COMPREHENSIVE ASSESSMENT OF THE POTENTIAL FOR THE APPLICATION OF HIGH EFFICIENCY COGENERATION AND EFFICIENT DISTRICT HEATING AND COOLING IN MONTENEGRO

(transposition of article 14 of the Energy Efficiency Directive)

Ministry of Energy and Mining
Montenegro

Contents

Tables and figures

Tables

Figures

Abbreviations and acronyms

AP	Action Plan
BAU	Business-As-Usual
CA	Comprehensive Assessment
CBA	Cost-Benefit Analysis
CC	Cross Cutting
CES	Clean Energy Solutions
CHP	Combined Heat and Power
COP	Coefficient of performance (of heat pumps)
DH	District heating
DHC	District heating and cooling
DHW	Domestic hot water
DSO	Distribution System Operator
EBRD	European Bank for Reconstruction and Development
ECA	Economic Consulting Associates
ECS	Energy Community Secretariat
EE	Energy efficiency
EED	Energy Efficiency Directive
ENPV	Economic net present value
FEC	Final energy consumption
FNPV	Financial net economic value
FiT	Feed-in Tariff
GHG	Greenhouse Gas
H&C	Heating and cooling
IBRD	International Bank for Reconstruction and Development
IRM	Integrated risk management
KfW	Kreditanstalt für Wiederaufbau (Credit Institute for Reconstruction)
LEAP	Low Emissions Analysis Platform
LEP	Local Area Plans
MEEP2	Montenegro Second Energy Efficiency Project
NECP	National Energy and Climate Plan
NEEAP	National Energy Efficiency Action Plan
NPV	Net present value
PEC	Primary energy consumption
PEEPB	Programme for energy efficiency in public buildings
REGAGEN	Energy and Water Regulatory Agency
RES	Renewable Energy Systems
TSO	Transmission System Operator

INTRODUCTION

Economic Consulting Associates Ltd (ECA) with support from Energy Institute Hrvoje Požar (EIHP) and EcoEnergy Consulting D.O.O (EcoEnergy) has been contracted by the European Bank for Reconstruction and Development (EBRD) to support the Ministry of Capital Investments of Montenegro (the beneficiary) in the transposition of the recently updated Article 14 of the Energy Efficiency Directive (EED) and the update of the previously prepared Comprehensive Assessment (CA) and Action Plan (AP).

More specifically, the objective of this assignment is to assist the beneficiary to:

1. Update the previously prepared CA to meet requirements of Article 14 of the EED, and requirements of the Commission Recommendation (EU) 2019/1659 of 25 September 2019 on the content of the CA of the potential for efficient heating and cooling under Article 14 of Directive 2012/27/EU, and Annexes 1 to 7 C(2019) 6625 of 25.9.2019 final, and

2. Prepare an AP covering the period 2021-2030, supporting integration into other strategic documents in particular the National Energy and Climate Plan (NECP).

This document provides the updated CA on efficient heating and cooling (H&C) for Montenegro, but in reality, it is a completely new document in comparison with the previous study on the potential for district heating/cooling and high-efficiency cogeneration prepared in 2016. The structure and content of this CA are aligned with the requirement of the revised Annex VIII of the EED and with the Commission Recommendation (EU) 2019/1659 on the content of the CA of the potential for efficient H&C under Article 14 of EED.

The CA presented in this document has four main parts. In **Part I** an **analysis of current final energy consumption and energy demand for H&C per sector** is provided. The sectors analysed include households, services and industry. The purpose of this analysis of the current situation is to better understand the fuels and technologies used for heating and cooling purposes and enables the definition of technical measures that would enhance the overall efficiency of H&C in Montenegro, which are then analysed in greater depth in Part III. The predictions of the future development of energy consumption and demand until 2030 are given accordingly.

Part II of the CA brings a short **overview of existing policy measures for more efficient H&C**. These measures are as defined in the previous AP, adopted in 2017 and based on the Article 20 of the Energy Law. The status of implementation of these measures is given. It is emphasised that this section of the CA would ideally also provide an evaluation of the impact of these existing measures on the improvement of the H&C efficiency, however due to the low level of actual implementation, it was not possible to undertake such an evaluation.

Part III provides the **identification of all measures that can be implemented in the analysed sectors that will improve the efficiency of H&C**. There is a comprehensive list of measures for individual heating systems in households and services, as well as industry.
However, the potential for development of district heating systems remains limited. For each identified measure, a cost-benefit analysis (CBA) has been conducted, resulting in data on financial and economic net present values (FNPV and ENPV) for each measure, based in which conclusions may be drawn on the need for financial support from public source for their implementation. For a more complete analysis of the potential, a sensitivity analysis was also carried out in order to identify parameters whose variations have a significant impact on the

profitability of the measure, and thus on the amount of Net Present Value (NPV) (financial and economic). For this purpose, the impact of possible changes in technical and economic assumptions on the results of a CBA from a microeconomic and macroeconomic perspective was investigated.

The CBA results, as well as the results of sensitivity analysis are finally used to prepare a list of **new policy measures** to be applied in the forthcoming period, as **presented in Part IV**. These measures will be further elaborated in the AP.

GENERAL INFORMATION

Climatic and demographic data

Montenegro is a country with three distinct climatic zones, namely the Northern Zone, Central Zone, and Coastal Zone (Figure 0-1). Monthly climate data for each municipality were acquired from the National Centres for Environmental Information. Based on these data and the EUROSTAT definition for calculating the heating degree days (HDD) and cooling degree days (CDD), HDD and CDD were obtained for each municipality in Montenegro (table below).

Figure 0-1 Climatic zones of Montenegro

According to the 2011 census, Montenegro had 620,029 inhabitants and 21 municipalities. From the mentioned census until today, three new municipalities were created: Gusinje (formerly part of Plav municipality), Petnjica (formerly part of Berane municipality) and Tuzi (formerly part of Podgorica municipality). Population data from 2011 are known for the new municipalities. To estimate the population in 2021, input data from the last population census and trends developed for the medium variant by the United Nations, Department of Economic and Social Affairs [1] were used. The aforementioned trends were applied for each municipality and an estimate of the number of inhabitants in 2021 in Montenegro was obtained, as shown in the table below. It can be seen here that more than 10 years have passed since the last census, but it is not expected that the survey results would have been different if a more recent census had been available.

Table 0-1 Climatic and demographic data of Montenegro

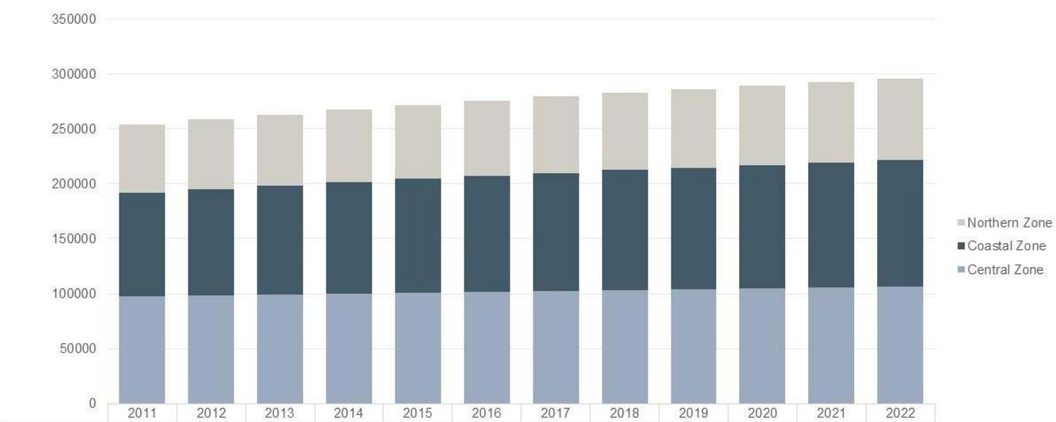
Climatic zone	Municipality	Climatic data		Population		
		HDD	CDD	2011	2015	2021
Northern Zone	Andrijevica	2,829	431	5,071	5,128	5.129
	Berane	2,602	492	28,515	28,834	28.839
	Bijelo Polje	2,482	523	46,051	46,565	46.575
	Gusinje	3,117	248	4,027	4,072	4.073
	Kolašin	3,117	248	8,380	8,474	8.475
	Mojkovac	3,012	400	8,622	8,718	8.720
	Petnjica	2,602	492	5,455	5,516	5.517
	Plav	3,451	186	9,081	9,182	9.184
	Plužine	2,556	400	3,246	3,282	3.283
	Pljevlja	3,208	400	30,786	31,130	31.136
	Rožaje	3,648	93	22,964	23,221	23.225
	Šavnik	2,920	248	2,070	2,093	2.094
	Žabljak	4,835	0	3,569	3,609	3.610
Coastal Zone	Budva	1,494	1,073	19,218	19,433	19.437
	Bar	1,132	1,041	42,048	42,518	42.526
	Herceg Novi	1,297	766	30,864	31,209	31.215
	Kotor	1,494	1,073	22,601	22,853	22.858
	Tivat	1,584	888	14,031	14,188	14.191
	Ulcinj	1,357	796	19,921	20,144	20.148
Central Zone	Cetinje	2,634	310	16,657	16,843	16.847
	Danilovgrad	1,344	1,471	18,472	18,678	18.682
	Nikšić	2,527	585	72,443	73,252	73.267
	Podgorica	1,344	1,471	174,515	176,465	176.500
	Tuzi	1,540	1,288	11,422	11,550	11.552
TOTAL:		**58,120**	**14,923**	**620,029**	**626,957**	**627,083**

Source: EIHP analyses

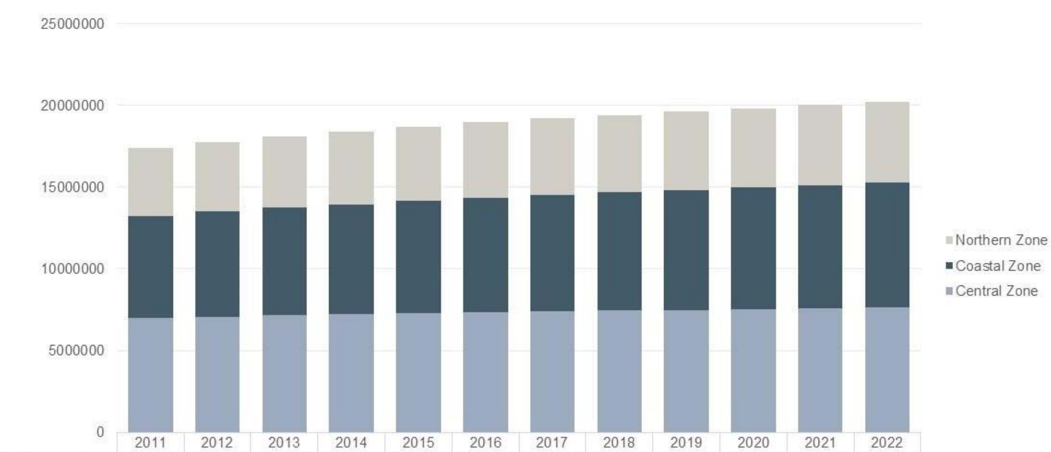
Overview of national building stock – households

An overview of the national building stock is available from the last population census of Montenegro from 2011. From the population census, buildings are classified according to the purpose, as well as according to the year of construction for each municipality separately. For the assessment of the national building fund in 2021, data from the Statistical Yearbooks of Montenegro (section Construction) [2] on the number and area of completed buildings for each year from 2011-2021 were used. The distribution of the newly built stock of buildings from 2011 - 2021 is divided by climatic zone based on the prices of square meters of apartments that are available in statistical yearbooks, considering that the price follows the laws of supply and demand. Additionally, after the distribution by climate zones, the same trend of construction as it was in 2011 by municipalities was assumed. Based on the above, the national building stock in household sector in 2021 was obtained, as shown in the figures and tables below. It is important to emphasise here that only official data were used for the analysis of households and that illegal construction is not included in the analysis, since there are no official and available data for it.

Figure 0-2 Number (top) and area (bottom) of the housing stock of buildings in Montenegro



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Northern Zone	62114	63364.8122	64689.3541	65929.2221	67170.2421	68321.9801	69375.5078	70402.251	71307.1674	72215.5399	73182.0897	74066.2697
Coastal Zone	94600	96738.6219	99003.3057	101123.215	103245.095	105214.321	107015.628	108771.14	110318.354	111871.477	113524.071	115035.829
Central Zone	97277	98230.5659	99240.3402	100185.563	101131.663	102009.699	102812.864	103595.609	104285.479	104977.983	105714.84	106388.901



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Northern Zone	4144454	4249864	4346347	4433325	4526351	4598064	4666322	4731987	4788437	4850934	4909687	4964697
Coastal Zone	6231521	6411750	6576714	6725428	6884483	7007098	7123803	7236077	7332594	7439451	7539907	7633961
Central Zone	6994221	7074581	7148135	7214444	7285363	7340034	7392071	7442131	7485166	7532811	7577602	7619539

Table 0-2 Number and area of the housing stock of buildings in Montenegro by municipality in 2021

Climatic zone	Municipality	Housing building stock	
		Number	Area [m^2]
Northern Zone	Andrijevica	3,155	179,107
	Berane	10,731	746,332
	Bijelo Polje	16,449	1,133,844
	Gusinje	1,461	118,333
	Kolašin	5,086	310,686
	Mojkovac	3,561	209,346
	Petnjica	2,053	142,794
	Plav	3,297	266,865
	Plužine	2,332	123,400
	Pljevlja	13,509	864,342
	Rožaje	6,939	508,995
	Šavnik	1,853	93,319
	Žabljak	3,640	212,324
Coastal Zone	Budva	22,894	1,330,281
	Bar	32,118	2,153,382
	Herceg Novi	23,908	1,471,280
	Kotor	12,510	910,210
	Tivat	8,802	599,287
	Ulcinj	14,804	1,075,465
Central Zone	Cetinje	8,047	507,848
	Danilovgrad	7,581	570,846
	Nikšić	25,514	1,672,255
	Podgorica	61,240	4,530,298
	Tuzi	4,006	296,356
TOTAL:		**295.491**	**20,027,196**

Source: EIHP analyses

Table 0-3 Housing stock of buildings in Montenegro by type and year of construction

Year of construction	Share in the total building fund [%]		
	Small houses (1-2 flats)	Medium (3-9 flats)	Large (> 10 flats)
before 1945	6.16	0.32	0.03
1946 – 1970	15.27	0.86	0.26
1971 – 1990	28.46	2.02	0.42
1991 – 2000	9.48	0.70	0.21
2001 – 2011	10.33	0.90	0.43
Unknown	4.49	0.17	0.03
After 2011	17.25	1.50	0.72

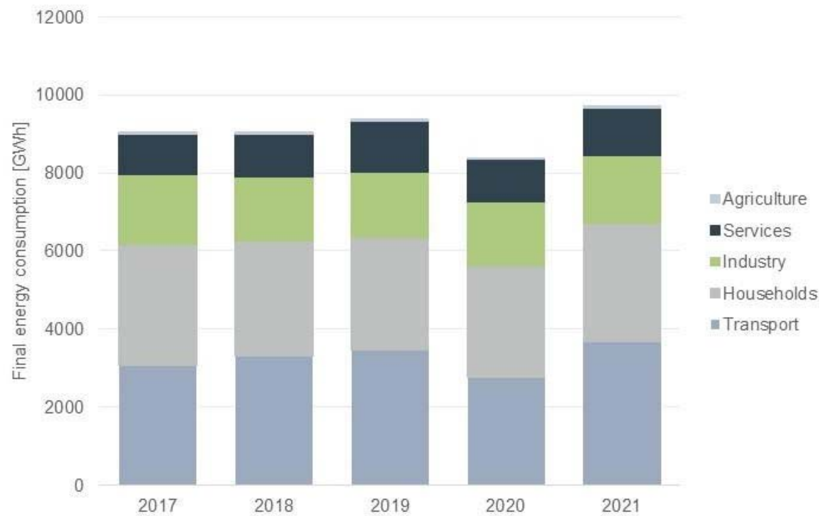
Source: EIHP analyses

PART 1: OVERVIEW OF HEATING AND COOLING

1 Final annual energy consumption for heating and cooling

Data on final energy consumption for the previous 5 years (2017 – 2021) in Montenegro were taken from Eurostat [1]. The total final energy consumption includes energy consumption in the following sectors: households, service sector, industry, agriculture and transport. The graphs below visually represent the final energy consumption data in GWh over the years.

Figure 1-1 Total final energy consumption (diagram above) and percentage distribution of consumption (graph below) in Montenegro



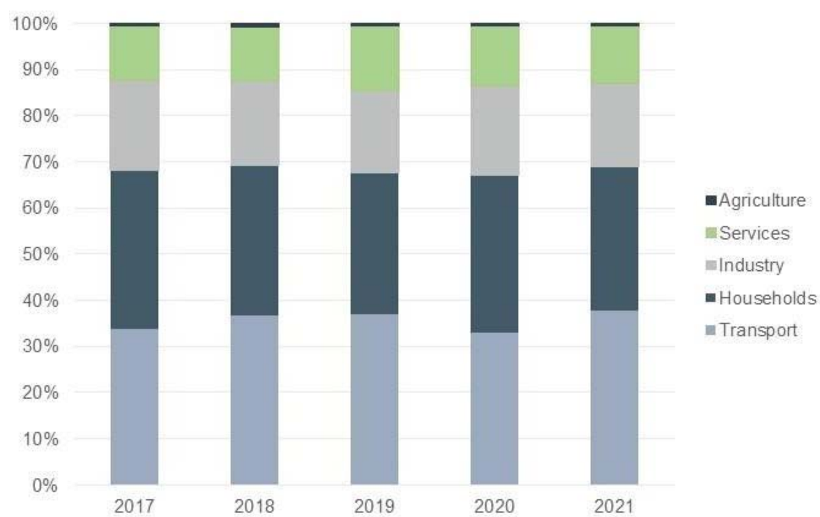


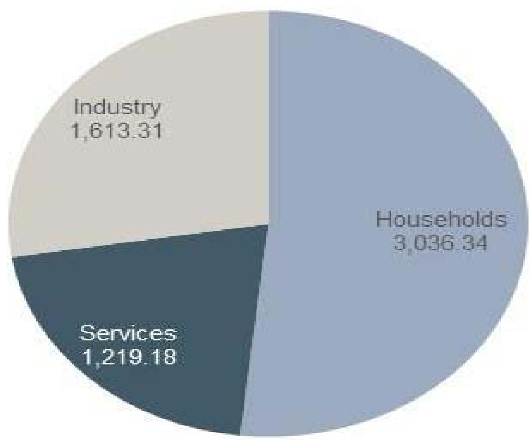
Table 1-1 Overview of total final energy consumption by sectors in Montenegro in 2021

Sector	Total final energy consumption by sectors in 2021 [GWh/a]	Share [%]
Agriculture	54.53	0.57
Services	1,219.18	12.72
Industry	1,613.31	16.83
Households	3,036.34	31.67
Transport	3,663.34	38.21
TOTAL	**9,586.71**	**100.00**

It is important to note that the final energy consumption in the transport sector does not include energy consumption for heating or cooling purposes and will not be included in this study. The agricultural sector's energy consumption represents a small proportion of the total consumption (less than 1%). Therefore, the agricultural sector will also not be analysed in this study.

Finally, all analyses given in this study are carried out for the following three sectors: households, service sector and industry. The shares of these sectors in total final energy consumption considered in this analysis is shown in the Figure below.

Figure 1-2 Total final energy consumption by sectors considered in Montenegro in 2021



The total final energy consumption in households, services, and industry in 2021 amounted to 5,868.83 GWh. Households consumed the highest amount of energy, accounting for 51.74% of the considered total final energy consumption in these three sectors. The industry sector followed with 27.49%, and the services sector consumed 20.77% of the total energy consumption.

The focus of the analysis is on the consumption of energy related to heating (space heating and domestic hot water (DHW) preparation), and space cooling, which is analysed separately for each of the three sectors. This approach allows for a more in-depth understanding of the energy consumption patterns within each sector and aids in identifying potential areas for energy savings and optimization. Section 2 provides more comprehensive information on the distribution of energy consumption by various energy sources, technologies, and a geographical representation of the data.

1.1 Households

In 2021, 31.67% of the total final energy (3,036.34 GWh) was consumed in the household sector. If only households, the service sector and industry are observed, the share of energy consumption in the household sector amounts to 51.74%. A more detailed distribution of consumption by energy sources, technologies, as well as a spatial representation of the data is given in the chapters below.

1.1.1 Final energy consumption by energy sources

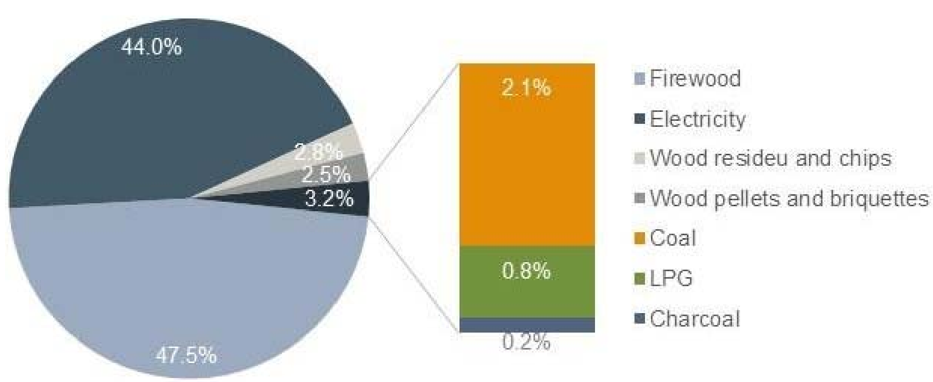
In Montenegro, firewood is the most used energy source for household energy consumption, accounting for 47.54% of the total, followed by electricity (44.01%). Other energy sources such as wood residue and chips, wood pellets and briquettes, coal, charcoal, and LPG are only used to a lesser extent, making up just 8.45% of the total household energy consumption. The actual amounts of energy consumed by each energy source in the household sector can be found in the table and figure below.

Table 1-2 Total final energy consumption by energy sources – households

Energy source	Final energy consumption [GWh/a]	Share [%]
Firewood	1,443.51	47.54
Electricity	1,336.40	*44.01*
Wood residue and chips	83.67	*2.76*
Wood pellets and briquettes	76.66	*2.52*
Coal	65.08	*2.14*
LPG	25.23	*0.83*
Charcoal	5.78	*0.19*
TOTAL	**3,036.34**	**100.00**

Source: EUROSTAT 2021, EIHP analyses

Figure 1-3 Total final energy consumption by energy sources – households



The energy consumption figures provided in the table above includes both thermal (space heating, DHW preparation and space cooling) and non-thermal (cooking, electric appliances, and lighting) consumption in the household sector. To separate only the thermal consumption, the following assumptions were used:

- the energy sources used for cooking are electricity and, to a lesser extent, LPG,

- electric appliances and lighting use only electricity,
- all wood fuels (firewood, wood residue and chips, wood pellets and briquettes, charcoal) are used for heating (space heating and DHW preparation),
- coal and LPG are used for heating (space heating and DHW preparation),
- only electricity is used for cooling.

EUROSTAT data on the energy consumption of the average EU household [4], surveys on consumption in the household sector available on the MONSTAT website [5], and empirical estimates of the EIHP were used as bases for determining the shares related to the consumption of electrical equipment and lighting, as well as cooking. As a result of the above, the consumption distribution shown in the table below was obtained.

Table 1-3 Total final energy consumption by thermal purpose – households

Energy source	**THERMAL CONSUMPTION [GWh/a]**	**NON – THERMAL CONSUMPTION [GWh/a]**		**TOTAL**
	Space heating, DHW preparation and space cooling	Electrical appliances and lighting	Cooking	
Firewood	1,443.51	-	-	
Electricity	776.05	386.49	173.87	
Wood residue and chips	83.67	-	-	
Wood pellets and briquettes	76.66	-	-	
Coal	65.08	-	-	
LPG	16.92	-	8.32	
Charcoal	5.78	-	-	
TOTAL	2,467.67	**386.49**	**182.18**	**3,036,34**
Share [%]	*81.27*	*12.73*	*6.00*	*100.00*

Source: EUROSTAT 2021, EIHP analyses

Thermal consumption accounts for 81.27% of the total energy consumption in Montenegro's household sector, while non-thermal consumption makes up the remaining 18.73%. Out of the non-thermal consumption, 6.00% is attributed to cooking, and 12.73% is attributed to electrical appliances and lighting. Thermal consumption includes heating (space heating and DHW preparation) and cooling (space cooling). According to the survey on consumption in the household sector available on the MONSTAT website [5], it can be seen that the majority of the population owns electric boilers (about 98%). Therefore, it can be concluded that the highest consumption of energy for the preparation of DHW refers to electricity. To a lesser extent, the preparation of DHW is provided by other energy sources, mostly where central heating is available (from the last population census, it is possible to access data on the percentage of apartments with central heating [6] - more details in the next section).

Additionally, electricity is used for space heating and space cooling, and based on data from surveys, as well as data on reference values of typical buildings in Montenegro (Annexes – part 1, Table 9-1 and Table 9-2), the distribution of electricity for H&C was obtained, as shown in the table below.

Table 1-4 Distribution of thermal energy consumption by energy sources - households

Energy source	**Space heating [GWh]/a**	**DHW preparation [GWh/a]**	**Space cooling [GWh/a]**	**TOTAL**
Firewood	1,388.36	55.15	-	**1,443.51**
Electricity	216.21	389.96	169.88	**776.05**
Wood residue and chips	80.48	3.20	-	**83.67**
Wood pellets and briquettes	73.74	2.93	-	**76.67**
Coal	63.68	1.41	-	**65.08**
LPG	13.64	3.28	-	**16.92**
Charcoal	5.56	0.22	-	**5.78**
TOTAL	**1,841.66**	**456.14**	**169.88**	**2,467.67**
Share [%]	*74.63*	*18.48*	*6.88*	*100.00*

Source: Montenegro_types_energy.xlsx (Table 9-1 and Table 9-2 in Annexes – part 1), EIHP analyses

1.1.2 Final energy consumption by technologies

The assessment of energy sources used in Montenegrin households can help identify the technologies utilised. Households that use wood fuels and coal are heated in a decentralised manner using individual stoves, or centrally using boilers. Households in which LPG consumption is recorded use it as an energy source for central heating. Electricity consumption for space heating includes the use of electric heaters or air conditioners (heat pumps), while electricity consumption for cooling refers to air conditioning technology.
Electricity is also used for the preparation of DHW using electric boilers.

From the last population census, it is possible to access data on the percentage of apartments with central heating by municipality [6]. The stated percentages were used to distribute the consumption of wood fuel and coal by technology at the municipality level. Additionally, from the population census and the survey on consumption in the household sector available on the MONSTAT website [5], the representation of air conditioners by municipality was taken. In this way, energy consumption for H&C using air conditioners was obtained, where it was assumed that air conditioners are mostly used for space cooling (approximately 90%). The rest of the total electricity consumption refers to the preparation of DHW using electric boilers and space heating using electric heaters. Finally, based on the above, the distribution of final energy consumption for H&C by technology was obtained, as shown in the table below - separately for each purpose.

Table 1-5 Total energy consumption for heating and cooling by technologies – households

Purpose	Technology	Solid wood fuel [GWh/a]	Coal [GWh/a]	LPG [GWh/a]	Electricity [GWh/a]	TOTAL [GWh/a]	**TOTAL [GWh/a]**
Space heating	Individual stoves	1.292.32	57.83	-	-	1,350.16	**1,841.66**
	Central heating - boilers	255.80	5.85	13.6405	-	275.29	
	Electrical heaters	-	-	-	173.74	173.74	
	AC/heat pumps	-	-	-	42.47	42.47	
DHW preparation	Central heating - boilers	61.49	1.41	3.2790	-	66.18	**456.14**
	Electrical heaters	-	-	-	389.96	389.96	
Space cooling	AC/heat pumps	-	-	-	169.88	169.88	**169.88**
TOTAL		**1,609.62**	**65.08**	**16.92**	**776.05**	**2,467.67**	**2,467.67**

Source: EIHP analyses

Table 1-6 presents the total final energy consumption for H&C by technology in the household sector in 2021[1].

Table 1-6 Total energy consumption for heating and cooling – households – 2021 (reporting based on the European Commission's template)

DELIVERED ENERGY PROVIDED ON-SITE			Unit	Value
HOUSEHOLDS	Fossil fuel sources	Heat only boilers	GWh/a	24.17
		High-efficiency cogeneration	GWh/a	0.00
		Other technologies	GWh/a	621.53
	Renewable energy sources	Heat only boilers	GWh/a	317.30
		High-efficiency cogeneration	GWh/a	0.00
		Heat pumps	GWh/a	212.35
		Other technologies	GWh/a	1,292.32
DELIVERED ENERGY PROVIDED OFF-SITE				
HOUSEHOLDS	Fossil fuel sources	Waste heat	GWh/a	0.00
		High-efficiency cogeneration	GWh/a	0.00
		Other technologies	GWh/a	0.00
	Renewable energy sources	Waste heat	GWh/a	0.00
		High-efficiency cogeneration	GWh/a	0.00
		Other technologies	GWh/a	0.00

Source: EIHP analyses

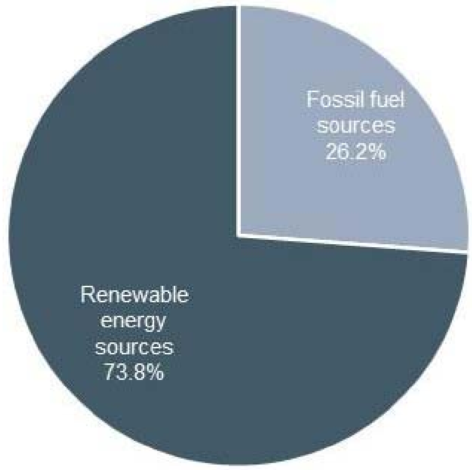
From the table above, it can be concluded that all energy for H&C is provided at the location of the buildings, that is, there are no district heating and cooling (DHC) systems in Montenegro. A total of 73.83% of the final energy for H&C is provided from renewable energy sources, which includes the technologies of wood-fired boilers, heat pumps (mainly air conditioners) and other technologies (individual wood fuel stoves). The rest of the final energy consumption for H&C (26.17%) is provided by coal and LPG boilers, individual coal stoves, and electrical resistance heating.

Table 1-7 Energy provided ON-SITE – households – 2021

Source of energy provided ON-SITE	Delivered energy provided ON-SITE for space heating/cooling/DHW [GWh/a]	*Share [%]*
Fossil fuel sources	645,70	26.17
Renewable energy sources	1.821,97	73.83
TOTAL	**2.467,67**	***100.00***

[1] *To simplify the reporting process in connection with the comprehensive assessment of the potential for efficient heating and cooling, the European Commission made available a template and recommends its use. When using this template to report on the current heating and cooling supply, a distinction is made between energy provided on-site and energy provided off-site. Within each sector, the data are then broken down into fossil fuel sources and renewable energy sources (as well as further distinctions).*

Figure 1-4 Energy provided ON-SITE – households – 2021



1.1.3 Spatial representation of final energy consumption by municipalities

The distribution of wood fuel (firewood, wood residue and chips, wood pellets and briquettes, charcoal) by municipalities is based on a detailed analysis of wood consumption from 2011 [8], and the same distribution of consumption by municipality is assumed today. Electricity consumption for space H&C by municipalities is assumed according to the share of air conditioners from the last population census (MONSTAT 2011) [5], and the same trend in the distribution of air conditioner use is also assumed today, only in larger quantities. Electricity consumption related to the DHW preparation is distributed by municipalities according to area of apartments and using the reference values of typical houses in Montenegro (Annexes – part 1, Table 9-1 and Table 9-2). For coal consumption, it was assumed that the largest amount of coal is consumed in the municipalities of Pljevlja and Berane due to the coal mines located in those municipalities. The rest of coal consumption, as well as LPG consumption, follows the trends of wood consumption by municipality, which will not cause a big error since coal and LPG make up only 0.92% of the total thermal energy consumption. Finally, the distribution of the consumption of each energy source for thermal consumption (H&C) by the municipalities of Montenegro is shown in the table below.

Table 1-8 Total thermal energy consumption of energy sources by municipalities – households

Energy source → **Municipality**	**Energy consumption [GWh/a]**							
	Firewood	Wood residue and chips	Wood pellets and briquettes	Charcoal	Electricity	Coal	LPG	TOTAL
Andrijevica	22.235	0.000	0.000	0.000	5.645	0.190	0.151	**28.221**
Berane	111.447	26.024	0.000	0.000	22.412	20.168	0.631	**180.681**
Bijelo Polje	170.309	15.305	44.506	0.000	34.883	1.202	0.958	**267.163**
Gusinje	17.264	0.000	0.000	0.000	3.082	0.125	0.100	**20.571**
Kolašin	42.419	2.648	0.000	0.000	9.150	0.329	0.262	**54.808**
Mojkovac	35.143	1.497	0.000	0.000	7.216	0.222	0.177	**44.255**
Petnjica	21.323	4.979	0.000	0.000	4.289	0.151	0.121	**30.862**
Plav	38.933	0.000	0.000	0.000	6.955	0.283	0.225	**46.397**
Plužine	16.062	0.000	0.000	0.000	4.008	0.131	0.104	**20.305**
Pljevlja	100.101	16.685	0.000	0.000	26.648	25.390	0.730	**169.553**
Rožaje	82.577	9.703	10.824	0.000	15.671	0.540	0.430	**119.744**
Šavnik	9.809	0.000	0.000	0.000	3.056	0.099	0.079	**13.043**
Žabljak	22.281	1.684	0.000	0.000	5.840	0.225	0.179	**30.209**
Budva	10.792	0.104	4.029	0.716	66.155	1.410	1.124	**84.330**
Bar	54.007	0.000	4.442	3.308	81.701	2.283	1.819	**147.562**
Herceg Novi	28.684	0.000	0.000	0.198	63.167	1.560	1.243	**94.852**
Kotor	18.761	0.000	0.000	0.468	36.984	0.965	0.769	**57.947**
Tivat	12.593	0.000	0.000	0.000	25.580	0.635	0.506	**39.314**
Ulcinj	35.754	0.000	10.706	0.536	37.801	1.140	0.909	**86.845**
Cetinje	50.326	0.000	0.000	0.000	16.784	0.538	0.429	**68.077**
Danilovgrad	49.030	0.000	0.000	0.000	20.988	0.605	0.482	**71.105**
Nikšić	200.913	4.978	0.000	0.000	58.465	1.773	1.413	**267.542**
Podgorica	263.440	0.057	1.941	0.497	206.085	4.803	3.827	**480.651**
Tuzi	29.306	0.006	0.216	0.055	13.484	0.314	0.250	**43.632**
TOTAL	**1,443.506**	**83.672**	**76.664**	**5.778**	**776.047**	**65.083**	**16.920**	**2,467.670**

Source: EIHP analyses

As already explained in Chapter 1.1.2, energy consumption for H&C can be shown by municipality according to the technologies used, as shown in the tables below.

Table 1-9 Total energy consumption for space heating by technologies – households

Technology & Energy source → Municipality	Individual stoves, GWh		Central heating – boilers, GWh			Electric heaters, GWh	AC/heat pumps, GWh
	Solid wood fuel	Coal	Solid wood fuel	Coal	LPG	Electricity	Electricity
Andrijevica	21.2562	0.1815	0.7892	0.0067	0.1220	1.4210	0.0133
Berane	101.1625	18.3070	29.2718	1.5004	0.5083	7.9901	0.0565
Bijelo Polje	149.3788	1.0544	65.0935	0.1191	0.7723	12.9040	0.0609
Gusinje	15.8092	0.1149	1.1726	0.0085	0.0806	1.1285	0.0058
Kolašin	35.8584	0.2784	7.4239	0.0411	0.2116	2.3481	0.0201
Mojkovac	32.1013	0.2027	3.6593	0.0155	0.1426	2.4160	0.0218
Petnjica	19.3551	0.1374	5.6005	0.0113	0.0973	1.5285	0.0109
Plav	35.6530	0.2591	2.6444	0.0192	0.1818	2.5445	0.0133
Plužine	15.3345	0.1249	0.5863	0.0048	0.0840	0.9096	0.0051
Pljevlja	85.6854	21.7335	25.0730	2.9478	0.5887	8.6265	0.0442
Rožaje	72.9447	0.4767	24.3142	0.0507	0.3467	6.4347	0.0187
Šavnik	9.5702	0.0965	0.1928	0.0019	0.0636	0.5802	0.0068
Žabljak	17.7906	0.1797	4.9779	0.0366	0.1446	1.0002	0.0085
Budva	9.7085	1.2688	4.7824	0.1141	0.9061	5.3852	6.1281
Bar	51.8669	2.1925	7.9743	0.0729	1.4667	11.7822	5.5302
Herceg Novi	26.6738	1.4505	1.7805	0.0881	1.0021	8.6484	4.6109
Kotor	16.9459	0.8716	1.8406	0.0753	0.6199	6.3330	2.8374
Tivat	11.8567	0.5982	0.5936	0.0300	0.4082	3.9317	2.0130
Ulcinj	34.4154	1.0975	10.1424	0.0344	0.7325	5.5822	2.5472
Cetinje	44.8305	0.4796	4.4304	0.0474	0.3459	4.6676	0.2906
Danilovgrad	44.5961	0.5505	3.5742	0.0441	0.3888	5.1760	1.1531
Nikšić	174.1781	1.5370	25.5669	0.1902	1.1390	20.2992	0.8714
Podgorica	238.7888	4.3535	21.8856	0.3623	3.0856	48.9008	15.2069
Tuzi	26.5637	0.2848	2.4344	0.0237	0.2018	3.2006	0.9949
TOTAL	**1.292.3244**	**57.8314**	**255.8045**	**5.8462**	**13.6405**	**173.7387**	**42.4695**

Source: EIHP analyses

Table 1-10 Total energy consumption for DHW preparation by technologies – households

Technology & Energy source → Municipality	Central heating – boilers, GWh			Electrical heaters, GWh
	Solid wood fuel	Coal	LPG	Electricity
Andrijevica	0.1897	0.0016	0.0293	4.1574
Berane	7.0366	0.3607	0.1222	14.1391
Bijelo Polje	15.6476	0.0286	0.1856	21.6746
Gusinje	0.2819	0.0020	0.0194	1.9247
Kolašin	1.7846	0.0099	0.0509	6.7011
Mojkovac	0.8797	0.0037	0.0343	4.6916
Petnjica	1.3463	0.0027	0.0234	2.7056
Plav	0.6357	0.0046	0.0437	4.3443
Plužine	0.1409	0.0011	0.0202	3.0732
Pljevlja	6.0272	0.7086	0.1415	17.8000
Rožaje	5.8448	0.0122	0.0833	9.1428
Šavnik	0.0464	0.0005	0.0153	2.4416
Žabljak	1.1966	0.0088	0.0348	4.7968
Budva	1.1496	0.0274	0.2178	30.1294
Bar	1.9169	0.0175	0.3526	42.2680
Herceg Novi	0.4280	0.0212	0.2409	31.4641
Kotor	0.4425	0.0181	0.1490	16.4642
Tivat	0.1427	0.0072	0.0981	11.5832
Ulcinj	2.4381	0.0083	0.1761	19.4824
Cetinje	1.0650	0.0114	0.0831	10.6635

Technology & Energy source → Municipality	Central heating – boilers, GWh			Electrical heaters, GWh
	Solid wood fuel	Coal	LPG	Electricity
Danilovgrad	0.8592	0.0106	0.0935	10.0461
Nikšić	6.1460	0.0457	0.2738	33.8092
Podgorica	5.2610	0.0871	0.7417	81.1499
Tuzi	0.5852	0.0057	0.0485	5.3085
TOTAL	**61.4921**	**1.4054**	**3.2790**	**389.9615**

Source: EIHP analyses

Table 1-11 Total energy consumption for space cooling by technologies – households

Technology & Energy source → Municipality	AC/heat pumps, GWh
	Electricity
Andrijevica	0,0531
Berane	0,2259
Bijelo Polje	0,2436
Gusinje	0,0231
Kolašin	0,0803
Mojkovac	0,0871
Petnjica	0,0436
Plav	0,0531
Plužine	0,0204
Pljevlja	0,1769
Rožaje	0,0749
Šavnik	0,0272
Žabljak	0,0340
Budva	24,5123
Bar	22,1209
Herceg Novi	18,4434
Kotor	11,3497
Tivat	8,0519
Ulcinj	10,1887
Cetinje	1,1623
Danilovgrad	4,6126
Nikšić	3,4856
Podgorica	60,8275
Tuzi	3,9797
TOTAL	**169,8778**

Source: EIHP analyses

Finally, spatial distribution of final energy consumption for heating (space heating and DHW preparation) and cooling (space cooling) of the households by municipalities in Montenegro is shown in the figure below. For both cooling and heating, the highest energy consumption was recorded in the capital Podgorica. The reason for this is that most of the population, as well as most of the residential buildings, are in Podgorica.

Figure 1-5 Final energy consumption for heating by municipalities in the household sector of Montenegro [GWh/a]

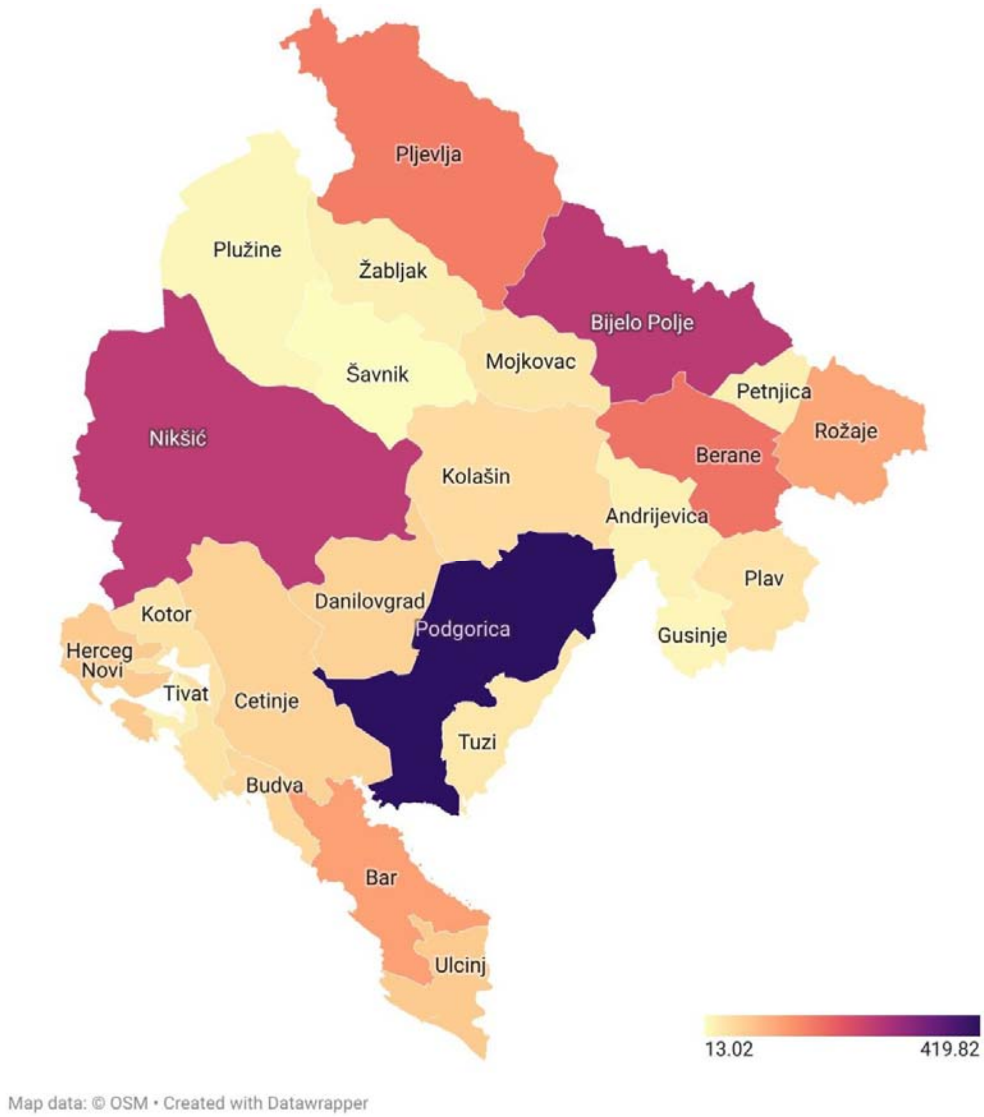
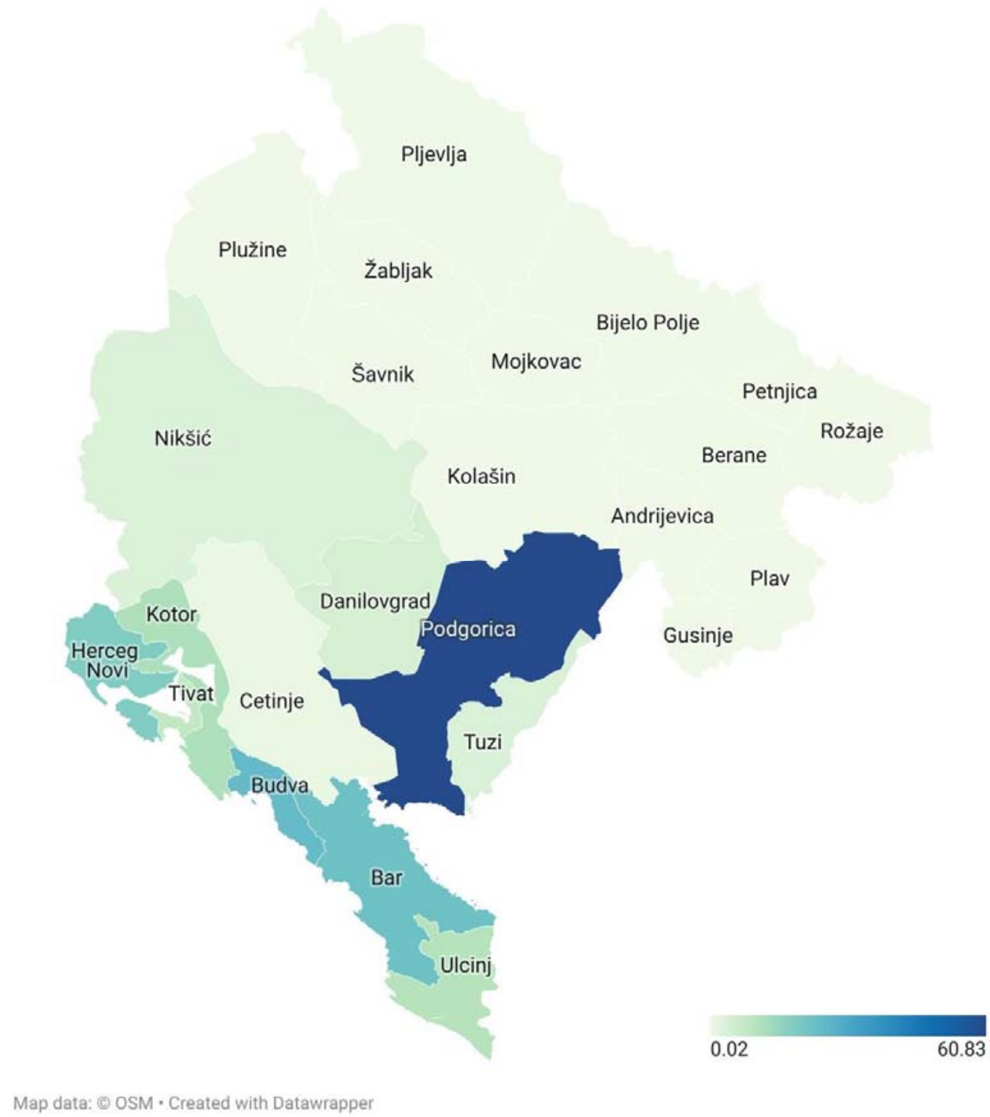


Figure 1-6 Final energy consumption for cooling by municipalities in the household sector of Montenegro [GWh/a]



1.2 Services

In 2021, the services sector consumed 1,219.18 GWh, which represented 12.72% of the total final energy consumption in Montenegro and 20.77% of the total final energy consumption in households, services, and industry. A more detailed distribution of consumption by energy sources, technologies, as well as a spatial representation of the data is given in the chapters below.

1.2.1 Final energy consumption by energy sources and type of buildings

The most represented energy source in the final energy consumption in the services in Montenegro is electricity (76.86%), followed by fuel oils (8.55%), wood fuels (7.55%), coal (4.74%) and LPG (2.30%). The absolute values of energy consumption by energy source in the services in Montenegro are shown in the table below.

Table 1-12 Total final energy consumption by energy sources – services (public lighting included)

Energy source	**Final energy consumption [GWh/a]**	***Share [%]***
Electricity	937.10	*76.86*
Fuel oils	104.23	*8.55*
Wood fuels	92.06	*7.55*
Coal	57.76	*4.74*
LPG	28.04	*2.30*
TOTAL	**1,219.18**	***100.00***

Source: EUROSTAT 2021

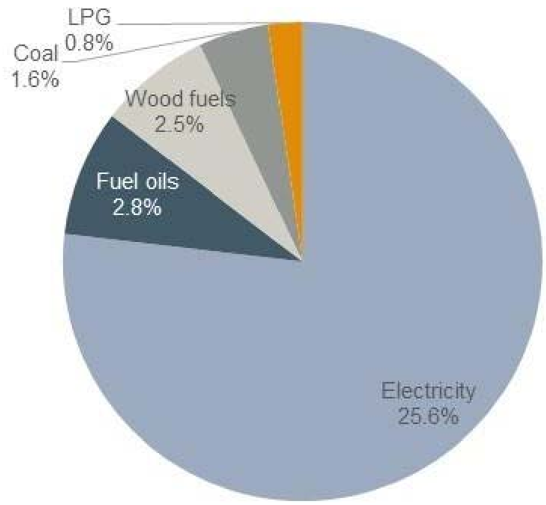
The total consumption shown above also includes the consumption of electricity for public lighting. To determine the consumption of electricity for public lighting, data on the consumption of public lighting from the study "*Energy consumption in the service sector in Montenegro*" [9] from 2014 was used. Over the years, new public lighting capacities were installed, which led to an increase in consumption, but part of the existing lighting was also replaced with more energy efficient units, which resulted in a decrease in electricity consumption per unit. Therefore, for the purposes of this research, the data on the electricity consumption of public lighting from 2014 is considered satisfactory and amounts to
143.80 GWh. If public lighting consumption is excluded from the table above, the total energy consumption in service sector buildings amounts to 1,075.385 GWh.

Table 1-13 Total final energy consumption by energy sources – services (public lighting excluded)

Energy source	**Final energy consumption [GWh/a]**	***Share [%]***
Electricity	793.30	*73.77*
Fuel oils	104.23	*9.69*
Wood fuels	92.06	*8.56*
Coal	57.76	*5.37*
LPG	28.04	*2.61*
TOTAL	**1,075.38**	**100.00**

Source: EIHP analyses

Figure 1-7 Total final energy consumption by energy sources – services (public lighting excluded)



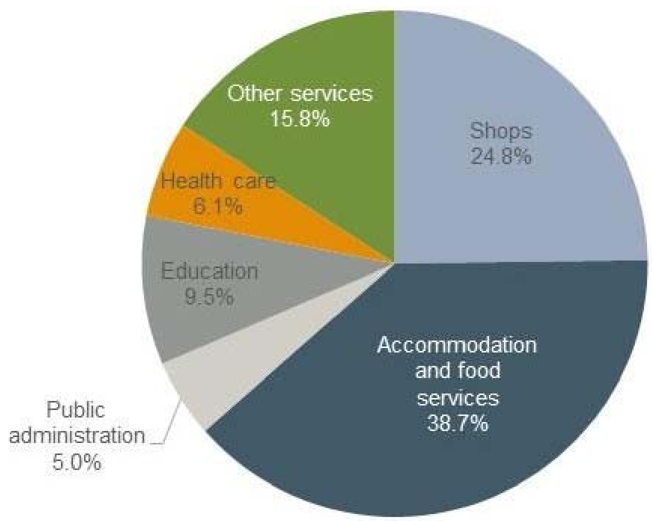
For the distribution of consumption by types of buildings, the consumption by types of buildings from the study [9] was used as a basis. In addition, on the basis of data from the Statistical Yearbooks of Montenegro [2] for the period from 2014 to 2021, which include the number of inhabitants, the total number of employees, the number of employees in health care, the number of students in the education system, the number of overnight stays, an increase or decrease in energy consumption was assumed by buildings and energy products with regard to the year 2014. As a result of the above, the consumption by energy sources and types of buildings of the service sector (without public lighting) in Montenegro in 2021 was obtained.

Table 1-14 Final energy consumption by energy sources and building types – services

Energy source → Building type	Fuel oils [GWh/a]	Wood fuels [GWh/a]	Coal [GWh/a]	LPG [GWh/a]	Electricity [GWh/a]	TOTAL [GWh/a]	***Share [%]***
Shops	1.2001	7,0073	2,7711	0,7054	254,9765	**266.66**	*24.80*
Accommodation and food services	32.8149	54,0387	0,0000	26,6813	302,8697	**416.40**	*38.72*
Public administration	7.5765	2,4248	14,8818	0,0716	28,9509	**53.91**	*5.01*
Education	31,5947	18,6710	25,3222	0,3529	26,5038	**102.44**	*9.53*
Health care	22,3818	0,0000	5,6635	0,0238	37,9958	**66.06**	*6.14*
Other services	8,6594	9,9163	9,1226	0,2031	142,0032	**169.90**	*15.80*
TOTAL	**104,2274**	**92,0581**	**57,7611**	**28,0380**	**793,2999**	**1,075.38**	***100.00***
Share [%]	*9.69*	*8.56*	*5.37*	*2.61*	*73.77*	***100.00***	

Source: EIHP analysis

Figure 1-8 Distribution of total final energy consumption by building types – services



Based on the data presented above, it is evident that the accommodation and food services sector has the highest total final energy consumption in the service sector, representing 38.72% of the overall energy consumption. The second-highest energy consumption is observed in shops, accounting for 24.80% of the total energy consumption followed by other services (15,80%). Other services include the following activities according to NACE REV.2 classification: 33, 36, 37, 38, 39, 52, 53, 58,59, 60, 61, 62, 63, 64, 65, 66, 68, 69, 70, 71, 72, 73, 74, 75, 77, 78, 79, 80, 81, 82, 90, 91, 92, 93, 94, 95, 96 and 99.

1.2.2 Final energy consumption by technologies

Given that there are no recent and relevant data, for modelling the distribution of final energy consumption by technology, ratios by used technologies and energy sources for each type of building from the study [9] were used. Non-thermal energy consumption is separated from the monthly energy consumption available in [9] using examples of good practice from the experience of conducting energy audits of buildings, as well as available energy audits of several public buildings in Montenegro that were processed as part of the project "Second Energy Efficiency Project - MEEP 2; Ref. no: MNE-MEEP_2-8870-ME-QCBS-CS-20-2.1”.
After obtaining consumption only for the needs of heating, DHW preparation and cooling, distribution ratios by technologies and energy sources from 2014 were applied and calibrated with consumption from 2021. Finally, the distribution of final energy consumption by technologies, energy sources and types of buildings in the services sector of Montenegro in 2021 was obtained, as shown in the table below.

Table 1-15 Final energy consumption according to energy sources, technologies and types of buildings in services

	Energy source → Technology	Fuel oils [GWh/a]	Wood fuels [GWh/a]	Coal [GWh/a]	LPG [GWh/a]	Electricity [GWh/a]	TOTAL [GWh/a]
SHOPS	Decentralised heating - individual sources	-	3.9270	-	-	10.4283	**14.3553**
	Centralised heating	1.2001	2.8493	2.6271	0.7040	3.8237	**11.2042**

	Energy source → Technology	Fuel oils [GWh/a]	Wood fuels [GWh/a]	Coal [GWh/a]	LPG [GWh/a]	Electricity [GWh/a]	TOTAL [GWh/a]
	Air conditioners units	-	-	-	-	18.4233	**18.4233**
	Decentralised DHW preparation - individual sources	-	-	-	-	4.4557	**4.4557**
	Centralised DHW preparation - boilers	-	0.2310	0.1440	-	-	**0.3750**
	Decentralised cooling	-	-	-	-	35.2594	**35.2594**
	Centralised cooling	-	-	-	-	1.7110	**1.7110**
	Non-thermal consumption	-	-	-	0.0014	180.8751	**180.8765**
	TOTAL	**1.2001**	**7.0073**	**2.7711**	**0.7054**	**254.9765**	**266.6604**
A&F SERVICES	Decentralised heating - individual sources	-	-	-	-	7.7476	**7.7476**
	Centralised heating	32.3165	48.9055	-	18.2051	-	**99.4271**
	Air conditioners units	-	-	-	-	17.9882	**17.9882**
	Decentralised DHW preparation - individual sources	-	-	-	-	6.4340	**6.4340**
	Centralised DHW preparation - boilers	0.4985	0.0345	-	-	-	**0.5330**
	Decentralised cooling	-	-	-	-	73.1130	**73.1130**
	Centralised cooling	-	-	-	-	10.8929	**10.8929**
	Non-thermal consumption	-	5.0987	-	8.4762	186.6941	**200.2689**
	TOTAL	**32.8149**	**54.0387**	**0.0000**	**26.6813**	**302.8697**	**416.4046**
PUBLIC ADMINISTRATION	Decentralised heating - individual sources	-	0.0092	-	-	1.8974	**1.9066**
	Centralised heating	7.1559	2.4156	14.8818	-	2.4709	**26.9242**
	Air conditioners units	-	-	-	-	4.8857	**4.8857**
	Decentralised DHW preparation - individual sources	-	-	-	-	0.9152	**0.9152**
	Centralised DHW preparation - boilers	0.4205	-	-	-	-	**0.4205**
	Decentralised cooling	-	-	-	-	3.3288	**3.3288**
	Centralised cooling	-	-	-	-	0.7038	**0.7038**
	Non-thermal consumption	-	-	-	0.0716	14.7491	**14.8206**
	TOTAL	**7.5765**	**2.4248**	**14.8818**	**0.0716**	**28.9509**	**53.9055**
EDUCATION	Decentralised heating - individual sources	-	14.4478	2.2831	-	4.9258	**21.6567**
	Centralised heating	31.4960	4.1991	23.0271	0.2973	2.6210	**61.6405**
	Air conditioners units	-	-	-	-	2.6601	**2.6601**
	Decentralised DHW preparation - individual sources	-	-	-	-	1.0095	**1.0095**
	Centralised DHW preparation - boilers	0.0987	0.0241	0.0120	0.0067	-	**0.1415**
	Decentralised cooling	-	-	-	-	2.7176	**2.7176**
	Centralised cooling	-	-	-	-	0.0955	**0.0955**
	Non-thermal consumption	-	-	-	0.0488	12.4743	**12.5231**
	TOTAL	**31.5947**	**18.6710**	**25.3222**	**0.3529**	**26.5038**	**102.4445**
HEALTH CARE	Decentralised heating - individual sources	-	-	-	-	4.7095	**4.7095**
	Centralised heating	21.7097	-	5.5788	-	3.6153	**30.9038**
	Air conditioners units	-	-	-	-	3.1647	**3.1647**
	Decentralised DHW preparation - individual sources	-	-	-	-	2.8724	**2.8724**

	Energy source → Technology	Fuel oils [GWh/a]	Wood fuels [GWh/a]	Coal [GWh/a]	LPG [GWh/a]	Electricity [GWh/a]	TOTAL [GWh/a]
	Centralised DHW preparation - boilers	0.6721	-	0.0847	-	-	**0.7567**
	Decentralised cooling	-	-	-	-	5.0599	**5.0599**
	Centralised cooling	-	-	-	-	0.2604	**0.2604**
	Non-thermal consumption	-	-	-	0.0238	18.3137	**18.3374**
	TOTAL	**22.3818**	**0.0000**	**5.6635**	**0.0238**	**37.9958**	**66.0648**
OTHERS	Decentralised heating - individual sources	-	3.6027	-	-	8.5400	**12.1427**
	Centralised heating	8.4001	6.1701	9.1226	0.0155	1.8153	**25.5236**
	Air conditioners units	-	-	-	-	37.6765	**37.6765**
	Decentralised DHW preparation - individual sources	-	-	-	-	4.7504	**4.7504**
	Centralised DHW preparation - boilers	0.2594	0.0172	-	-	-	**0.2765**
	Decentralised cooling	-	-	-	-	35.1606	**35.1606**
	Centralised cooling	-	-	-	-	4.4135	**4.4135**
	Non-thermal consumption	-	0.1263	-	0.1875	49.6470	**49.9607**
	TOTAL	**8.6594**	**9.9163**	**9.1226**	**0.2031**	**142.0032**	**169.9046**

Source: EIHP analyses

The overall final energy consumption for space heating and DHW preparation, as well as space cooling, in the service sector can be summarized as follows.

Table 1-16 Total final energy consumption for H&C – services – 2021 (reporting based on the European Commission's template)

DELIVERED ENERGY PROVIDED ON-SITE			Unit	Value
SERVICES	Fossil fuel sources	Heat only boilers	GWh/a	178.93
		High-efficiency cogeneration	GWh/a	0.00
		Other technologies	GWh/a	75.31
	Renewable energy sources	Heat only boilers	GWh/a	64.85
		High-efficiency cogeneration	GWh/a	0.00
		Heat pumps	GWh/a	257.51
		Other technologies	GWh/a	21.99
DELIVERED ENERGY PROVIDED OFF-SITE				
SERVICES	Fossil fuel sources	Waste heat	GWh/a	0.00
		High-efficiency cogeneration	GWh/a	0.00
		Other technologies	GWh/a	0.00
	Renewable energy sources	Waste heat	GWh/a	0.00
		High-efficiency cogeneration	GWh/a	0.00
		Other technologies	GWh/a	0.00

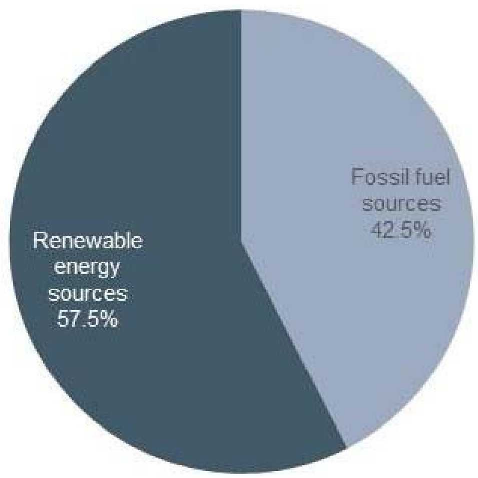
Source: EIHP analysis

Based on the table above, it can be concluded that all H&C energy is generated on-site, indicating that there are no district H&C systems. Of the total final energy consumption for H&C, 57.53% is derived from renewable energy sources, such as wood-fired boilers, heat pumps (primarily air conditioners), and other technologies (like individual wood fuel stoves). The remaining 42.47% of the final energy consumption for H&C is obtained from coal, LPG, and fuel oil boilers, individual coal stoves, and electrical resistance heating. This data highlights the importance of utilising renewable energy sources for H&C purposes, which can reduce energy costs, decrease reliance on fossil fuels, and contribute to a sustainable future.

Table 1-17 Energy provided ON-SITE – services – 2021

Source of energy provided ON-SITE	Delivered energy provided ON-SITE for space heating/cooling/DHW [GWh/a]	*Share [%]*
Fossil fuel sources	254,24	42,47
Renewable energy sources	344,35	57,53
TOTAL	**598,59**	***100,00***

Figure 1-9 Energy provided ON-SITE – services – 2021



1.2.3 Spatial representation of final energy consumption by municipalities

Based on the following parameters, it is possible to divide the total final consumption for H&C by municipality and building type:

- number of populations by municipality for distribution of energy consumption for H&C of public administration and other service buildings,
- the total number of employees per municipality for the distribution of energy consumption for H&C of shops building,
- the number of employees in healthcare by municipality for the distribution of energy consumption for H&C of healthcare buildings,
- the number of overnight stays by municipality for the distribution of energy consumption for H&C of buildings that provide accommodation and food services,

- the number of students in the education system (primary schools, high schools and faculties) by municipality for the distribution of energy consumption for H&C of education buildings.

By applying the above assumptions, the total distribution of final energy consumption for H&C by municipalities and types of buildings in the service sector of Montenegro was obtained, as shown in the table below, and spatially in Figure 1-10 and Figure 1-11.

Table 1-18 Total final energy consumption by municipalities in the service sector of Montenegro

Type of building → Municipality	Shops [GWh/a]	A&F services [GWh/a]	Public administration [GWh/a]	Education [GWh/a]	Health care [GWh/a]	Other services [GWh/a]	TOTAL [GWh/a]
Andrijevica	0.2398	0.0865	0.3197	0.5343	0.1917	0.3353	**1.7072**
Berane	1.8547	0.1489	1.7975	3.9840	2.3002	2.5933	**12.6788**
Bijelo Polje	3.6029	0.3252	2.9029	6.2251	2.4492	5.0376	**20.5429**
Gusinje	0.3001	0.0545	0.2539	0.3517	0.1788	0.4196	**1.5587**
Kolašin	0.5758	1.4947	0.5283	0.8413	0.2840	0.8051	**4.5291**
Mojkovac	0.5442	0.1229	0.5435	0.8727	0.3763	0.7610	**3.2206**
Petnjica	0.4388	0.0285	0.3439	0.6431	0.4400	0.6135	**2.5077**
Plav	0.3767	0.2034	0.5724	1.4058	0.4033	0.5267	**3.4883**
Plužine	0.2049	0.1181	0.2046	0.2309	0.0781	0.2865	**1.1231**
Pljevlja	2.5222	0.2263	1.9407	2.9058	1.7606	3.5265	**12.8820**
Rožaje	1.3948	0.2067	1.4476	4.0336	0.6815	1.9503	**9.7145**
Šavnik	0.1296	0.0570	0.1305	0.1136	0.0639	0.1812	**0.6758**
Žabljak	0.2903	1.6929	0.2250	0.3215	0.0568	0.4059	**2.9924**
Budva	6.5241	68.6837	1.2114	3.7979	0.6176	9.1221	**89.9569**
Bar	5.4113	30.0633	2.6506	6.3508	2.3072	7.5662	**54.3494**
Herceg Novi	4.5205	46.4601	1.9456	4.0022	2.3356	6.3206	**65.5845**
Kotor	3.0839	10.1779	1.4247	3.1017	3.2230	4.3119	**25.3230**
Tivat	2.3755	17.4520	0.8845	2.3607	0.3621	3.3215	**26.7563**
Ulcinj	2.1221	32.2462	1.2558	2.7535	0.5253	2.9672	**41.8701**
Cetinje	1.5866	0.9731	1.0500	1.6499	1.5121	2.2184	**8.9902**
Danilovgrad	1.6861	0.2368	1.1644	2.3945	0.3763	2.3576	**8.2158**
Nikšić	6.2746	0.4324	4.5666	9.7667	3.9755	8.7732	**33.7889**
Podgorica	37.1244	4.3591	11.0009	29.4162	21.8014	51.9077	**155.6097**
Tuzi	2.6000	0.2853	0.7200	1.8639	1.4269	3.6353	**10.5313**
TOTAL	**85.7839**	**216.1357**	**39.0849**	**89.9214**	**47.7274**	**119.9439**	**598.5971**

Source: EIHP analysis

Figure 1-10 Final energy consumption for heating by municipalities in the services sector of Montenegro [GWh/a]

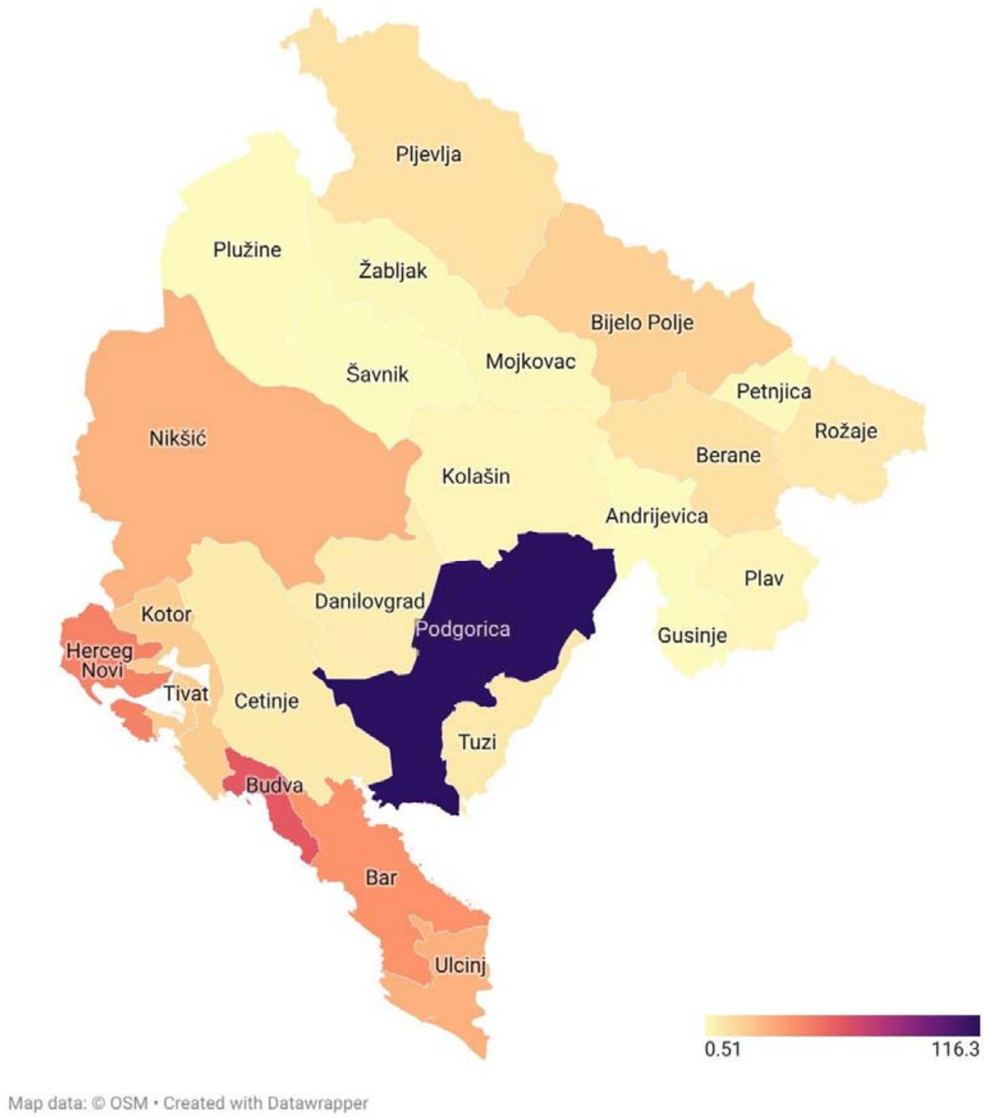


Figure 1-11 Final energy consumption for cooling by municipalities in the services sector of Montenegro [GWh/a]

1.3 Industry

For a detailed assessment of heating and cooling in the industrial sector, it is necessary to collect the following data:

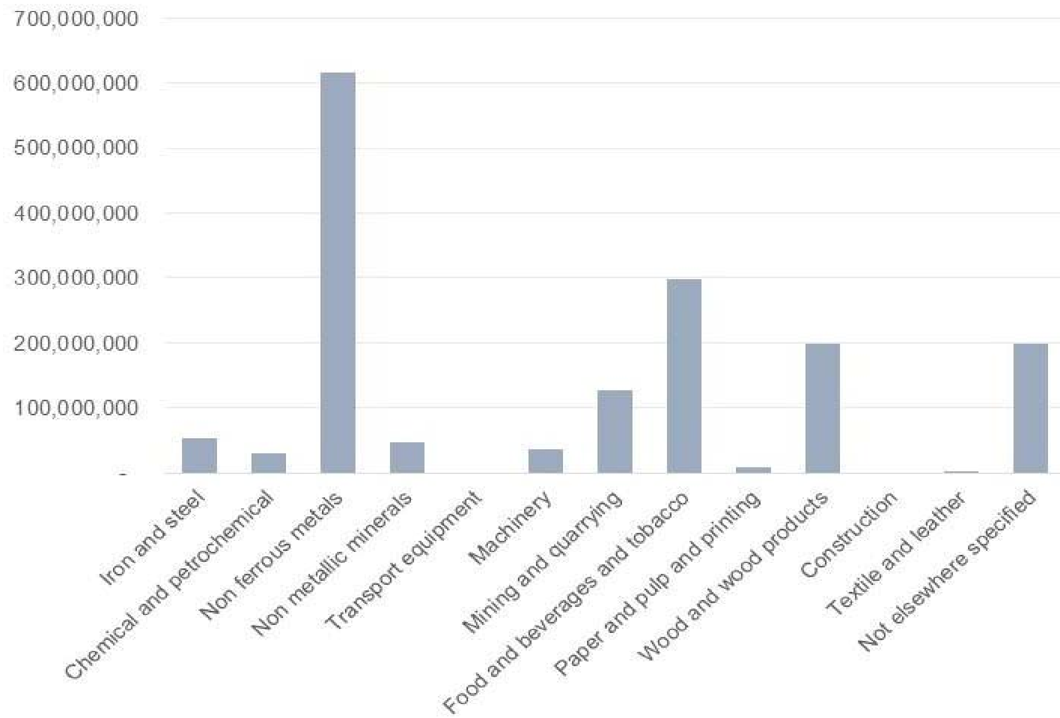
- Address or latitude and longitude of each industrial facility to determine and display exact location,
- Type of activity for each industry- it is possible to use NKD codes,
- Type of energy source(s) consumed that is consumed at the location of the building of each industrial plant for heating/cooling purposes,
- Exact annual consumption of a particular type of energy source for 2021 with the indication of the unit of measurement of the energy source,
- In the case of steam and water, which is consumed at the industry's location as an energy source, it is necessary to state the origin of the steam and water (method of obtaining):
  - Supply directly from central heating systems (CHS),
  - Production from industrial boiler rooms,
  - Production from industrial cogeneration plants.

Additionally, for industrial boiler rooms for the production of steam and water, the following information must be provided: type of energy source(s), annual consumption of energy source(s) for steam production, annual steam production, while for industrial cogeneration plants for the production of steam and water, the following information must be provided: type of energy source(s), annual consumption of energy source(s) for the production of electricity and heat, annual produced electricity and annual produced heat energy. In addition to the above, it is desirable to define the average efficiency value of technologies for energy sources that burn in the combustion chamber (e.g., coal, coke, various types of fuel oil, LPG, wood, pellets, wood chips).

However, it was not possible to provide all the above-mentioned data, and therefore it was necessary to perform an analysis with the EUROSTAT available data as shown below. For a more detailed analysis such as that in the household and service sectors, it is essential to provide all the above data.

In 2021, the total energy consumption of the industry sector was 1,613.31 GWh. Looking at the branches of industry, data for 11 branches of industry are available in EUROSTAT energy balance. It should be noted that data on energy consumption in the Construction sector are not listed separately, and the energy consumption of that sector is included in the "Not elsewhere specified" category. The total energy consumption in industry is shown in the following graph.

Figure 1-12 Final energy consumption in Industry in 2021 (EUROSTAT)



Consumption in the category "Non-ferrous metals" is dominant with a share of 38.2 % of total energy demand in industry, followed by "Food, beverages and tobacco" industry with a share of 18.5 %. The category "Not Elsewhere Specified" represents a share of 12.3%, and probably the largest part of it was realised for construction purposes.

Usually, in the industry sector, energy use can be analysed according to three basic purposes:

- Thermal uses,
- Specific use of electricity,
- Motive power.

From the consumption energy data from the energy balance, consumption of diesel fuel and motor gasoline are classified for motive power needs, all, or a certain part of consumption of electricity is classified as Specific use of electricity, and the remaining consumption of all other energy sources is used for Thermal uses. In accordance with such distribution, energy consumption in the industry sector for the base year was modelled by end-use categories as shown in the table below. Additionally, Table 1-19 shows the distribution of energy consumption by energy source.

Table 1-19 Energy consumption in industry by end-uses

End-use	Energy consumption [GWh/a]	%
Thermal uses	598.46	37%
Electricity specific use	508.80	32%
Motive power	506.05	31%
Total	**1,613.31**	**100%**

Source: EIHP analysis

Table 1-20 Energy consumption in industry by end-uses and fuels

Energy source	Thermal uses [GWh/a]	Electricity specific use [GWh/a]	Motive power [GWh/a]	TOTAL [GWh/a]
Electricity	169.60	508.80	0.00	**678.40**
Natural gas	46.00	0.00	0.00	**46.00**
Motor gasoline	0.00	0.00	9.91	**9.91**
Diesel	0.00	0.00	496.14	**496.14**
Fuel oil	38.16	0.00	0.00	**38.16**
LPG	86.71	0.00	0.00	**86.71**
Coal	59.32	0.00	0.00	**59.32**
Fuelwood	111.11	0.00	0.00	**111.11**
Light fuel oil	87.55	0.00	0.00	**87.55**
TOTAL	**598.46**	**508.80**	**506.05**	**1,613.31**

Source: EIHP analysis

2 Energy demand for heating and cooling

2.1 Households

The energy demand for space heating, DHW preparation and space cooling in the households have been modelled on the basis of:

- data on the building area, location and building type available and determined from the population census of Montenegro 2011,
- data on areas of newly built buildings, which are available from the Statistical Yearbooks,
- data on the specific energy needed for space heating, DHW preparation and space cooling for different types of buildings and three climate zones (coastal, central and northern) – Annexes – part 1: Table 9-1 and Table 9-2).

As a result of the above, the energy demand for space heating, DHW preparation and space cooling for each municipality was obtained, as shown in the table below.

Table 2-1 Energy demand for heating and cooling – households

Municipality	ENERGY DEMAND [GWh/a]			
	Space heating	DHW preparation	Space cooling	TOTAL
Andrijevica	64.3507	5.8541	4.6157	**74.8206**
Berane	292.2626	25.7035	20.6507	**338.6168**
Bijelo Polje	454.9104	39.1282	32.2177	**526.2563**
Gusinje	48.4669	4.2425	3.4639	**56.1733**
Kolašin	93.3256	8.5139	6.5284	**108.3680**
Mojkovac	84.0856	7.2925	6.0114	**97.3896**
Petnjica	55.9185	4.9179	3.9511	**64.7875**
Plav	109.3107	9.5686	7.8122	**126.6914**
Plužine	35.5738	3.3190	2.5361	**41.4289**
Pljevlja	327.8753	29.0339	23.7644	**380.6736**
Rožaje	180.1400	15.7458	12.4984	**208.3842**
Šavnik	27.3809	2.6144	2.0043	**31.9996**
Žabljak	44.1313	4.2043	2.9781	**51.3137**
Budva	160.3664	32.6558	56.1109	**249.1331**
Bar	293.7779	55.5057	109.1583	**458.4419**
Herceg Novi	208.8587	39.3923	78.8481	**327.0991**
Kotor	144.8988	27.6501	56.2506	**228.7995**
Tivat	95.0862	17.8115	36.0294	**148.9270**
Ulcinj	154.8515	28.8308	58.8555	**242.5378**
Cetinje	129.5448	15.7213	34.3103	**179.5764**
Danilovgrad	138.2362	16.6080	35.4164	**190.2605**
Nikšić	456.5570	54.4815	119.1456	**630.1841**
Podgorica	1,293.6263	151.4030	325.4743	**1,770.5036**
Tuzi	84.6247	9.9043	21.2914	**115.8204**
TOTAL	**4,978.1606**	**610.1030**	**1,059.9235**	**6,648.1870**

Source: EIHP analysis

The largest share of energy demand refers to space heating (74.88%), followed by space cooling (15,94%) and the DHW preparation (9,18%). In addition, it can be observed that the highest energy demand refers to Podgorica (26,63%).

In general, much higher energy needs than the delivered energy can be observed. The reason for this is that the majority of households in Montenegro use decentralised heating (individual stoves, electric heaters, and air conditioners), that is, they heat only certain rooms, and do not cover the needs of the entire building.

All the data from the above table are additionally shown spatially by municipalities of Montenegro, as shown in the figures below.

Figure 2-1 Energy demand for heating by municipalities of Montenegro [GWh]

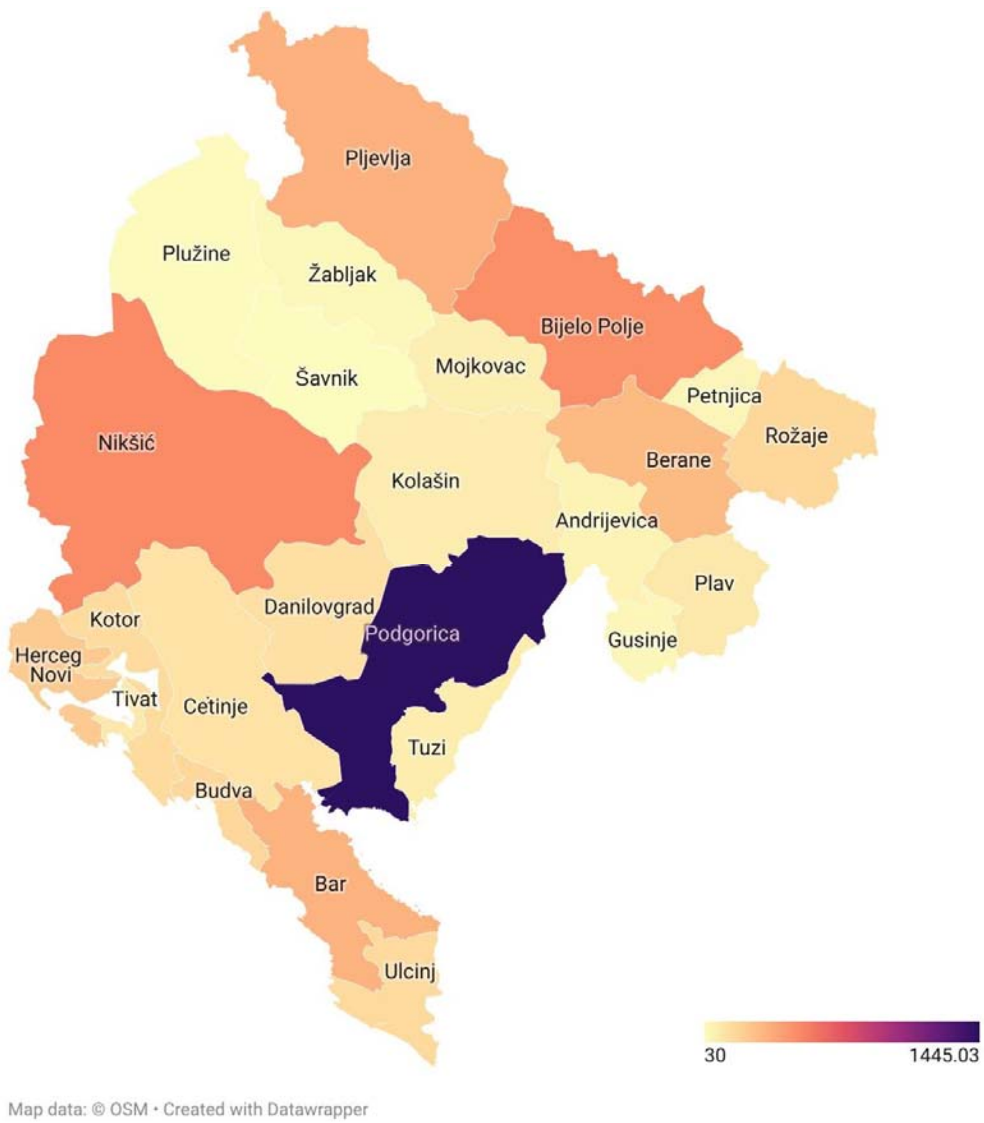


Figure 2-2 Energy demand for cooling by municipalities of Montenegro [GWh]

2.2 Services

Given that all energy sources and technologies for H&C in the service sector are modelled and shown in Table 1-15, it is possible to obtain the H&C energy demand through the product of final energy consumption energy for each technology and the energy efficiency coefficient.
However, it is important to note that not all buildings are heated or cooled, so that part must also be considered when calculating the energy demand for H&C. For each type of building from the study [9], the proportion of buildings that are not heated, cooled, or do not have DHW preparation is known. This part was considered when calculating the demand for H&C energy in such a way that the need for H&C energy was obtained as a product of final energy consumption and energy efficiency coefficients additionally increased by the percentage of the part that is not heated, cooled or does not have DHW preparation. The energy efficiency coefficients used to calculate the demand for H&C are shown in Table 2-2, while the calculated H&C energy for each type of building is shown in Table 2-3.

Table 2-2 Energy efficiency coefficients used for calculation of heating and cooling energy demand

		Energy efficiency coefficients [-]		
Technology	**Purpose → Energy source**	Space heating	DHW preparation	Space cooling
Individual sources	Wood fuels	0.65	0.50	-
	Coal	0.65	0.50	-
	Electricity	0.98	0.92	-
Boilers	Fuel oils	0.80	0.75	-
	Wood fuels	0.80	0.75	-
	Coal	0.80	0.75	-
	LPG	0.85	0.80	-
Air conditioners	Electricity	2.80	-	2.80
Heat pumps	Electricity	3.50	-	3.30

Source: EIHP analysis

Table 2-3 Heating and cooling energy demand – services

Type of building	Heating demand [GWh]	Cooling demand [GWh]	TOTAL [GWh]
Shops	82.9641	135.2724	**218.2365**
Accommodation and food services	161.4784	240.7846	**402.2631**
Public administration	39.2669	14.7053	**53.9722**
Education	74.6505	13.8203	**88.4708**
Health care	42.5290	19.2797	**61.8087**
Other services	151.3693	144.9972	**296.3665**
TOTAL	**552.2583**	**568.8595**	**1,121.1178**

Source: EIHP analysis

In the service sector, the most common energy source for H&C is electricity, i.e., the use of air conditioners for space H&C, as well as electric resistance heating. Air conditioners are characterized by higher energy efficiency coefficients compared to conventional heating sources. Therefore, the H&C demand is greater than the final energy consumption. An additional reason for this is that when calculating the demand for H&C, spaces that are not currently heated/cooled, but in which there is a need for heating/cooling, are also considered.

The distribution of H&C energy demand by municipality was performed as explained earlier in Chapter 1.2.3. The numerical distribution of the H&C demand for services sector in

Montenegro is shown in Table 2-4, while the spatial representation is given in Figure 2-3 and Figure 2-4.

Table 2-4 Heating and cooling energy demand by municipalities in the service sector of Montenegro

Type of building → Municipality	Shops [GWh]	A&F services [GWh]	Public administration [GWh]	Education [GWh]	Health care [GWh]	Other services [GWh]	TOTAL [GWh]
Andrijevica	0.6101	0.1609	0.4414	0.5256	0.2482	0.8286	**2.8149**
Berane	4.7185	0.2772	2.4822	3.9198	2.9789	6.4078	**20.7843**
Bijelo Polje	9.1658	0.6053	4.0086	6.1246	3.1718	12.4472	**35.5234**
Gusinje	0.7635	0.1015	0.3505	0.3461	0.2316	1.0369	**2.8301**
Kolašin	1.4648	2.7820	0.7295	0.8277	0.3677	1.9893	**8.1610**
Mojkovac	1.3846	0.2287	0.7505	0.8586	0.4873	1.8802	**5.5900**
Petnjica	1.1162	0.0530	0.4748	0.6327	0.5699	1.5158	**4.3624**
Plav	0.9582	0.3786	0.7905	1.3831	0.5223	1.3013	**5.3340**
Plužine	0.5212	0.2199	0.2826	0.2271	0.1011	0.7078	**2.0597**
Pljevlja	6.4164	0.4212	2.6799	2.8590	2.2800	8.7136	**23.3700**
Rožaje	3.5485	0.3847	1.9990	3.9685	0.8826	4.8189	**15.6022**
Śavnik	0.3298	0.1060	0.1802	0.1118	0.0827	0.4478	**1.2584**
Žabljak	0.7386	3.1507	0.3107	0.3163	0.0735	1.0030	**5.5929**
Budva	16.5975	127.8314	1.6729	3.7366	0.7998	22.5395	**173.1778**
Bar	13.7666	55.9526	3.6602	6.2483	2.9879	18.6951	**101.3108**
Herceg Novi	11.5002	86.4697	2.6866	3.9376	3.0247	15.6173	**123.2361**
Kotor	7.8455	18.9427	1.9674	3.0516	4.1739	10.6542	**46.6352**
Tivat	6.0434	32.4810	1.2214	2.3226	0.4689	8.2070	**50.7443**
Ulcinj	5.3987	60.0154	1.7341	2.7091	0.6803	7.3315	**77.8691**
Cetinje	4.0364	1.8111	1.4500	1.6233	1.9582	5.4814	**16.3603**
Danilovgrad	4.2896	0.4408	1.6079	2.3559	0.4873	5.8252	**15.0067**
Nikšić	15.9627	0.8048	6.3060	9.6091	5.1484	21.6774	**59.5084**
Podgorica	94.4454	8.1130	15.1912	28.9416	28.2336	128.2574	**303.1822**
Tuzi	6.6144	0.5310	0.9943	1.8338	1.8479	8.9823	**20.8037**
TOTAL:	**218.2365**	**402.2631**	**53.9722**	**88.4708**	**61.8087**	**296.3665**	**1,121.1178**

Source: EIHP analysis

Figure 2-3 Heating energy demand by municipalities in the services sector of Montenegro [GWh/a]

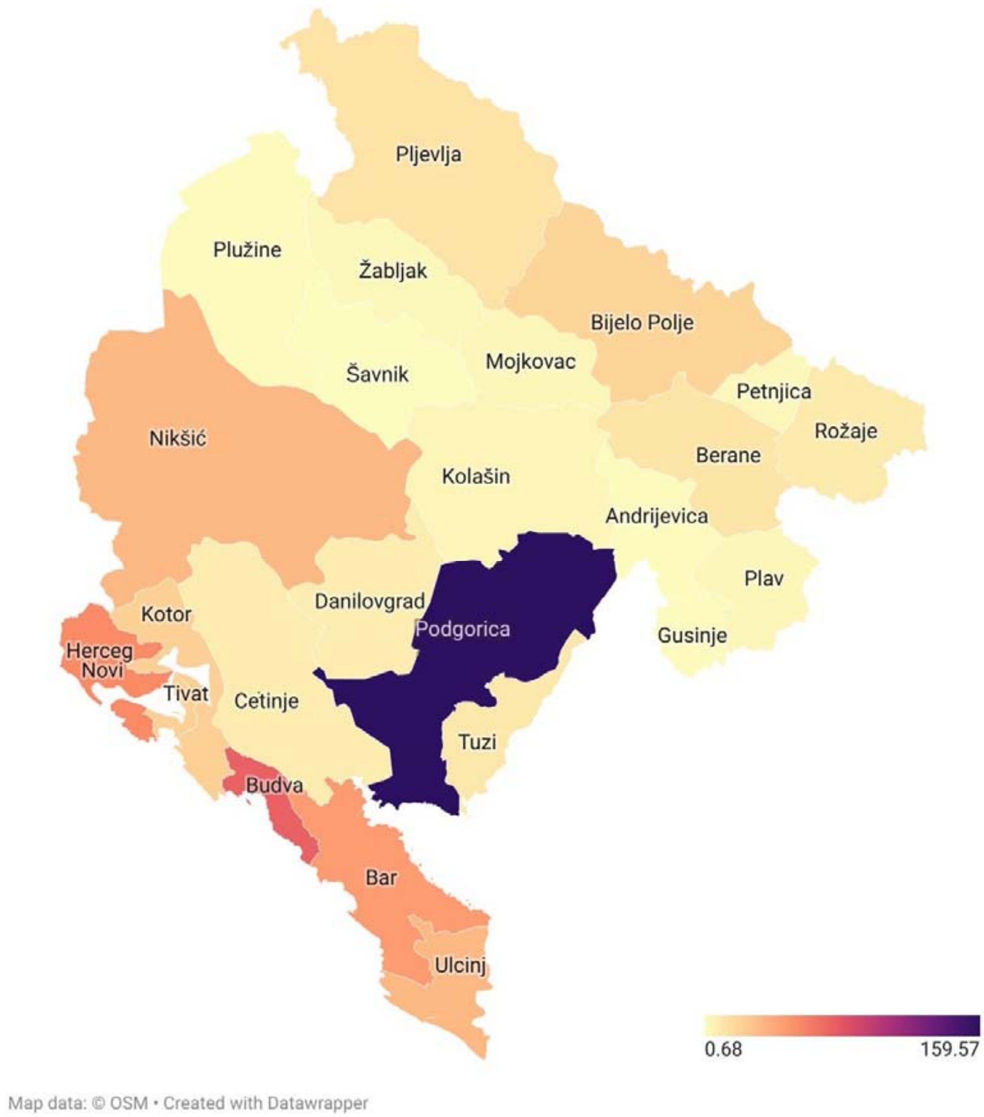
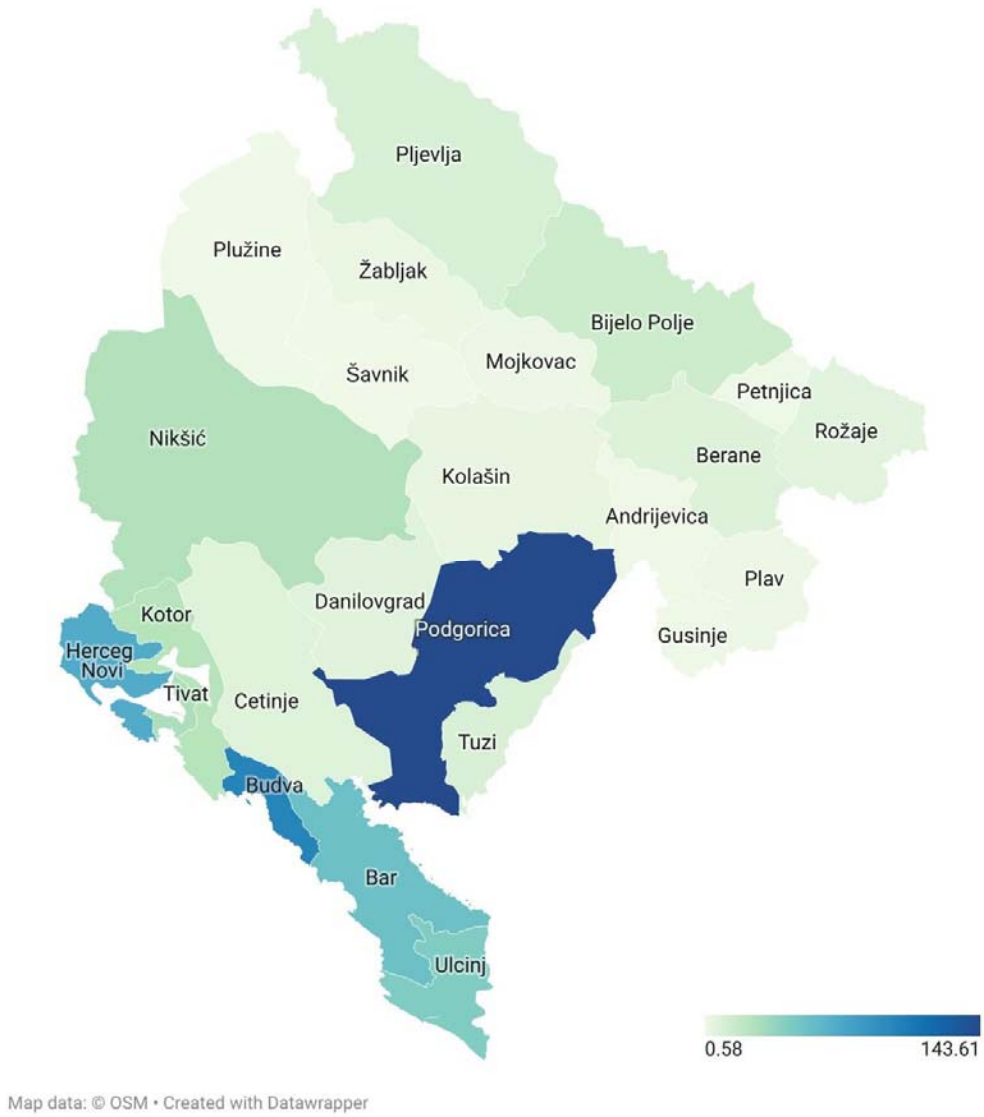


Figure 2-4 Cooling energy demand by municipalities in the services sector of Montenegro [GWh/a]



2.3 Industry

In terms of useful energy, the analysis determined useful energy demand according to end- use categories. For the purposes of energy planning, sectoral GDP is usually determined as the basic driver of energy consumption for the industry sector. Energy consumption in industry per unit of GDP realised in the industry sector is called energy intensity. It represents a parameter that, together with efficiencies, is projected into the future and as such forms the basis for the analysis of future energy demand in the industry sector. The determined consumption of useful energy, sectoral GDP and energy intensity for the base year 2021 are given in the following table.

Table 2-5 Useful energy demand in industry by end-uses

End-use	Useful energy demand [GWh/a]	GDP of industry sector [billion EUR]	Energy intensity [kWh/EUR]
Thermal uses	468.56	0.589	0.795
Electricity specific use	508.80		0.863
Motive power	506.05		0.859
Total	**1,483.41**	**0.589**	-

Source: EIHP analysis

3 Sources for energy production for heating and/or cooling

Currently, wood biomass and electricity are used to the greatest extent as energy sources for H&C in Montenegro. The electricity used is obtained from the electricity grid, while wood biomass is consumed in individual stoves and central boilers. An evaluation of the potential for using wood biomass in Montenegro is described below. In addition to wood biomass, Montenegro currently has potential for the use of other renewable energy sources (aerothermal and hydrothermal energy). Central heating in Montenegro exists to a very limited extent (detailed in Section 3.1), and there are currently no cogeneration plants in the country. Also, currently there are no facilities in Montenegro that use waste heat and waste incineration for the production of thermal energy. The potential development district heating systems is described in Part 3 (Chapter 6) of this study.

3.1 District heating

District heating in Montenegro exists on a very limited scale. It has not been developed or sufficiently researched, despite the fact that the climatic conditions and the availability of suitable energy sources for use for this purpose (e.g., biomass) in mountainous areas are favourable. According to the available data from the Energy Development Strategy of Montenegro until 2030 [10], at present only two boiler plants of minor importance exist and operate in Pljevlja (Public Company Heating (6 MW) and Sports Centre Ada (2MW) respectively) that produce heat for district heating. The energy sources they use are lignite and wood chips. Currently, part of residential buildings with a total area of 26,668 m^2, and business premises with an area of 10,618 m^2 are supplied with heat energy from district heating system. The plan is to expand the district heating system in Pljevlja, whose technical and economic potential is given in chapter 6.1.

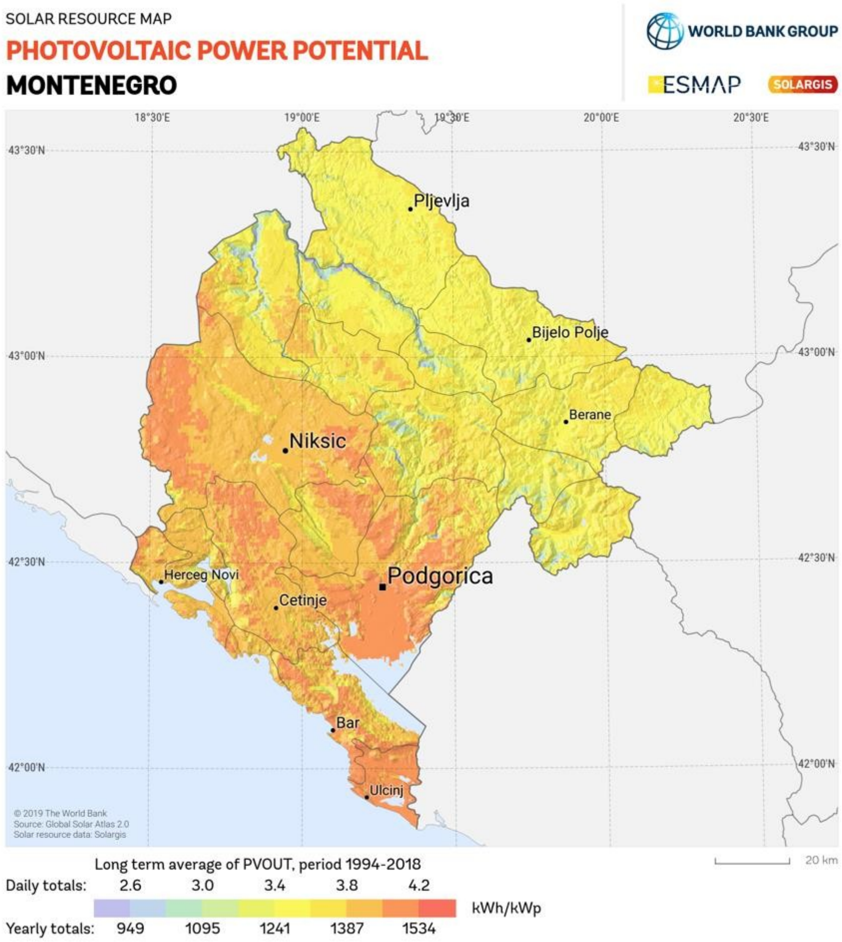
3.2 Renewable energy sources

According to MONSTAT data from 2021, 790,506 m^3 of firewood and wood residues and wood chips were used for the production of domestic primary energy. The stated amount of wood, wood residues and wood chips is provided domestically in Montenegro, that is, there is no recorded importation. Additionally, 73,401 tons of wood pellets were used for the production of domestic primary energy, of which 1,680 tons are imported, while 53,708 tons of pellets are exported. Finally, the gross supply of energy from wood pellets amounts to 21,373 tons.
Charcoal is exclusively imported with a total amount of 299 tons needed for energy supply. Given the above, it can be concluded that the potential of wood biomass for heating in the territory of Montenegro is significant. Driven in part by already adopted ecodesign regulations, modern biomass is expected to occupy larger shares in energy consumption in Montenegro due to more efficient technologies for heating and DHW preparation, while the share of traditional biomass (firewood) is expected to gradually decrease. It is assumed that in the future, when using modern biomass, the sustainability criteria from RED II will be met.

Montenegro is characterized by insolation similar to other southern European countries. Horizontal insolation, that is, the annual amount of solar radiation available as a primary

source of energy per square meter in Podgorica is about 1600 kWh/m^2 per year [10]. A map of solar resources is shown below, where it can be seen that the greatest potential of solar radiation lies in the coastal and central climate zone, while it is lower in the northern zone.
This resource holds significant potential for the use of solar energy for space heating and the DHW preparation using solar collector technologies in Montenegro.

Figure 3-1 Solar resource map of Montenegro



The coastal and central part of Montenegro has a Mediterranean climate with relatively mild winters and high average temperatures in the winter months, which represents good conditions for the use of heat pumps that use the heat of the outside air. Heat pumps that use aerothermal energy are already a well known and used technology for heating services and households in these parts of Montenegro.

Hydrothermal energy of rivers, underground waters, lakes, and seas can be used as a source of thermal energy for the use of heat pumps in places near such sources. In this context, in Montenegro, it is important to highlight the cities of Podgorica and Nikšić, which are located on underground lakes, so the hydrothermal energy of underground water can be used for H&C purposes, as well as for the DHW preparation. In addition, most of the other cities in Montenegro are located on the banks of rivers or seas, so it can be concluded that there is an extremely large potential for using hydrothermal energy in Montenegro.

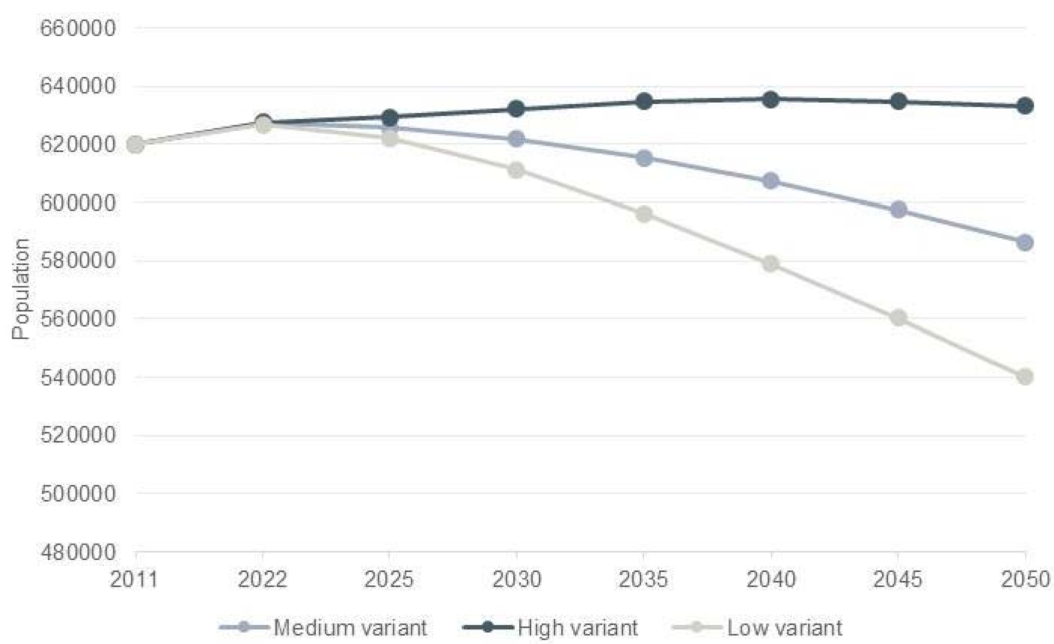
Existing global maps of geothermal potential do not recognise this potential as a significant renewable resource energy for Montenegro.

4 Future development plan

4.1 Projection of demographic trends

According to the 2011 census, Montenegro had 620,029 inhabitants and 21 municipalities. From the mentioned census until today, three new municipalities were created: Gusinje (formerly part of Plav municipality), Petnjica (formerly part of Berane municipality) and Tuzi (formerly part of Podgorica municipality). Population data from 2011 are known for the new municipalities. For projections of population trends until 2050, input data from the last population census and population trends of Montenegro prepared by the United Nations Department for Economic and Social Affairs [1] were used. The Department for Economic and Social Affairs has developed three possible variants of demographic trends: low variant, medium variant and high variant, as shown in the diagram below.

Figure 4-1 Demographic trends projection of Montenegro



For projection of the population by municipalities of Montenegro, demographic trends of projections for the medium variant were used and applied to the number of inhabitants of Montenegro by municipalities from the 2011 population census. The obtained projections of the number of inhabitants until 2050 by the municipalities of Montenegro are shown in the table below.

Table 4-1 Projection of demographic trends in Montenegro until 2050 by municipality

Municipality	Population						
	2021	2025	2030	2035	2040	2045	2050
Andrijevica	5,129	5,117	5,085	5,033	4,966	4,886	4,796
Berane	28,839	28,772	28,592	28,303	27,925	27,474	26,968

Municipality	Population						
	2021	2025	2030	2035	2040	2045	2050
Bijelo Polje	46,575	46,466	46,175	45,709	45,098	44,370	43,552
Gusinje	4,073	4,063	4,038	3,997	3,944	3,880	3,808
Kolašin	8,475	8,456	8,403	8,318	8,207	8,074	7,925
Mojkovac	8,720	8,700	8,645	8,558	8,444	8,307	8,154
Petnjica	5,517	5,504	5,470	5,415	5,342	5,256	5,159
Plav	9,184	9,163	9,105	9,014	8,893	8,750	8,588
Plužine	3,283	3,275	3,255	3,222	3,179	3,128	3,070
Pljevlja	31,136	31,064	30,869	30,557	30,149	29,662	29,115
Rožaje	23,225	23,171	23,026	22,794	22,489	22,126	21,718
Šavnik	2,094	2,089	2,076	2,055	2,027	1,994	1,958
Žabljak	3,610	3,601	3,579	3,543	3,495	3,439	3,375
Budva	19,437	19,391	19,270	19,075	18,820	18,517	18,175
Bar	42,526	42,427	42,161	41,736	41,178	40,513	39,766
Herceg Novi	31,215	31,142	30,947	30,635	30,225	29,737	29,189
Kotor	22,858	22,805	22,662	22,433	22,133	21,776	21,375
Tivat	14,191	14,158	14,069	13,927	13,741	13,519	13,270
Ulcinj	20,148	20,101	19,975	19,773	19,509	19,194	18,840
Cetinje	16,847	16,807	16,702	16,533	16,312	16,049	15,753
Danilovgrad	18,682	18,639	18,522	18,335	18,090	17,798	17,470
Nikšić	73,267	73,097	72,638	71,905	70,944	69,799	68,512
Podgorica	176,500	176,090	174,984	173,220	170,904	168,145	165,045
Tuzi	11,552	11,525	11,453	11,337	11,186	11,005	10,802
TOTAL:	**627,083**	**625,623**	**621,696**	**615,427**	**607,201**	**597,397**	**586,385**

4.2 Projections of trends in the national building stock

Data from the Statistical Yearbooks of Montenegro (section Construction) [2] on the number and area of completed buildings for each year from 2011-2021 were used to evaluate the projections of the housing stock of buildings until 2050. The distribution of the newly built stock of buildings from 2011 - 2021 is divided by climatic zone based on the prices of square meters of apartments that are available in statistical yearbooks, considering that the price follows the laws of supply and demand. Additionally, after the distribution by climate zones, the same construction trend as in 2011 was assumed for the distribution by municipalities within a certain climate zone. Based on the above, the national stock of buildings in the household sector from 2011 to 2021 was obtained, presented in the chapter: *General information; Overview of national building stock - households*. For the projections of the building stock until 2050, a linear regression analysis was used based on the trends in the period from 2011 to 2021 for each municipality, as shown in the table below.

Table 4-2 Projections of building areas in the household sector of Montenegro until 2050

Municipality	Building area [m^2]						
	2021	2025	2030	2035	2040	2045	2050
Andrijevica	181,114	190,560	203,923	217,287	230,651	244,015	257,378
Berane	754,694	794,055	849,741	905,427	961,113	1,016,799	1,072,485
Bijelo Polje	1,146,548	1,206,346	1,290,945	1,375,545	1,460,145	1,544,744	1,629,344
Gusinje	119,658	125,899	134,728	143,557	152,387	161,216	170,045
Kolašin	314,167	330,552	353,734	376,915	400,096	423,277	446,459
Mojkovac	211,692	222,732	238,352	253,972	269,592	285,212	300,832
Petnjica	144,394	151,925	162,579	173,234	183,888	194,542	205,196
Plav	269,855	283,929	303,841	323,753	343,664	363,576	383,488
Plužine	124,783	131,291	140,498	149,706	158,913	168,120	177,328
Pljevlja	874,026	919,611	984,102	1,048,593	1,113,085	1,177,576	1,242,067

Municipality	Building area [m²]						
	2021	2025	2030	2035	2040	2045	2050
Rožaje	514,698	541,542	579,519	617,497	655,475	693,453	731,430
Šavnik	94,364	99,286	106,249	113,212	120,174	127,137	134,100
Žabljak	214,703	225,901	241,743	257,585	273,427	289,270	305,112
Budva	1,346,875	1,424,985	1,535,492	1,645,998	1,756,505	1,867,012	1,977,518
Bar	2,180,244	2,306,683	2,485,565	2,664,447	2,843,329	3,022,211	3,201,092
Herceg Novi	1,489,633	1,576,022	1,698,242	1,820,461	1,942,681	2,064,900	2,187,120
Kotor	921,564	975,009	1,050,620	1,126,231	1,201,842	1,277,454	1,353,065
Tivat	606,763	641,951	691,734	741,517	791,300	841,082	890,865
Ulcinj	1,088,881	1,152,029	1,241,368	1,330,707	1,420,046	1,509,385	1,598,724
Cetinje	510,659	523,888	542,605	561,322	580,038	598,755	617,472
Danilovgrad	574,005	588,876	609,914	630,953	651,992	673,030	694,069
Nikšić	1,681,510	1,725,072	1,786,703	1,848,334	1,909,965	1,971,596	2,033,227
Podgorica	4,555,370	4,673,385	4,840,349	5,007,313	5,174,277	5,341,241	5,508,205
Tuzi	297,996	305,716	316,638	327,560	338,483	349,405	360,327
TOTAL:	**20,218,196**	**21,117,245**	**22,389,186**	**23,661,126**	**24,933,067**	**26,205,007**	**27,476,948**

For the service sector, there is no data available on building area. However, historical data [2] is known about the number of educational institutions, health institutions, cultural buildings, as well as the number of employed by sectors, overnight stays, which will be the basis for projecting the demand for H&C in the buildings of the service sector of Montenegro until 2050.

4.3 Projection of developments in energy demand and final energy consumption for heating and cooling

For the purposes of the analysis of future energy demand in Montenegro, an energy model was created that includes the household, service and industry sectors. The energy model was created using the software tool LEAP (The Low Emissions Analysis Platform)[2]. LEAP is a complex and versatile software system developed at the Stockholm Environment Institute for integrated energy planning and climate change mitigation assessment.

Energy demand projections were made by applying the end-use model with the bottom-up approach. In contrast to econometric models, the end-use model does not require perennial input data time series and is characterized by mathematical simplicity. A possible shortcoming is a requirement for a vast number of input data.

The energy model evaluated future energy demand based on medium to long-term socio-economic, technological and demographic development scenarios. The model systematically relates the specific energy demand for producing various goods and services identified in the model to the corresponding social, economic and technological factors that affect this demand. The nature and level of the demand for goods and services are a function of several determining factors, including population growth, number of inhabitants per dwelling, number of electrical appliances used in households, people's mobility and preferences for transportation modes, national priorities for the development of specific industries or economic sectors, the evolution of the efficiency of certain types of equipment, market penetration of

[2] Heaps, C.G., 2022. *LEAP: The Low Emissions Analysis Platform.* [Software version: 2020.1.80] Stockholm Environment Institute. Somerville, MA, USA. https://leap.sei.org

new technologies or energy forms, etc. The expected future trends for these determining factors, which constitute a scenario, are exogenously introduced.

For the purposes of this study, a reference so-called BAU scenario (Business-as-usual) was developed, which represents future trends in energy flows in accordance with expected improvements in technology and structural changes in energy consumption driven mainly by market principles and without active implementation of energy efficiency measures.

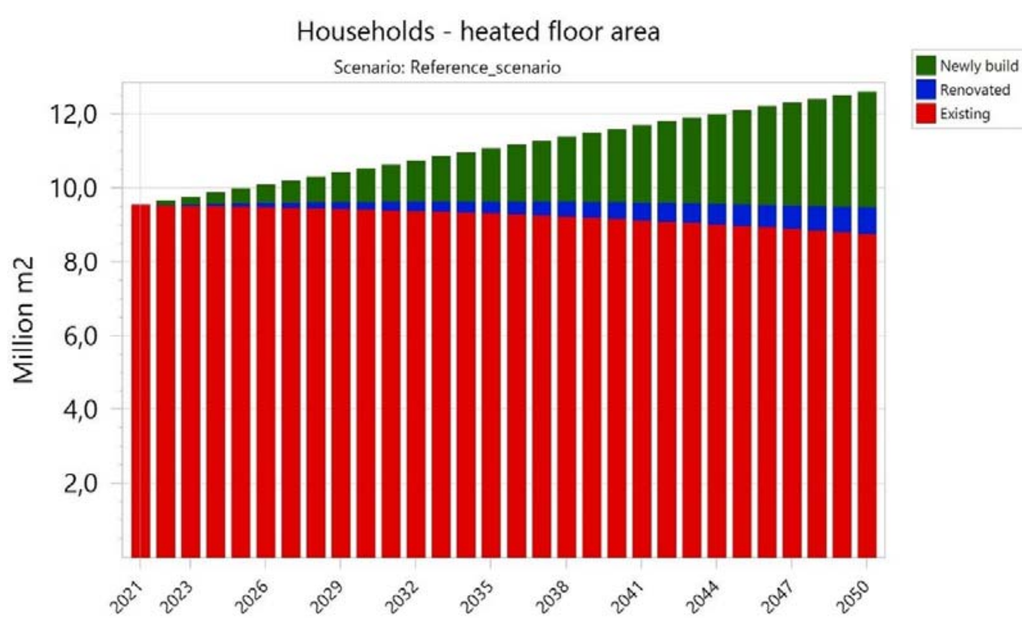
The basic principles of modelling are described below according to the analysed sectors.

Household sector

Some of the key indicators for the projection of energy consumption in residential buildings are the projection of the population, the average size of apartments, the rate of renovation of the existing housing stock, the rate of new construction and the assessment of the housing stock that is not used for living.

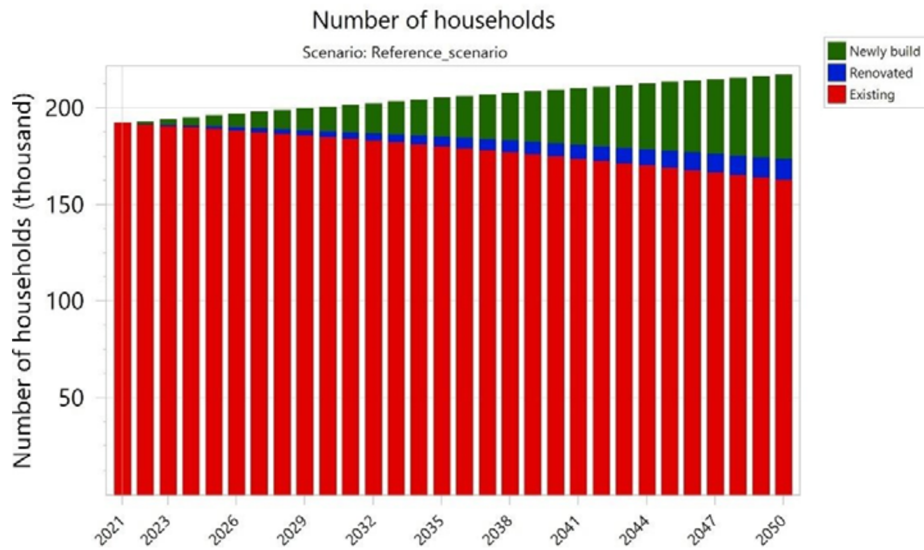
On the basis of the mentioned indicators, the projection of the total heated floor area of the housing stock of buildings as well as the area with regard to the status of the building (old, renovated, new) was determined. The total floor area of households (used for permanent living) amounts to 15,9 million m^2 in the base year and will increase up to 16,7 million m^2 in 2030, and 18,3 million m^2 in 2050. The floor area that is actually heated is 9.5 million m^2 in the base year of 2021 and will grow to 10.5 million m^2 in 2030 and 12.6 million m^2 in 2050 (Figure 4-2).

Figure 4-2 Heated floor area



As part of the BAU scenario, it was assumed that in 2030, 6.2% of the total number of households will be newly built, 92.2% will be old buildings, and only 1.4% will b energy renovation. In 2050, 20% of the total number of households will be newly built, 75% will be old buildings, and only 5% will undergo energy renovation. (Figure 4-3).

Figure 4-3 Number of households considering the status of construction and renovation (BAU scenario)



In the household sector, the modelling includes energy consumption in family houses and apartments for five purposes (end-uses): space heating, hot water, cooking, cooling and non-thermal purposes.

According to such assumptions, despite the fact that the structure of representation of energy sources for H&C is distinguished with regard to the status of the facility, due to the significant share of households that will not be renovated, the overall structure of energy consumption in the entire household sector will not change significantly.

Service sector

The basic determinant of energy consumption in the service sector is the floor area. In order to predict the future area of the service sector, it is necessary to calculate the area of the service sector per inhabitant, and compare this indicator with that of more economically developed countries. Based on this, the future increase in the area of the service sector per inhabitant can be estimated, which will follow the economic development of the country. The total area of the service sector is calculated by multiplying the described indicator and the population projection.

As part of the created BAU scenario, the total floor area of the service sector is estimated at 4.5 million square meters, which represents a ratio of 7.2 m^2 per capita. This parameter is projected to reach a value of 12 m^2 per capita in the future. Taking into account the population projections, the future floor area is projected to be 5.4 million square meters in 2030, or 7 million square meters in 2050.

Additionally, an important parameter for determining the useful energy demand for heating and cooling is the load factor, that is, the share of the surface that requires heating or cooling. In the base year, the load factor for the heated surface is set at 0.6 and slightly increases to 0.65, while the load factor for the cooled surface is 0.4 and also slightly increases to 0.45 by 2050.

It should be noted that in the services sector, the consumption related to public lighting and the consumption of energy that is realised outside of buildings is separated, and therefore only buildings within the services sector were analysed in detail.

Industry sector

The future energy demand in the Industry sector is made based on expected changes in energy intensity, i.e. specific consumption of useful energy per monetary unit realised in that sector (Sectoral GDP). In this sense, for the purposes of the BAU scenario, a future increase in total GDP with an annual growth rate of 3% is defined. Looking at the structure of GDP, a slight increase in the share of GDP of industry from the current 11.9% to 15% by 2050 is assumed.

The energy intensities determined for all three end-uses (thermal uses, electricity specific uses and motive power) are projected to fall slightly, which means that the growth rate of energy consumption in industry will be lower than the growth of industry GDP, i.e. that with the same energy to produce greater value added.

As a result of the above, projections of energy consumption by sector and purpose were obtained, as shown in the tables below.

Table 4-3 Final energy consumption projection for heating and cooling in households and services – BAU scenario, [GWh/a]

	PURPOSE	Year → Energy source	2021	2030	2040	2050
HOUSEHOLDS	Space heating	Electricity	216.23	203.66	216.23	219.40
		LPG	13.64	11.02	6.48	2.58
		Coal	63.68	57.13	49.67	42.12
		Firewood	1,388.65	1,279.30	1,115.41	948.46
		Modern biomass	159.80	190.96	202.32	198.62
		TOTAL	**1,842.00**	**1,742.07**	**1,590.10**	**1,411.18**
	DHW preparation	Electricity	389.96	386.42	372.61	349.30
		LPG	3.28	2.80	1.93	1.15
		Coal	1.41	0.92	0.42	0.00
		Firewood	54.85	50.87	45.66	40.02
		Solar	0.00	6.46	14.98	24.63
		Modern biomass	6.31	13.31	21.80	30.79
		TOTAL	**455.81**	**460.78**	**457.39**	**445.89**
	Space cooling	Electricity	169.88	186.60	193.39	191.96
		TOTAL	**169.88**	**186.60**	**193.39**	**191.96**
SERVICES	Space heating	Electricity	137.40	142.23	135.60	118.51
		LPG	19.22	16.56	12.45	8.07
		Coal	57.52	40.53	19.21	0.00
		Firewood	60.70	62.01	58.77	51.53
		Modern biomass	25.83	44.44	60.32	67.86
		Fuel oils	102.28	96.08	82.21	64.32
		TOTAL	**402.95**	**400.52**	**366.13**	**307.36**
	DHW preparation	Electricity	20.44	17.90	15.08	12.26
		LPG	0.01	0.01	0.01	0.01
		Coal	0.24	0.17	0.08	0.00
		Firewood	0.21	0.24	0.24	0.23

	PURPOSE	Year → Energy source	2021	2030	2040	2050
		Solar	0.00	4.55	13.97	29.09
		Modern biomass	0.09	0.62	1.45	2.50
		Fuel oils	1.95	2.14	2.21	2.11
		TOTAL	**22.94**	**25.63**	**33.04**	**46.20**
	Space cooling	Electricity	172.70	183.68	183.84	172.91
		TOTAL	**172.70**	**183.68**	**183.84**	**172.91**

Table 4-4 Final energy consumption projection in industry – BAU scenario, [GWh/a]

	PURPOSE	Year → Energy source	2021	2030	2040	2050
INDUSTRY	**Thermal uses**	Electricity	169.60	298.25	417.78	580.23
		Natural gas	46.00	36.98	57.31	87.58
		Fuel oil	38.16	49.92	68.50	93.61
		LPG	86.71	115.90	162.62	226.90
		Coal	59.32	75.61	100.61	133.15
		Firewood	111.11	64.02	76.65	87.58
		Hydrogen	0.00	0.00	18.02	49.26
		Other biomass	0.00	14.23	30.66	58.38
		Extra light fuel oil	87.55	114.54	157.17	214.78
		TOTAL	**598.46**	**769.44**	**1,089.32**	**1,531.46**
	Other	Electricity	508.80	581.96	665.66	700.61
		TOTAL	**508.80**	**581.96**	**665.66**	**700.61**

PART 2: OBJECTIVES, STRATEGIES AND POLICY MEASURES

5 Objectives, strategies, and policy measures

In 2016, a study on the potential for district heating/cooling and high-efficiency cogeneration was prepared by consultants and funded by the EU under the project "Developing Sustainable Energy Use in Montenegro" (EuropeAid/132799/C/SER/ME, hereon "the Study"). It contains the elaboration of several different scenarios and performs a comparative analysis of different technologies, especially from the aspect of cost-effectiveness of district heating/cooling development and the use of individual systems and their impact on the environment. The Study reveals the economically viable potential for the development of district heating systems as well as for combined heat and power (CHP) plants running on biomass.

The Study served as a background for the AP for the development and use of efficient H&C technologies in Montenegro, which was prescribed as a legal obligation in the Energy Law, in Article 20. Therefore, the measures defined in that AP represent the existing policy measures for H&C in Montenegro. The comprehensive list of measures with status of their implementation is given in the table below. However, as can be seen, and in line with the content of the previous CA, these measures were primarily focused on the enabling framework for district heating systems and CHP development.

Action	Status	Notes
1. District heating and CHP		
1.1 Performing national assessments of H&C potentials	Partially	Contained within previous CA, update is provided within this study (CA 2023).
1.2 Performing local assessments of H&C potentials	Partially	Analysis of thermal consumption of heating of the city of Pljevlja was conducted by Municipality of Pljevlja. Prefeasibility study for district for Municipality of Žabljak developed by EBRD. Identification and analysis of possible sustainable heating solutions in Pljevlja in Montenegro prepared by CEE Bankwatch. A Biomass Project Identification Study in Montenegro was prepared by Clean Energy Solutions (CES) for some municipalities.
1.2 (Ctd) Preparation of relevant regulation for thermal energy supply	Not started	
1.3 Extension of the role of the Energy and Water Regulatory Agency (REGAGEN) with specific activities related to regulation of district heating (DH)	Not started	
1.4 Development of methodology for primary energy saving calculation and determining of efficiency degree of CHP	Completed	Rulebook on the methodology of calculating primary energy savings from cogeneration was adopted to determine the overall degree of efficiency of the cogeneration facility.
1.5 Ensuring priority or guaranteed access to the grid of electricity from CHP	Completed	Article 114, point 15, of the Energy Law, Non-discriminatory access to all producers in terms of connection to the network is provided.

Action	Status	Notes
		Article 122, point 12, and Article 114 point 14, prescribe the manner of giving priority in accessing distribution system operator (DSO) and transmission system operator (TSO) taking over electricity produced from renewable sources and highly efficient cogeneration. This is for existing privileged producers. After expiration of this status, they will compete on the open market.
1.6 Support schemes for the DH networks and CHP	Partially	Partially completed by adoption of Regulation on fee for incentive of electricity production from renewable sources and highly efficient cogeneration ("Official Gazette of Montenegro", No. 029/19 dated 05/24/2019). This regulation is however not in force since the Government Decision adopted on 29.07.2021. This does not support the DH network but only the production of electricity by providing subsidies for privileged producers. After obtaining a status of privileged producer, the investor signs a contract with COTEE. This contract gives the investor a guarantee that their energy will be purchased after obtaining the status of a privileged producer and concluding the contract for the purchase of electricity.
1.7 Defining the relation between public and private sector in DH/CHP development	Not completed	However, the Law on Public-Private Partnership was adopted ("Official Gazette of Montenegro", no. 73/2019 of 27.12.2019, entered into force on 4.1.2020).
1.8 Capacity building of local authorities and information campaigns for potential users and investors	In progress	
2. Individual (building based) efficient heating and cooling technologies		
2.1 Development of regulations on certification schemes or equivalent qualification schemes for installers	Partially implemented	Law on Energy (Art. 26) has introduced a certification scheme for the installers of small scale biomass boilers, heat pumps and solar systems (Photovoltaic and for water heating). However, this scheme has not been established into practice so far.
2.2 Development of regulations on manner of calculation of energy from heat pumps	Not started	The new Renewable Energy System (RES) Law will prescribe the method of calculating energy from heat pumps – its preparation is ongoing.
2.3 Development and adoption of appropriate financial or fiscal support mechanisms	Completed with implementation of a Feed-in-Tariff (FiT) – pending new Law on RES	The FiT regulation is however not in force since the Government Decision adopted on 29.07.2021. A new supporting mechanism will be adopted by preparation of Law on RES. New market-based incentive scheme for RES to be developed/adopted (New RES Law, Auction based mechanism for Premium feed-in support).

Action	Status	Notes
2.4 Strengthening of educational institutions	In progress	With a specialised program developed by the Center for Vocational Education. With a specialised masters program for energy efficiency and utilisation of RES by the University of Montenegro.
2.5 Strengthening of the industry associations	In progress	
2.6 Development of ecodesign and Energy Labelling regulations	Completed	In general the Montenegro national framework in the energy labelling and ecodesign is aligned with the relevant EU acquis.
2.6 (Ctd) Establishing quality assurance system	In progress	Market surveillance of the technologies available on the market is done by Market Inspection which also control if the requirements regarding ecodesign and energy labelling are fulfilled.
2.7 Creating and maintaining a database for HPs, SWHs, etc	Not started	
2.8 Specific information campaigns for consumers	Partially implemented	As a part of the general campaign for energy efficiency and promotional supporting schemes for households for use of high-efficient technologies for H&C (modern biomass boilers, heating pumps etc).

Additionally, in the field of energy efficiency, the most relevant current document is the National Energy Efficiency Action Plan (NEEP)[3]. The latest Montenegrin National Energy Efficiency Action Plan (NEEAP) covers the period 2019-2021 and the following policy measures are relevant for improving energy efficiency of H&C systems in Montenegro:

- R.2 Financial support to citizens for EE investments – Energy Efficient Home program provided subsidies on commercial loans interest and loan processing fees for households for the following energy efficiency measures: installation of heating systems based on modern forms of biomass, installation of highly efficient heat pumps for heating, installation of split and multi-split systems for heating/cooling, installation of thermal insulation on the facade of the residential building, installation of energy efficient facade joinery. 657 households received financing through this programme. Within the Program, citizens had the opportunity to apply for interest-free loans up to a maximum amount of 10,000 euros, with a repayment period of up to 6 years, for the implementation of the aforementioned energy measures efficiency in their households.

- P.2 Improvement of the energy performance of public sector buildings – under this policy measure a continuation of two financing programs was envisaged: MEEP2 financed by IBRD loan and implemented by the Ministry of Capital Investments and Ministry in health with focus on health sectors and PEEPB financed by KfW loan and EU donation and implemented by Ministry of Capital Investments Ministry of Finance, Ministry of Education, Ministry of Labor and Social Welfare

[3] Montenegro, as a Contracting Party of Energy Community, is currently in the process of preparation its Integrated national Energy and Climate Plan (NECP), which will take over the role of the most relevant policy document for overall energy and climate policy, including energy efficiency and decarbonisation of heating and cooling systems.

and Administration for Cadaster and State Property and focused on selected public buildings. Through the first phase of MEEP 25 public buildings (9 educational and 16 health) were upgraded. The implementation of the second phase of the project started on 1 September 2018 and is planned to last until 31 December 2023. The preparation of various building renovation projects is ongoing. The value of the project budget is 6 million euros. The PEEPB project is funded from KfW bank loan in the amount of 45 million euros and from a donation from the European Union (WBIF-Reep Plus) in the amount of 4.7 million euros. Also, own contribution from recipients in the amount of 10 million euros is planned. Within this project. Central information system for monitoring energy and water consumption in public buildings has been established, energy audits of public buildings are being performed as well as preparation of project and tender documentation for renovation of buildings.

- C.1 Establishing financial support mechanisms for EE investments – this measure builds upon the program Low-carbon tourism in Montenegro, that was implemented by UNDP. There are no information about actual realisation of this measures in the previous period, i.e. about the establishment of the targeted financing instrument for business sector.

While residential and public sector EE measures are well established and has been implemented in the previous 10-year period, the support for EE investments for business sector is rather limited. Eligible EE investments include also efficient H&C technologies. The financial support and the list of eligible actions can be more diversified, based on the results of the CBA, which is performed and presented in the following chapter.

An important step for accelerating the implementation of energy efficiency policy in Montenegro was the establishment of the Eco Fund[4] in November 2018. Eco Fund activities include financing the preparation, implementation and development of programs, projects and similar activities in the field of preservation, sustainable use, protection and improvement of the environment, energy efficiency and the use of renewable sources of energy at the state and local levels. The Eco Fund started its activities with co-financing programmes for electric and hybrid vehicles, but in the recent years (2021 and 2022) it opened public calls for co- financing photovoltaics for households and entrepreneurs, for self-supply of electricity, in cooperation with Electric Utility (EPCG).

[4] More information about the Eco Fund is available here: https://www.eko-fond.me/

PART 3: ANALYSIS OF ECONOMIC POTENTIAL FOR EFFICIENCY IN HEATING AND COOLING

6 Analysis of the implementation of measures for efficient heating and cooling

After reviewing the current state of the building stock in terms of energy consumption for H&C, as well as current policies, this chapter considers measures that can make existing heating and cooling more efficient. In this context, measures were first defined for which the technical and economic potential was later quantitatively expressed by applying a CBA. Finally, the discussion and conclusions within this chapter are the basis for the potential development of new strategies and policy measures.

6.1 Energy efficiency measures for district heating and/or cooling systems

The current state of DH in Montenegro is described in chapter 3.1. In Montenegro, the options for CHP plant are limited due to small local heat demands. In the *Study on potential for district heating and/or cooling and high-efficiency cogeneration* [12], different options of CHP plants are defined:

- Steam CHP: A steam boiler with steam turbine, in which steam at high temperature and pressure runs a turbine and an alternator to generate electricity. DH is extracted from the turbine at the desired temperature.
- Gas CHP: wood gasification with gas engine, in which wood chips are gasified at high temperature but in the absence of oxygen. The wood gas is purified and fed to a piston engine designed to run on lean gas. The engine runs an alternator and heat is recovered from three components: oil lubrication, engine cooling and the flue gases.
- Air CHP: Wood firing heats up air which is led to the microturbine running on air. The heat energy is taken to the DH network.
- ORC CHP: Organic Rankine Cycle, an organic fluid, usually oil is used as a driving fluid to be steamed and condensed to run the turbine. The process is the same but organic fluid is used instead of water. In practice this process is favoured by most experts for use in the West Balkan’s area.

Electrical ratings, efficiencies, investments, fixed operating costs, life expectancy and consumer discount rate assumptions for CHP and LFO back-up boilers considered as candidate technologies in [12] are taken as shown in the figure below.

Table 6-1 CHP/LFO Back-Up Boiler Parameter Summary

Fuel	Biomass	Biomass	Light fuel oil	Light fuel oil	Light fuel oil	Light fuel oil	Light fuel oil
Technology	CHP	CHP	Efficient boiler	Efficient boiler	Efficient boiler	Efficient boiler	Efficient boiler
Modality	District heat	District heat	District heat	District heat	District heat	District heat	District heat
Sector	Residential/ Commercial	Residential/ Commercial	Residential/ Commercial	Residential/ Commercial	Residential/ Commercial	Residential/ Commercial	Residential/ Commercial
Rating	0.6 MW_e	1 MW_e	250 kW_t	500 kW_t	1.5 MW_t	2 MW_t	5 MW_t
Heating efficiency	50%	50%	95%	95%	95%	95%	95%
Cooling efficiency	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Investment [EUR/kW]	6200	4700	1000	975	866	800	750
Fixed costs [EUR/kW]	123	97	68	67	59	55	51
Lifetime [years]	20	20	20	20	20	20	20
Discount rate	10%	10%	10%	10%	10%	10%	10%

Source: Study on potential for district heating and/or cooling and high-efficiency cogeneration, Table 7-18

DH and CHP *(Case 3 in [12])* offer significant energy efficiency gains with a potential improvement in average of 36% by 2040 compared to the base case scenario (doing nothing scenario). This would yield estimated CO_2 emission savings of 4,736,853 tons of CO_2.
Additionally, this measure is characterized by a positive financial NPV (378,728,000 EUR) and positive economic NPV value (5,682,099,000 EUR). It is important to emphasise here that the technical and economic potential of the implementation of a DH system has not been evaluated for the coastal zone because the HDD in this climate zone are too low to support DH services. The technical and economic indicators of the implementation of DH systems by climate zones of Montenegro are given in the table below. Also, the results for all municipalities of Montenegro, where district heating is feasible, are shown in Table 6-3, as well as spatially in figures 5 and 6.

Table 6-2 Technical and economic potential of efficient district heating and cooling

Climate zone	Primary energy supply [GWh]	Potential energy efficiency improvement	Net present value (euro ’000)	CO_2 savings (tons)	ENPV (euro ’000)
Northern Zone	2,553	29%	46,155	1,463,921	1,150,178
Coastal Zone	n/a	n/a	n/a	n/a	n/a
Central Zone	2,179	40%	159,800	804,202	(57,259)
National level	**12,560**	**36%**	**378,728**	**4,736,853**	**5,682,099**

Source: Study on potential for district heating and/or cooling and high-efficiency cogeneration, Table 0-3

Table 6-3 Technical and economic potential of efficient district heating and cooling by municipalities

Climatic zone	Municipality	DH analysis - Case 3			
		Potential Energy Efficiency Improvement	Net Present Value (euro '000)	FNPV (euro '000)	ENPV (euro '000)
Northern Zone	Andrijevica	27.00%	921	829	16,961
	Berane	28.00%	8,288	11,058	211,934
	Bijelo Polje	37.00%	8,658	11,488	219,400

	Gusinje	-	-	-	-
	Kolašin	23.00%	1,982	2,446	45,698
	Mojkovac	32.00%	1,982	4,191	60,582
	Petnjica	-	-	-	-
	Plav	32.00%	1,982	5,093	66,682
	Plužine	27.00%	1,139	1,153	22,819
	Pljevlja	27.00%	13,138	18,101	357,704
	Rožaje	25.00%	4,987	5,114	104,934
	Šavnik	22.00%	822	530	11,699
	Žabljak	21.00%	1,922	1,118	34,616
TOTAL:		**29.00%**	**46,155**	**61,187**	**1,150,178**
Coastal Zone	Budva	n/a	n/a	n/a	n/a
	Bar	n/a	n/a	n/a	n/a
	Herceg Novi	n/a	n/a	n/a	n/a
	Kotor	n/a	n/a	n/a	n/a
	Tivat	n/a	n/a	n/a	n/a
	Ulcinj	n/a	n/a	n/a	n/a
TOTAL:		**n/a**	**n/a**	**n/a**	**n/a**
Central Zone	Cetinje	32.00%	13,107	12,511	225,214
	Danilovgrad	-	-	-	-
	Nikšić	42.00%	146,693	(70,743)	(689,802)
	Podgorica	-	-	-	-
	Tuzi	-	-	-	-
TOTAL:		**0.40**	**159,800**	**(58,232.00)**	**(57,259.00)**

Source: Study on potential for district heating and/or cooling and high-efficiency cogeneration, Table 0-3

Figure 6-1 Spatial presentation of the financial NPV due to the implementation of the district heating system by the municipalities of Montenegro

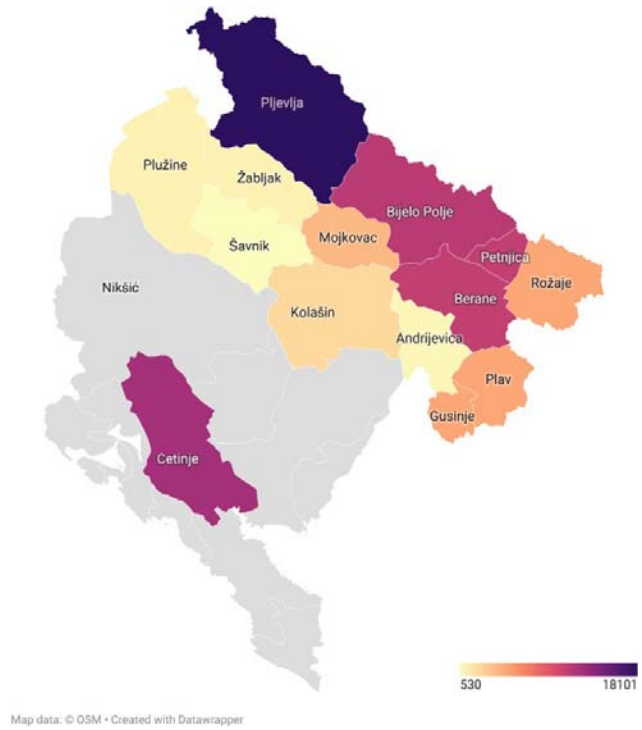
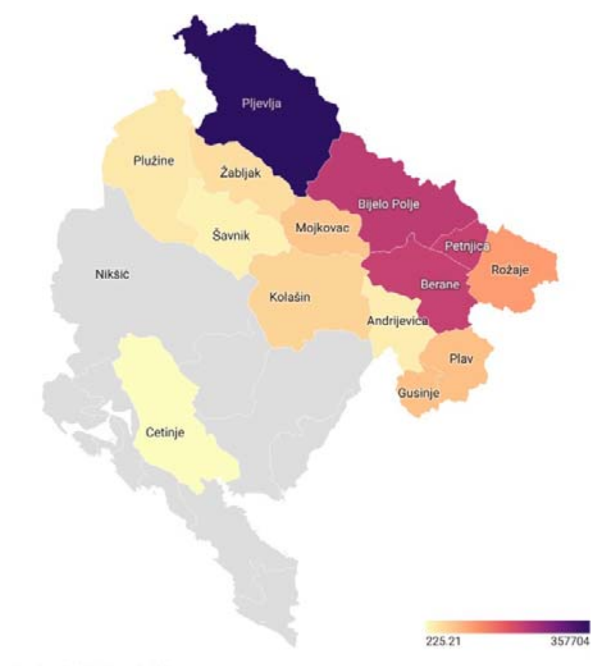


Figure 6-2 Spatial presentation of the economic NPV due to the implementation of the district heating system by the municipalities of Montenegro



Additionally, the energy development strategy of Montenegro [10] envisages the development of DH in Montenegro based on biomass. In this context, the implementation of DH in the municipality of Pljevlja (in Northern Zone) is planned. The municipality of Pljevlja, due to significant environmental problems with the current coal-based heating and single-point heating systems (around 5,000 individual fireplaces in the city and 40 in residential blocks), has already started preparatory activities for a biomass DH project with an installed thermal capacity of approximately 18 MW_{th} on wood residue. According to the Energy Development Strategy of Montenegro, the estimated costs for the realisation of this project are around EUR 7.2 million. In the initial phase, the DH system will supply only about 20% of the inhabitants of the city of Pljevlja. The heat needs of the city of Pljevlja in 2025 are estimated at 147.5 MW_{th}, of which around 50-70 MW_{th} could be connected to the DH system. The planned duration of the development of this project is estimated at a time frame of 20 to 25 years. When it comes to the development of cogeneration and high-efficiency cogeneration, the Strategy [10] recommends the implementation of the following activities:

- Create additional assessments of the availability of resources for the introduction of industrial and small plants for cogeneration and high-efficiency cogeneration in Montenegro and feasibility studies in local conditions in order to determine the economic potential of using cogeneration and high-efficiency cogeneration in concrete projects,

- Create and adopt the Program for the development and use of highly efficient cogeneration,

- Monitor the development of the legislative and regulatory framework in the EU and timely transpose Montenegro's obligations towards the Energy Community into legislation and regulation regarding cogeneration and highly efficient cogeneration.

The study *Identification and analysis of possible sustainable heating solutions in Pljevlja in Montenegro for CEE Bankwatch [14]* from 2021 also supports the implementation of DH in the city of Pljevlja. As already stated, existing consumers in Pljevlja are supplied by means of combustion of biomass and lignite either burned in small individual heating boilers (consumer group A) or in large boiler rooms which supply 31% of the inhabitants who are connected in “microgrids” (consumer group B). Given this variety of consumer types, a few crucial actions had to be proposed to achieve diametrical technological improvement to the heating system. Firstly, energy efficiency measures are necessary to allow the transition to renewable heating technologies and a certain share of building retrofits is presupposed in this study. To improve the energy transmission and reduce fuel consumption as well as incorporate alternative heating solutions with high spatial requirements which are feasible only outside of the condensed living area, the implementation of a DH network (consumer group C) is also considered. This last group of consumers is created by either connection of the microgrid users into larger DH networks or the connection of individually heated properties to a new heating pipeline. Several identified technology options and combinations for each of the distinguished consumer groups were assessed using an Integrated Risk Matrix (IRM) approach. The IRM has been conducted for four main DH expansion scenarios (I. – IV.) where the most suitable sizing of a possible DH grid is sought. Within each scenario, all groups of consumers are assessed separately for the most suitable form of renewable heating technology option which would satisfy their heating needs at the lowest cost and higher environmental improvement.

The final results of this study show that if no subsidies for renewable energy technologies are assumed, the overall investment costs indicate that no DH network should be set up and the current heat distribution based on individuals and microgrids should remain in place (Scenario I.). When incentives at 80% of total investment in heat pumps and solar thermal with seasonal storage are included, the development of a DH in the wider centre of the town is most promising (Scenario III.). A summary of the findings is presented in Table 6-4.

Table 6-4 Summary of IRM results for the most recommended scenarios

Scenario	Consumer group	Technology	Heat contribution [MWh/a]	CO_2 reduction [tCO_2/a]	Simple payback [year]	Indicative heat price [EUR/MWh]	Indicative NPV [EUR]
I.	A	New biomass boiler small	136,000	36,000	7,8	25	17,900,000
	B	Air source heat pumps medium	36,000	8,000	7,9	19	7,400,000
III. with subsidies	A	New biomass boiler small	99,000	26,000	7,8	25	13,100,000
	B	Air source heat pumps medium	20,000	4,000	1,5	9	7,200,000
	C	Subsidized: Open space solar thermal + storage	52,000	15,000	8,4	24	18,100,000

Source: Identification and analysis of possible sustainable heating solutions in Pljevlja in Montenegro for CEE Bankwatch, Table 1

In addition to Pljevlja, the potential for the implementation of the biomass utilisation project in DH systems has also been identified for other buildings in the northern climate zone of Montenegro. Thus, in 2020, a pre-feasibility study was prepared for the implementation of biomass district heating system in the municipality of Žabljak, which is located in northern climate zone of Montenegro. The main technical and economic results of the mentioned study are given in the figures below.

Table 6-5 Technical indicators of the implementation of the biomass district heating system in Žabljak

Item	Value	Unit
Total length of DH network (trench)	4,431	m
Total yearly heat energy demand consumers	7,728	MWh/a
Total yearly heat energy demand consumers inclusive DH losses	8,972	MWh/a
Total connected consumer heat capacity	5,362	kW
Utilisation factor (connection consumers to DH)	0.84	-
Total max. heat capacity consumers	4,503	kW
Total max. heat capacity consumers inclusive	4,630	kW
Network heat capacity density (consumers)	1.21	kW/m
Network heat density (consumers)	1.74	MWh/m
Duration of operation per year	8,760	h

Source: Report Montenegro, Žabljak Biomass District Heating Project, Pre-Feasibility Study

Table 6-6Economic indicators of the implementation of the biomass district heating system in Žabljak

Financial Results – Calculations without taxes	Value	Unit
Sold heat energy to consumers	7,728	MWh/a
Total CAPEX	3.33	mio €
Specific CAPEXs – total plant (related to installed biomass heat capacity)	2,381	€/kW
Net present value (NPV)	1.99	mio €
Discounted payback time/amortization (PB)	12	years
Internal rate of return (IRR)	14.01%	-

Financial Results – Calculations without taxes	Value	Unit
Benefit cost ratio (BCR)	1.27	-
Economic internal rate of return (EIRR)	16.72%	-

Source: Report Montenegro, Žabljak Biomass District Heating Project, Pre-Feasibility Study

In conclusion, it is important to emphasise that the optimal solution for a community can dramatically vary from case to case, as it is subject to the local needs and objectives for the town.

6.2 Energy efficiency measures for individual (on-site) systems

Energy efficiency measures for the individual systems in the households and the service sector include the replacement of fossil fuels with renewable energy sources, the introduction of more efficient technologies such as centralised systems and heat pumps, as well as use of solar energy for heating and DHW preparation. The proposed measures are presented in more detail in the table below.

Table 6-7 On-site measures for efficient heating and cooling

	PURPOSE	LABEL	TITLE OF MEASURES
H-HHOUSEHOLDS	**Space heating**	H_H_WF_1	Replacement of individual firewood stoves with central modern biomass boilers
		H_H_WF_2	Replacement of individual firewood stoves with heat pumps
		H_H_WF_3	Replacement of central firewood boilers with central modern biomass boilers
		H_H_WF_4	Replacement of central firewood boilers with heat pumps
		H_H_C_1	Replacement of individual coal stoves with central modern biomass boilers
		H_H_C_2	Replacement of individual coal stoves with heat pumps
		H_H_C_3	Replacement of central coal boilers with central modern biomass boilers
		H_H_C_4	Replacement of central coal boilers with heat pumps
		H_H_LPG_1	Replacement of central LPG boilers with central biomass boilers
		H_H_LPG_2	Replacement of central LPG boilers with heat pumps
		H_H_E_1	Replacement electric resistance heating sources with heat pumps
		H_H_E_2	Replacement of existing air conditioners and heat pumps with more efficient systems
	DHW preparation	H_DHW_WF_1	Replacement of central firewood boilers with heat pumps
		H_DHW_WF_2	Replacement of central firewood boilers with central modern biomass boilers
		H_DHW_WF_3	Installation of solar collectors for DHW preparation (where firewood is currently used as an energy source for DHW preparation)
		H_DHW_LPG_1	Replacement of central LPG boilers with central modern biomass boilers
		H_DHW_LPG_2	Replacement of central LPG boilers with heat pumps
		H_DHW_LPG_3	Installation of solar collectors for DHW preparation (where LPG is currently used as an energy source for DHW preparation)
		H_DHW_E_1	Replacement electrical heaters with heat pumps
		H_DHW_E_2	Replacement electrical heaters with solar collectors

	PURPOSE	LABEL	TITLE OF MEASURES
	Space cooling	H_C_E_1	More efficient technology use (replacement of air conditioners with heat pumps (air source heat pumps, waters source heat pumps or ground source heat pumps))
SERVICES	**Space heating**	S_H_WF_1	Replacement of individual firewood stoves with central modern biomass boilers
		S_H_WF_2	Replacement of individual firewood stoves with heat pumps
		S_H_WF_3	Replacement of central firewood boilers with central modern biomass boilers
		S_H_WF_4	Replacement of central firewood boilers with heat pumps
		S_H_FO_1	Replacement of central fuel oil boilers with central modern biomass boilers
		S_H_FO_2	Replacement of central fuel oil boilers with heat pumps
		S_H_LPG_1	Replacement of central LPG boilers with central modern biomass boilers
		S_H_LPG_2	Replacement of central LPG boilers with heat pumps
		S_H_E_1	Replacement electric resistance heating sources with heat pumps
		S_H_E_2	Replacement of existing air conditioners and heat pumps with more efficient systems
	DHW preparation	S_DHW_WF_1	Replacement of central firewood boilers with heat pumps
		S_DHW_WF_2	Installation of solar collectors for DHW preparation (where firewood is currently used as an energy source for DHW preparation)
		S_DHW_WF_3	Replacement of central firewood boilers with central modern biomass boilers
		S_DHW_FO_1	Replacement of central fuel oil boilers with central modern biomass boilers
		S_DHW_FO_2	Replacement of central fuel oil boilers with heat pumps
		S_DHW_FO_3	Installation of solar collectors for DHW preparation (where fuel oil is currently used as an energy source for DHW preparation)
		S_DHW_LPG_1	Replacement of central LPG boilers with central modern biomass boilers
		S_DHW_LPG_2	Replacement of central LPG boilers with heat pumps
		S_DHW_LPG_3	Installation of solar collectors for DHW preparation (where LPG is currently used as an energy source for DHW preparation)
		S_DHW_E_1	Replacement electrical heaters with heat pumps
		S_DHW_E_2	Replacement electrical heaters with solar collectors
	Space cooling	S_C_E_1	More efficient technology use (replacement of air conditioners with heat pumps (air source heat pumps, waters source heat pumps or ground source heat pumps))

Heat pumps include all types of heat pumps (air source heat pumps, ground source heat pumps, water source heat pumps) with an average efficiency coefficient of 3.5. For a comprehensive assessment of the potential, this approach is considered satisfactory, while later in the sensitivity analysis, efficiency coefficients that depend on the external climatic conditions will be varied, especially in the case of air source heat pumps.

6.2.1 Technical potential

For each of the above-mentioned measures in individual systems, the technical potential until 2050 has been quantified. Energy efficiency measures are implemented to the BAU scenario defined in chapter 4.3 in order to assess their impact. For space heating in households and service sectors, measures generally include the replacement of fossil fuels with modern biomass or the electrification of heating through the installation of heat pumps. Therefore, two possible development scenarios were analysed: the tendency of greater use of modern biomass and the tendency of greater use of electricity for space heating. When analysing trends in energy consumption and the distribution of energy sources for the DHW preparation, an additional development scenario was analysed – the largest possible implementation of solar collectors. For the purposes of space cooling, it is assumed that more efficient technologies will be implemented by 2050. Based on the above, the capacities of new technologies that need to be installed, as well as energy savings due to the implementation of energy efficiency measures until 2030, were calculated, which is shown in the table below.

Table 6-8 Technical potential of on-site measures for efficient heating and cooling until 2050

	PURPOSE	LABEL	BEFORE MEASURE IMPLEMENTATION			AFTER MEASURE IMPLEMENTATION			Energy savings [GWh]	CO_2 emissions savings [tCO_2]
			Energy source	Energy consumption [GWh]	Installed capacity [MW]	Energy source	Energy consumption [GWh]	Installed capacity [MW]		
H-HHOUSEHOLDS	Space heating	H_H_WF_1	Firewood	11,38	10,96	Modern biomass	7,78	7,50	3,59	69,56
		H_H_WF_2	Firewood	540,38	520,60	Electricity	100,36	96,68	440,02	-7.845,01
		H_H_WF_3	Firewood	8,53	8,22	Modern biomass	7,19	6,92	1,35	6,93
		H_H_WF_4	Firewood	8,53	8,22	Electricity	1,95	1,88	6,58	-209,67
		H_H_C_1	Coal	31,59	30,44	Modern biomass	21,62	20,82	9,98	10.599,17
		H_H_C_2	Coal	31,59	30,44	Electricity	5,87	5,65	25,73	9.947,35
		H_H_C_3	Coal	10,53	10,15	Modern biomass	8,87	8,54	1,66	3.477,22
		H_H_C_4	Coal	10,53	10,15	Electricity	2,41	2,32	8,12	3.209,81
		H_H_LPG_1	LPG	2,58	2,48	Modern biomass	2,31	2,22	0,27	594,86
		H_H_LPG_2	LPG	2,58	2,48	Electricity	0,63	0,60	1,95	525,33
		H_H_E_1	Electricity	26,33	25,36	Electricity	7,52	7,25	18,81	4.415,80
		H_H_E_2	Electricity	26,33	25,36	Electricity	21,06	20,29	5,27	1.236,42
	DHW preparation	H_DHW_WF_1	Firewood	34,54	7,88	Electricity	7,89	1,80	26,64	-848,91
		H_DHW_WF_2	Firewood	34,54	7,88	Modern biomass	28,19	6,44	6,34	57,94
		H_DHW_WF_3	Firewood	34,54	7,88	Solar	28,19	6,44	6,34	1.004,64
		H_DHW_LPG_1	LPG	1,15	0,26	Modern biomass	1,03	0,24	0,12	266,49
		H_DHW_LPG_2	LPG	1,15	0,26	Electricity	0,28	0,06	0,87	235,34
		H_DHW_LPG_3	LPG	1,15	0,26	Solar	1,00	0,23	0,15	301,17
		H_DHW_E_1	Electricity	34,93	7,97	Electricity	9,98	2,28	24,95	5.858,52
		H_DHW_E_2	Electricity	35,98	8,21	Solar	35,98	8,21	0,00	8.447,99
	Space cooling	H_C_E_1	Electricity	153,57	52,29	Electricity	122,85	41,83	30,72	7.213,36

	PURPOSE	LABEL	BEFORE MEASURE IMPLEMENTATION			AFTER MEASURE IMPLEMENTATION			Energy savings [GWh]	CO_2 emissions savings [tCO_2]
			Energy source	Energy consumption [GWh]	Installed capacity [MW]	Energy source	Energy consumption [GWh]	Installed capacity [MW]		
SERVICES	Space heating	S_H_WF_1	Firewood	13,95	13,44	Modern biomass	9,54	9,19	4,40	85,27
		S_H_WF_2	Firewood	13,95	13,44	Electricity	2,59	2,50	11,36	-202,35
		S_H_WF_3	Firewood	32,54	31,35	Modern biomass	27,40	26,40	5,14	26,50
		S_H_WF_4	Firewood	32,54	31,35	Electricity	7,44	7,17	25,10	-800,40
		S_H_FO_1	Fuel oil	64,32	61,96	Modern biomass	54,16	52,18	10,16	18.140,05
		S_H_FO_2	Fuel oil	64,32	61,96	Electricity	14,70	14,16	49,62	16.506,80
		S_H_LPG_1	LPG	8,07	7,78	Modern biomass	7,22	6,96	0,85	1.863,16
		S_H_LPG_2	LPG	8,07	7,78	Electricity	1,96	1,89	6,11	1.645,40
		S_H_E_1 (Scenario: tendency towards space heating electrification)	Electricity	1,19	1,14	Electricity	0,34	0,33	0,85	199,59
		S_H_E_1 (Scenario: tendency towards biomass using)	Electricity	95,99	92,48	Electricity	27,43	26,42	68,56	16.098,57
		S_H_E_2 (Scenario: tendency towards space heating electrification)	Electricity	2,37	2,28	Electricity	1,90	1,83	0,47	110,36
		S_H_E_2 (Scenario: tendency towards biomass using)	Electricity	29,63	28,54	Electricity	23,70	22,83	5,93	1.392,42
	DHW preparation	S_DHW_WF_1	Firewood	0,23	0,05	Electricity	0,05	0,01	0,18	-5,72
		S_DHW_WF_2	Firewood	0,23	0,05	Solar	0,19	0,04	0,04	6,77
		S_DHW_WF_3	Firewood	0,23	0,05	Modern biomass	0,19	0,04	0,04	0,39
		S_DHW_FO_1	Fuel oil	2,11	0,48	Modern biomass	1,78	0,41	0,33	595,99
		S_DHW_FO_2	Fuel oil	2,11	0,48	Electricity	0,38	0,09	1,74	567,54
		S_DHW_FO_3	Fuel oil	2,11	0,48	Solar	1,73	0,39	0,39	655,75

	PURPOSE	LABEL	BEFORE MEASURE IMPLEMENTATION			AFTER MEASURE IMPLEMENTATION			Energy savings [GWh]	CO_2 emissions savings [tCO_2]
			Energy source	Energy consumption [GWh]	Installed capacity [MW]	Energy source	Energy consumption [GWh]	Installed capacity [MW]		
		S_DHW_LPG_1	LPG	0,01	0,00	Modern biomass	0,01	0,00	0,00	1,68
		S_DHW_LPG_2	LPG	0,01	0,00	Electricity	0,00	0,00	0,01	1,48
		S_DHW_LPG_3	LPG	0,01	0,00	Solar	0,01	0,00	0,00	1,90
		S_DHW_E_1	Electricity	2,70	0,62	Electricity	0,77	0,18	1,93	452,46
		S_DHW_E_2	Electricity	6,37	1,46	Solar	6,37	1,46	0,00	1.496,60
	Space cooling	S_C_E_1	Electricity	172,91	58,88	Electricity	138,33	47,10	34,58	8.119,73

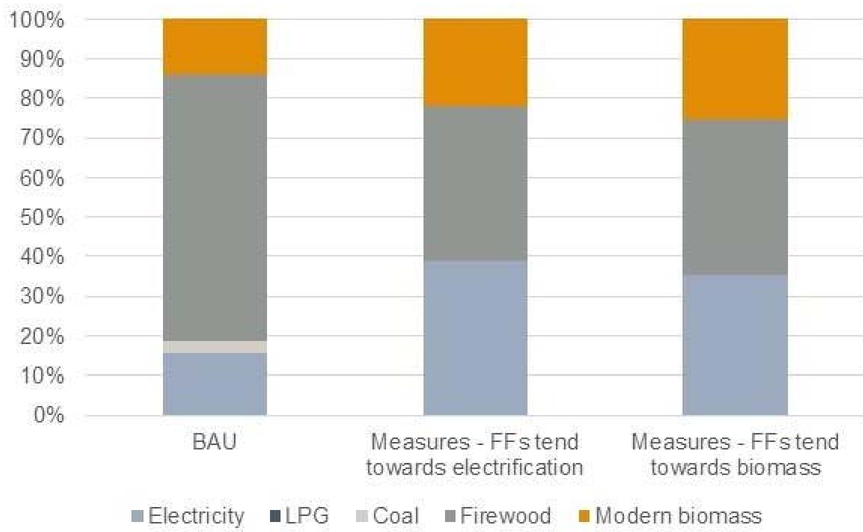
After the implementation of energy efficiency measures, the energy mix and energy consumption for each purpose and sector is obtained, as shown in the figures below. For each scenario, the implemented measures are listed in the diagram. It is important to note here that for space cooling the energy mix diagram is not shown for either households or for the service sector, because only electricity consumption is predicted, and the absolute consumption in 2050 can be expressed as the difference between energy consumption in the BAU scenario (chapter 4.3) and savings energy for space cooling shown in the table above.

Figure 6-3 HOUSEHOLDS (SPACE HEATING) – Comparison of the BAU scenario and the scenario after the implementation of energy efficiency measures in 2050

Measures – Fossil fuels tend towards electrification: H_H_WF_1, H_H_WF_2, H_H_WF_3, H_H_WF_4, H_H_C_2, H_H_C_4, H_H_LPG_2, H_H_E_1, H_H_E_2

Measures – Fossil fuels tend towards modern biomass: H_H_WF_1, H_H_WF_2, H_H_WF_3, H_H_WF_4, H_H_C_1, H_H_C_3, H_H_LPG_1, H_H_E_1, H_H_E_2

Energy mix (2050)



Final energy consumption (2050)

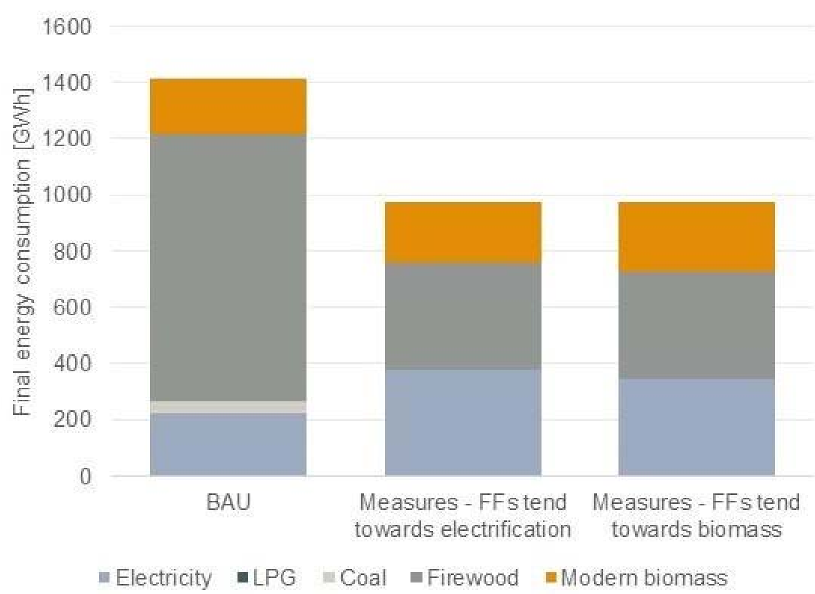
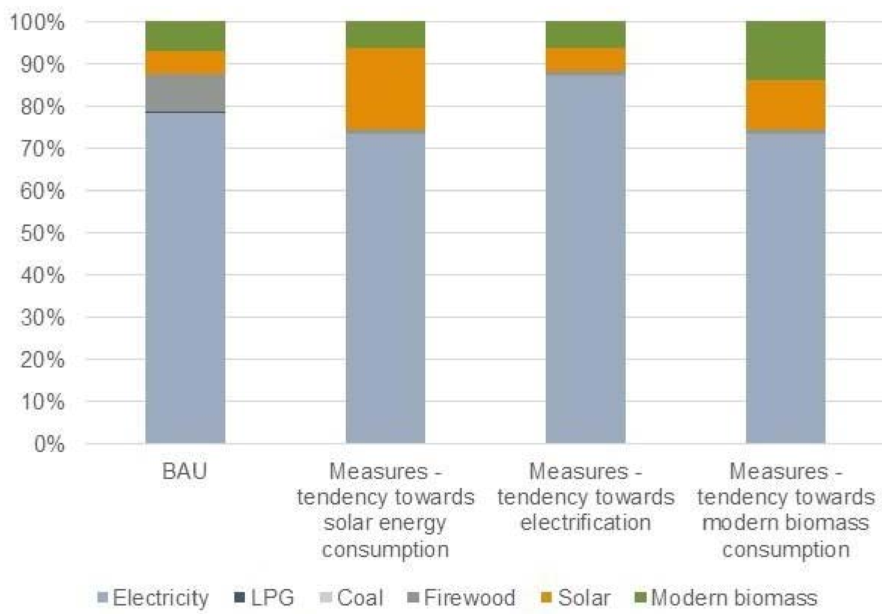


Figure 6-4 HOUSEHOLDS (DHW PREPARATION) – Comparison of the BAU scenario and the scenario after the implementation of energy efficiency measures in 2050

Measures – Tendency towards solar energy consumption: H_DHW_WF_2, H_DHW_LPG_3, H_DHW_E_2 Measures – Tendency towards electrification: H_DHW_WF_1, H_DHW_LPG_2, H_DHW_E_1

Measures – Tendency towards modern biomass consumption: H_DHW_WF_3, H_DHW_LPG_1

Energy mix (2050)



Final energy consumption (2050)

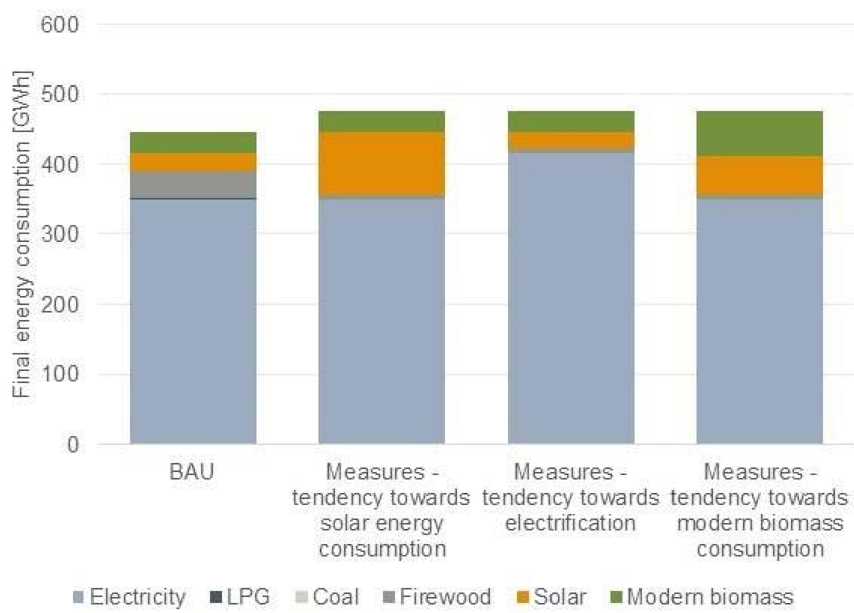
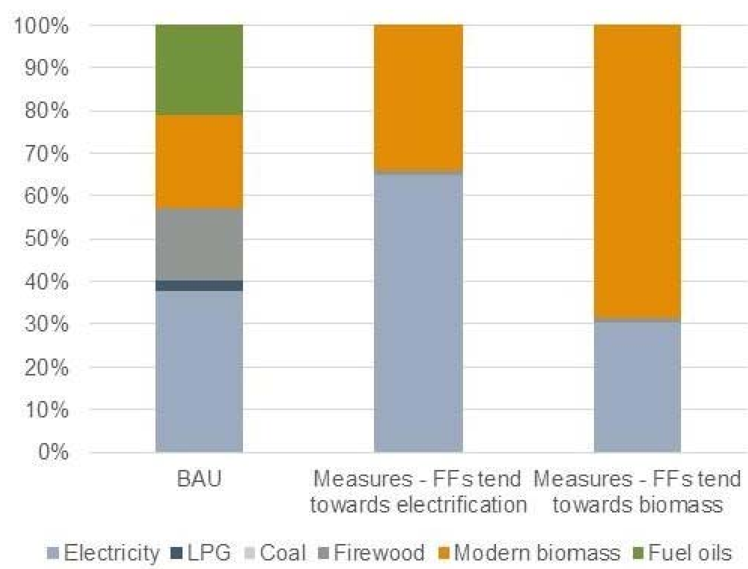


Figure 6-5 SERVICE SECTOR (SPACE HEATING) – Comparison of the BAU scenario and the scenario after the implementation of energy efficiency measures in 2050

Measures – Fossil fuels tend towards electrification: S_H_WF_2, S_H_WF_4, S_H_LPG_2, S_H_FO_2, S_H_E_1, , S_H_E_2

Measures – Fossil fuels tend towards modern biomass: S_H_WF_1, S_H_WF_3, S_H_LPG_1,S_H_FO_1, S_H_E_1, S_H_E_2

Energy mix (2050)



Final energy consumption (2050)

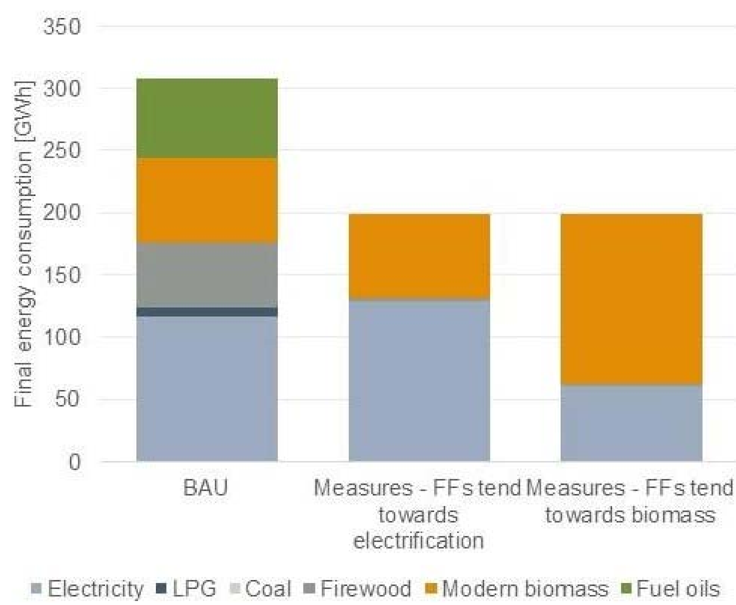
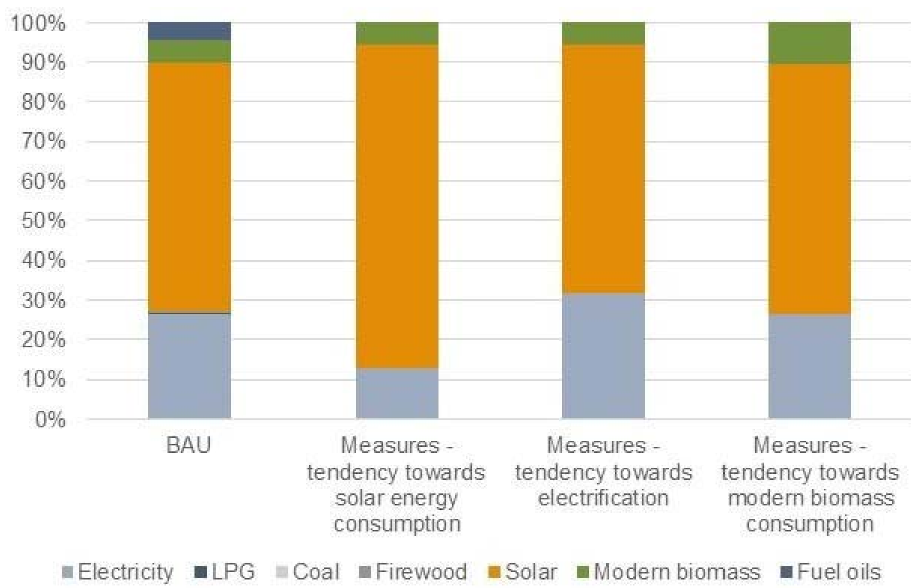


Figure 6-6 SERVICE SECTOR (DHW PREPARATION) – Comparison of the BAU scenario and the scenario after the implementation of energy efficiency measures in 2050

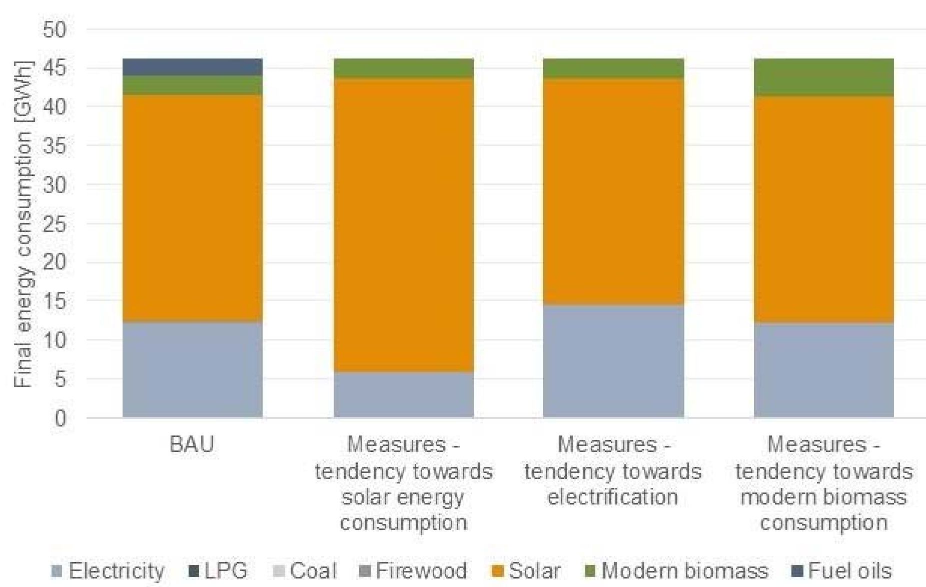
Measures – Tendency towards solar energy consumption: S_DHW_WF_2, S_DHW_LPG_3, S_DHW_FO_3, H_DHW_E_2

Measures – Tendency towards electrification: S_DHW_WF_1, S_DHW_LPG_2, S_DHW_FO_2, S_DHW_E_1 Measures – Tendency towards modern biomass consumption: S_DHW_WF_3, S_DHW_LPG_1, S_DHW_FO_1

Energy mix (2050)



Final energy consumption (2050)



6.2.2 Economic potential – Cost and benefit analysis

In addition to the technical potential for each measure of energy efficiency, the economic potential was calculated in absolute and specific amounts (EUR/GWh). In this context, a CBA was carried out in order to identify technical solutions which might be more cost-effective than all recognised H&C solutions.

This analysis compares the costs and benefits between the following two scenarios:

- reference or BAU (business-as-usual) scenario, which presumes development with the application of existing measures, and
- scenario with integrated measures for each sector and purpose.

The BAU scenario serves as a point of reference against which alternative scenarios are assessed. It describes the current situation and its potential evolution if none of the parameters of the existing situation change. The alternative scenario includes the implementation of energy efficiency measures defined in Section 6.2.1 to the BAU scenario, where a CBA was performed for each measure. The first step in undertaking the analysis is the assessment of costs and benefits. They are assessed separately for the baseline scenario and the alternative scenario. Costs and benefits that remain constant in both scenarios do not have to be considered because they would cancel each other in the process of assessing their change between both scenarios. The same applies when implementing partial measures in the given year. A part of the baseline scenario that has not been replaced by a measure is not assessed because the same values appear in both scenarios. Also, H&C consumption is the same in both scenarios, which is why it is not necessary to show these values.

Costs and benefits include:

- **Benefits:**
  - value of output to the consumer (heating, cooling and electricity),
  - external benefits such as environmental, greenhouse gas emissions and health and safety benefits, to the extent possible,
  - labour market effects, energy security and competitiveness, to the extent possible.
- **Costs:**
  - capital costs of plants and equipment (CAPEX),
  - variable and fixed operating costs (OPEX),
  - energy costs,
  - environmental, health and safety costs, to the extent possible.

Cost estimates

Capital expenditures for H&C systems include the funds necessary for the implementation of an individual technology. In this context, the costs presented in the Table 6-9 were used to assess the economic potential of various energy efficiency measures. Operational costs (OPEX) refer to the consumption of material, maintenance, administration, cost of labour etc. They can be fixed or variable. Fixed costs of maintenance and management include labour, insurance, regular maintenance and routine replacement of plant components, such as boilers, carburettors, raw material handling equipment, etc. Replacement parts and additional servicing costs constitute the greatest share of variable costs of management and maintenance. These can also include other costs, such as the cost of biomass ash management. In this analysis, due to their nature and limited data availability, the variable costs of management and maintenance for individual systems have been estimated jointly with the fixed costs, as shown in Table 6-9.

Table 6-9 CAPEX and OPEX by individual technology

Technology	Cost of investment [EUR/kW]	Fixed and variable maintenance costs [EUR/kW]
Individual firewood stoves	55.00	6.50
Central firewood boilers	155.00	13.00
Central modern biomass boilers	145.00	33.60
Heat pumps	590.00	16.00
Solar collectors*	665.00	1.35
Individual coal stoves	55.00	6.50
Central coal boilers	155.00	13.00
Central LPG boilers	135.00	16.00
Electric resistance space heating	35.00	0.13
Air conditioners	235.00	13.00
Central fuel oil boilers	135.00	24.00
Electrical heaters	65.00	0.13
Central compression chillers	465.00	16.00

*the price of solar collectors is expressed in EUR/m^2 Source: EIHP analysis

Costs of energy sources are determined separately. Energy costs are taken from national documents and the EUROSTAT database, as shown in the table below. The total amount is derived by multiplying total energy consumption with the relative price of a specific energy source.

Table 6-10 Unit prices of energy and CO_2 emission by year

	2021	2025	2030	2035	2040	2045	2052
Electricity (only households), [EUR/kWh]	0.0988	0.1111	0.1317	0.1482	0.1620	0.1759	0.1952
Electricity (only services), [EUR/kWh]	0.0773	0.0870	0.1030	0.1160	0.1268	0.1376	0.1527
Firewood, [EUR/kWh]	0.0280	0.0286	0.0297	0.0305	0.0313	0.0320	0.0331
Modern biomass, [EUR/kWh]	0.0730	0.0788	0.0885	0.0972	0.1053	0.1134	0.1247
Coal, [EUR/kWh]	0.0260	0.0266	0.0275	0.0283	0.0290	0.0297	0.0307
LPG, [EUR/kWh]	0.1300	0.1536	0.1930	0.2230	0.2467	0.2704	0.3037
Solar energy, [EUR/kWh]	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	2021	2025	2030	2035	2040	2045	2052
Fuel oil, [EUR/kWh]	0.1460	0.1742	0.2337	0.3135	0.4207	0.5645	0.8519
CO_2 prices, [EUR/tCO_2]	31.8831	46.7345	65.2988	71.7452	78.1916	84.6380	93.7187

Source: National documents, EUROSTAT, EIHP analysis

To calculate the costs of CO_2 emissions, it is necessary to calculate the CO_2 emissions resulting from the use of a certain energy source The formula for calculating annual greenhouse gas emissions is:

$$E_{CO_2} = \frac{E_{consumption} \cdot e}{1000}$$

where:

E_{CO2} [tCO_2/a] – greenhouse gas emission,

$E_{consumption}$ [kWh/a] – total energy consumption,

e [kgCO_2/kWh] – emissions factor, depending on the energy product.

For this purpose, emission factors were used depending on the energy used, as shown in the table below. The data were taken from the Croatian assessment of the potential for efficiency heating and cooling in Croatia under Annex VII to Directive 2012/27/EU [11].

Table 6-11 CAPEX and OPEX by individual technology

Energy product	CO_2 emissions factor [tCO2/GWh]
Electricity	234.81
Solar energy	0.00
Firewood	29.09
Modern biomass	33.58
Coal	358.47
LPG	260.88
Fuel oil	310.31

Source: Croatian assessment of the potential for efficiency heating and cooling in Croatia under Annex VII to Directive 2012/27/EU

Benefit estimates

In this analysis, the following main benefits of the implementation of the proposed measures have been recognised:

1. **Differential cost of energy used for heating or cooling**

   Energy product costs are usually lower in alternative scenarios compared to BAU scenario. Only the measures envisaging the use of more expensive energy products compared to the ones used in BAU scenario actually generate higher energy product costs for consumers. Such measures are recommended to be implemented if economically feasible due to greater reduction in CO_2 emissions. Their implementation usually requires some form of government incentives.

2. **Residual value**

This is the residual value of technology, which represents its market value or liquidation value if it is sold off at the end of the year under observation. For certain technologies whose lifetime will not have ended by then the residual value at the end of the observation period has been estimated. That value was added to total income under alternative and BAU scenarios. A positive difference between the residual values in an alternative scenario and BAU scenario represents income and contributes to a higher NPV of measure implementation. The opposite is true as well.

3. **Difference in CO_2 emissions**

In the economic analysis, a positive difference in CO_2 emissions between an alternative scenario and BAU scenario represents additional value for society. The amount of CO_2 emission reduction is expressed in tonnes [tCO_2/a] and monetised by multiplying it with the appropriate emission price. In addition, the government may provide incentives or subsidies for certain technologies. No such cases are included in this analysis.

Analysis procedure

The present value of expected cash flows is calculated for the entire assessment period by discounting annual cash flows, which represent differential cost and benefits of the implementation of a certain measure in respect of the current situation. The following formula is used in the calculation:

$$S_o = \sum_{t=1}^{T} \frac{V_t}{(1+k)\cdot k}$$

Where:

S_0 – net present value,

T – total assessment period,

V_t – cash flow in year t,

k – discount factor (opportunity cost).

The net present value of a measure compared to the situation with no change (baseline scenario or BAU scenario) is calculated by adding up discounted differences in benefits and cost differential in a single year within the observation period. According to the net present value criterion, the higher the net present value, the more cost-effective the measure is.

A CBA includes financial analysis from the point of view of the investor, as well as economic analysis which also considers socio-economic and environmental factors and includes costs of CO_2 emissions. In calculating NPV, the financial analysis applies the financial discount rate, representing opportunity cost for the consumer, while the economic analysis applies the economic discount rate to assess the justification of the project for society as a whole. A measure is financially justified if the financial NPV is above zero. Otherwise, the measure is not cost-effective for the consumer. If a measure has a negative financial NPV and a positive economic NPV, the desirability of subsidies for the implementation of the measure or some other form of support should be explored because the implementation of such a measure is considered desirable for society as a whole. The economic analysis serves to support the adoption of appropriate policies. The benefit of conducting the analysis from both perspectives consists in identifying potential areas in which appropriate policies should be implemented, considering the gap between the cost-effectiveness of the measure and its benefit from the point of view of society. Based on that gap, actions to support or promote the measure or the cancellation of the existing or planned support mechanisms, if the assessment proves it not to be justified society-wise, are proposed. According to national documents, it is foreseen to introduce prices for CO_2 emissions from 2025 in Montenegro. Therefore, the price of CO_2 is calculated from the year 2025 in this analysis.

The discount rate used in the economic analysis to calculate the net present value is chosen according to European or national guidelines. A 5% financial discount rate and a 2% social discount rate are applied in this analysis. In the absence of national guidelines, the discount rate values used are similar to those used by EU Member States in their analyses. By applying an appropriate discount rate, future costs and benefits can be expressed in the corresponding present value to render them comparable over time.

The analysis is conducted using constant prices defined in the base year, given that a real discount rate is applied. When a significant change in the prices of some input variables or products is expected, either above or below the average inflation rate, that difference should be considered in respective cash flow projections. In this analysis, this primarily applies to price trends of energy sources, including electricity. The prices of energy sources have thus been corrected by the expected 2% inflation rate in the observed period.

Cost-benefit analysis results

As already stated, a CBA was carried out for each energy efficiency measure defined in chapter **Error! Reference source not found.**. The results of the CBA analysis are presented in the table below.

Table 6-12 Results of completed financial and economic CBA up to 2052

Measure code	NPV [EUR/GWh]	ENPV [EUR/GWh]
H_H_WF_1	-244,939.34	-438,295.11
H_H_WF_2	10,333.52	-1,625.39
H_H_WF_3	-345,546.57	-622,165.03
H_H_WF_4	-31,364.59	-84,725.37
H_H_C_1	-258,606.28	-188,654.36
H_H_C_2	-3,333.42	248,015.37
H_H_C_3	-359,213.50	-372,524.27
H_H_C_4	-45,031.53	164,915.39
H_H_LPG_1	904,533.69	1,831,657.10
H_H_LPG_2	1,238,352.04	2,402,686.75
H_H_E_1	696,055.50	1,386,742.90
H_H_E_2	194,807.38	388,160.57
H_DHW_WF_1	-31,414.31	-84,809.63
H_DHW_WF_2	-329,054.95	-592,029.62
H_DHW_WF_3	191,006.53	358.485.06
H_DHW_LPG_1	904,595.38	1,831,764.58
H_DHW_LPG_2	1,238,300.29	2,402,596.20
H_DHW_LPG_3	1,474,622.43	2,873,596.80
H_DHW_E_1	696,128.43	1,386,855.47

Measure code	NPV [EUR/GWh]	ENPV [EUR/GWh]
H_DHW_E_2	974,163.65	1,940,987.31
H_C_E_1	194,918.95	388,344.34
S_H_WF_1	-244,939.34	-438,295.11
S_H_WF_2	49,720.76	68,961.77
S_H_WF_3	-345,546.57	-622,165.03
S_H_WF_4	17,112.01	2,151.13
S_H_FO_1	2,188,212.32	4,472,757.85
S_H_FO_2	2,550,870.90	5,097,074.01
S_H_LPG_1	904,533.69	1,831,657.10
S_H_LPG_2	1,289,858.43	2,494,993.03
S_H_E_1 (both scenarios – towards space heating electrification and towards modern biomass consumption)	544,566.12	1,115,253.84
S_H_E_2 (both scenarios – towards space heating electrification and towards modern biomass consumption)	152,390.35	312,143.64
S_DHW_WF_1	17,062.29	2,066.87
S_DHW_WF_2	191,006.53	358,485.06
S_DHW_WF_3	-329,054.95	-592,029.62
S_DHW_FO_1	2,188,226.98	4,472,784.53
S_DHW_FO_2	2,589,514.55	5,176,238.32
S_DHW_FO_3	2,724,723.03	5,453,332.50
S_DHW_LPG_1	904,595.38	1,831,764.58
S_DHW_LPG_2	1,289,806.68	2,494,902.48
S_DHW_LPG_3	1,474,622.43	2,873,596.80
S_DHW_E_1	544,639.05	1,115,366.40
S_DHW_E_2	762,078.51	1,560,902.63
S_C_E_1	152,463.84	312,251.53

Source: EIHP analysis

A financial and economic CBA was carried out for a total of 43 energy efficiency measures. A total of 30 measures are characterized by a positive value of financial and economic NPV, which means that these measures are profitable for the consumer and have a positive effect from the point of view of society. A total of ten measures are characterized by a negative financial and economic NPV value. A total of two measures of energy efficiency are characterized by a negative financial value of NPV and a positive economic value of NPV, while only one measure has a positive financial value of NPV and a negative economic value of NPV. A representation of the energy efficiency measures according to the results of the CBA is presented graphically in the table below, while the discussion and conclusions based on this analysis are presented in the next chapter.

Table 6-13 Graphic representation of energy efficiency measures according to financial and economic NPV values

FINANCIAL ANALYSIS, NPV	
negative (-)	positive (+)

ECONOMIC ANALYSIS, NPV		
positive (+)	H_H_C_2, H_H_C_4	H_H_LPG_1, H_H_LPG_2 H_H_E_1, H_H_E_2 H_DHW_WF_3 H_DHW_LPG_1, H_DHW_LPG_2, H_DHW_LPG_3 H_DHW_E_1, H_DHW_E_2 H_C_E_1 S_H_WF_2, S_H_WF_4 S_H_FO_1, S_H_FO_2 S_H_LPG_1, S_H_LPG_2 S_H_E_1, S_H_E_2 S_DHW_WF_1, S_DHW_WF_2 S_DHW_FO_1, S_DHW_FO_2, S_DHW_FO_3 S_DHW_LPG_1, S_DHW_LPG_2, S_DHW_LPG_3 S_DHW_E_1, S_DHW_E_2 S_C_E_1
negative (-)	H_H_WF_1, H_H_WF_3, H_H_WF_4 H_H_C_1, H_H_C_3 H_DHW_WF_1, H_DHW_WF_2 S_H_WF_1, S_H_WF_3, S_DHW_WF_3	H_H_WF_2

Sensitivity analysis

The results of the economic analysis presented above in respect of different H&C alternatives depend on changes in the parameters covered by the analysis. Therefore, in order to ensure that the analysis of potential is complete, it is also necessary to conduct a sensitivity analysis to identify the parameters whose variations have a significant impact on the cost-effectiveness of a measure, and thus also on the NPV amount (financial and economic). The sensitivity analysis is aimed at examining uncertainty or a range of the outcomes. To this end, the impact of possible changes in technical and economic assumptions is investigated and the effect of such changes on the results of the CBA is examined from a microeconomic and macroeconomic perspective. These are usually increases/decreases in the unit cost of technologies, increases in energy product prices, variations in CO_2 prices, changes in discount rates, etc. The results of the analysis serve for estimating the absolute change in NPV in an individual scenario caused by a change to a certain parameter and also to assess the extent of any changes in the relationships (relative advantages) between alternative scenarios. In that context, the following parameters were varied in the sensitivity analysis:

- investment and operation costs (CAPEX and OPEX), ± 50%
- discount factors for financial and economic analysis, ± 50% and +100%,
- prices of energy sources, ± 50%
- price of CO_2 emissions, ± 50%,

- the value of the coefficient of efficiency of heat pumps (1.75, 2.63, 4.40).

The results of the sensitivity analysis due to varying each of the mentioned parameters are shown in Annexes – part 3, while a more detailed discussion of the results is given in the next chapter.

6.2.3 Discussion and conclusions

Based on the results of the CBA analysis for referent state, four characteristic groups of energy efficiency measures can be distinguished:

1. **Measures with positive financial and economic NPV values**

   In this group there are a total of 30 energy efficiency measures, which include the complete replacement of LPG for space heating and the preparation of DHW in households and the service sector, the complete replacement of fuel oil in the service sector for space heating and the DHW preparation and the replacement of electrical resistant heating and existing air conditioners with heat pumps in households and the service sector for space heating and space cooling.
   Additionally, for the preparation of DHW, this group includes energy efficiency measures that include the replacement of electric boilers with heat pumps and solar collectors in households and the service sector. When it comes to the replacement of firewood, positive financial and economic values of NPV have measures include replacement of individual firewood stoves with heat pumps in the households and service sector, replacement of central firewood boilers with heat pumps in service sector, installation of solar collectors for DHW preparation in the households and service sector, and replacement of central firewood boilers with heat pumps for DHW preparation in service sector. The mentioned measures are profitable for the consumer and have a positive social effect. Any policy support (through financial incentives or other) should therefore be carefully checked that it addresses and targets real market failures while avoiding free riders (recipients who would have undertaken the measure even in the absence of support). The most cost-effective measures are all measures that include the replacement of fuel oil.

2. **Measures with negative financial and economic NPV values**

   In this group there are a total of ten energy efficiency measures, which include replacement of individual firewood stoves and central firewood boilers with central modern biomass boilers for space heating in households and service sector, replacement of central firewood boilers with heat pumps for space heating in households, replacement of individual coal stoves and central firewood boilers with central modern biomass boilers for space heating in households, replacement of central firewood boilers with heat pumps for DHW preparation in households, replacement of central firewood boilers with central modern biomass boilers for DHW preparation in households and service sector. These measures are not considered profitable due to the negative NPV values.

3. **Measures with negative financial and positive economic NPV values**

   There are a total of two energy efficiency measures in this group, both of which refer to the household sector. Measures include replacement of individual coal stoves and central coal boilers with heat pumps for space heating. The mentioned measures are not profitable for the consumer but have a positive social effect. These measures represent potential areas in which appropriate policies should be implemented, given that they are socially justified but unlikely to see significant uptake without financial support. Therefore, actions are proposed to support or promote these measures.

4. **Measure with positive financial and negative economic NPV value**

   There is only one measure in this group, which is the replacement of individual wood stoves with heat pumps in households. The reason for the negative economic value of NPV is the big difference in the emission factors of electricity and firewood, where the emission factor of electricity is even eight times higher. It is expected that by 2050 electricity will be produced from cleaner energy sources in terms of CO_2 emissions. If the emission factor of electricity is reduced by 5%, the measure from group 4 will move to group 1, i.e., it will be characterized by a positive financial and economic NPV.

Following all of the above, it can be concluded that the measures from group 1 should be promoted to investors because they represent cost-effective energy efficiency measures, while the measures from group 3 need to be financially supported considering that they represent cost-effective measures from the point of view of social benefit. There may still be need to support group 1 measures, at least in initial stages where market penetration is weak, should specific market failures be identified that limit uptake but any such support needs to be carefully targeted and withdrawn once reasonable penetration is achieved in order to avoid free ridership (i.e. the receipt of support by those who would have undertaken the measure anyhow in its absence).

For a more complete analysis of the potential, a sensitivity analysis was also carried out in order to identify parameters whose variations have a significant impact on the profitability of the measure, and thus on the amount of NPV (financial and economic). For this purpose, the impact of possible changes in technical and economic assumptions on the results of CBA from a microeconomic and macroeconomic perspective was investigated.

The variation of CAPEX and OPEX does not lead to significant changes in financial and economic NPV (Table 9-3, 9.2 Annexes – part 3). The reason for this is because higher technology costs mean higher costs of both energy efficient and energy inefficient technologies.

Varying the financial and economic discount rate expectedly leads to more significant changes in the financial and economic values of NPV depending on the measure of energy efficiency. The results of a sensitivity analysis varying discount rates for each measure of energy efficiency are given in Table 9-4 (9.2 Annexes – part 3). However, most measures occupy the same quadrant in the context of positive and negative values of financial and economic NPV, except for the following measures:

- Replacement of individual coal stoves with heat pumps in households (H_H_C_2): An increase in discount rates by 50% results in a positive financial NPV, which makes this measure cost-effective considering the reference state,

- Replacement of individual firewood stoves with heat pumps in households (H_H_WF_1): An increase in discount rates by 50% results in a positive economic NPV, which makes this measure positive for social effect,

- Replacement of central firewood boilers with heat pumps for space heating and DHW preparation in services (S_H_WF_4 and S_DHW_WF_1): A 50% decrease in discount rates results in a negative economic NPVs, which makes these measures in that case negative for the social effect.

Varying the prices of energy sources expectedly also leads to significant changes in the financial and economic values of NPV depending on the measure of energy efficiency. The results of sensitivity analysis due to varying energy source prices for each measure of energy efficiency are given in Table 9-5 (9.2 Annexes – part 3). However, most measures occupy the same quadrant in the context of positive and negative values of financial and economic NPV, except for the following measures:

- Replacement of individual coal stoves with central modern biomass boilers in households (H_H_C_1): A 50% decrease in prices of energy sources results in a positive economic NPV, which makes this measure positive for social effect,

- Replacement of individual firewood stoves with heat pumps in households (H_H_WF_2): A 25% increase in prices of energy sources results in a positive economic NPV, which makes this measure positive for social effect,

- Replacement of central firewood boilers with heat pumps for space heating and DHW preparation in services (S_H_WF_4 and S_DHW_WF_1): A 25% decrease in prices of energy sources results in a negative economic NPVs, which makes these measures in that case negative for the social effect.

Variations in the prices of CO_2 emissions affect only the economic NPV, while the financial NPV remains constant. The results of sensitivity analysis due to varying CO_2 emissions prices for each measure of energy efficiency are given in Table 9-6 (9.2 Annexes – part 3). Most measures occupy the same quadrant in the context of positive and negative values of economic NPV, except for the following measures:

- Replacement of individual firewood stoves with heat pumps in households (H_H_WF_2): A 25% decrease in prices of CO_2 emissions results in a positive economic NPV, which makes this measure positive for social effect,

- Replacement of central firewood boilers with heat pumps for space heating and DHW preparation in services (S_H_WF_4 and S_DHW_WF_1): A 25% increase in prices of CO_2 emissions results in a negative economic NPVs, which makes these measures in that case negative for the social effect.

The variation of different energy efficiency coefficients of heat pumps (COP) was carried out only for those combinations that include the replacement of energy inefficient technologies with heat pumps. A COP of 3.50 was taken to evaluate the overall assessment of the potential for efficient H&C for the reference state. However, COP is significantly dependent on outside weather conditions, especially when it comes to air source heat pumps. Therefore, a sensitivity analysis varying the COP was performed (Table 9-7, 9.2 Annexes – part 3) in order to gain insight into its impact on economic indicators (financial and economic NPV). Also, it can be assumed that the COP in the northern climate zone will be lower, while in the coastal zone of Montenegro it will be higher than the reference state. This means that in this way one can gain an insight into the cost-effectiveness of installing heat pumps in different climatic zones of Montenegro. The results of the sensitivity analysis due to COP variation led to the following conclusions:

- Measures H_H_WF_2 (replacement of individual firewood stoves with heat pumps for heating in households), H_H_E_2 (replacement of existing air conditioners and heat pumps with more efficient systems for heating in households), H_C_E_1 (more efficient technology use (replacement of air conditioners with heat pumps (air source heat pumps, waters source heat pumps or ground source heat pumps)) for cooling in households), S_H_WF_2 (replacement of individual firewood stoves with heat pumps for heating in services), S_H_WF_4 (replacement of central firewood boilers with heat pumps for heating in services), S_H_E_2 (replacement of existing air conditioners and heat pumps with more efficient systems for heating in services), S_DHW_WF_1 (replacement of central firewood boilers with heat pumps for DHW preparation in services) and S_C_E_1 (more efficient technology use (replacement of air conditioners with heat pumps (air source heat pumps, waters source heat pumps or ground source heat pumps)) for cooling in services) for COP values of 1.75 and 2.63 have negative financial NPV values, while for the reference state they were financially profitable. **Based on the above, it can be concluded that the implementation of air source heat pumps for the measures here is not profitable in the northern zone of Montenegro**. However, the installation of all other heat pumps (water source heat pumps and ground source heat pumps) implies a higher COP, and it can be concluded that their implementation is profitable even in northern climate zone.

- Measures H_H_WF_4 (replacement of central firewood boilers with heat pumps for heating in households), H_H_C_2 (replacement of individual coal stoves with heat pumps for heating in households), H_H_C_4 (replacement of central coal boilers with heat pumps for heating in households) and H_DHW_WF_1 (replacement of central firewood boilers with heat pumps for DHW preparation in households) for the reference state are characterized by a negative financial NPV value, while increasing the COP to 4.40 these measures become financially profitable, that is, they are characterized by a positive financial NPV value. **From this it can be concluded that in the case of using air source heat pumps in the coastal climate zone of Montenegro, these measures are profitable**. Also, for all other heat pumps characterized by a COP of 4.4, these measures are financially profitable regardless of the climate zone.

- Measures H_H_E_2 (replacement of existing air conditioners and heat pumps with more efficient systems for heating in households), H_C_E_1 (more efficient technology use (replacement of air conditioners with heat pumps (air source heat pumps, waters source heat pumps or ground source heat pumps)) for cooling in households), S_H_WF_2 (replacement of individual firewood stoves with heat pumps for heating in services), S_H_WF_4 (replacement of central firewood boilers with heat pumps for heating in services), S_H_E_2 (replacement of existing air conditioners and heat pumps with more efficient systems for heating in services), S_DHW_WF_1 (replacement of central firewood boilers with heat pumps for DHW preparation in services) and S_C_E_1 (more efficient technology use (replacement of air conditioners with heat pumps (air source heat pumps, waters source heat pumps or ground source heat pumps)) for cooling in services) for COP value of 2.6 have negative economic NPV values, while for the reference state they have positive economic NPV values. With the additional reduction of COP to 1.70, two more measures (H_H_C_2 (replacement of individual coal stoves with heat pumps for heating in households) and H_H_C_4 (replacement of central coal boilers with heat pumps for heating in households)) are characterized by a negative value of the economic NPV. **From this it can be concluded that using air source heat pumps in the northern climate zone, the mentioned measures do not have a positive social effect, while for the use of all other heat pumps whose COP is 3.50 and higher, mentioned measures have a positive social effect.**

- Measures H_H_WF_2 (replacement of individual firewood stoves with heat pumps for heating in households), H_H_WF_4 (replacement of central firewood boilers with heat pumps for heating in households) and H_DHW_WF_1 (replacement of central firewood boilers with heat pumps for DHW preparation in households) for the reference state are characterized by a negative economic NPV value, while increasing the COP to 4.40 these measures are characterized by a positive economic NPV value. **From this it can be concluded that in the case of the use of air source heat pumps in the coastal climate zone of Montenegro, these measures have a positive social effect.** Also, for all other heat pumps characterized by a COP of 4.4, these measures are characterized by a positive social effect.

The above presented results of the sensitivity analysis may be further used in the definition of policy measures and refinement of criteria for providing support for different technologies and in different areas of Montenegro.

PART 4: POTENTIAL NEW STRATEGIES AND POLICY MEASURES

7 Potential new strategies and policy measures

7.1 Approach to identifying policy measures

This CA has been laid out according to the requirements of Article 14 of the EED, as transposed for Energy Community Contracting Parties, and Commission Recommendation (EU) 2019/1659. An integral part of the CA according to EED Annex VIII and the Commission Recommendation is to include strategies and policies that may be adopted to realise the potential socio-economic benefits identified through Part 3.

For Montenegro, the CA has been prepared in conjunction with a stand-alone AP. The AP describes in detail the policy measures proposed to support the uptake of the financially and/or economically attractive technical actions identified in Part 3:

- They key identified trends are on-site towards modern biomass boilers (focus in north of Montenegro) and heat pumps (focus in south and coastal areas of Montenegro) for space heating, and heat pumps and solar collectors for DHW.

- Some off-site potential for DH exists, notably in Pljevlja, Žabljak and potentially upon further assessment, in other northern town, however this is not expected to form the primary driver of decarbonisation of H&C in Montenegro.

- The large majority of technical actions identified are both financially and economically attractive. It is therefore reasonable to expect that any constraints to their uptake are not a result of the actions being financially unattractive to consumers. Nevertheless, there may remain market barriers that constrain optimal uptake. These may relate to quality issues regarding products and installations, a lack of knowledge, and/or access to capital constraints by way of examples.

- Some other technical actions (relating to heat pump replacing coal stoves/boilers with heat pumps) were identified as economically, but not financially, attractive. These measures may suffer similar barriers to those noted above, in addition to being financially unattractive to end consumers and therefore in need of financial support to bridge the viability gap.

The proposed policy measures are therefore intended to ensure the holistic framework needed to enable a true transition to a cleaner and decarbonised H&C sector in Montenegro is developed. Many of the measures are themselves a requirement for additional analysis to enable the detailed design to be developed and implemented.

For completeness, a brief summary of the measures provided in the AP is given below.

7.2 Proposed policy measures

A “Theory of Change” framework has been used to map and describe the causal chain from current status and market context through the intended impact of the policy measures as shown in Figure 7-1 below.

Figure 7-1 Theory of Change framework for a clean and cost efficient heating and cooling sector in Montenegro

Context	Firewood stoves and electricity dominate building heating and cooling	All delivered energy is from on-site sources	Heat pumps, modern biomass and solar collectors form basis of transition	
Inputs	Set-up policy strategy and planning framework for sector:	• CC1 and CC2 > National and local assessments of potential • CC3 and CC4 > Ongoing policy planning and capacity building • CC5 > Tracking of progress		
Activities	Market assessment and support mechanism design: CTA1, DTA1	• CC6 > Education and certification • CC7 > Quality assurance	• CC8 > Scoping and refining regulatory framework	Information campaigns and events: CTA2, DTA2
Outputs	Financial support or access mechanisms for cost efficient solutions	Implemented education, accreditation and quality assurance processes	Amended legal and regulatory framework for heating and cooling activities	Enhanced understanding of opportunity and heating and cooling solutions
Outcomes	Montenegrin consumers can finance cost efficient heating and cooling solutions	Montenegrin companies offer trustworthy and competitive solutions	Heating and cooling services *provided under a* robust and fair governance framework	Improved knowledge leads to *increased demand for cost* effective and clean solutions
Impact	An accelerated transition in Montenegro towards a clean and cost efficient heating and cooling sector			

The objective of this transition is most likely to be achieved if the proposed H&C solutions are financially beneficial to consumers, the H&C solutions are provided by trustworthy and competitive providers, the ensuing H&C services, especially when shared across legal entities are provided under a robust and fair governance framework that offers consumer protection, and the consumers do indeed choose to uptake the identified H&C solutions, driving up the demand in the market. These are the outcomes that the proposed policies and measures described in the AP are designed to deliver.

Therefore, the policies and measures aim towards some specific outputs, or objectives, tied to the aforementioned target outcomes. Firstly, the identified H&C solutions need to be made financially viable to consumers (if they are only economically viable as per the CA) or, in the case of already financially viable solutions, to ensure that finance can be accessible to those consumers that need it to uptake the said solutions. Secondly, trust in the H&C sector can be built through properly trained professionals who have the relevant educational background and formal accreditation while an established quality assurance process is also followed. Thirdly, the legal and regulatory framework around H&C services needs to be amended and updated to account for the new H&C solutions being rolled out in the Montenegrin market. Finally in terms of outputs, the consumers whether households or companies, need to be educated about the available H&C solutions and their advantages (financial but not only) to enhance their awareness and understanding such that they can make the optimal choices given their circumstances and drive the rollout.

Given the above, a total of 12 policies and measures across three categories were identified according to the targeted H&C solutions; the cross cutting (CC) measures, the measures targeting the rollout of centralised technical actions (CTA) and the measures targeting the rollout of decentralised technical actions (DTA). A brief description of these measures is provided in Table 7-1 below while further elaboration is provided in the AP.

Table 7-1 List of proposed policy measures

Overview of proposed policies and measures	
Cross cutting policies and measures	
CC1	Performing national assessments of H&C potentials
CC2	Performing local assessments of H&C potentials and incorporating H&C assessments in Local Energy Plans (LEPs) of municipalities
CC3	Institutional planning – a H&C Coordination Body
CC4	Capacity building for municipalities
CC5	Creating and maintaining a database for installed H&C technologies
CC6	Identification of educational institute to deliver certification schemes or equivalent qualification schemes for installers and relevant tertiary education
CC7	Establishing quality assurance system
CC8	Defining the need and scope of regulation of DHC and centralised on-site H&C solutions in Montenegro
Measures to promote centralised technical actions	
CTA1	Barrier scoping exercise and design of support schemes for centralised technical actions
CTA2	Information campaigns for potential installers, investors, property developers and the supply chain

Overview of proposed policies and measures	
Measures to promote decentralised technical actions	
DTA1	Barrier scoping exercise and design of support schemes for decentralised technical actions
DTA2	Information campaigns for potential users

8 LITERATURE

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9 ANNEXES

9.1 Annexes – part 1

Table 9-1 Typology of the building fund in households

Year of construction	Type of buildings	Distribution of buildings according to year of construction	Label
Before 1945	Small houses (1-2 flats)	94,70%	A1
	Medium (3 - 9 flats)	4,88%	B1
	Medium (> 10 flats)	0,42%	C1
1946-1970	Small houses (1-2 flats)	93,16%	A2
	Medium (3 - 9 flats)	5,23%	B2
	Medium (> 10 flats)	1,61%	C2
1971-1990	Small houses (1-2 flats)	92,11%	A3
	Medium (3 - 9 flats)	6,53%	B3
	Medium (> 10 flats)	1,36%	C3
1991-2000	Small houses (1-2 flats)	91,28%	A4
	Medium (3 - 9 flats)	6,71%	B4
	Medium (> 10 flats)	2,01%	C4
2001-2011	Small houses (1-2 flats)	88,59%	A5
	Medium (3 - 9 flats)	7,73%	B5
	Medium (> 10 flats)	3,68%	C5
Unknown*	Small houses (1-2 flats)	91,28%	A4
	Medium (3 - 9 flats)	6,71%	B4
	Medium (> 10 flats)	2,01%	C4

* It is assumed that the buildings are from the period 1991 – 2000

SOURCES: a) Population census 2011, MONSTAT, b) The typology of the residential building stock of Montenegro and modelling its low-carbon transformation 2015, SLED (Support for Low-Emission Development in South Eastern Europe (SLED))

Table 9-2 Required energy for space heating, DHW preparation and space cooling by zones and types of buildings in Montenegro

Zone	Building type	Space heating [kWh/m^2]	DHW preparation [kWh/m^2]	Space cooling [kWh/m^2]
Coastal Zone	A1	153	39	80
	A2	163	36	80
	A3	207	30	80
	A4	189	28	80
	A5	124	29	30
	B1	192	37	60
	B2	139	38	60
	B3	122	29	60
	B4	75	30	60
	B5	49	36	30
	C1	102	67	60
	C2	102	42	60
	C3	99	34	60
	C4	93	39	60
	C5	56	38	30
Central Zone	A1	239	39	80
	A2	254	36	80
	A3	322	30	80
	A4	294	28	80
	A5	194	29	30
	B1	300	37	60
	B2	216	38	60

Zone	Building type	Space heating [kWh/m2]	DHW preparation [kWh/m2]	Space cooling [kWh/m2]
	B3	189	29	60
	B4	117	30	60
	B5	76	36	30
	C1	160	67	60
	C2	160	42	60
	C3	154	34	60
	C4	145	39	60
	C5	88	38	30
Central Zone	A1	320	39	30
	A2	341	36	30
	A3	432	30	30
	A4	394	28	30
	A5	260	29	11
	B1	402	37	23
	B2	290	38	23
	B3	254	29	23
	B4	157	30	23
	B5	102	36	11
	C1	214	67	23
	C2	214	42	23
	C3	206	34	23
	C4	194	39	23
	C5	117	38	11

SOURCES: a) The typology of the residential building stock of Montenegro and modelling its low-carbon transformation 2015, SLED (Support for Low-Emission Development in South Eastern Europe (SLED), b) file Montenegro_types_energy.xls, available at www.sled.rec.org

9.2 Annexes – part 3

Table 9-3 The results of the sensitivity analysis due to the variation of the CAPEX and OPEX

Measure label	-50%		-25%		Referent state		+25%		+50%	
	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]
H_H_WF_1	-244,880	-438,195	-244,910	-438,245	-244,939	-438,295	-244,969	-438,345	-244,999	-438,396
H_H_WF_2	10,336	-1,624	10,335	-1,625	10,334	-1,625	10,332	-1,626	10,331	-1,627
H_H_WF_3	-345,509	-622,098	-345,528	-622,132	-345,547	-622,165	-345,565	-622,198	-345,584	-622,232
H_H_WF_4	-31,397	-84,781	-31,381	-84,753	-31,365	-84,725	-31,348	-84,698	-31,332	-84,670
H_H_C_1	-258,547	-188,554	-258,576	-188,604	-258,606	-188,654	-258,636	-188,705	-258,666	-188,755
H_H_C_2	-3,331	248,017	-3,332	248,016	-3,333	248,015	-3,335	248,015	-3,336	248,014
H_H_C_3	-359,176	-372,457	-359,195	-372,491	-359,214	-372,524	-359,232	-372,558	-359,251	-372,591
H_H_C_4	-45,064	164,860	-45,048	164,888	-45,032	164,915	-45,015	164,943	-44,999	164,971
H_H_LPG_1	904,574	1,831,728	904,554	1,831,692	904,534	1,831,657	904,513	1,831,622	904,493	1,831,587
H_H_LPG_2	1,238,318	2,402,627	1,238,335	2,402,657	1,238,352	2,402,687	1,238,369	2,402,716	1,238,386	2,402,746
H_H_E_1	696,101	1,386,813	696,078	1,386,778	696,056	1,386,743	696,033	1,386,708	696,010	1,386,672
H_H_E_2	194,864	388,244	194,836	388,202	194,807	388,161	194,779	388,119	194,751	388,077
H_DHW_WF_1	-31,422	-84,823	-31,418	-84,816	-31,414	-84,810	-31,410	-84,803	-31,407	-84,797
H_DHW_WF_2	-329,047	-592,015	-329,051	-592,022	-329,055	-592,030	-329,059	-592,037	-329,063	-592,044
H_DHW_WF_3	191,172	358,726	191,089	358,606	191,007	358,485	190,924	358,365	190,841	358,244
H_DHW_LPG_1	904,605	1,831,781	904,600	1,831,773	904,595	1,831,765	904,591	1,831,756	904,586	1,831,748
H_DHW_LPG_2	1,238,292	2,402,582	1,238,296	2,402,589	1,238,300	2,402,596	1,238,304	2,402,603	1,238,308	2,402,610
H_DHW_LPG_3	1,474,798	2,873,853	1,474,710	2,873,725	1,474,622	2,873,597	1,474,535	2,873,469	1,474,447	2,873,341
H_DHW_E_1	696,137	1,386,870	696,133	1,386,863	696,128	1,386,855	696,124	1,386,848	696,119	1,386,841
H_DHW_E_2	974,384	1,941,312	974,274	1,941,150	974,164	1,940,987	974,053	1,940,825	973,943	1,940,662
H_C_E_1	194,939	388,374	194,929	388,359	194,919	388,344	194,909	388,330	194,899	388,315
S_H_WF_1	-244,880	-438,195	-244,910	-438,245	-244,939	-438,295	-244,969	-438,345	-244,999	-438,396
S_H_WF_2	49,724	68,963	49,722	68,962	49,721	68,962	49,719	68,961	49,718	68,960
S_H_WF_3	-345,509	-622,098	-345,528	-622,132	-345,547	-622,165	-345,565	-622,198	-345,584	-622,232
S_H_WF_4	17,079	2,096	17,096	2,124	17,112	2,151	17,128	2,179	17,145	2,206
S_H_FO_1	2,188,222	4,472,775	2,188,217	4,472,767	2,188,212	4,472,758	2,188,208	4,472,749	2,188,203	4,472,740
S_H_FO_2	2,550,811	5,096,969	2,550,841	5,097,022	2,550,871	5,097,074	2,550,901	5,097,126	2,550,931	5,097,179
S_H_LPG_1	904,574	1,831,728	904,554	1,831,692	904,534	1,831,657	904,513	1,831,622	904,493	1,831,587
S_H_LPG_2	1,289,825	2,494,934	1,289,841	2,494,963	1,289,858	2,494,993	1,289,875	2,495,023	1,289,892	2,495,052
S_H_E_1	544,612	1,115,324	544,589	1,115,289	544,566	1,115,254	544,543	1,115,219	544,521	1,115,183
S_H_E_2	152,447	312,227	152,419	312,185	152,390	312,144	152,362	312,102	152,334	312,060
S_DHW_WF_1	17,055	2,054	17,058	2,060	17,062	2,067	17,066	2,073	17,070	2,080
S_DHW_WF_2	191,172	358,726	191,089	358,606	191,007	358,485	190,924	358,365	190,841	358,244
S_DHW_WF_3	-329,047	-592,015	-329,051	-592,022	-329,055	-592,030	-329,059	-592,037	-329,063	-592,044

Measure label	-50%		-25%		Referent state		+25%		+50%	
	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]
S_DHW_FO_1	2,188,229	4,472,789	2,188,228	4,472,787	2,188,227	4,472,785	2,188,226	4,472,782	2,188,225	4,472,780
S_DHW_FO_2	2,589,498	5,176,210	2,589,506	5,176,224	2,589,515	5,176,238	2,589,523	5,176,252	2,589,531	5,176,267
S_DHW_FO_3	2,724,882	5,453,562	2,724,802	5,453,447	2,724,723	5,453,333	2,724,644	5,453,218	2,724,564	5,453,103
S_DHW_LPG_1	904,605	1,831,781	904,600	1,831,773	904,595	1,831,765	904,591	1,831,756	904,586	1,831,748
S_DHW_LPG_2	1,289,799	2,494,888	1,289,803	2,494,895	1,289,807	2,494,902	1,289,811	2,494,910	1,289,815	2,494,917
S_DHW_LPG_3	1,474,798	2,873,853	1,474,710	2,873,725	1,474,622	2,873,597	1,474,535	2,873,469	1,474,447	2,873,341
S_DHW_E_1	544,648	1,115,381	544,644	1,115,373	544,639	1,115,366	544,635	1,115,359	544,630	1,115,352
S_DHW_E_2	762,299	1,561,228	762,189	1,561,065	762,079	1,560,903	761,968	1,560,740	761,858	1,560,578
S_C_E_1	152,484	312,281	152,474	312,266	152,464	312,252	152,454	312,237	152,444	312,222

Table 9-4 The results of the sensitivity analysis due to the variation of the financial and economic discount rate

Measure label	-50%		-25%		Referent state		+25%		+50%		+100%	
	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]
H_H_WF_1	-399,842	-541,807	-311,217	-486,879	-244,939	-438,295	-194,916	-395,261	-156,812	-357,086	-104,790	-293,000
H_H_WF_2	10,578	-5,076	10,613	-3,203	10,334	-1,625	9,876	-300	9,329	810	8,164	2,506
H_H_WF_3	-562,065	-768,098	-438,245	-690,674	-345,547	-622,165	-275,501	-561,456	-222,079	-507,580	-149,008	-417,078
H_H_WF_4	-56,932	-107,506	-42,147	-95,381	-31,365	-84,725	-23,449	-75,351	-17,598	-67,093	-9,988	-53,379
H_H_C_1	-421,526	-233,260	-328,332	-209,579	-258,606	-188,654	-205,955	-170,138	-165,829	-153,728	-111,004	-126,221
H_H_C_2	-11,106	303,471	-6,502	274,096	-3,333	248,015	-1,163	224,823	312	204,168	1,950	169,285
H_H_C_3	-583,749	-459,551	-455,361	-413,374	-359,214	-372,524	-286,540	-336,333	-231,096	-304,223	-155,221	-250,299
H_H_C_4	-78,616	201,041	-59,262	181,919	-45,032	164,915	-34,488	149,772	-26,615	136,265	-16,202	113,400
H_H_LPG_1	1,478,650	2,264,566	1,150,212	2,034,868	904,534	1,831,657	719,074	1,651,618	577,785	1,491,876	384,884	1,223,629
H_H_LPG_2	2,015,354	2,966,444	1,571,067	2,667,367	1,238,352	2,402,687	986,879	2,168,105	795,046	1,959,894	532,593	1,610,060
H_H_E_1	1,126,773	1,709,249	880,643	1,538,194	696,056	1,386,743	556,325	1,252,449	449,556	1,133,193	303,106	932,669
H_H_E_2	315,377	478,443	246,478	430,558	194,807	388,161	155,694	350,567	125,808	317,182	84,815	261,048
H_DHW_WF_1	-57,009	-107,608	-42,208	-95,473	-31,414	-84,810	-23,489	-75,427	-17,632	-67,163	-10,012	-53,437
H_DHW_WF_2	-535,474	-731,011	-417,423	-657,273	-329,055	-592,030	-262,291	-534,217	-211,380	-482,914	-141,759	-396,741
H_DHW_WF_3	303,126	438,817	239,230	396,252	191,007	358,485	154,258	324,924	125,983	295,054	86,788	244,660
H_DHW_LPG_1	1,478,747	2,264,697	1,150,289	2,034,986	904,595	1,831,765	719,124	1,651,715	577,826	1,491,964	384,913	1,223,703
H_DHW_LPG_2	2,015,271	2,966,334	1,571,002	2,667,267	1,238,300	2,402,596	986,838	2,168,023	795,012	1,959,819	532,569	1,609,998
H_DHW_LPG_3	2,397,915	3,546,910	1,870,030	3,189,725	1,474,622	2,873,597	1,175,694	2,593,396	947,603	2,344,675	635,419	1,926,726
H_DHW_E_1	1,126,877	1,709,381	880,729	1,538,316	696,128	1,386,855	556,387	1,252,553	449,610	1,133,290	303,148	932,752
H_DHW_E_2	1,577,058	2,392,428	1,232,537	2,152,987	974,164	1,940,987	778,579	1,753,005	629,135	1,586,073	424,153	1,305,384
H_C_E_1	315,540	478,661	246,612	430,758	194,919	388,344	155,788	350,736	125,888	317,338	84,876	261,182
S_H_WF_1	-399,842	-541,807	-311,217	-486,879	-244,939	-438,295	-194,916	-395,261	-156,812	-357,086	-104,790	-293,000
S_H_WF_2	74,337	81,909	60,445	75,085	49,721	68,962	41,357	63,459	34,768	58,506	25,316	50,005
S_H_WF_3	-562,065	-768,098	-438,245	-690,674	-345,547	-622,165	-275,501	-561,456	-222,079	-507,580	-149,008	-417,078
S_H_WF_4	21,541	-448	19,185	973	17,112	2,151	15,297	3,122	13,712	3,917	11,123	5,082

Measure label	-50%		-25%		Referent state		+25%		+50%		+100%	
	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]
S_H_FO_1	3,781,311	5,639,682	2,862,235	5,018,510	2,188,212	4,472,758	1,689,831	3,992,642	1,318,263	3,569,716	827,163	2,867,211
S_H_FO_2	4,364,917	6,407,332	3,319,665	5,710,157	2,550,871	5,097,074	1,980,629	4,557,220	1,554,054	4,081,213	987,293	3,289,372
S_H_LPG_1	1,478,650	2,264,566	1,150,212	2,034,868	904,534	1,831,657	719,074	1,651,618	577,785	1,491,876	384,884	1,223,629
S_H_LPG_2	2,098,731	3,080,194	1,636,232	2,769,743	1,289,858	2,494,993	1,028,046	2,251,482	828,313	2,035,341	555,023	1,672,174
S_H_E_1	881,546	1,374,692	688,981	1,237,088	544,566	1,115,254	435,245	1,007,222	351,713	911,288	237,136	749,979
S_H_E_2	246,714	384,767	192,813	346,248	152,390	312,144	121,791	281,903	98,411	255,049	66,343	209,895
S_DHW_WF_1	21,464	-550	19,124	881	17,062	2,067	15,256	3,045	13,678	3,847	11,099	5,023
S_DHW_WF_2	303,126	438,817	239,230	396,252	191,007	358,485	154,258	324,924	125,983	295,054	86,788	244,660
S_DHW_WF_3	-535,474	-731,011	-417,423	-657,273	-329,055	-592,030	-262,291	-534,217	-211,380	-482,914	-141,759	-396,741
S_DHW_FO_1	3,781,335	5,639,715	2,862,254	5,018,540	2,188,227	4,472,785	1,689,843	3,992,666	1,318,272	3,569,738	827,169	2,867,229
S_DHW_FO_2	4,427,475	6,504,913	3,368,558	5,797,970	2,589,515	5,176,238	2,011,514	4,628,716	1,579,011	4,145,899	1,004,119	3,342,606
S_DHW_FO_3	4,646,434	6,846,504	3,539,657	6,105,352	2,724,723	5,453,333	2,119,556	4,878,954	1,666,297	4,372,289	1,062,939	3,528,898
S_DHW_LPG_1	1,478,747	2,264,697	1,150,289	2,034,986	904,595	1,831,765	719,124	1,651,715	577,826	1,491,964	384,913	1,223,703
S_DHW_LPG_2	2,098,649	3,080,083	1,636,167	2,769,643	1,289,807	2,494,902	1,028,005	2,251,400	828,279	2,035,267	554,999	1,672,112
S_DHW_LPG_3	2,397,915	3,546,910	1,870,030	3,189,725	1,474,622	2,873,597	1,175,694	2,593,396	947,603	2,344,675	635,419	1,926,726
S_DHW_E_1	881,650	1,374,824	689,068	1,237,210	544,639	1,115,366	435,307	1,007,326	351,767	911,384	237,177	750,062
S_DHW_E_2	1,233,741	1,924,049	964,211	1,731,439	762,079	1,560,903	609,068	1,409,687	492,155	1,275,405	331,794	1,049,618
S_C_E_1	246,814	384,892	192,898	346,364	152,464	312,252	121,855	282,004	98,468	255,143	66,388	209,978

Table 9-5 The results of the sensitivity analysis due to the variation of energy source prices

Measure label	-50%		-25%		Referent state		+25%		+50%	
	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]
H_H_WF_1	-122,529	-216,709	-183,734	-327,502	-244,939	-438,295	-306,144	-549,088	-367,349	-659,881
H_H_WF_2	5,164	-6,843	7,749	-4,234	10,334	-1,625	12,918	983	15,503	3,592
H_H_WF_3	-172,811	-310,812	-259,179	-466,489	-345,547	-622,165	-431,915	-777,841	-518,282	-933,518
H_H_WF_4	-15,650	-52,515	-23,507	-68,620	-31,365	-84,725	-39,222	-100,831	-47,079	-116,936
H_H_C_1	-129,363	44,889	-193,985	-71,883	-258,606	-188,654	-323,228	-305,426	-387,850	-422,198
H_H_C_2	-1,669	254,756	-2,501	251,385	-3,333	248,015	-4,165	244,645	-4,997	241,275
H_H_C_3	-179,644	-49,214	-269,429	-210,869	-359,214	-372,524	-448,998	-534,179	-538,783	-695,835
H_H_C_4	-22,483	209,083	-33,757	186,999	-45,032	164,915	-56,306	142,831	-67,580	120,748
H_H_LPG_1	452,226	1,011,615	678,380	1,421,636	904,534	1,831,657	1,130,687	2,241,678	1,356,841	2,651,699
H_H_LPG_2	619,210	1,286,056	928,781	1,844,371	1,238,352	2,402,687	1,547,923	2,961,002	1,857,494	3,519,318
H_H_E_1	347,982	762,949	522,019	1,074,846	696,056	1,386,743	870,092	1,698,640	1,044,129	2,010,536
H_H_E_2	97,347	213,498	146,077	300,829	194,807	388,161	243,538	475,492	292,268	562,823
H_DHW_WF_1	-15,699	-52,599	-23,557	-68,704	-31,414	-84,810	-39,272	-100,915	-47,129	-117,020
H_DHW_WF_2	-164,536	-295,333	-246,795	-443,681	-329,055	-592,030	-411,315	-740,378	-493,574	-888,727
H_DHW_WF_3	95,338	191,082	143,172	274,783	191,007	358,485	238,841	442,187	286,675	525,889
H_DHW_LPG_1	452,288	1,011,723	678,442	1,421,744	904,595	1,831,765	1,130,749	2,241,786	1,356,903	2,651,807

Measure label	-50%		-25%		Referent state		+25%		+50%	
	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]
H_DHW_LPG_2	619,158	1,285,965	928,729	1,844,281	1,238,300	2,402,596	1,547,871	2,960,912	1,857,442	3,519,227
H_DHW_LPG_3	737,135	1,544,876	1,105,879	2,209,236	1,474,622	2,873,597	1,843,366	3,537,957	2,212,109	4,202,317
H_DHW_E_1	348,055	763,062	522,092	1,074,959	696,128	1,386,855	870,165	1,698,752	1,044,202	2,010,649
H_DHW_E_2	486,861	1,067,676	730,512	1,504,332	974,164	1,940,987	1,217,815	2,377,643	1,461,466	2,814,298
H_C_E_1	97,439	213,648	146,179	300,996	194,919	388,344	243,659	475,692	292,399	563,041
S_H_WF_1	-122,529	-216,709	-183,734	-327,502	-244,939	-438,295	-306,144	-549,088	-367,349	-659,881
S_H_WF_2	24,858	28,451	37,289	48,706	49,721	68,962	62,152	89,217	74,584	109,473
S_H_WF_3	-172,811	-310,812	-259,179	-466,489	-345,547	-622,165	-431,915	-777,841	-518,282	-933,518
S_H_WF_4	8,589	-9,077	12,850	-3,463	17,112	2,151	21,374	7,765	25,635	13,379
S_H_FO_1	1,094,097	2,353,479	1,641,154	3,413,118	2,188,212	4,472,758	2,735,270	5,532,397	3,282,328	6,592,037
S_H_FO_2	1,275,496	2,655,214	1,913,183	3,876,144	2,550,871	5,097,074	3,188,558	6,318,004	3,826,246	7,538,934
S_H_LPG_1	452,226	1,011,615	678,380	1,421,636	904,534	1,831,657	1,130,687	2,241,678	1,356,841	2,651,699
S_H_LPG_2	644,963	1,332,209	967,411	1,913,601	1,289,858	2,494,993	1,612,306	3,076,385	1,934,754	3,657,777
S_H_E_1	272,238	627,205	408,402	871,229	544,566	1,115,254	680,730	1,359,278	816,895	1,603,303
S_H_E_2	76,138	175,490	114,264	243,817	152,390	312,144	190,516	380,470	228,642	448,797
S_DHW_WF_1	8,539	-9,161	12,801	-3,547	17,062	2,067	21,324	7,681	25,586	13,295
S_DHW_WF_2	95,338	191,082	143,172	274,783	191,007	358,485	238,841	442,187	286,675	525,889
S_DHW_WF_3	-164,536	-295,333	-246,795	-443,681	-329,055	-592,030	-411,315	-740,378	-493,574	-888,727
S_DHW_FO_1	1,094,111	2,353,505	1,641,169	3,413,145	2,188,227	4,472,785	2,735,285	5,532,424	3,282,343	6,592,064
S_DHW_FO_2	1,294,774	2,699,673	1,942,144	3,937,956	2,589,515	5,176,238	3,236,885	6,414,521	3,884,255	7,652,804
S_DHW_FO_3	1,362,203	2,855,297	2,043,463	4,154,315	2,724,723	5,453,333	3,405,983	6,752,350	4,087,243	8,051,368
S_DHW_LPG_1	452,288	1,011,723	678,442	1,421,744	904,595	1,831,765	1,130,749	2,241,786	1,356,903	2,651,807
S_DHW_LPG_2	644,911	1,332,119	967,359	1,913,511	1,289,807	2,494,902	1,612,254	3,076,294	1,934,702	3,657,686
S_DHW_LPG_3	737,135	1,544,876	1,105,879	2,209,236	1,474,622	2,873,597	1,843,366	3,537,957	2,212,109	4,202,317
S_DHW_E_1	272,310	627,317	408,475	871,342	544,639	1,115,366	680,803	1,359,391	816,968	1,603,415
S_DHW_E_2	380,818	877,634	571,448	1,219,268	762,079	1,560,903	952,709	1,902,537	1,143,339	2,244,171
S_C_E_1	76,212	175,598	114,338	243,925	152,464	312,252	190,590	380,578	228,716	448,905

Table 9-6 The results of the sensitivity analysis due to the variation of CO_2 emission prices

Measure label	-50%		-25%		Referent state		+25%		+50%	
	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]
H_H_WF_1	-244,939	-440,834	-244,939	-439,565	-244,939	-438,295	-244,939	-437,026	-244,939	-435,756
H_H_WF_2	10,334	4,403	10,334	1,389	10,334	-1,625	10,334	-4,640	10,334	-7,654
H_H_WF_3	-345,547	-622,502	-345,547	-622,334	-345,547	-622,165	-345,547	-621,996	-345,547	-621,828
H_H_WF_4	-31,365	-74,518	-31,365	-79,622	-31,365	-84,725	-31,365	-89,829	-31,365	-94,933
H_H_C_1	-258,606	-327,971	-258,606	-258,313	-258,606	-188,654	-258,606	-118,996	-258,606	-49,338
H_H_C_2	-3,333	117,266	-3,333	182,641	-3,333	248,015	-3,333	313,390	-3,333	378,765
H_H_C_3	-359,214	-509,639	-359,214	-441,082	-359,214	-372,524	-359,214	-303,967	-359,214	-235,409

Measure label	-50%		-25%		Referent state		+25%		+50%	
	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]
H_H_C_4	-45,032	38,345	-45,032	101,630	-45,032	164,915	-45,032	228,201	-45,032	291,486
H_H_LPG_1	904,534	1,735,800	904,534	1,783,729	904,534	1,831,657	904,534	1,879,586	904,534	1,927,514
H_H_LPG_2	1,238,352	2,318,034	1,238,352	2,360,360	1,238,352	2,402,687	1,238,352	2,445,013	1,238,352	2,487,340
H_H_E_1	696,056	1,317,094	696,056	1,351,919	696,056	1,386,743	696,056	1,421,567	696,056	1,456,391
H_H_E_2	194,807	368,659	194,807	378,410	194,807	388,161	194,807	397,911	194,807	407,662
H_DHW_WF_1	-31,414	-74,602	-31,414	-79,706	-31,414	-84,810	-31,414	-89,913	-31,414	-95,017
H_DHW_WF_2	-329,055	-592,726	-329,055	-592,378	-329,055	-592,030	-329,055	-591,681	-329,055	-591,333
H_DHW_WF_3	191,007	346,405	191,007	352,445	191,007	358,485	191,007	364,525	191,007	370,565
H_DHW_LPG_1	904,595	1,735,908	904,595	1,783,836	904,595	1,831,765	904,595	1,879,693	904,595	1,927,622
H_DHW_LPG_2	1,238,300	2,317,943	1,238,300	2,360,270	1,238,300	2,402,596	1,238,300	2,444,923	1,238,300	2,487,249
H_DHW_LPG_3	1,474,622	2,765,263	1,474,622	2,819,430	1,474,622	2,873,597	1,474,622	2,927,764	1,474,622	2,981,930
H_DHW_E_1	696,128	1,317,207	696,128	1,352,031	696,128	1,386,855	696,128	1,421,680	696,128	1,456,504
H_DHW_E_2	974,164	1,843,480	974,164	1,892,233	974,164	1,940,987	974,164	1,989,741	974,164	2,038,495
H_C_E_1	194,919	368,839	194,919	378,592	194,919	388,344	194,919	398,097	194,919	407,850
S_H_WF_1	-244,939	-440,834	-244,939	-439,565	-244,939	-438,295	-244,939	-437,026	-244,939	-435,756
S_H_WF_2	49,721	74,990	49,721	71,976	49,721	68,962	49,721	65,947	49,721	62,933
S_H_WF_3	-345,547	-622,502	-345,547	-622,334	-345,547	-622,165	-345,547	-621,996	-345,547	-621,828
S_H_WF_4	17,112	12,359	17,112	7,255	17,112	2,151	17,112	-2,953	17,112	-8,056
S_H_FO_1	2,188,212	4,355,640	2,188,212	4,414,199	2,188,212	4,472,758	2,188,212	4,531,317	2,188,212	4,589,875
S_H_FO_2	2,550,871	4,990,501	2,550,871	5,043,788	2,550,871	5,097,074	2,550,871	5,150,360	2,550,871	5,203,647
S_H_LPG_1	904,534	1,735,800	904,534	1,783,729	904,534	1,831,657	904,534	1,879,586	904,534	1,927,514
S_H_LPG_2	1,289,858	2,410,340	1,289,858	2,452,666	1,289,858	2,494,993	1,289,858	2,537,320	1,289,858	2,579,646
S_H_E_1	544,566	1,045,605	544,566	1,080,430	544,566	1,115,254	544,566	1,150,078	544,566	1,184,902
S_H_E_2	152,390	292,642	152,390	302,393	152,390	312,144	152,390	321,894	152,390	331,645
S_DHW_WF_1	17,062	12,274	17,062	7,171	17,062	2,067	17,062	-3,037	17,062	-8,141
S_DHW_WF_2	191,007	346,405	191,007	352,445	191,007	358,485	191,007	364,525	191,007	370,565
S_DHW_WF_3	-329,055	-592,726	-329,055	-592,378	-329,055	-592,030	-329,055	-591,681	-329,055	-591,333
S_DHW_FO_1	2,188,227	4,355,667	2,188,227	4,414,226	2,188,227	4,472,785	2,188,227	4,531,343	2,188,227	4,589,902
S_DHW_FO_2	2,589,515	5,064,713	2,589,515	5,120,476	2,589,515	5,176,238	2,589,515	5,232,001	2,589,515	5,287,764
S_DHW_FO_3	2,724,723	5,324,472	2,724,723	5,388,902	2,724,723	5,453,333	2,724,723	5,517,763	2,724,723	5,582,193
S_DHW_LPG_1	904,595	1,735,908	904,595	1,783,836	904,595	1,831,765	904,595	1,879,693	904,595	1,927,622
S_DHW_LPG_2	1,289,807	2,410,249	1,289,807	2,452,576	1,289,807	2,494,902	1,289,807	2,537,229	1,289,807	2,579,556
S_DHW_LPG_3	1,474,622	2,765,263	1,474,622	2,819,430	1,474,622	2,873,597	1,474,622	2,927,764	1,474,622	2,981,930
S_DHW_E_1	544,639	1,045,718	544,639	1,080,542	544,639	1,115,366	544,639	1,150,191	544,639	1,185,015
S_DHW_E_2	762,079	1,463,395	762,079	1,512,149	762,079	1,560,903	762,079	1,609,657	762,079	1,658,410
S_C_E_1	152,464	292,750	152,464	302,501	152,464	312,252	152,464	322,002	152,464	331,753

Table 9-7 The results of the sensitivity analysis due to the variation of heat pumps COP

Measure label	COP=1.75		COP=2.63		Referent state (COP=3.50)		COP=4.40	
	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]	FNPV [EUR/GWh]	ENPV [EUR/GWh]
H_H_WF_2	-170,705	-362,280	-49,589	-120,987	10,334	-1,625	47,301	72,042
H_H_WF_4	-254,211	-528,656	-105,160	-231,702	-31,365	-84,725	14,078	5,854
H_H_C_2	-184,372	-112,640	-63,256	128,654	-3,333	248,015	33,634	321,683
H_H_C_4	-267,878	-279,016	-118,827	17,939	-45,032	164,915	411	255,495
H_H_LPG_2	1,001,583	1,931,017	1,159,949	2,246,529	1,238,352	2,402,687	1,286,638	2,498,930
H_H_E_1	417,590	831,979	603,931	1,203,215	696,056	1,386,743	752,999	1,500,195
H_H_E_2	-584,751	-1,164,950	-63,091	-125,640	194,807	388,161	354,223	705,781
H_DHW_WF_1	-254,145	-528,554	-105,093	-231,600	-31,414	-84,810	14,144	5,956
H_DHW_LPG_2	1,001,653	1,931,125	1,160,019	2,246,637	1,238,300	2,402,596	1,286,708	2,499,038
H_DHW_E_1	417,681	832,119	604,020	1,203,351	696,128	1,386,855	753,086	1,500,328
H_C_E_1	-584,477	-1,164,496	-62,843	-125,237	194,919	388,344	354,451	706,144
S_H_WF_2	-91,930	-221,106	2,828	-27,049	49,721	68,962	78,631	128,191
S_H_WF_4	-157,258	-354,903	-40,647	-116,087	17,112	2,151	52,639	74,961
S_H_FO_2	2,376,471	4,739,967	2,493,074	4,978,769	2,550,871	5,097,074	2,586,353	5,169,803
S_H_LPG_2	1,104,596	2,115,630	1,228,494	2,369,370	1,289,858	2,494,993	1,327,609	2,572,355
S_H_E_1	326,696	669,085	472,487	967,650	544,566	1,115,254	589,115	1,206,493
S_H_E_2	-457,499	-936,899	-49,382	-101,072	152,390	312,144	277,102	567,568
S_DHW_WF_1	-157,192	-354,801	-40,581	-115,985	17,062	2,067	52,705	75,063
S_DHW_FO_2	2,453,983	4,898,674	2,544,674	5,084,409	2,589,515	5,176,238	2,617,224	5,232,991
S_DHW_LPG_2	1,104,666	2,115,738	1,228,564	2,369,478	1,289,807	2,494,902	1,327,679	2,572,464
S_DHW_E_1	326,788	669,225	472,575	967,786	544,639	1,115,366	589,202	1,206,626
S_C_E_1	-457,303	-936,597	-49,185	-100,769	152,464	312,252	277,298	567,871