	HP
	WB
	Source: IJS-CEU
	Useful heat [TWh]
	H2-CHP
	NG-CHP
	GEO

4.14 Energy balances of scenarios

In both scenarios, total energy end-use for waste heat falls from today's 22.5 TWh, although this process occurs more quickly in the ALT scenario, falling below 19 TWh by 2030 and to 16 TWh by 2050 (to 18 TWh in the BASE scenario). By 2050, the reduction in buildings exceeds 6 TWh, while end-use in industry will remain at today's level if economic growth proceeds as expected (Figure 76). There are significant changes not only in the volume but also the structure of energy end-use, with increases in the share of RES, DHE, electricity and e-fuels as a result of the phasing-out of fossil fuels (Figure 77).



Vir: IJS-CEU

Figure 76: End-use of energy for heating and cooling by sector – comparison of baseline and alternative scenarios

	Final energy [TWh]
	Industry
	Services
	Households
	BASE
	ALT
	Source: IJS-CEU

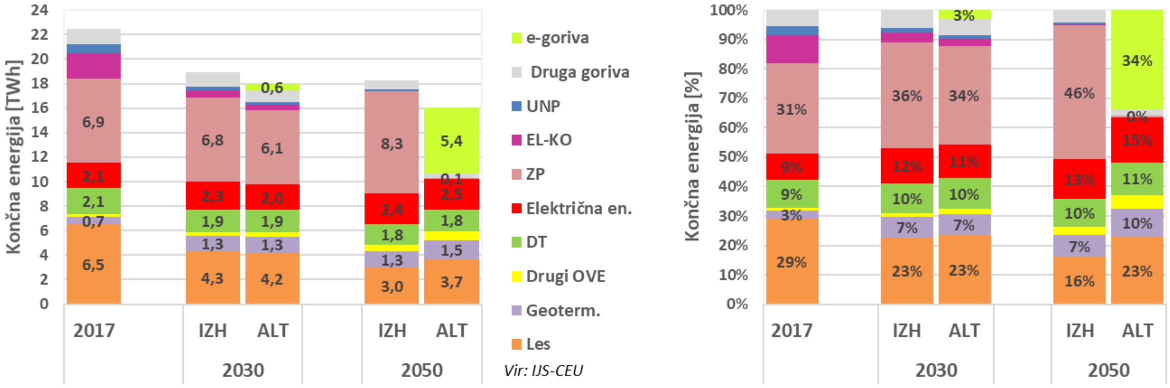


Figure 77: Volume and structure of total energy end-use for heating and cooling – comparison of baseline and alternative scenarios

	Final energy [TWh]
	e-fuels
	Other fuels
	LPG
	ELHO
	NG
	Electricity
	DHE
	Other RES
	GEO
	WB
	BASE
	ALT
	Source: IJS-CEU
	Final energy [%]

Under the ALT scenario, and as a result of the large increase in the efficiency of buildings, the total volume of RES in buildings falls by almost 40% by 2050 (or by 2.5 TWh), while the share of RES in final energy increases to 54%. Alongside this, the share of DHE and electricity practically doubles (to 21 and 19%, respectively), with the remaining 5% share in buildings comprising e-fuels, particularly for CHP in services (Figure 78).

With the forecast significant economic growth, the volume of final energy for HC in industry will fall only to a minor extent (and increase by 20% under the baseline scenario), alongside an increase in the share of RES of 23% (mainly WB), while e-fuels, as a replacement for NG under the ALT scenario, will account for almost 60% in 2050 and the share taken by electricity will increase to 12% (Figure 79).

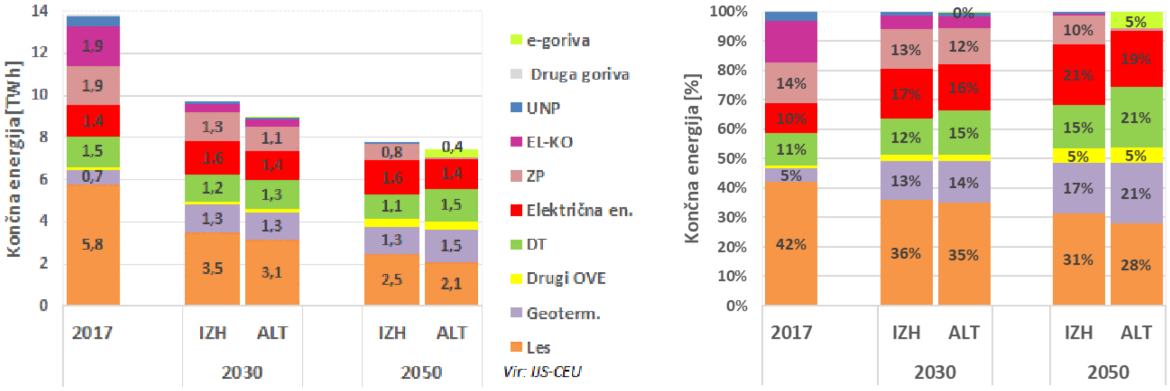


Figure 78: Volume and structure of energy end-use for HC in buildings – comparison of baseline and alternative scenarios

	Final energy [TWh]
	e-fuels
	Other fuels
	LPG
	ELHO
	NG
	Electricity
	DHE
	Other RES
	GEO
	WB
	BASE
	ALT
	Source: IJS-CEU
	Final energy [%]

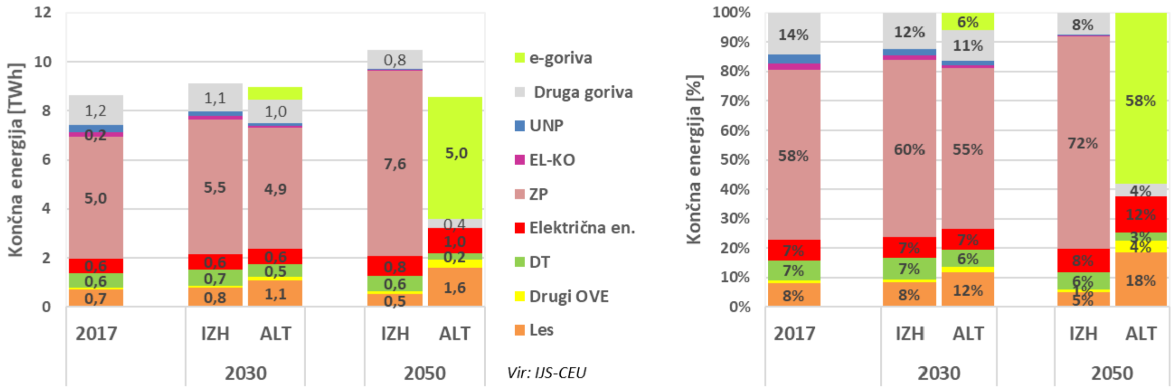


Figure 79: Volume and structure of energy end-use for HC in industry – comparison of baseline and alternative scenarios

	Final energy [TWh]
	e-fuels
	Other fuels
	LPG
	ELHO
	NG
	Electricity
	DHE
	Other RES
	WB
	BASE
	ALT
	Source: IJS-CEU
	Final energy [%]

Table 24: Current and future energy end-use for heating and cooling – Alternative scenario

[GWh/year]		Sector	2017	2020	2025	2030	2035	2040	2045	2050
Final energy	**Heating**	Households	10 566	9 417	7 715	6 489	5 614	5 110	4 939	4 813
		Services	2 958	2 872	2 643	2 455	2 294	2 257	2 286	2 324
		Industry	8 633	8 579	8 442	8 298	8 418	8 363	8 534	8 532

	TOTAL	**22 157**	**20 652**	**18 566**	**17 051**	**16 222**	**15 723**	**15 790**	**15 748**
Cooling	Households	90	77	88	96	115	125	118	120
	Services	172	173	168	164	195	210	191	180
	Industry	28	28	28	29	29	29	29	30
	TOTAL	**290**	**278**	**284**	**289**	**339**	**364**	**338**	**330**
TOTAL final energy		**22 447**	**20 930**	**18 850**	**17 340**	**16 561**	**16 087**	**16 128**	**16 078**

4.15 Emission balances

4.15.1 Greenhouse gases

Between 2005 and 2017, total direct GHG emissions for heating fell from 4.7 $MtCO_2$ equivalent to 2.8 $MtCO_2$ equivalent – a fall of almost 60%. Under the ALT scenario, emissions will fall dramatically because of greater energy efficiency and the more rapid replacement of fossil fuels by RES, to be lower by more than 40% in 2030 relative to 2017 (1.6 $MtCO_2$ equivalent), and by more than 95% in 2050, with only minimal amounts being produced (0.2 $MtCO_2$ equivalent), as shown in Figure 80 and Table 25. The share of GHG emissions for heating taken by buildings will fall to just over 25% by 2030 (that share was 43% in 2017), while the decarbonisation of gas supply by 2050 presents a key challenge to efforts to reduce emissions in industry (Figure 81). Under the BASE scenario, emissions will fall to 2.1 $MtCO_2$ equivalent by 2030, and remain at that level in the years leading up to 2050.

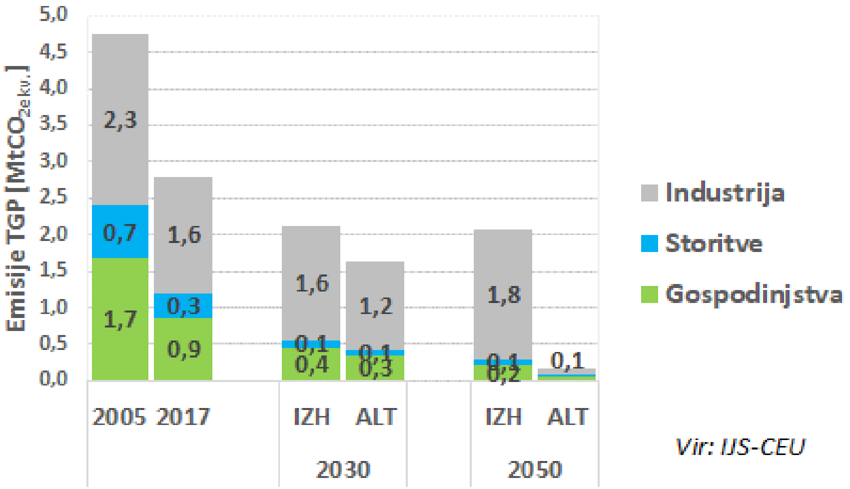


Figure 80: Total direct GHG emissions (CO_2 equivalent) for heating by sector – comparison of baseline and alternative scenarios

	Emissions [$MtCO_2$ equivalent]
	Industry
	Services
	Households
	BASE
	ALT
	Source: IJS-CEU

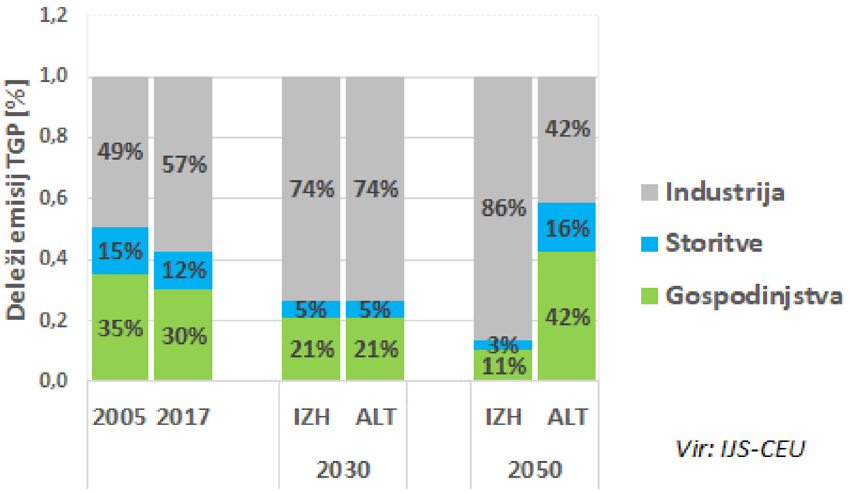


Figure 81: Sectoral structure of direct GHG emissions (CO_2 equivalent) for heating, by sector – comparison of baseline and alternative scenarios

	Shares of GHG emissions [%]
	Industry
	Services
	Households
	BASE
	ALT
	Source: IJS-CEU

Table 25: Direct GHG emissions for heating – Baseline and Alternative scenarios [$ktCO_2$ equivalent]

Scenario	Sector	2005	2017	2025	2030	2035	2040	2045	2050
BASE	Households	1 678	851	575	448	351	285	245	218
	Services	722	345	186	111	78	70	67	67
	Industry	2 336	1 601	1 623	1 572	1 627	1 680	1 731	1 778
	TOTAL	**4 735**	**2 797**	**2 384**	**2 130**	**2 056**	**2 035**	**2 043**	**2 063**
ALT	Households			527	344	219	140	88	64
	Services			133	84	56	42	30	24
	Industry			1 426	1 196	1 093	865	495	63
	TOTAL			**2 086**	**1 625**	**1 368**	**1 046**	**613**	**152**

4.15.2 Air pollution

As a result of the replacement of technologies, there are significant reductions in air pollution emissions in both scenarios: $PM_{2.5}$, nitrogen oxides (NO_x), volatile organic compounds (NMVOC) and sulphur dioxide (SO_2). The reduction is greater in the ALT scenario, where the reduction in emissions will fluctuate between 50 and 60% in 2030 and around 70% by 2050 relative to emissions in 2017 (Figure 85). Lowering air pollution emissions has a significant impact on quality of life and health, thereby reducing the external costs of heating and cooling considerably.

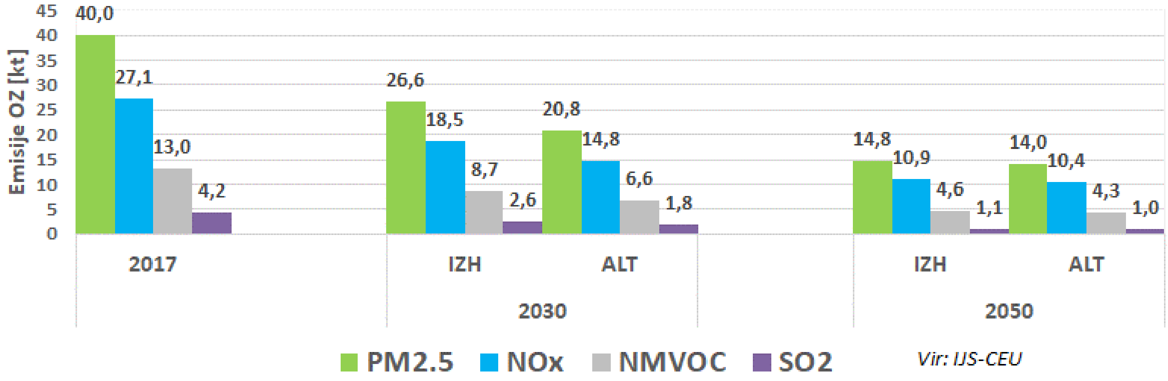


Figure 82: Total emissions of air pollutants for heating – comparison of the baseline and alternative scenarios

	Air pollution emissions [kt]
	BASE
	ALT
	$PM_{2.5}$
	NO_X
	NMVOC
	SO_2
	Source: IJS-CEU

4.16 Cost-benefit analysis

A cost-benefit analysis for both scenarios was produced for buildings (households and services), although industry was omitted because of the considerable specificity of new technologies and the uncertainty surrounding technological development.[68]

4.16.1 Baselines and assumptions

A sectoral economic model was used for the cost-benefit analysis of the scenarios for HC in buildings (households and services). The total HC costs are estimated using an estimate of the current level of costs, with the following costs being included:

1. **investments:**
   - building renovation costs: including investments in various degrees of building renovation (renovation, improved renovation, low-energy renovation). Labour costs and the costs of construction material are included. The specific costs of renovation are the same in the two scenarios, while the volume of renovation is greater in the AMA scenario than in the EM scenario;
   - costs of replacing HC technologies: investment costs;
2. **operation and maintenance of technologies;**
3. **purchase of energy:** the cost of energy, with taxes and levies, relative to the projections of energy use in buildings for both scenarios (all existing taxes and network fees, except for VAT, are included);
4. **external costs of emissions:** estimated on the basis of the specific costs of mitigating environmental damage and the air pollution projections for both scenarios:
   - CO_2 and
   - air pollution – NO_x, SO_2, NMVOC, NH_3, $PM_{2.5}$ and PM_{10}.

The energy use costs are based on the presented projections of energy use in buildings (heating, production of DHW and other energy use in buildings). The analysis takes account of energy product prices, and of taxes and levies[69] in line with the NECP.

The analysis also evaluated the external costs of CO_2 emissions and air pollution, which includes the wider social impact on health, material damage, damage to agricultural products and biodiversity.[70] The projected external costs of CO_2 emissions are EUR 100/tCO_2 in the period up to 2030 and EUR 200/tCO_2[71] in the period up to 2050. In the modelling calculations, these costs are split between the CO_2 levy (included in the energy costs – EUR 96/tCO_2 by 2050), with the remainder included in external costs (Figure 83).

The assumptions underlying the analysis are presented in greater detail in the annex to the report.

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[68] Slovenia has a high proportion of energy-intensive industries in which alternative decarbonisation technologies are still undergoing intensive development. Any estimate of the costs and benefits is therefore extremely uncertain.

[69] The planned increase in the contribution for energy efficiency and the gradual increase in the CO_2 levy – approaching the values in the ETS, in line with the NECP (the current levy is EUR 17.3 per unit of air pollution with CO_2 (tCO_2)), increasing to EUR 96 by 2050.

[70] The specific costs of air pollution are set out in the following studies: Bunger, B., & Matthey, A. (2020). Methodenkonvention 3.1 zur Ermittlung von Umweltkosten. Methodische Grundlagen, URL: https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2020-12-21_methodenkonvention_3_1_kostensaetze.pdf in What can we learn from the Dutch national carbon tax? – Carbon Market Watch

[71] The projection was drawn up on the basis of the planned CO_2 levies in the Netherlands (EUR 30/tCO_2 in 2021 and EUR 125/tCO_2 in 2030) and in Norway (proposed EUR 200/tCO_2 by 2030).

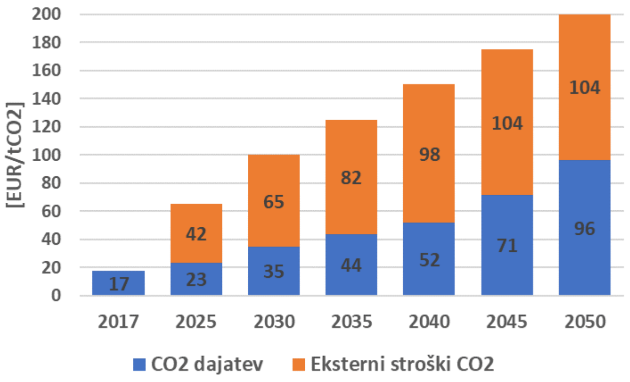

Figure 83: Projection of external costs of CO$_2$ – modelling division into CO$_2$ levies and external costs.

	[EUR/tCO$_2$]
	CO$_2$ levy
	External CO$_2$ costs

Energy use costs account for the biggest share of the total costs in the 2021-2050 period within households and services. While the volume of investments in the renovation of buildings and the replacement of technologies for heating and the production of domestic hot water is higher in the ambitious scenario, external and energy-use costs are lower as a result of the measures implemented (Table 26 and Table 27). The differences between the scenarios as regards investments in buildings (renovation and the replacement of heating and DHW technologies) are not that great, with the main difference lying in the speed of building renovation. This is quicker in the ALT scenario, which lowers the costs of the introduction of carbon-free HC technologies.

Table 26: Cumulative overview of costs by period – Baseline scenario

BASE scenario	2021-2025	2021-2030	2021-2035	2021-2040	2021-2045	2021-2050
			Investments [EUR millions]			
Building renovation	736	1 267	1 724	2 066	2 336	**2 560**
Technologies	1 220	2 336	3 309	4 102	4 765	**5 333**
Energy	7 119	13 144	18 203	22 423	26 043	**29 154**
External costs	3 660	5 868	7 215	8 093	8 721	**9 195**
TOTAL	**12 735**	**22 615**	**30 451**	**36 685**	**41 866**	**46 241**

Table 27: Cumulative overview of costs by period – Alternative scenario

ALT scenario	2021-2025	2021-2030	2021-2035	2021-2040	2021-2045	2021-2050
			Investments [EUR millions]			
Building renovation	1 048	1 826	2 325	2 637	2 862	**3 101**
Technologies	1 205	2 370	3 408	4 241	4 932	**5 515**
Energy	7 045	12 890	17 647	21 500	24 764	**27 553**
External costs	3 526	5 554	6 727	7 457	7 966	**8 346**
TOTAL	**12 824**	**22 640**	**30 106**	**35 835**	**40 524**	**44 515**

4.16.2 Comparison of scenarios

The results of the analysis show that, despite the greater volume of investment in building renovation (21% higher) and the replacement of systems for heating and for the production of domestic hot water (3% higher), as shown in Figure 84 and Figure 85, the more ambitious ALT scenario leads to 5% lower energy use costs and 9% lower indirect external emission costs after 2030 (and cumulatively throughout the entire period), resulting in 4% lower total costs in the period up to 2050 (Figure 86 and Figure 87). The estimated total costs of ALT for the 2021-2050 period therefore amount to EUR 44.5 billion, which is EUR 1.7 billion less than the estimated total costs of the baseline existing measures (Table 28).

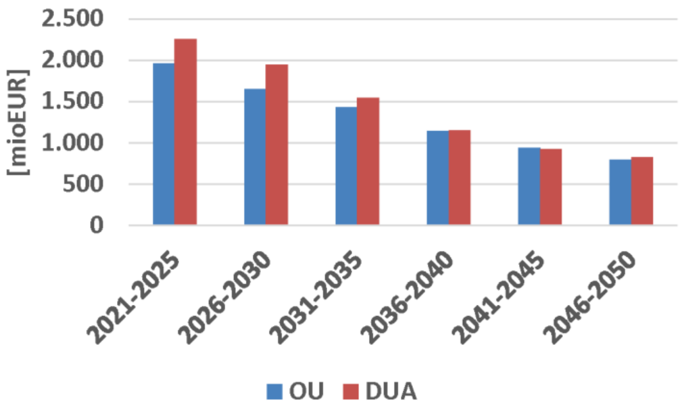

Figure 84: Investments in building renovation and the replacement of technologies for heating and the production of hot water for both scenarios

	[EUR millions]
	EM
	AMA

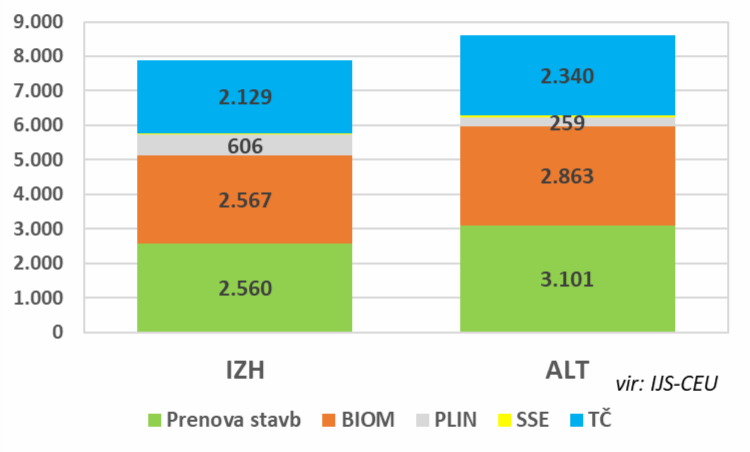

Figure 85: Comparison of cumulative investments 2021-2050 for both scenarios

	BASE
	ALT
	Building renovation
	BIOMASS
	GAS
	SEC
	HP
	Source: IJS-CEU

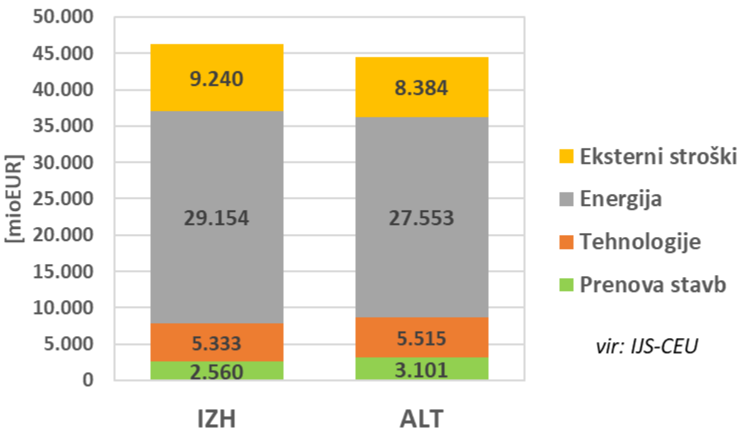

Figure 86: Total costs of both scenarios 2021-2050

	[EUR millions]
	BASE
	ALT
	External costs
	Energy
	Technologies
	Building renovation
	Source: IJS-CEU

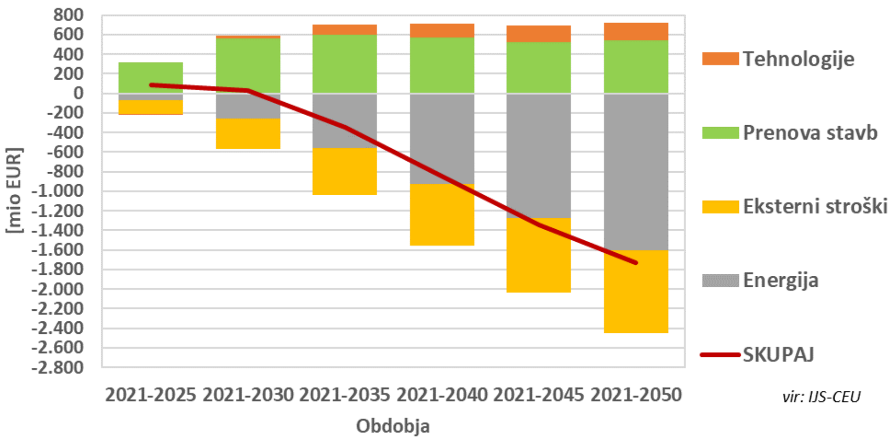

Figure 87: Cumulative difference in the costs of the scenarios (AMA – EM), by period

	[EUR millions]
	Periods
	Technologies
	Building renovation
	External costs
	Energy
	TOTAL
	Source: IJS-CEU

Table 28: Comparison of cumulative total costs of both scenarios 2021-2050

[EUR millions]	BASE	ALT	Differences between scenarios

	2021-2050	2021-2050	2021-2050
Building renovation	2 560	3 101	**541**
Technologies	5 333	5 515	**182**
Energy	29 154	27 553	**-1 600**
External costs	9 195	8 346	**-849**
TOTAL	**46 241**	**44 515**	**-1 727**

4.16.3 Sensitivity analysis

The sensitivity analysis looks at the impact of the different level of external costs of CO_2 emissions on total HC costs in buildings. In relation to the analysed baseline scenario of external costs of CO_2 emissions, two more scenarios were studied (Figure 88):

- **50% higher** external costs of CO_2 emissions, which will reach the price of **EUR 300 EUR/tCO_2 by 2050;** and
- **50% lower** external costs of CO_2 emissions, which will reach the price of **EUR 100 EUR/tCO_2 by 2050.**

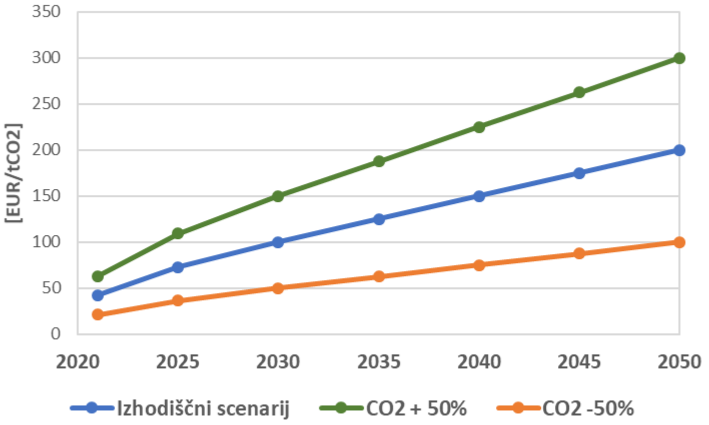

Figure 88: Changes to external costs of CO_2 for the scenario-based analysis of the sensitivity of the total costs of the heating and cooling of buildings

	[EUR/tCO_2]
	Baseline scenario
	CO_2 + 50
	CO_2 - 50

The difference in external CO_2 costs increases over time between the two scenarios because of the increase in the difference in the volume of CO_2 emissions (higher in the BASE scenario) and in the increase in external CO_2 costs. In the period up to 2050, the external costs of the ALT scenario are almost EUR 40 million per year lower, or more than EUR 622 million lower cumulatively over the 2021-2050 period than in the BASE scenario (Figure 89). In the -50% scenario, the difference in the estimated external costs of CO_2 emissions between BASE and ALT falls/halves (the difference is EUR 311 million cumulatively over the 2021-2050 period), and increases to EUR 933 million in the +50% scenario. **In the event of 50% higher external CO_2 costs, the cumulative costs of buildings under the ALT scenario in the 2021-2050 period are more than EUR 2 billion lower than the costs under the BASE scenario, which confirms that the approach set out in the ALT scenario is the correct one.**

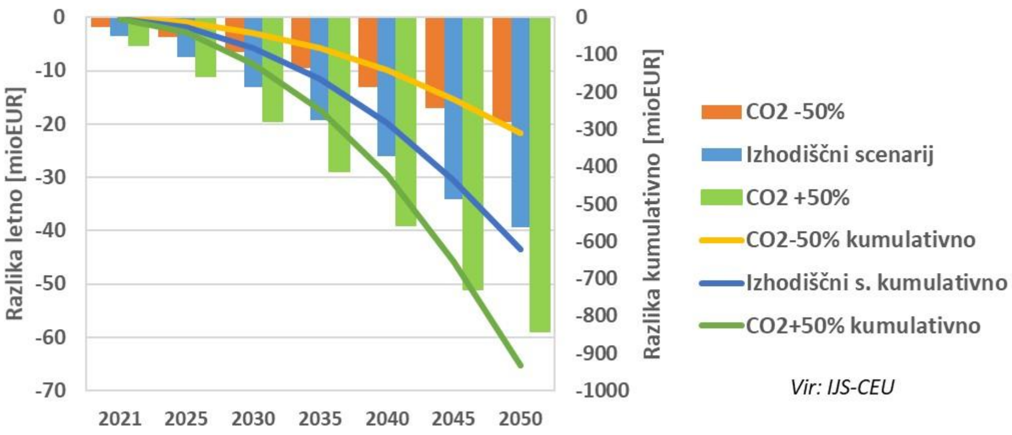

Figure 89: Sensitivity analysis of total heating and cooling costs for buildings relative to the external costs of CO_2 emissions – annual and cumulative differences

	Annual difference [EUR millions]
	Cumulative difference [EUR millions]
	CO_2 -50%
	Baseline scenario
	CO_2 +50%
	CO_2 -50% cumulative
	Baseline scenario cumulative
	CO_2 +50% cumulative
	Source: IJS-CEU

5 NEW STRATEGIES AND MEASURES

Slovenia has already adopted most of the measures for achieving the potential for efficient HC in the NECP. Prior to adopting the new measures, it first had to ensure that they could be implemented effectively and to the planned extent.

Of the planned NECP measures, the following are particularly important if the potential is to be achieved:

Heating and cooling strategy

- **clear medium- and long-term objectives and priorities regarding the methods and sources of HC by sector** – particularly with regard to the phasing-out of fossil-fuel use and the future development of energy infrastructure (DHS, gas network, etc.)

Action Plan for District Heating and Cooling

- **measures necessary to improve the effectiveness and speed of the development of district heating and cooling systems**, in particular an increase in efficiency, the replacement of fossil fuels by WH and RES, digital transformation and the development of services for consumers, the effective interconnecting of energy systems, etc.

Heat map and tools for local planning

- **To establish the uniform and up-to-date collection of databases for the heat map and the tools necessary for supporting local planning** (local energy plans, overhaul of SECAP methodology, training, etc.)

Information and publicity

- **comprehensive national promotional and literacy campaign on the importance and method of transition to a climate-neutral society** (e.g. raising the awareness of and educating users of wood biomass appliances regarding the proper fuel and the correct method of heating, raising the awareness of and training vendors and installers of RES and EE appliances, business managers, energy managers, etc.)

Alleviation of fuel poverty

- **to define fuel poverty in the sectoral legislation and lay down an obligation to periodically measure the extent of fuel poverty and set measurable objectives** (to determine target indicators for energy poverty)
- **to produce an action plan for overcoming energy poverty** (improvements to and an increase in the scope of instruments, additional measures to be determined as required)
- **monitoring of the implementation of measures** (social and housing policies, and targeted energy poverty measures)

Promotion of research and innovation for transition to a climate-neutral society

- **more targeted orientation towards research and innovation** (including in the humanities, social sciences and social-natural sciences, targeted research programmes in the fields of WH use, efficient cooling, etc.)
- **to increase the volume of funds** (predictability and permanence of instruments)
- **incentives for the development of green technologies and innovations in enterprises, support for demonstration projects, etc.**

6 ANNEX

6.1 Economic data for a cost-benefit analysis

Table 29: Projection of household energy prices

Price excluding VAT [EUR/MWh]	2017	2030	2040	2050
Electricity	132	198	193	210
WB	28	36	37	38
Wood chips	18	34	35	36
Pellets	43	44	44	44
Natural gas	45	67	76	88
Syngas	96	82	74	66
Hydrogen	96	82	74	66
District heat	66	83	86	88

Table 30: Projection of energy prices for the service sector

Price excluding VAT [EUR/MWh]	2017	2030	2040	2050
Electricity	99	146	143	157
WB	28	36	37	38
Wood chips	18	34	35	36
Natural gas	41	62	72	86
Syngas	96	82	74	66
Hydrogen	96	82	74	66
District heat	66	83	86	88

Table 31: Specific external cost per tonne of emissions[72]

[EUR/t]	Total	Adverse impact on health	Material damage	Adverse impact on agricultural products	Adverse impact on biodiversity
SO_2	17 030	15 500	640	-170	1 060
NO_x	20 340	16 600	140	850	2 750
NMVOC	2 300	1 300	0	1 000	0
NH_3	36 600	24 800	0	-190	11 990
$PM_{2.5}$	64 900	64 900	0	0	0
PM_{10}	45 800	45 800	0	0	0

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[72] Bunger, B., & Matthey, A. (2020). Methodenkonvention 3.1 zur Ermittlung von Umweltkosten. Methodische Grundlagen, URL: https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/2020-12-21_methodenkonvention_3_1_kostensaetze.pdf

Table 32: Specific investment in the renovation of a single-family house

[EUR/m^2] original class	target class	2020	2030	2040	2050
None	Renovation	68-129	75-142	83-156	91-172
None	Improved renovation	203-240	224-265	246-292	272-322
None	Low-energy renovation	278-329	306-362	338-399	372-440
None	Above-standard	233-233	256-256	283-283	312-312
None	Low-energy building	254-302	280-333	309-367	341-404
Renovation	Improved renovation	84-149	93-164	103-181	113-199
Renovation	Low-energy renovation	160-233	176-257	194-283	214-312
Improved renovation	Low-energy renovation	75-89	83-98	91-108	101-119
Above-standard	Low-energy building	22	24	26	29

Table 33: Specific investment in the renovation of a multi-family house

[EUR/m^2] original class	target class	2020	2030	2040	2050
None	Renovation	19-52	21-57	23-63	25-69
None	Improved renovation	52-127	57-140	63-154	69-170
None	Low-energy renovation	166-183	183-201	202-222	223-244
None	Above-standard	36-36	39-39	43-43	48-48
None	Low-energy building	162-167	178-184	196-203	216-224
Renovation	Improved renovation	28-75	30-83	33-91	37-101
Renovation	Low-energy renovation	121-156	133-171	146-189	161-208
Improved renovation	Low-energy renovation	45-128	50-141	55-156	61-172
Above-standard	Low-energy building	126	139	153	169

Table 34: Specific investment in the replacement of technologies for heating and the production of domestic hot water in households

[EUR/appliance]	Single-family houses	Multi-family houses	
		Floor	Central
HP GEO	15 000	42 000	
HP COLLECTOR	12 000	52 500	
HP AIR	6 800	3 000	
STANDARD GAS BOILER	4 500	2 500	30 000
GAS CONDENSING BOILER	6 000	3 500	38 000
WBB LOGS	12 000	2 500	32 000
WBB PELLETS	20 100	3 000	53 600
WBB WOOD CHIPS	12 900	2 500	34 400
SEC IMPROVED	830		
SEC VACUUM	855		

Table 35: Specific investment in the replacement of technologies for heating and the production of domestic hot water in the service sector

[EUR/appliance]	
IMPROVED GAS BOILER	42 000
WBB PELLETS	40 200
WBB WOOD CHIPS	25 800
HP GEO	28 800
HP WATER	24 000
SEC IMPROVED	830
SEC VACUUM	588

7 REFERENCES

EU, 2013. COMMISSION STAFF WORKING DOCUMENT Guidance note on Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EC, and repealing Directives 2004/8/EC and 2006/32/EC Article 14: Promotion of efficiency in heating and cooling Accompanying the document COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL Implementing the Energy Efficiency Directive – Commission Guidance. {SWD/2013/0449 final}.
Available at: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52013SC0449.

EU, 2016. COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. An EU Strategy on Heating and Cooling. {SWD(2016) 24 final}.
Available at: https://ec.europa.eu/energy/sites/ener/files/documents/1_EN_ACT_part1_v14.pdf

Summary of the analysis of scenarios for deciding on Slovenia's Long-Term Climate Strategy to 2050, LIFE Climate Path 2050, 2020.
Available at: https://www.energetika-portal.si/dokumenti/strateski-razvojni-dokumenti/nacionalni-energetski-in-podnebni-nacrt/dokumenti/

Improving solar potential map: ditching net-metering, embracing demand curve and local weather. Marko Kovač, Gašper Stegnar, Boris Sučič, Stane Merše. 2019, DOI:10.24094/kghk.019.50.1.51.

Marko Kovač, Andreja Urbančič, Damir Staničič. Deliverable C1.1: Climate Mitigation 2050 Potentials and Mid-term Challenges Part 5B: Photovoltaic Rooftop Potential in Slovenia by 2050. IJS-DP-12619, Version 1.0., Ljubljana, Institut Jožef Stefan, June 2018.

TABULA IEE: Typology Approach for Building Stock Energy Assessment. Brussels: European Commission, 2012.

Photovoltaic Research. National Renewable Energy Laboratory. [Electronic] NREL, 2017. https://www.nrel.gov/pv/.

Report of the working group tasked with dealing with the issue of efficient and multi-purpose use of geothermal energy, draft government decision, 12 April 2021. Available at:
http://84.39.218.201/MANDAT20/VLADNAGRADIVA.NSF/18a6b9887c33a0bdc12570e50034eb54/8c7516304b85e877c12586b600209813/$FILE/ATTV4IF6_P.pdf

Analysis of the shallow geothermal energy potential in Slovenia up to 2050, LIFE ClimatePath2050 project, Geological Survey of Slovenia, 2018. Available at: https://www.podnebnapot2050.si/