HELLENIC REPUBLIC
MINISTRY OF ENVIRONMENT AND ENERGY
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Ref.: ΥΠΕΝ/ΔΗΕ/21959/821
Date: 4.3.2022

DECISION

SUBJECT: Approval of the comprehensive assessment of the potential for implementation of high-efficiency co-generation and efficient district heating and cooling (Law 4342/2015, Article 15(1) and (2))

THE MINISTER FOR THE ENVIRONMENT AND ENERGY

Having regard to:

1. Law 4622/2019 'Executive State: organisation, functioning and transparency of the government, governmental bodies and central public administration' (Government Gazette, Series I, No 133/7.8.2019) and in particular Article 109 thereof.
2. Article 90 of Presidential Decree 63/2005 'Codification of legislation regarding the Government and Governmental Bodies' (Government Gazette, Series I, No 98).
3. Presidential Decree 70/2015 'Reconstitution of the Ministries of Culture and Sports, of Infrastructure, Transport and Networks, of Agricultural Development and Food; Reconstitution of the Ministry of Shipping and the Aegean and its renaming as the Ministry of Shipping and Island Policy; Renaming of the Ministry of Culture, Education and Religious Affairs to Ministry of Education, Research, and Religious Affairs; of the Ministry of Economy, Infrastructure, Shipping and Tourism to Ministry of Economy, Development and Tourism; and of the Ministry of Productive Reconstruction, Environment and Energy to Ministry of Environment and Energy; Transfer of the Secretariat-General for Industry to the Ministry of Economy, Development and Tourism' (Government Gazette, Series I, No 114).
4. Presidential Decree 132/2017 'Organisation of the Ministry of Environment and Energy' (Government Gazette, Series I, No 160/30.10.2017).
5. Presidential Decree 2/2021 'Appointment of Ministers, Deputy Ministers and State Secretaries' (Government Gazette, Series I, No 2/5.1.2021).
6. Law 3468/2006 'Electric power generation from renewable energy sources and co-generation of high-efficiency heat and power, and other provisions' (Government Gazette, Series I, No 129/27.6.2006), as amended and in force.
7. Law 3734/2009 'Promotion of co-generation of two or more useful forms of energy, regulation of matters relating to the Mesochora Hydroelectric Power Plant, and other provisions' (Government Gazette, Series I, No 8/28.1.2009).
8. Law 3851/2010 'Acceleration of the development of Renewable Energy Sources to address

climate change, and other provisions on matters within the competence of the Ministry of Environment, Energy and Climate Change' (Government Gazette, Series I, No 85/4.6.2010).

9. Law 4342/2015 'Pension arrangements, incorporation into Greek law of Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC' (Government Gazette, Series I, No 143/9.11.2015), as amended by Law 4843/2021 (Government Gazette, Series I, No 193/20.10.2021) and, more specifically, Article 15(1) and (2) thereof.
10. Document ref. ΥΠΕΝ/ΔΗΕ/116316/1922 dated 6 December 2021, sent by the Directorate for Electrical Energy to the Directorate for the Budget and Financial Reports of the Directorate-General for Financial Services of the Ministry of Environment and Energy.
11. Recommendation ref. ΥΠΕΝ/ΔΠΔΑ/118166/2663 dated 10 December 2021 of the Director-General for Financial Services of the Ministry of Environment and Energy, according to which no costs to the regular budget arise herefrom.

WE HEREBY DECIDE

To approve the Comprehensive Assessment of the Potential for Efficient Heating and Cooling of Article 15(1) and (2) of Law 4342/2015, which accompanies this document as Annex I and forms an integral part hereof.

Minister for the Environment and Energy

K. Skrekas

Internal Distribution:
— *Office of the Minister*
— *Office of the Secretary-General*
— *Directorate-General for Energy*

ANNEX I

Comprehensive Assessment

OF THE POTENTIAL FOR EFFICIENT HEATING AND COOLING

ATHENS 2021

IN ACCORDANCE WITH ARTICLE 15(1) OF LAW 4342/2015
(ARTICLE 14(1) OF DIRECTIVE 2012/27/EU)

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List of abbreviations

RES	Renewable energy sources
IA	Industrial area
DEPA	Public Gas Corporation
IMF	International Monetary Fund
IRR	Internal rate of return
EC	European Commission
ESCO	Energy Service Companies
EEX	European Power Exchange
ECB	European Central Bank
ELSTAT	Hellenic Statistical Authority
NTUA	National Technical University of Athens
HACHP	Hellenic Association for the Cogeneration of Heat and Power
ETMEAR	Special duty for reduction of gas emissions
DHW	Domestic hot water
SH	Space heating
CRES	Centre for Renewable Energy Sources and Saving
REPB	Regulation on the Energy Performance of Buildings
NPV	Net Present Value
CSF	Community Support Framework
LAGIE	Greek Electricity Market Operator
RAE	Regulatory Authority for Energy
CHP	Co-generation of heat and power
HECHP	High-efficiency co-generation of heat and power
CC	Clause coefficient
MEE	Ministry of Environment and Energy
NG	Natural gas
F-i-T	Feed-in-Tariff
NUTS	Nomenclature of territorial units for statistics

ATH	Region of Attica
CMC	Region of Central Macedonia
CRT	Region of Crete
CYC	Region of Cyclades
DOD	Region of Dodecanese
EMC	Region of Eastern Macedonia and Thrace
EPI	Region of Epirus
ION	Region of Ionian Islands
NAG	Region of North Aegean
PEL	Region of Peloponnese
STR	Region of Central Greece
THE	Region of Thessaly
WGR	Region of Western Greece
WMC	Region of Western Macedonia

Summary

The comprehensive assessment addresses, on an integrated basis, the possibility of meeting the heating and cooling needs at a nationwide level in an energy-efficient manner. The study estimates the demand for heating and cooling in all sectors of economic activity for the year 2020, and forecasts demand based on the additional policies and measures scenario (WAM) of the National Energy and Climate Plan (NECP) for 2050. The study also estimates waste heat and assesses the potential for covering demand, in a cost-effective manner, for different types of technologies, both for efficient district heating systems and individual on-site electricity generation systems.

In order to explore and determine the most cost-effective manner of meeting the demand for heating and cooling, a cost-benefit analysis is carried out, taking into account the climate conditions, the economic feasibility and the technical capabilities for implementing the technologies examined, in accordance with Part 1 of Annex IX to Law 4342/2015, as amended by Commission Regulation (EU) 2019/826.

More specifically, the demand for thermal energy for space heating and cooling and domestic hot water (DHW) at the level of municipalities throughout the Greek territory is determined in Chapter 1. The climatic data of the municipalities, the population, all tertiary sector buildings inside the municipality borders and primary energy consumption data, as recorded in the context of the implementation of the Regulation on the Energy Performance of Buildings (REPB), are taken into account to determine such demand. The aggregated demand for heating and cooling per sector in Greece is presented in Chapter 1 hereof, and the methodology for calculating thermal demand at municipal level is presented in detail in Annex I hereto.

Chapter 2 begins by describing the current situation of heating and cooling supply in Greece. Thereafter, it gives an overview of the current situation of district heating in the Region of Western Macedonia and in Megalopoli, and, finally, it presents the geographical maps of heating and cooling generation and demand in the Greek territory for the year 2020 (http://beta.cres.gr/chp/cool_heat). These maps show potential locations where waste heat is available and apply to existing power plants with capacity above 50 GWh, existing HECHP facilities, existing and planned district heating installations and networks, as well as industrial areas (IA) with potential useful waste heat.

Chapter 3 forecasts the evolution of the energy system in Greece and the evolution of the demand for heating and cooling until 2050. For this purpose, the TIMES model is used for its projections in the context of elaborating the National Energy and Climate Plan (NECP) and, more specifically, the additional policies and measures scenario (WAM), published in December 2019[1]. The geographic analysis of the model for energy demand and generation is carried out at regional level (NUTS 2), and all sectors of energy consumption and generation are analysed.

Chapter 4 discusses the current national objectives and the measures and policies with regard to heating and cooling, as embodied in the National Energy and Climate Plan (NECP).

Chapter 5 presents an economic analysis and a cost-benefit analysis, at community level, of the technically exploitable potential for efficient heating and cooling. Six (6) scenarios are defined

[1] https://ec.europa.eu/energy/sites/default/files/documents/el_final_necp_main_el.pdf

for analysis purposes. The first three examine technologies related to systems supplying energy remotely by means of district heating systems, and the fourth, fifth and sixth scenarios examine various technologies for systems generating energy on site (stand-alone systems). Each of the first four scenarios is assessed comparatively to the baseline scenario, which relates to the current situation of heat generation using oil-fired boilers for space heating and electricity-powered water heaters for DHW generation. For the fifth scenario, an alternative baseline scenario is examined, which relates to the current situation of heat generation using NG-fired boilers for space heating and DHW generation. The sixth scenario studies the substitution of biomass-fired boilers by heat pumps for space heating in the residential sector.

More specifically, the scenarios are as follows:

Scenario 1: The thermal demand per settlement type is covered by district heating systems using available waste heat from existing facilities.

Scenario 2: The thermal demand per settlement type is covered by district heating systems using heat generated from new heat generation facilities by use of natural gas and biomass.

Scenario 3: The thermal demand per settlement type is covered by district heating systems using heat generated from high-efficiency co-generation systems (HECHP) fuelled with natural gas.

Scenario 4: Penetration of various technologies for individual installations in the residential, tertiary, and industrial sectors.

- ***Scenario 4.1:*** Penetration of heat pumps
- ***Scenario 4.2:*** Penetration of geothermal heat pumps
- ***Scenario 4.3:*** Penetration of solar water heaters
- ***Scenario 4.4:*** Penetration of stand-alone biomass-fired boilers
- ***Scenario 4.5:*** Penetration of natural gas-fired co-generation

Scenario 5: Penetration of heat pumps for individual installations in the residential and tertiary sectors, with a baseline scenario involving natural gas-fired boilers.

Scenario 6: Penetration of heat pumps for individual installations in the residential sector, with a baseline scenario involving biomass-fired boilers.

Chapter 6 calculates, for each technology, the economic potential for efficient space heating and DHW generation. The additional policies and measures scenario (WAM) of the NECP is used as the baseline scenario for the evolution of the demand for useful energy through 2050, as well as covering such demand using various fuels and technologies, and an alternative scenario is elaborated for meeting such demand using various technologies, taking into account the results of the cost-benefit analysis in Chapter 5. Please note that the WAM scenario takes into account the energy-efficient upgrading of building shells and the replacement of existing systems by new, more energy-efficient, ones; as a result, the study focuses only on the substitution of the systems. Chapter 6 provides the main assumptions for elaborating an alternative scenario and the results of covering the demand for heating and DHW through 2050.

Finally, Chapter 7 presents the new measures and policies that may be implemented through 2050 to maximise the potential for efficient heating and cooling.

1. Demand for heating and cooling per sector

Based on aggregate data taken from the National Energy and Climate Plan (NECP), and specifically the additional policies and measures scenario (WAM) of the TIMES model, Table 1 summarises the demand for heating and cooling in Greece in terms of final and useful energy per sector up to 2050. For 2018, the data available from the national balance have been used and broken down per use, implementing the methodology followed in the TIMES model. Specifically, the values for 2018 are determined using a combined methodology that incorporates the main assumptions of the TIMES model (e.g. available technologies to meet demand, efficiency, heating degree-days, etc.) as those were used at national level for drawing up the NECP, calibrating the actual final consumption based on the official data of the national balance for 2018. In addition, to further develop this methodology, other available data is also used, such as the breakdown of final consumption per use in the residential sector (EUROSTAT 2018), data from an older project of the Centre for Renewable Energy Sources and Saving (CRES 2015) for the tertiary sector, etc. This whole process is repeated as the model is normalised each time to achieve a match with the data of the energy balance and improve the assumptions made.

The demand for heating in terms of final energy was 38.3 TWh in the residential sector in 2018, and the remaining sectors, including the industrial, service and the other sectors, followed with 23.4 TWh, 13.5 TWh and 2.5 TWh respectively.

The demand for heating in terms of useful energy was 30.8 TWh in the residential sector in 2018, and the remaining sectors, including the industrial, service and the other sectors, followed with 19.3 TWh, 15 TWh and 1.6 TWh respectively. More specifically, in the residential sector, where the highest demand was recorded in 2018, it is expected to decrease gradually and be close to 23.2 TWh in 2050, whereas demand is expected to increase in the other three sectors over the next 30 years. In particular, demand in the industrial sector, the service sector, and the other sectors is expected to rise to 20.7 TWh, 19.6 TWh and 2.1 TWh respectively in 2050.

The demand for cooling in terms of final energy was 835 GWh in 2018 in the residential sector, while the service sector was in the lead at 6.9 TWh.

The demand for cooling in terms of useful energy was 1.5 TWh in the residential sector in 2018 and over 12.3 TWh in the service sector. Demand for cooling in both sectors is estimated to increase over the next 30 years, reaching 2.1 TWh in the residential sector and 19.9 TWh in the service sector.

Table 1 – Demand for heating and cooling per sector in Greece

				Year						
		Unit	2018	2020	2025	2030	2035	2040	2045	2050
Demand for heating, **final** energy	Residential sector	GWh/a	38 305	38 231						
	Service sector	GWh/a	13 535	13 884						
	Industrial sector	GWh/a	23 459	23 127						
	Other sectors	GWh/a	2 491	2 400						
Demand for cooling, **final** energy	Residential sector	GWh/a	835	858						
	Service sector	GWh/a	6 921	9 133						
	Industrial sector	GWh/a								
	Other sectors	GWh/a								
Demand for heating, **useful** energy	Residential sector	GWh/a	30 816	31 420	30 197	30 358	27 986	26 612	24 955	23 158
	Service sector	GWh/a	14 962	14 980	15 794	16 396	17 049	17 728	18 404	19 609
	Industrial sector	GWh/a	19 322	19 516	18 358	18 012	17 433	17 534	18 743	20 684
	Other sectors	GWh/a	1 571	1 537	1 618	1 743	1 809	1 915	2 027	2 119
Demand for cooling, **useful** energy	Residential sector	GWh/a	1 502	1 544	1 636	1 730	1 830	1 926	2 026	2 126
	Service sector	GWh/a	12 310	13 450	14 561	15 532	16 584	17 637	18 742	19 952
	Industrial sector	GWh/a								
	Other sectors	GWh/a								

The energy demand for heating and cooling is determined for each final consumption sector at the level of municipalities for the entirety of Greece (administrative division level: 5). The methodology used takes into account data from the overall energy balance of Greece for 2018 and from the TIMES model for 2020; the last census of population and buildings performed in 2011 by the Hellenic Statistical Authority (ELSTAT); the Household Budget Survey of 2018; the geographical and climate location; the processing of available results relating to the energy performance of buildings in the residential and tertiary sectors; and the results of an older CRES project entitled ‘National information system for measuring energy efficiency, pursuant to Directive 2006/32/EC’.

A separate methodology is applied for each final consumption sector, depending on the availability of data and their correctness. **Annex I** presents in detail how these methodologies were applied.

2. Assessment of current heating and cooling supply

Following the methodology of the previous chapter, heating and cooling are supplied to four (4) sectors, i.e. residential, service, industrial, and other sectors. The energy in each sector can be classified as deriving from fossil fuel sources or renewable energy sources, through the use of various technologies, as presented in Table 2.

In the residential sector, the energy generated on site by fossil fuel sources was 16.1 TWh in heat-only boilers in 2018, and over 3.1 TWh for other technologies, with zero contribution from HECHPs. Energy from RES generated on site was 6.3 TWh in heat-only boilers, with approximately equal contributions from heat pumps and other technologies (3 TWh and 3.9 TWh, respectively).

In the service sector, the energy generated on site by fossil fuel sources was 2.7 TWh in heat-only boilers in 2018, and over 6.7 TWh for other technologies, with zero contribution from HECHPs. Most of the energy produced from RES involves heat pumps at 17.8 TWh, while heat-only boilers account for 9 GWh.

In the industrial sector, energy generated on site by fossil fuel sources was 15.9 TWh in heat-only boilers in 2018, with HECHPs exceeding 1.4 TWh, and zero contribution from other technologies. RES energy supplied on site to heat-only boilers exceeded 2.1 GWh; no data is available on other technologies.

In other sectors (e.g. agricultural), the on-site energy generated from fossil fuel sources was 2.5 TWh in heat-only boilers in 2018, but there is no data available on other technologies, as is the case in the corresponding situation for RES energy.

Finally, the energy produced off-site in 2018 for the residential sector was 0.5 TWh, and it relates to the existing district heating networks that use waste heat from fossil fuel power plants to cover the demand. The next Chapter provides a comprehensive analysis of the current district heating situation in Greece.

Table 2 – Current heating supply in Greece per sector and technology, 2018

Energy generated on site			Unit	Value
Residential sector	Fossil fuel sources	Heat-only boilers	GWh/a	16 052
		Other technologies	GWh/a	3 131
		HECHP	GWh/a	0
	Renewable energy sources	Heat-only boilers	GWh/a	6 299
		HECHP	GWh/a	0
		Heat pumps	GWh/a	2 956
		Other technologies	GWh/a	3 880
Service sector	Fossil fuel sources	Heat-only boilers	GWh/a	2 648
		Other technologies	GWh/a	6 674
		HECHP	GWh/a	
	Renewable energy sources	Heat-only boilers	GWh/a	9
		HECHP	GWh/a	
		Heat pumps	GWh/a	17 747
		Other technologies	GWh/a	193
Industrial sector	Fossil fuel sources	Heat-only boilers	GWh/a	15 873
		Other technologies	GWh/a	
		HECHP	GWh/a	1 392
	Renewable energy sources	Heat-only boilers	GWh/a	2 057
		HECHP	GWh/a	
		Heat pumps	GWh/a	
		Other technologies	GWh/a	
Other sectors	Fossil fuel sources	Heat-only boilers	GWh/a	2 491
		Other technologies	GWh/a	
		HECHP	GWh/a	
	Renewable energy sources	Heat-only boilers	GWh/a	
		HECHP	GWh/a	
		Heat pumps	GWh/a	
		Other technologies	GWh/a	

Energy generated off-site				
Residential sector	Fossil fuel sources	Waste heat	GWh/a	449
		HECHP	GWh/a	
		Other technologies	GWh/a	
	Renewable energy sources	Waste heat	GWh/a	
		HECHP	GWh/a	
		Other technologies	GWh/a	
Service sector	Fossil fuel sources	Waste heat	GWh/a	
		HECHP	GWh/a	
		Other technologies	GWh/a	
	Renewable energy sources	Waste heat	GWh/a	
		HECHP	GWh/a	
		Other technologies	GWh/a	

2.1. Overview of the current district heating situation

District heating has been used in Greece for the past 30 years, and today there are five district heating systems in operation (or in development) which are powered by steam-driven power plants of the Public Power Corporation (PPC), and one private system, which operates with HECHP units and natural gas fuel (District heating of Serres).

Until now, district heating in Greece has been directly associated with the PPC lignite power plants in the Region of Western Macedonia and in Megalopoli.

The challenge of rapid lignite phase-out that resulted from Greece's obligations to align its national energy policy with EU climate policies, and specifically the emission reduction goals for 2020 and 2030, has led to the phase-out of the older and more polluting lignite plants. Specifically, in accordance with the updated National Energy and Climate Plan (NECP), it is expected that all PPC lignite plants will be withdrawn by the end of 2023 (except for the new one under construction, i.e. Ptolemaida 5, which is estimated to be withdrawn in 2028), with a total output of about 4 GW, and that all lignite mines in the Region of Western Macedonia and in Megalopoli will close.

An image of domestic power generation is being formed, wherein the PPC uses to a small degree, or not at all, lignite plants and does so only in certain situations to meet the demand for district heating.

It is understandable then that in the framework of these developments, in order to maintain district heating where it is already present, it is necessary to use alternative energy sources, such as biomass or natural gas.

2.1.1. District heating in the Region of Western Macedonia

The Region of Western Macedonia is the first one in Greece where district heating systems have been operating for about 30 years. More specifically, there are district heating systems in three cities: Ptolemaida, Kozani, Amyntaio. Approximately 42 000 households and businesses use district heating, with a total demand of ~600 GWh.

Table 3 – District heating in Western Macedonia

Operator	Location	Number of households (thous.)	District heating consumption (GWh)
Municipal District Heating Company of the Wider Region of Amyntaio (DETEPA)	AMYNTAIO	2	40
Municipal Enterprise for Water Supply and Sewerage of Kozani (DEYAK)	KOZANI	25	340

District Heating Municipal Company of Ptolemaida (DETIP)	PTOLEMAIDA	15	220
WESTERN MACEDONIA TOTAL		**42**	**600**

Sources: PPC, DEYAK, DETEPA, DETIP

2.1.1.1. District Heating in the City of Ptolemaida

The Municipality of Eordaia, formerly Municipality of Ptolemaida, installed in the period 1991–1993, with co-financing from the European programme VALOREN, and has operated since 1994, the first district heating system in Greece. The system has been operated during this entire time by the District Heating Municipal Company of Ptolemaida (DETIP).

According to the company's data, during the first 25 years of operation of district heating in Ptolemaida, investments made in infrastructure, amounting to EUR 55 million, allowed for connections to be made with over 3 800 buildings and almost 15 000 households, supplying heating and domestic hot water for the inhabitants of the area at prices lower than any other fuel; at the same time, the emissions of air pollutants dropped significantly as compared to such emissions if oil had been used for heating and DHW generation.

The thermal energy supplied by the PPC to the district heating network of Ptolemaida is in the form of superheated water, 95$_{o}$–120$_{o}$C, depending on the heat load, and a maximum pressure of 25 bar(g), provided that the water supply to the steam-driven power plant, after passing through Pumping Station AK1, has a temperature of 70$_{o}$C and a pressure of at least 5 bar(g).

Based on information from the company, the number of buildings/households connecting to the district heating network in the last 25 years follows an upward trend (+140 %), as does the heat load, in MWth (increase approx. +220 %).

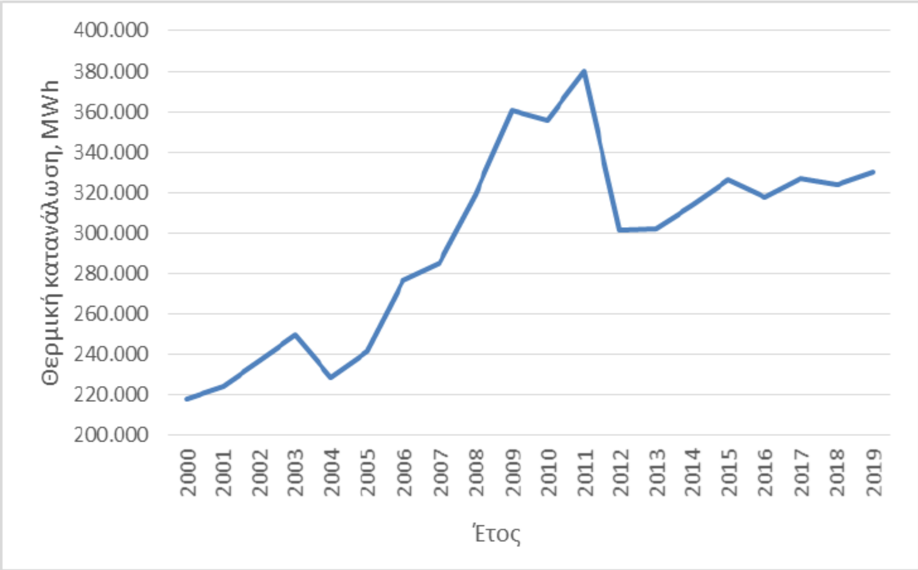
2.1.1.2. District Heating in the City of Kozani

The District Heating of Kozani has been in operation since 1993, heating approximately 25 000 households, in a total of about 4 900 buildings, and consumes 340 GWh annually. The investment cost EUR 75 million, which came from the European programme VALOREN, the Public Investments Programme (PDE), and own resources of DEYAK, the Municipal Enterprise for Water Supply and Sewerage of Kozani, i.e. the company that operates the city's district heating system.

District Heating of Kozani receives the necessary heat load from the steam-extraction facilities of Plants III, IV, and V of the Agios Dimitrios PPC steam-driven power plant, and it has a peak load boiler room, pumping stations for transmission and distribution, and a supply and distribution network with a total length over 450 kilometres. The thermal energy supplied by the PPC to the district heating network of Kozani is in the form of hot water, 95–120 °C, depending on the heat load, with a maximum pressure of 25 bar(g), provided that the water supply to the steam-driven power plant, after passing through Pumping Station A3, has a temperature of 65–75 °C and a pressure of 8–12 bar(g).

Graph 1 shows the annual supply of thermal energy from the facilities of the Agios Dimitrios steam-driven power plant to the district heating system of Kozani, from 2013 to 2019, according to PPC data.

Graph 1 – Annual supply of thermal energy from Plants III and IV of the Agios Dimitrios steam-driven power plant to the district heating system of Kozani, 2000–2019



Source: PPC

	Thermal input, MWh
	Year

Throughout the 25-year period, the district heating network has undergone extension and upgrading works, the most significant of which are the following:

- The extension of the hot water transmission system of the Agios Dimitrios steam-driven power plant to the city of Kozani with the construction of a second transmission pipeline, doubling its heat-transmission power from 70 to 140 MWt.
- The procurement and installation a new boiler with an output of 27.5 MWt in the peak load boiler station; by virtue of this boiler, the total reserve of the system is maintained at levels over 50 % of the highest demand.
- The construction of a new network for distribution of district heating to the settlement of New Charavgi, with a capacity of 300 buildings and distribution pipes with a total length of 30 kilometres.
- The construction of a network for distribution of district heating to the areas included in the extended plan for the city of Kozani. This network may power at least 1 700 buildings, and its total length reaches 155 kilometres.
- The procurement and installation of 2 200 heating substations powering an additional 500 000 m2.
- The construction of a heat storage boiler (1 600 m3) with an energy capacity of 70 MWh.

2.1.1.3. District Heating in the City of Amyntaio

District heating began in Amyntaio in 2005 and constitutes the principal activity of the Municipal District Heating Company of the Wider Region of Amyntaio (DETEPA)[2], which was established in 1997. The district heating investment amounts to EUR 18.3 million, which came from Development Law 1892/90, a bank loan, and co-financing under PA 2014–2020.

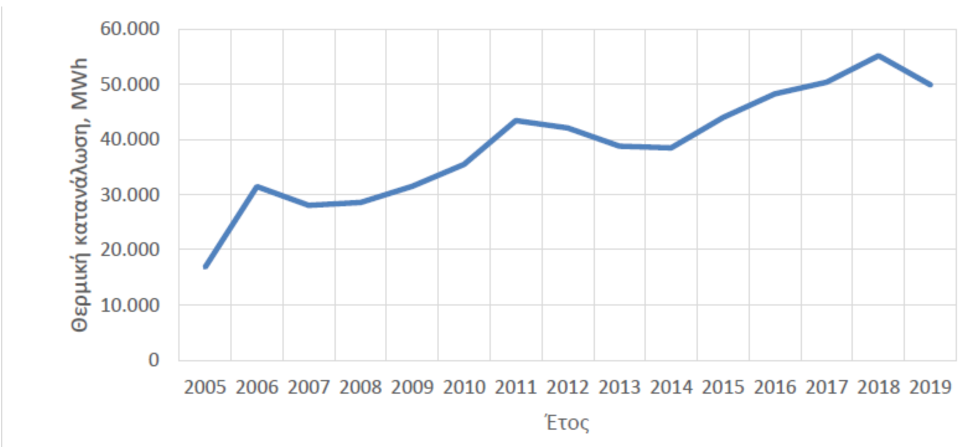
The supply of thermal energy to the district heating facilities is ensured by the lignite-fired plant of the Amyntaio PPC steam-driven power plant using heat and power co-generation technology (CHP). The thermal energy supplied by the PPC to the DETEPA network is in the form of hot water, 95–120 °C, depending on the heat load, with a maximum pressure of 10 bar(g), provided that the water supply to the steam-driven power plant, after passing through the DETEPA Pumping Station, close to the steam-driven power plant, has a temperature of between 65 °C and [number missing] and a pressure of at least 5 bar(g).

The district heating system of the wider region of Amyntaio was constructed in three phases, as follows: Phase 1, 2000–2004; became operational in 2005, Phase 2: extensions in the period 2008–2009, and Phase 3: extensions from 2014 to 2015, supplying buildings in the settlements of Amyntaio, Levaia, and Filotas with thermal energy.

The thermal energy of the system is derived from the steam-driven power plant of Amyntaio by extracting turbine steam. The district heating system is connected with both facilities of the steam-driven power plant, with a 100 % back-up capacity. Currently, one extraction from each turbine is ready and operational, with a nominal heat output of 25 MWth. If the subsequent extraction from each turbine is also connected with the district heating system, the nominal output of the system may increase to 40 MWth.

Graph 2 shows the annual supply of thermal energy from the facilities of the Amyntaio steam-driven power plant to the district heating system of the city of Amyntaio, from 2005 to 2019, according to PPC data.

Graph 2 – Annual supply of thermal energy from the facilities of the Amyntaio steam-driven power plant to the district heating system of the city of Amyntaio, 2005–2019



[2] DETEPA website: www.detepa.gr

Source: PPC

	Thermal input, MWh
	Year

2.1.1.4. District Heating System in the City of Florina

In 2005 the municipality of Florina began the process of implementing the project for the district heating of Florina by the steam-driven power plant / PPC of Meliti, the Municipal Enterprise for Water Supply and Sewerage of Florina (DEYAF) acting as operator.

According to information from the study conducted, the heat carrier will be the hot or superheated water or steam, the population of residents served is approximately 23 000, there are 2 534 buildings to be connected, and the installed heat load is 98.7 MW. The district heating will cover the buildings included in the approved city plan of Florina. Buildings will be connected to the system indirectly, with underground pre-insulated supply/return pipelines, with a diameter ranging from DN 20 mm to DN 100 mm, and by installing a thermal substation equipped with a heat exchanger to ensure hydraulic separation.

2.1.2. District Heating in the Region of Peloponnese - Megalopoli

The district heating system of Megalopoli, municipality of Arcadia, was designed and installed to meet the needs of the citizens and for the following reasons:

- In the region there are lignite mines and PPC power generation plants, where the thermal energy generated is transmitted to cooling towers and, finally, released into the atmosphere.
- The city of Megalopoli is classified as Climate Zone 3, according to Technical Guidelines of the Technical Chamber of Greece (TEE-TCG) 20701-2/2010, which indicates low temperatures during the winter period.
- In previous years, serious environmental problems were observed – mainly air pollution – resulting from electricity generation by PPC stations and the use of oil (or fuel oil or other fuel) by the residents of the city of Megalopoli for space heating and DHW generation.

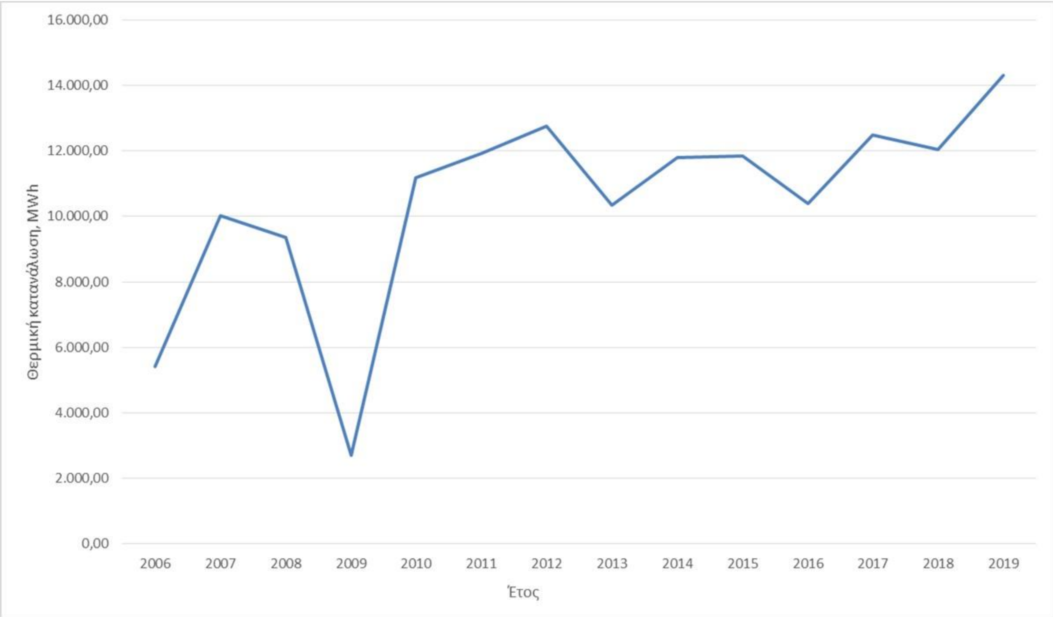
2.1.2.1. District Heating in the city of Megalopoli

Megalopoli District Heating started operating in 2007 and supplies Megalopoli with thermal energy for space heating and domestic hot water. The district heating distribution network covers approximately 30 % of the city, i.e. 516 buildings, about one third of the existing buildings, and the surface area heated by means of district heating is ~90 000 m2. This is the primary activity of ‘Megalopoli District Heating – Local Government Public Limited Company’, which was established in 2011 for this purpose. The district heating investment in Megalopoli amounts to EUR 18.3 million.

The total nominal installed load is 21.8 MWth. The district heating of Megalopoli is based on deriving thermal energy from Plant III of the PPC lignite steam-driven power plant of Megalopoli, located at a distance of ~4.5 km from the city centre and providing a heat output of 20 MWth. The thermal power is transported with the assistance of pumping stations by way of an existing system of pre-insulated pipelines for transmission to the facility’s central distribution pumping station.

Graph 3 shows the annual supply of thermal energy from the facilities of the Megalopoli steam-driven power plant to the district heating system of the city, from 2006 to 2019, according to PPC data.

Graph 3 – Annual supply of thermal energy from the facilities of the Megalopoli steam-driven power plant to the district heating system of the city, 2006–2019



Source: PPC

	Thermal input, MWh
	Year

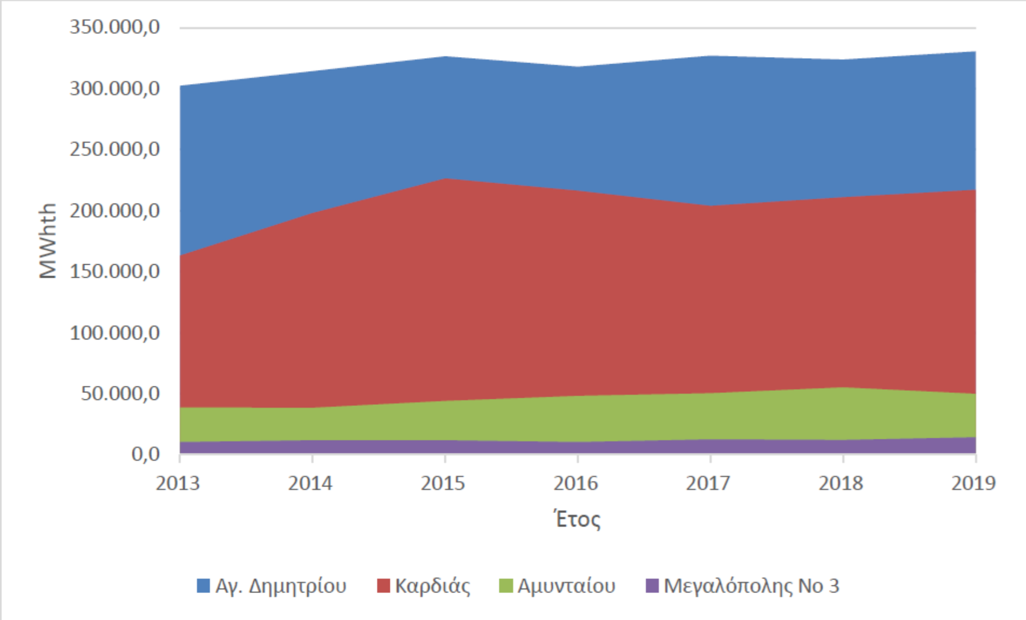
The entire district heating system is designed to meet consumption needs with feed water temperatures ranging from 50 °C to 85 °C on a seasonal basis, with 90 °C as the ceiling of operation. The existing building installations allow return temperatures with a secondary seasonal variation between 40 °C and 65 °C.

The buildings and district heating transport system are connected indirectly. For this purpose, thermal substations for hot water are used, whose output varies, depending on the energy needs of the buildings, ranging from 29 kWth to 233 kWth.

To cover peak demand and back-up needs, there is a boiler station with two boilers and diesel/biomass fuel, with a total nominal heat output of 14 MWth. The peak/back-up system is assisted by an existing thermal energy storage tank with a capacity of 1 617 m3, and the thermal energy storage capacity is 60 MWth.

Graph 4 shows the annual thermal input, in MWh, for all district heating systems assisted by lignite steam-driven power plants.

Graph 4 – Annual thermal input for all district heating systems assisted by lignite steam-driven power plants, 2013–2019



Source: PPC

	Agios Dimitrios
	Kardia
	Amyntaio
	Megalopoli No 3

2.2. Identification of facilities generating waste heat

To **identify the facilities that generate waste heat** and determine the potential supply of heating or cooling from such facilities, the following were taken into account:

(i) thermal power generating facilities with a total nominal heat output over 50 MW;

(ii) heat and electricity co-generation facilities with a total nominal heat output over 20 MW.

YEAR 2020	Limit	Unit	Value
Thermal power generation facilities	50 MW	GWh/a	14 813
CHP	20 MW	GWh/a	762
Waste incineration plants	-	GWh/a	
Facilities generating power from RES	20 MW	GWh/a	
Industrial facilities	20 MW	GWh/a	

Table 4 – Available waste heat

Due to the absence of available data for the industrial sector, it is not possible to estimate the waste heat from industrial facilities with a total heat output over 20 MW.

2.3. Geographical map of demand for heating and cooling, and waste heat supply

This chapter presents maps of the entire Greek territory, where the following are identified:

(a) the regions with heating and cooling demand, as analysed in Chapter 1;

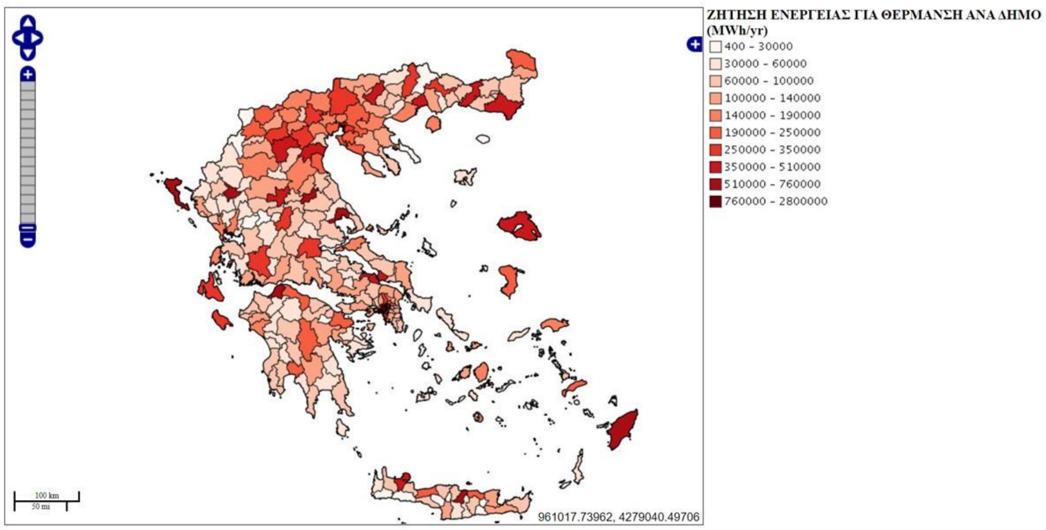
(b) the existing points of heating and cooling supply indicated in subchapter 2.2, and the existing district heating transmission installations indicated in subchapter 2.1;

(c) the planned heating and cooling supply points and the planned district heating transmission installations.

Sites of demand for heating and cooling

Maps 1 and 2 present the energy demand for heating and cooling, respectively, per municipality, as determined by the methodology analysed in Annex I of this study.

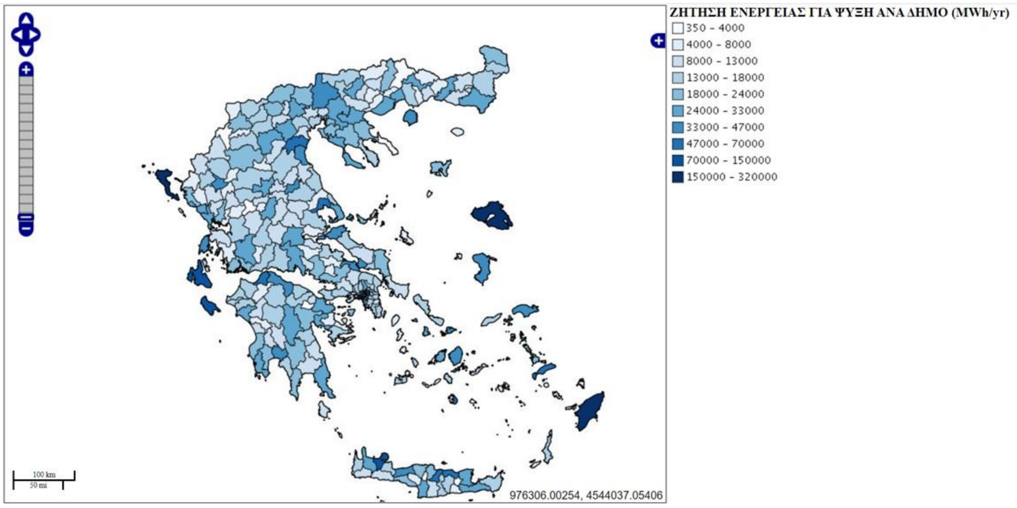
Map 1 – Demand for thermal energy per municipality (MWh/yr)



Source: http://beta.cres.gr/chp/cool_heat

	ENERGY DEMAND FOR HEATING PER MUNICIPALITY (MWh/yr)

Map 2 – Energy demand for cooling per municipality (MWh/yr)



Source: http://beta.cres.gr/chp/cool_heat

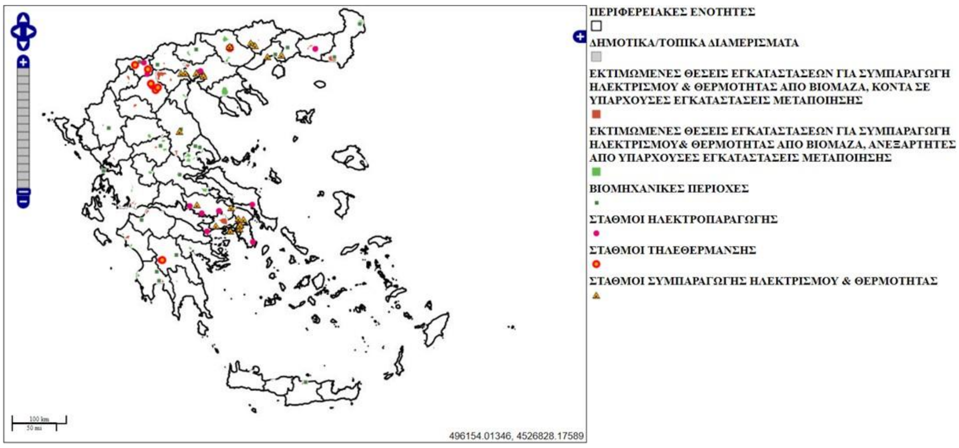
	ENERGY DEMAND FOR COOLING PER MUNICIPALITY (MWh/yr)

<u>Facilities generating waste heat</u>

Potential sites where waste heat is available are shown in Map 3 for the following facilities. These sites relate to:

- Power plants with a capacity over 50 MW
- Existing CHP – HECHP plants with a capacity over 20 MW
- Existing and planned district heating installations and networks
- Industrial facilities with potential useful waste heat (IA)

Map 3 – Waste heat supply sites



Source: http://beta.cres.gr/chp/chp.html

	REGIONAL UNITS
	MUNICIPAL/LOCAL DISTRICTS
	ESTIMATED SITES OF PLANTS FOR CO-GENERATION OF ELECTRICITY & HEAT FROM BIOMASS, NEAR EXISTING PROCESSING FACILITIES
	ESTIMATED SITES OF PLANTS FOR CO-GENERATION OF ELECTRICITY & HEAT FROM BIOMASS, INDEPENDENT FROM EXISTING PROCESSING FACILITIES
	INDUSTRIAL AREAS
	POWER GENERATION PLANTS
	DISTRICT HEATING PLANTS
	COMBINED HEAT AND POWER PLANTS

3. Forecast of the evolution of demand for heating and cooling until the year 2050

The TIMES model [3] (The Integrated MARKAL-EFOM System) – more specifically, the data from the additional policies and measures scenario (WAM), developed in the context of the NECP – is used for forecasting the evolution of the energy system in Greece.

The geographical breakdown of the model for energy demand and generation is at the level of Region (NUTS 2)[4] and all energy-consuming and generating sectors are analysed. The evolution of demand for useful energy drives developments in all energy generation and consumption sectors and is found through correlations with the evolution of economic fundamentals. In particular, the evolution of energy demand for space heating and cooling and for heat in industrial processes is calculated by applying the general methodology described below for the residential, tertiary and industrial sector.

3.1 Residential sector

The evolution of energy demand for heating, hot water and cooling in the residential sector in each Region is related to the GDP change rate and is calculated by the equation:

$$D_t + 1 = D_t \cdot (1 + G_t + 1) \qquad \textbf{\textit{(1)}}$$

Where:

Dt+1 is the demand for useful energy for space heating or cooling in the year t+1

Dt is the demand for useful energy for space heating or cooling in the year t

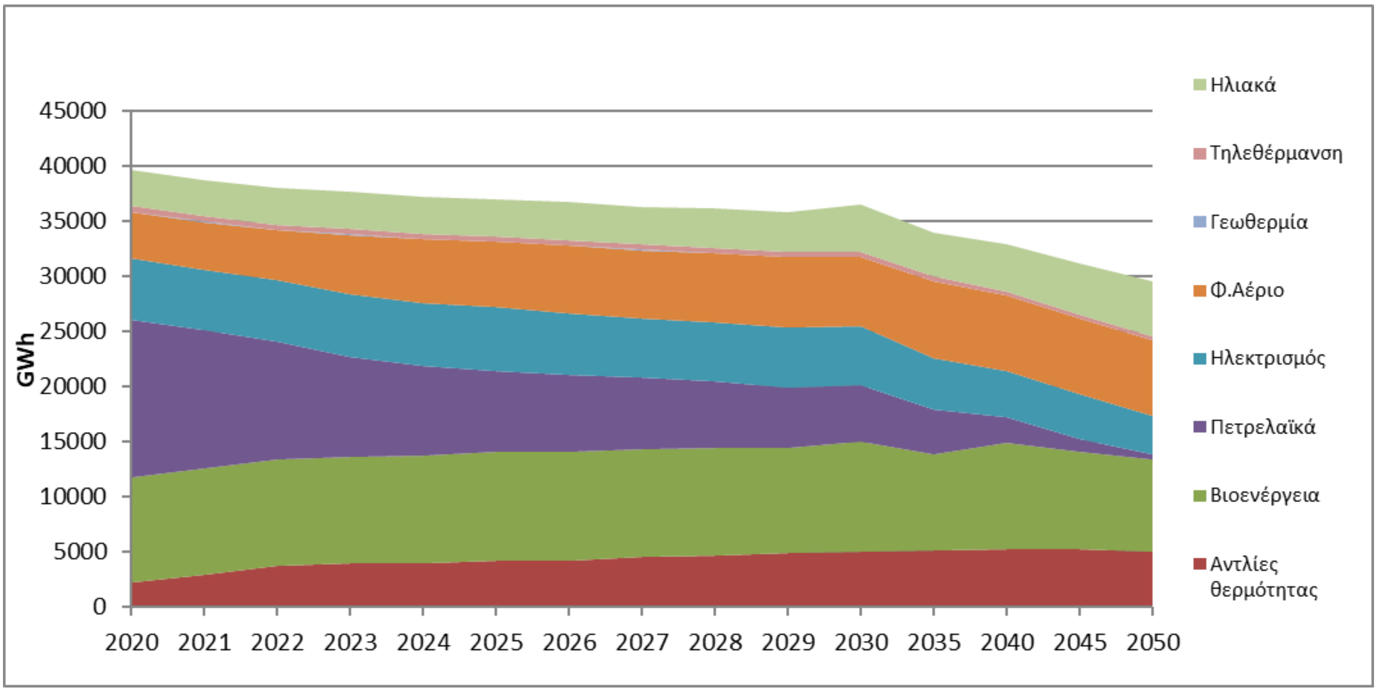
Gt+1 is the GDP change rate from year t to year t+1

ε is the elasticity of demand for useful energy for space heating or cooling in relation to the GDP change. This elasticity has been calculated using historical data.

The forecast of the GDP change rate at a nationwide level is derived from forecasts of the Ministry of Finance, in agreement with the Ministry of Environment and Energy. The forecast is then broken down at regional level (NUTS 2), using historical data relating to the contribution of each Region to the national GDP, assuming that the relevant weight of each Region will not change during the time scale of the analysis.

[3] http://www.iea-etsap.org/web/Times.asp
[4] http://ec.europa.eu/eurostat/web/nuts/overview

Graph 5 – Final consumption for heating, DHW, and cooling per fuel type in the residential sector, 2020–2050



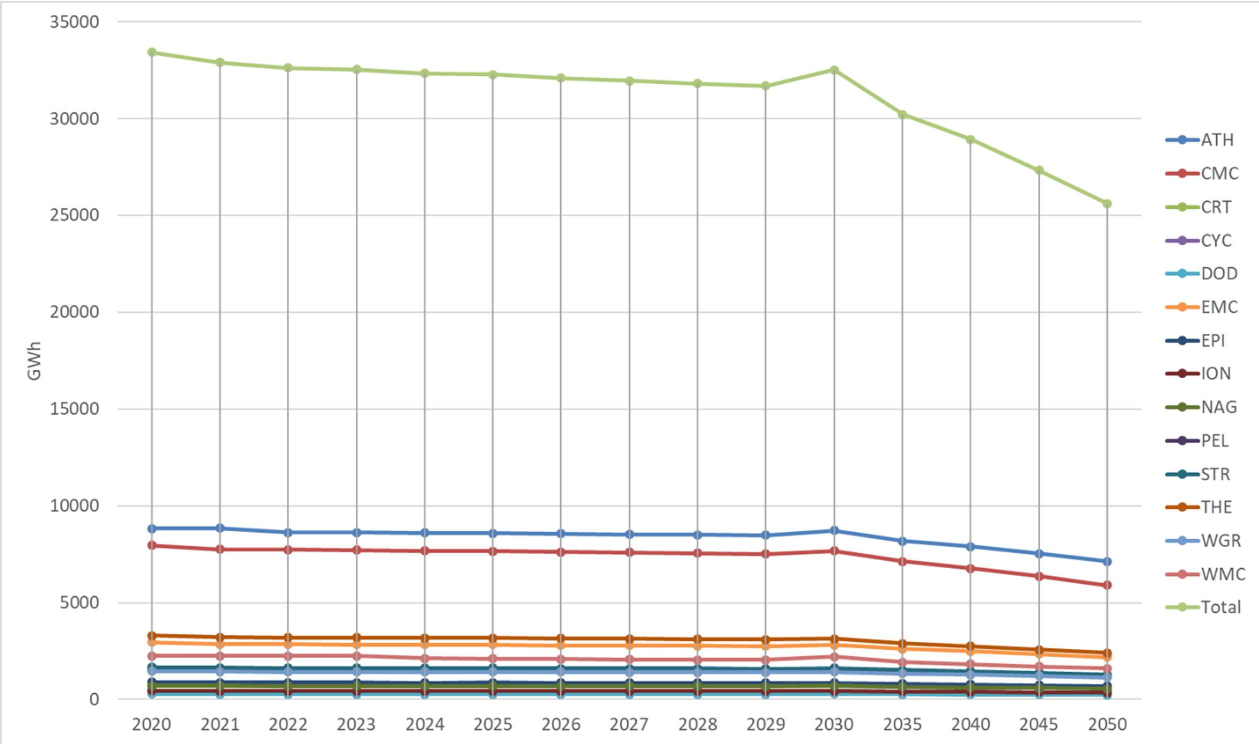
Source: TIMES model, additional policies and measures scenario (WAM), NECP.

Ηλιακά	Solar
Τηλεθέρμανση	District heating
Γεωθερμία	Geothermal energy
Φ.Αέριο	Natural gas
Ηλεκτρισμός	Electricity
Πετρελαϊκά	Petroleum products
Βιοενέργεια	Bioenergy
Αντλίες θερμότητας	Heat pumps

Final consumption of heating and cooling in the residential sector (Graph 5) is expected to decline over the next 30 years, from 39.6 TWh in 2020 to 29.6 TWh in 2050. Oil use is expected to record the biggest decline, from 14.3 TWh in 2020 to 421 GWh in 2050.

As illustrated in Graph 6, demand for heating and cooling in the residential sector is expected to follow a slightly downward trend until 2030 and, for the subsequent 20 years through 2050, a sharp decrease. The greatest demand for heating and cooling in the residential sector per Region is recorded in the Regions of Attica and Central Macedonia.

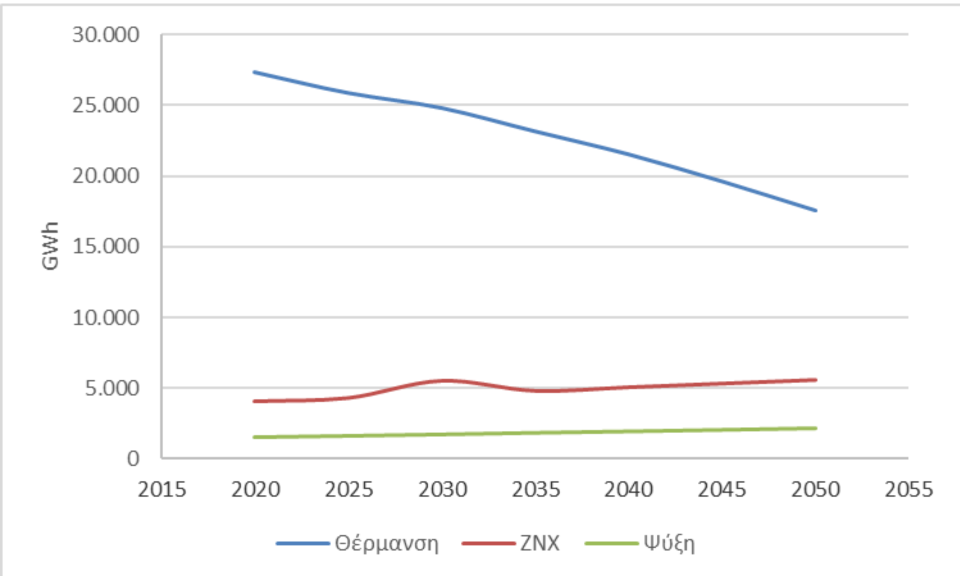
Graph 6 – Demand for heating, DHW, and cooling per Region in the residential sector, 2020–2050



Source: TIMES model, additional policies and measures scenario (WAM), NECP.

Graph 7 illustrates energy demand for heating, DHW, and cooling in the residential sector over the next 30 years, which is expected to decline for space heating but remains relatively steady, with a slight increase, in space cooling and DHW.

Graph 7 – Energy demand in the residential sector per use, 2020–2050



Source: TIMES model, additional policies and measures scenario (WAM), NECP.

■ Θέρμανση	■ Heating
■ ZNX	■ DHW
■ Ψύξη	■ Cooling

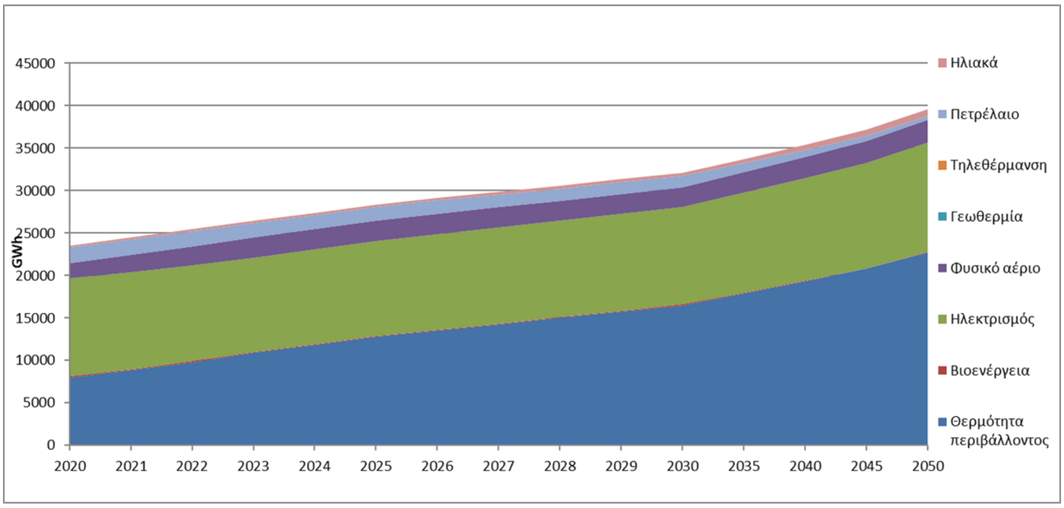
3.2 Tertiary sector

The tertiary sector is broken down into the following sub-sectors with different characteristics in the analysis of the demand for energy:

- Educational buildings
- Private office buildings
- Public office buildings
- Hospitals
- Hotels
- Trade establishments
- Sports facilities
- Airports
- Other services

Energy consumption for heating and cooling in the tertiary sector (Graph 8) is expected to nearly double over the next 30 years, from 23.5 TWh in 2020 to 39.6 TWh in 2050. The use of ambient heat is expected to rise significantly, from 8.0 TWh in 2020 to 22.7 GWh in 2050.

Graph 8 – Consumption for heating and cooling per fuel type in the tertiary sector, 2020–2050



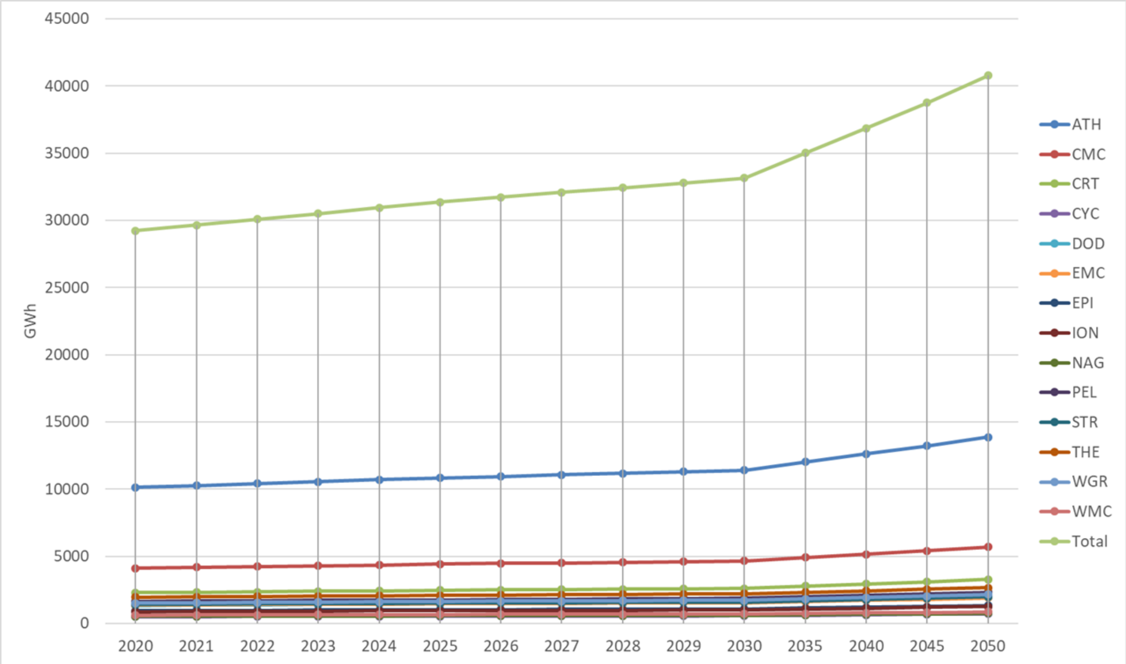
Source: TIMES model, additional policies and measures scenario (WAM), NECP.

	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Ambient heat

As illustrated in Graph 9, demand for heating and cooling in the tertiary sector is expected to increase steadily through 2030, after which time it is expected to record an even sharper increase through 2050. The greatest demand for heating and cooling in the tertiary sector per Region is recorded in the Regions of Attica and Central Macedonia.

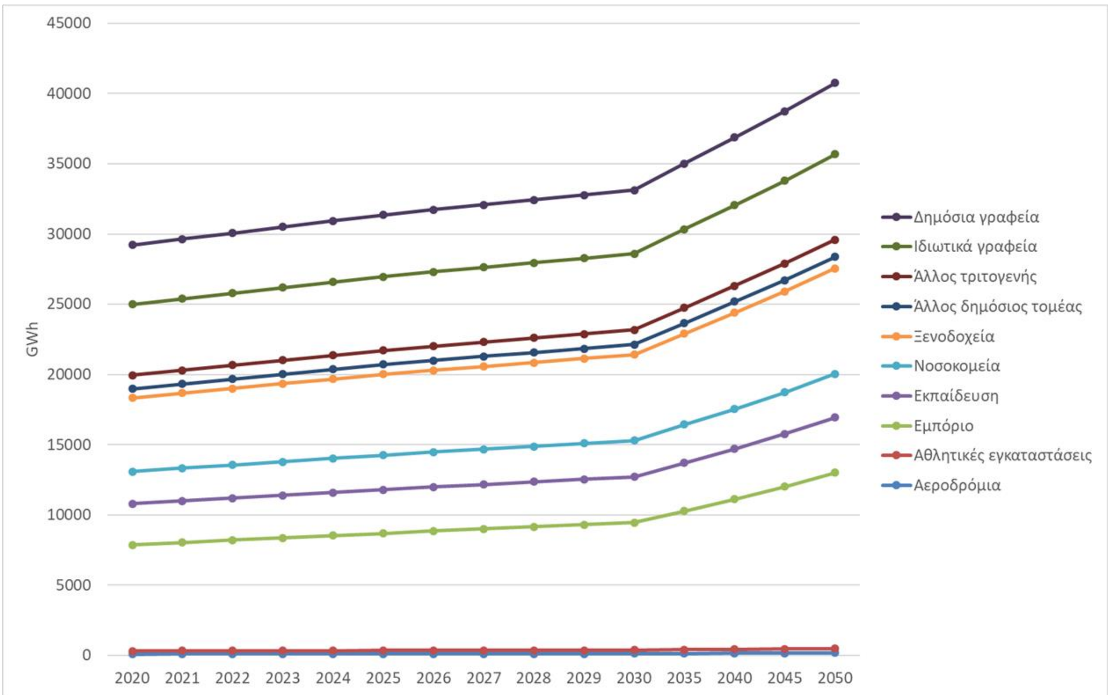
Furthermore, Graph 10 shows demand for heating and cooling in the tertiary sector per type of building, where a steady increase is expected through 2030 and an even sharper increase thereafter, through 2050. The greatest demand for heating and cooling in the tertiary sector per type of building is observed in public and private office buildings.

Graph 9 – Demand for heating and cooling per Region in the tertiary sector, 2020–2050



Source: TIMES model, additional policies and measures scenario (WAM), NECP.

Graph 10 – Demand for heating and cooling per building type in the tertiary sector, 2020–2050



Source: TIMES model, additional policies and measures scenario (WAM), NECP.

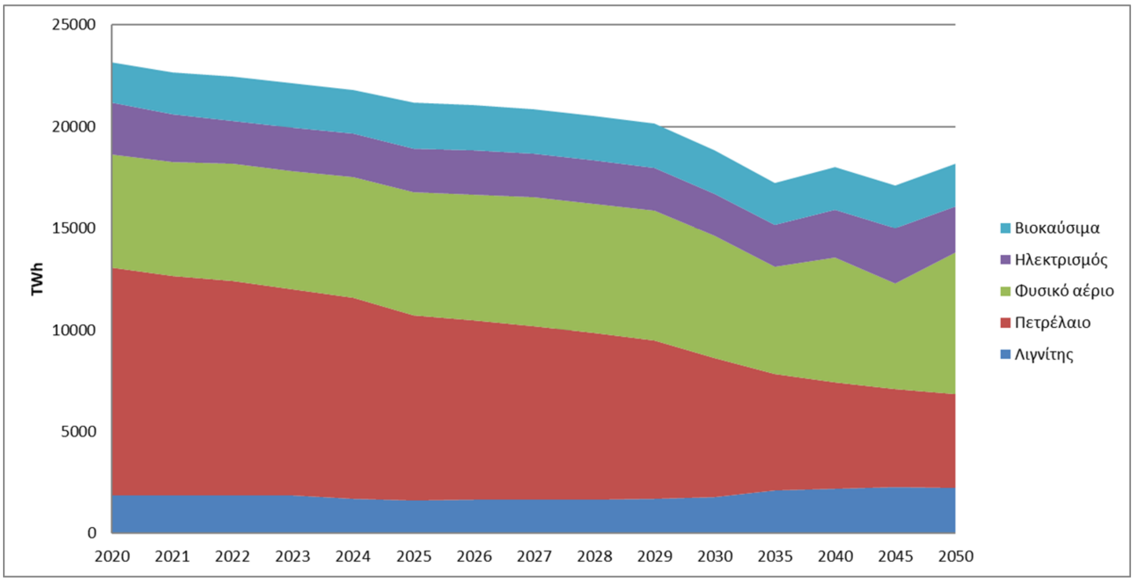
Δημόσια γραφεία	Public office buildings
Ιδιωτικά γραφεία	Private office buildings
Άλλος τριτογενής	Other (tertiary sector)
Άλλος δημόσιος τομέας	Other (public sector)
Ξενοδοχεία	Hotels
Νοσοκομεία	Hospitals
Εκπαίδευση	Educational buildings
Εμπόριο	Trade establishments
Αθλητικές εγκαταστάσεις	Sports facilities
Αεροδρόμια	Airports

3.3 Industrial sector

The estimates of demand for heating in the industrial sector are based on different approaches for energy-intensive sectors and for non-energy-intensive sectors. Therefore, a forecast of the demand for natural product (e.g. tonnes of cement) is made in the sectors of iron/steel, cement, glass, aluminium, ammonia. The demand for energy (and, therefore, heating) needed for the manufacture of a product, is calculated on the basis of existing technologies and the potential future technologies to be implemented within the time scale of the analysis.

For the other industrial sectors, the evolution of useful demand is related to the evolution of the added value of the sector, on the basis of a relation of the same form as equation (1). Forecasts of the added value of each sector were obtained from the Ministry of Finance in agreement with the Ministry of Environment and Energy.

Graph 11 – Consumption for heating and cooling per fuel type in the industrial sector, 2020–2050



Source: TIMES model, additional policies and measures scenario (WAM), NECP.

	Biofuel
	Electricity
	Natural gas
	Oil
	Lignite

Energy consumption for heating and cooling in the industrial sector (Graph 11) is expected to decline over the next 30 years, from 23.1 TWh in 2020 to 21.6 TWh in 2050. Oil use is expected to record the biggest decline, from 11.2 TWh in 2020 to 4.6 TWh in 2050.

4. Objectives, strategies, and policy measures

This section indicates and examines existing objectives, strategies, and policy measures related directly or indirectly to efficient heating and cooling, with regard to the following five aspects:

- decarbonisation and RES
- improvement of energy efficiency
- energy security
- internal energy market
- research, innovation, and competitiveness

based on which EU Member States draw up their NECPs. The following chapters present the objectives, existing strategies, and policy measures related to heating and cooling, as those are detailed in Greece's NECP.

4.1. Current National Objectives

The objectives set forth in the NECP and relating directly or indirectly to heating and cooling are presented in Table 5. The fundamental objective is a decrease by at least 40 % of the total greenhouse gas emissions relative to 1990. Moving toward decarbonisation, an objective set forth is a timeline for the withdrawal of lignite-fired power generating plants by 2028, which would also mark the energy transition of the country's power generating system. Beyond the target for a share of RES in gross electricity generation and gross final consumption of energy, a specific target is set for a minimum RES share of 40 % in covering heating and cooling needs.

The improved energy efficiency objective is set at 38 % (in line with the European methodology); this is one of the greatest challenges for the policies scheduled to be implemented by 2030 and a cross-cutting priority in the wider framework of policies and measures to be adopted. Another objective is that the final consumption of energy will not exceed 16.5 Mtoe in the year 2030.

Improvement in energy efficiency has a direct effect on the demand for and consumption of energy, the technologies used, and how the consumers' energy needs are met. Another significant challenge is the optimal use of RES technologies to cover heating and cooling needs, as well as of RES self-production systems to cover the needs of buildings for electricity *inter alia* by empowering consumers.

Table 5 – National energy and environmental objectives for 2021–2030, relating to heating and cooling

Main objective	Relevant Energy Union dimension
Total greenhouse gas emissions to be reduced by at least 40 % relative to 1990 (reduction achieved >42 %)	Decarbonisation
Withdrawal of lignite-fired power generating units by 2028	Decarbonisation
The share of RES in heating and cooling must exceed 40 %	Decarbonisation, RES generation
Improve energy efficiency by 38 % in accordance with the European methodology	Energy efficiency
Final energy consumption not to exceed 16.5 Mtoe in 2030 (contribution of ambient heat excluded from the calculation)	Energy efficiency

Source: NECP, December 2019

Table 6 shows how key results for the domestic energy system for the year 2030 have evolved. The results, based on the objectives of the final NECP for 2030, show increased penetration of RES in gross and final energy consumption, greater improvement of energy efficiency, and termination of the use of lignite-fired plants for power generation.

Table 6 – Key results for the energy system for 2030

Key NECP indicators	
Total greenhouse gas emissions ($MtCO_2eq$)	60.6
RES share in gross final energy consumption [%]	35 %
RES share in final consumption for heating and cooling [%]	43 %
RES share in gross electricity consumption [%]	61 %
Energy production [€10 million/ktoe]	11.03

Source: NECP, December 2019

The target of a 35 % RES share in final consumption leads to a 43 % share of RES in the heating and cooling sector, and 61 % in the sector of gross power consumption.

These quantitative objectives, depending on how final consumption is shaped, translate into specific quantitative values either in terms of installed capacity or number of RES technologies/systems in final use (e.g. biomass-fired boilers to cover heating and domestic hot water needs, heat pumps in buildings to cover heating and cooling needs, solar water heating, etc.). Consequently, the quantitative correlation of these values is directly associated with achieving the relevant objectives for improving energy efficiency.

With regard to the evolution of RES participation in final consumption, Table 7 shows the projected trend of such shares at specific time points. In particular, specific reference is made to RES participation in final consumption for heating and cooling, which is expected to reach 42.5 % in 2030 from 30.6 % in 2020.

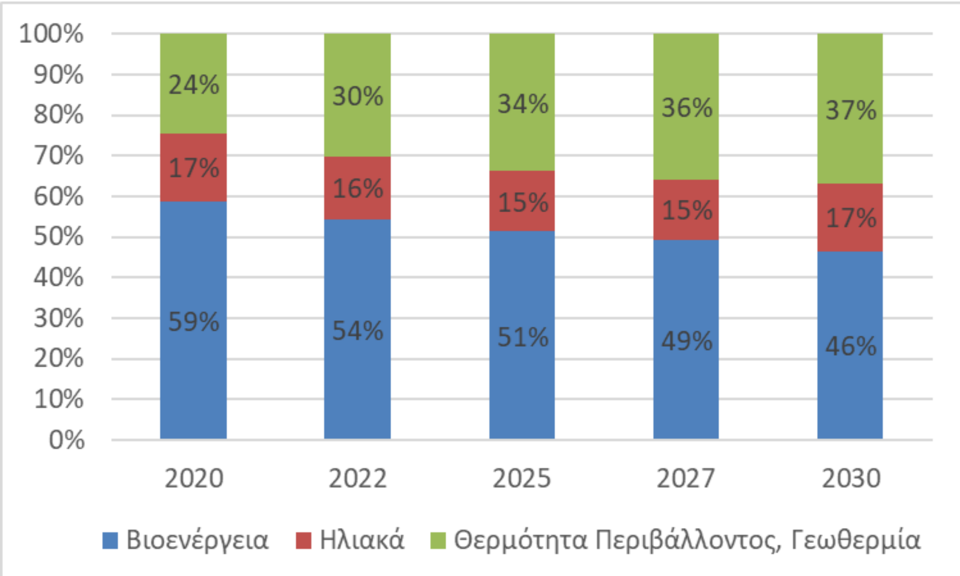
Table 7 – Evolution of RES share in heating and cooling by 2030

RES for heating and cooling	2020	2022	2025	2 027	2030
RES share in final consumption for heating and cooling [%]	30.6 %	33.8 %	36.8 %	38.3 %	**42.5 %**
Progress regarding RES share in final consumption for heating and cooling	-	27.0 %	52.3 %	64.5 %	100 %

Source: NECP. December 2019

More specifically, the RES share in heating and cooling appears to evolve in a relatively linear fashion through 2030. Concerning RES penetration and participation in final energy consumption to cover heating needs, the following are expected: significant enhancement of the role of heat pumps, especially in the tertiary sector; enhanced participation of solar heating and geothermal energy systems; and steady contribution by biomass, as shown in Graph 12.

Graph 12 – RES participation in final consumption to cover heating needs



Source: NECP. December 2019

	■ Bioenergy
	■ Solar
	■ Ambient heating, Geothermal energy

It is also projected that RES district heating networks will have a small contribution, using primarily geothermal energy and biomass, while the target is for a gradual application of injections into the natural gas network of either biomethane or hydrogen.

4.2. Overview of existing strategies

The existing strategies, expressed as Priority Policies (PP) in the NECP and related directly or indirectly to heating and cooling, are provided in the table below.

Table 8 – Priority Policies for the period 2021–2030, concerning heating and cooling

Strategy / Priority Policy	Key objective of policy or strategy	Relevant Energy Union dimension
PP1.1	Achieve a net-zero emissions economy, by means of lignite phase-out, promoting RES in the energy mix of the country, and interconnection of the autonomous island systems	Decarbonisation
PP1.6	Strategy plans for waste management	Decarbonisation
PP2.7	Regulatory obligations for minimum RES participation in covering energy needs in the building sector	Decarbonisation, RES generation
PP2.8	Promote the use of RES systems to cover heating and cooling needs	Decarbonisation, RES generation
PP3.2	Strategy for renovating the building stock in the residential and tertiary sectors	Energy efficiency
PP3.11	Promote efficient heating and cooling	Energy efficiency
PP4.3	Reduce energy dependence; develop domestic energy sources	Security of energy supply
PP4.4	Promote systems providing flexibility, and storage and demand response systems; ensure the country's output adequacy	Security of energy supply
PP5.8	Comprehensive plans for development, investment activities, and financial programs for lignite-powered regions in transition	Internal energy markets
PP6.3	Develop innovative technologies for decarbonisation	Research, innovation, and competitiveness
PP6.6	Develop innovative applications for storing energy, and technologies for CO2 capture, storage, and use	Research, innovation, and competitiveness
PPN.7	Promote RES use and actions to improve energy efficiency in tourist facilities	Agricultural sector, Shipping, and Tourism

Source: NECP. December 2019

4.3. Overview of existing policy measures

The existing policy measures, as detailed in the NECP and relating directly or indirectly to heating and cooling, are provided in the table below.

Table 9 – Existing policy measures for the period 2021–2030, concerning heating and cooling

Policy measure	Key policy objective	Relevant Energy Union dimension	Implementation period	Implementation status
M1	Withdraw lignite-fired power plants and interconnect autonomous island systems	Decarbonisation	2016–2030	Implementation; Updating–Reforming
M2	Promote natural gas as an intermediate fuel for reducing the carbon footprint of the energy system	Decarbonisation	2016–2030	Implementation; Updating–Reforming
M3	Promote RES, storage systems, and production of fuel from RES	Decarbonisation	2016–2030	Implementation; Updating–Reforming
M5	Improve energy efficiency in buildings, industry, and infrastructure	Decarbonisation	2016–2030	Implementation; Updating–Reforming
M7	Reduce fluorinated gas emissions	Decarbonisation	2016–2030	Implementation; Updating–Reforming
M6	Use guarantees of origin	Decarbonisation, RES generation	2020–2030	Implementation; Updating–Reforming
M11	Maintain self-production and energy-offset scheme, reviewing and updating, where necessary, the regulatory framework for its operation	Decarbonisation, RES generation	2015–2030	Implementation; Updating–Reforming
M16	Develop and improve licensing framework and technical specifications for district heating from RES and for biogas injection into the NG network, and exploitation of geothermal fields	Decarbonisation, RES generation	2020–2030	Implementation; Updating–Reforming
M18	Public buildings	Decarbonisation, RES generation	2014–2027	Implementation; Updating–Reforming
M8	Replace fuel imports by RES for heating/cooling	Security of energy supply	2016–2030	Implementation; Updating–Reforming
M1	Develop innovative technologies for energy conservation	Research, innovation, and competitiveness	2016–2030	Implementation; Updating–Reforming
M2	Develop innovative technologies for decarbonisation, and implement methods for capture, storage, and use of carbon emissions	Research, innovation, and competitiveness	2016–2030	Implementation; Updating–Reforming
M2	Organise supply chain and establish sites for temporary storage of agricultural/forest residual biomass of urban [text missing]	Agricultural sector	2016–2030	Implementation; Updating–Reforming
M3	Maintain and expand the sustainability certification scheme for biofuels, bioliquids and solid fuels	Agricultural sector	2016–2030	Implementation; Updating–Reforming
M5	Produce solid biofuels by promoting woody biomass or coppice energy crops	Agricultural sector	2016–2030	Implementation; Updating–Reforming
M10	Promote RES systems for heating and cooling	Agricultural sector	2016–2030	Implementation; Updating–Reforming

Source: NECP. December 2019

- **Withdraw lignite-fired power plants and interconnect autonomous island systems**

The objective of this specific measure is to withdraw inefficient and polluting lignite-fired power generation plants by the year 2028 in the context of the country's goal to phase out lignite completely. In November 2020, the Just Development Transition Plan was presented (SDAM); a roadmap to development for the post-lignite era. The Just Development Transition Plan includes a set of measures and projections relating to, *inter alia*, investment and tax incentives, new infrastructure, new technologies, exploitation of local natural resources, support of agricultural production and tourism, etc. In addition, the programme for phasing out lignite-fired plants takes into account the smooth functioning of district heating systems for covering heating needs in the energy regions, and will examine all alternative solutions, including the development of a natural gas network in those regions. Additional greenhouse gas emission reductions are also expected from the interconnection of autonomous island systems with the continental system, where local, highly polluting power plants will be phased out.

- **Promote natural gas as an intermediate fuel for reducing the carbon footprint of the energy system**

This measure aims to promote natural gas for power generation and in specific sectors of final consumption, such as the building sector, industry, and transport, by means of various existing and envisaged policy measures.

- **Promote RES, storage systems, and production of fuel from RES**

This measure includes all measures for RES penetration in power generation, heating and transport.

- **Improve energy efficiency in buildings, industry, and infrastructure**

This measure concerns the implementation of measures for improving energy efficiency, which were included in the policy priorities for the improvement of energy efficiency in the building sector and industry, including infrastructure for electricity and natural gas. In addition, heat production by HECHP plants and the promotion of district heating to cover the heating needs of buildings, as well as the exploitation of waste heat for the purpose of energy production, will contribute to the reduction of greenhouse gas emissions because of the reduced consumption of petroleum products and other conventional fuels.

- **Reduce fluorinated gas emissions**

This measure relates to the reduction of fluorinated gas emissions by preventing leaks and emissions and monitoring the use of fluorinated gases. Examples include: discontinuing the production of new refrigeration and freezing equipment for household use that works with fluorinated gases with GWP>150; production of firefighting equipment that contains HFC-23 fluorinated gases; training and certification of technical personnel that handles fluorinated gases; installing leak detection systems in large cooling systems, air conditioners, and fire protection systems; and circulation of vehicles using fluorinated gases that do not have GWP>150.

- **Use guarantees of origin**

Measure M6 concerns the development of environmental markets using Guarantees of Origin for RES-generated electricity, acting as a supplementary market mechanism which will contribute further to the proper functioning of the Special Account. Adopting Guarantees of Origin for biogas and hydrogen from various forms of energy and connecting the systems of Guarantees of Origin of various energy media (electricity, gas fuel, heating and cooling energy) will contribute to the penetration of renewable energy sources in final consumption.

- **Maintain self-production and energy-offset scheme, reviewing and updating, where necessary, the regulatory framework for its operation**

This measure relates to the maintenance and extension of self-production and energy offset schemes already implemented. However, it is necessary to monitor and update, whenever deemed necessary, the regulatory framework governing their operation, so as to take into account technological developments and ensure proper functioning of the power networks and cost effectiveness in the energy system.

- **Develop and improve licensing framework and technical specifications for district heating from RES and for biogas injection into the NG network, and exploitation of geothermal fields**

This measure concerns the development and improvement of the licensing framework, including establishing technical specifications, which is considered a necessary pre-condition for implementing projects relating to the construction of RES district heating systems, the injection of the biogas produced into the NG network, and the further exploitation of available geothermal fields.

- **Public buildings**

This measure enhances the exemplary role that public buildings are required to fulfil, by setting a required minimum RES contribution, taking into account the criteria for economic sustainability and energy benefits.

- **Replace fuel imports by RES for heating/cooling**

This measure aims to replace fuel imports by RES in the heating and cooling sector by means of targeted actions, given that RES are a domestic source, with the exception of biofuels that do not originate from EU countries.

- **Develop innovative technologies for energy conservation**

This measure aims to support Research & Innovation (R&I) activities in the building sector that relate to new materials; prefabricated active elements for facades and roofs; economically efficient, smart, and adaptable heat pumps and heat pumps suitable for high temperatures; digital planning for buildings and optimising their operation. In the industrial sector, energy-efficient technologies for heating and cooling, heating/cooling recovery, and system integration will be supported.

- **Develop innovative technologies for decarbonisation, and implement methods for capture, storage, and use of carbon emissions**

This measure aims to support R&I in solar thermal technology both in centralised solar water heating systems and in heating-cooling applications. Regarding wind power, actions regarding electrical infrastructure of wind parks and offshore wind parks, the operation and maintenance of wind parks, micro-wind turbines, and other actions, such as methodologies and tools for comprehensive recording and assessment of the environmental footprint of wind parks, systems for managing the end of life for wind turbines, etc., will be supported. The R&I activities that will be supported for photovoltaic energy relate to the incorporation of photovoltaic energy systems in buildings and other infrastructure, the development of multi-junction, high-efficiency photovoltaic cells, and systems for monitoring and operating photovoltaic infrastructure.

R&I actions for bioenergy and intermediate carriers of bioenergy relate to the development of high-efficiency co-generation of heat and electricity from biomass on a large scale, as well as the development, demonstration and scaling up of solid, liquid and gaseous intermediate carriers of bioenergy through biochemical/thermochemical/chemical conversion from sustainable biomass. Finally, actions for geothermal energy will be supported insofar as they relate to geothermal heating in urban regions; the materials, methods, and equipment for improving its availability for operation; the improved permeability of conventional geothermal reservoirs; the improvement of efficiency in converting to electricity and of the direct use of heat; the development of new technologies to investigate geothermal potential; the incorporation of geothermal heat and electric power in the system; and the development of a zero-emissions geothermal power station. Finally, targeted research activities will be planned for the purpose of assessing and implementing technologies for capture, storage, and use of carbon emissions.

- **Organise supply chain and establish sites for temporary storage of agricultural/forest residual biomass**

This measure is intended to enhance the supply chain from the collection of residual raw materials in the primary sector to its processing and conversion in the secondary sector, and support heat and power distribution networks, as well as engineers, supervisors, technicians, and maintenance providers through relevant actions. Such actions include supporting the development of infrastructure for temporary deposit, pre-treatment and storage of residual biomass in private spaces/land and/or central collection points which will serve to combat the negative practice of open burning observed in outdoor spaces.

- **Maintain and expand the sustainability certification scheme for biofuels, bioliquids and solid fuels**

This measure aims to support the actions for maintaining and extending the sustainability certification scheme so as to ensure that only sustainable biofuels, bioliquids and solid fuels are used in the Greek territory.

- **Produce solid biofuels by promoting woody biomass or coppice energy crops**

This measure aims to support participation of the primary sector in the production of biomass (solid biofuels) from the cultivation of short rotation-period forest species and other perennial crops through targeted actions, such as: support for such investments; simplification of the process for the cultivation of such crops by natural or legal persons; and/or allocation of land in

Regions throughout the country where the cultivation of such crops does not create competition with other markets.

- **Promote RES systems for heating and cooling in the agricultural sector**

This measure aims to promote RES systems for heating and cooling in crop and livestock farms, such as using geothermal energy and other forms of RES in greenhouses.

5. Cost-benefit analysis at a nationwide level

This section presents an economic analysis and a cost-benefit analysis, at community level, of the technically exploitable potential for efficient heating and cooling. The analysis takes into account the variation in the demand for heating and cooling per climate zone, as well as the variation of the economic potential in relation to the source of the available energy for covering heating and cooling needs.

A cost-benefit analysis at community level is carried out in any case, taking into account the external costs and benefits resulting from the penetration of the technologies provided for by the scenarios considered. In addition, in cases where there is no economic potential but the benefit-to-cost ratio for the community is higher than one, the amount of the funding gap that needs to be covered for the investments in those technologies to be economically viable is examined.

Six (6) scenarios are defined for analysis purposes. The existence of economic potential is in any case dependent on the availability of a source of heat considered in each scenario, as well as the financial viability of the investment, as resulting from the economic analysis, taking into account the cash flows of the investments. In any case, the economic benefit to result from the sale of the energy generated must be high enough to render the investment financially viable.

Each scenario is assessed comparatively to the baseline scenario, which relates to the current situation of heating and cooling generation by use of conventional technologies.

Four the first four scenarios, the basic assumption of the baseline/reference scenario is that:

- the total energy demand for space heating is covered by conventional oil-fired boilers
- the total energy demand for domestic hot water is covered by electric water heaters.

For Scenario 5, a baseline/reference scenario that is examined involves the view that total energy demand for space heating and DHW generation is covered by an NG-fired boiler.

Finally, in Scenario 6, a baseline/reference scenario that is examined involves the view that total energy demand for space heating is covered by a biomass-fired boiler.

The scenarios considered are as follows:

Scenario 1: The thermal demand per settlement type is covered by district heating systems using available waste heat from existing facilities.

This scenario is used to examine the Region of Western Macedonia, where there are already district heating facilities and a district heating network. Individual scenarios are considered for a cross-cutting analysis of potential economic aid to ensure the viability of the investments.

Scenario 2: The thermal demand per settlement type is covered by district heating systems using heat generated from new heat generation facilities by use of natural gas and biomass.

This scenario examines possible regions to install new district heating plants along the natural gas transmission network and in close proximity to the network, and regions with a high availability of biomass to install new biomass plants. Individual scenarios are examined for the amount of economic aid to ensure the viability of the investments either on a cross-cutting level or on the basis of the fuel selected.

Scenario 3: The thermal demand per settlement type is covered by district heating systems using heat generated from high-efficiency co-generation systems fuelled with natural gas.

This scenario examines possible regions to install new HECHP plants along the natural gas transmission network and in close proximity to the network. Individual scenarios are examined regarding the amount of economic aid necessary to ensure the viability of the investments.

Scenario 4: Penetration of various technologies for individual installations in the residential, tertiary, and industrial sectors.

This scenario examines the complete replacement of conventional oil-fired boilers used for space heating and electric water heaters for domestic hot water at facility level. The total thermal demand, which is being replaced, depends on the potential of the technology under consideration to penetrate the building stock. Individual scenarios are examined using a sensitivity analysis and considering various critical parameters.

Scenario 5: Penetration of heat pumps for individual installations in the residential and tertiary sectors, with a baseline scenario involving natural gas-fired boilers.

This scenario examines the complete replacement of natural gas-fired boilers used for space heating and combined space heating and DHW generation, at facility level, by heat pumps. Individual scenarios are examined using a sensitivity analysis and considering various critical parameters.

Scenario 6: Penetration of heat pumps for individual installations in the residential sector, with a baseline scenario involving biomass-fired boilers.

This scenario examines the complete replacement of biomass-fired boilers used for space heating by air-water heat pumps. Individual scenarios are examined using a sensitivity analysis and considering various critical parameters.

The scenarios are analysed in the subsequent sections, while the technical potential for efficient heating and cooling is also identified.

5.1. Scenario 1: District heating by use of waste heat from existing facilities

Substituting conventional heat-generating systems in settlements for each climate zone separately by use of waste heat in district heating networks with a view to covering the thermal needs of a settlement is examined in this section. The analysis performed takes into account the potential distance of the settlement from the thermal source, as well as the population of the settlement.

The economic viability of the investments is examined, while a cost-benefit analysis is carried out in order to identify cases where the installation of district heating networks is beneficial to the community.

The thermal demand that may be covered by district heating and cooling networks is determined for each climate zone on the basis of the available certificates of energy performance and the allocation of demand for energy per end use in the building sector in Greece. The necessary nominal heating and cooling output is determined by analysing the heating and cooling degree-days per climate zone for the last three years.

The heating and cooling degree-days are obtained for each climate zone from main weather stations located in the areas inside each climate zone (www.degreedays.net). The following assumptions are taken into account for allocating heating and cooling loads on a monthly basis and for determining the heating and cooling output provided:

- The monthly allocation of loads is consistent with the relevant allocation of heating and cooling degree-days in each area.
- The demand for domestic hot water is considered (for purposes of method simplification, to the extent that the estimates are macroscopic) as equally allocated to all months of the year.

An analysis is made for the following types of settlements:

- Small mountain settlements with no more than 500 residents
- Settlements with 500 to 2 000 residents
- Towns with 2 000 to 10 000 residents
- Urban areas with more than 10 000 residents

Annex III provides the key assumptions used in this study, which relate to the supply of heat through district heating networks, such as the determination of the nominal thermal demand of a settlement, the heat output of thermal energy transmission, network costs, the costs of thermal energy generation plants and pumping stations, the costs of the thermal energy transmission and distribution network, and prices for sale to consumers.

Thus, the selling price of the energy available from district heating networks is determined taking into account the energy demand per end use, the efficiency of the conventional technologies and the selling price of conventional fuels.

The specific method of calculating the selling price of the available energy disconnects the analysis made from the potential impact of the selling price of conventional fuels to the final consumer, under the baseline scenario, on the cash flows of the investment. A potential change to the fuel price of conventional systems is directly reflected in the selling price of the energy made available from the district heating systems.

The results of the economic analysis and the cost-benefit analysis are presented below.

For an investment to be designated as economically viable and for economic potential to be deemed as existing, the economic indicators must record the following values:

Table 10: Indicators of economic viability of the investment

Indicator	Abbreviation	Unit	Value
Net Present Value	NPV	€	>0
Internal rate of return	IRR	%	≥10 %

Indicators of economic viability of the investment

The results of the economic analysis relating to the use of waste heat for covering heating and DHW needs is presented in the following graph, per climate zone.

The curves on the graph represent the points where the economic indicators of the investments record the values cited in Table 10 for the given population and distance between the waste heat source and the point of demand for energy. The points under the curves represent points where the internal rate of return (IRR) of the investments is less than 10 % and, therefore, there is no economic potential for the development of district heating networks. Accordingly, investments are economically viable at the points over the curves. The dotted curves on the graph represent the population ceilings of the categories of settlements examined.

Graph 13 – Economic viability of district heating networks in relation to the population of the settlement and the distance from the waste heat source

	Economic viability of district heating networks
	Population
	Distance from the waste heat source (km)
	Climate Zone D
	Climate Zone C
	Climate Zone B
	Climate Zone A
	Small settlement
	Medium-sized settlement
	Town

As shown in the above graph, there is economic potential within a short distance from the thermal source, even in towns in climate zones A and B (low thermal demand).

In settlements with high thermal demand (climate zones C and D), economic potential exists in towns at greater distances of up to 10 km from the thermal source.

In addition, the economic potential for district heating increases in all cases where the population and the distance from the thermal source increase.

The cost and benefit components that are taken into account in the cost-benefit analysis, are as follows:

(+) Income: Includes revenues from the sale of the electricity and thermal energy generated from the co-generation plant.

(-) Operating costs: Include the district heating network maintenance costs.

(+) Operating benefit from the substitution of oil and electricity used for heating: Includes the cost of heating oil and electricity that is avoided.

(+) External benefit from the substitution of oil and electricity used for heating: Includes the external benefit from the heating oil avoided and the electricity avoided and relates to the impact on climate change, health, ecosystems, national economy due to reduction in the consumption of imported conventional fuels, etc.

According to the analysis made and as shown in the tables below, the indicators used for assessing the penetration of the district heating networks improve when moving from the climate zone with the minimum thermal demands (climate zone A) to the climate zone with the maximum thermal demands (climate zone D).

In most cases, other than in climate zones A and B for very small settlements and long distances from the thermal source, the benefit-to-cost (B/C) ratio is, according to the analysis, higher than one. For that reason, the amount of financial aid that may be granted for the investments to become economically viable has been examined.

The tables below present the results of the cost-benefit analysis per climate zone, as well as the minimum rate of financial aid that may be granted either in the form of grants or under subsidised loans, so that the investments are economically viable.

Table 11: Economic viability under Scenario 1

Climate Zone A		Population							
		500	1 000	2 000	5 000	10 000	20 000	50 000	100 000
Distance (km)	1	36 %	21 %	10 %					
	5	67 %	55 %	43 %	18 %				
	10	80 %	70 %	61 %	40 %	15 %			
	15	B/C<1	78 %	71 %	53 %	31 %	6 %		
	20	B/C<1	B/C<1	76 %	61 %	42 %	19 %		
	30	B/C<1	B/C<1	B/C<1	71 %	56 %	37 %		
	40	B/C<1	B/C<1	B/C<1	77 %	64 %	48 %	17 %	
	50	B/C<1	B/C<1	B/C<1	81 %	70 %	56 %	28 %	

Climate Zone B		Population							
		500	1 000	2 000	5 000	10 000	20 000	50 000	100 000
Distance (km)	1	34 %	18 %	8 %					
	5	64 %	51 %	39 %	14 %				
	10	77 %	67 %	58 %	35 %	10 %			
	15	B/C<1	75 %	67 %	48 %	25 %			
	20	B/C<1	80 %	73 %	57 %	36 %	13 %		
	30	B/C<1	B/C<1	81 %	68 %	51 %	30 %		
	40	B/C<1	B/C<1	B/C<1	74 %	60 %	42 %	9 %	
	50	B/C<1	B/C<1	B/C<1	78 %	66 %	51 %	21 %	

Climate Zone C		Population							
		500	1 000	2 000	5 000	10 000	20 000	50 000	100 000
Distance (km)	1	31 %	15 %	5 %					
	5	60 %	46 %	34 %	8 %				
	10	74 %	63 %	53 %	29 %				
	15	81 %	72 %	63 %	42 %	18 %			
	20	B/C<1	77 %	69 %	51 %	29 %	4 %		
	30	B/C<1	B/C<1	77 %	63 %	44 %	22 %		
	40	B/C<1	B/C<1	82 %	70 %	54 %	34 %		
	50	B/C<1	B/C<1	B/C<1	75 %	61 %	44 %	11 %	

Climate Zone D		Population							
		500	1 000	2 000	5 000	10 000	20 000	50 000	100 000
Distance (km)	1	30 %	14 %						
	5	58 %	44 %	32 %	5 %				
	10	72 %	61 %	50 %	26 %				
	15	79 %	70 %	60 %	39 %	14 %			
	20	B/C<1	75 %	67 %	48 %	25 %			
	30	B/C<1	82 %	76 %	60 %	40 %	17 %		
	40	B/C<1	B/C<1	81 %	67 %	51 %	30 %		
	50	B/C<1	B/C<1	B/C<1	73 %	58 %	39 %	5 %	

As shown in the above tables, the benefit-to-cost ratio falls below one as the thermal demands of the region decrease, either due to climate zone or due to the small number of the residents of the settlements, and as the distance of the thermal source from the settlement increases.

In any case, where the benefit-to-cost ratio is higher than one, the maximum rate of financial aid needed for the implementation of investments in district heating networks is 80 %.

In addition, financial aid for the same settlement varies between climate zones. For the same type of settlement and distance from the thermal source, the rate of necessary financing increases when moving from climate zone D (maximum thermal demands) to climate zone A (minimum thermal demands).

5.2. Scenario 2: District heating using heat generated from new heat generation facilities by use of natural gas and biomass

Scenario 2 examines how thermal demand per settlement type is covered by district heating systems using heat generated from new heat generation facilities fuelled with natural gas and biomass.

Specifically, it is assessed whether a settlement's thermal needs can be covered by means of a district heating network and shared heat generation, i.e. 50 % by a biomass-fired boiler and 50 % by an NG-fired boiler.

An economic analysis of investments and a cost-benefit analysis at community level are carried out.

The analysis of the economic potential of Scenario 2 demonstrated that there is no economic potential for this specific manner of producing energy-efficient heat.

The cost and benefit components that are taken into account in the cost-benefit analysis, are as follows:

(+) Income: Includes revenues from the sale of the electricity and thermal energy generated from the co-generation plant.
(-) Operating costs: Include the district heating network maintenance costs. **(-) Operating costs of the boiler**: Include the biomass and natural gas purchase costs.
(+) Operating benefit from the substitution of heating oil: Includes the cost of heating oil that is avoided.
(+) Operating benefit from the substitution of electricity for the generation of DHW: Includes the electricity cost avoided for DHW.
(-) External cost of biomass-fired boiler: Includes the external cost of the co-fired boiler and relates to the impact on climate change, health, ecosystems, etc.
(-) External cost of NG-fired boiler: Includes the external cost of the co-fired boiler and relates to the impact on climate change, health, ecosystems, etc.
(+) External benefit from the substitution of heating oil: Includes the external benefit from the heating oil avoided and relates to the impact on climate change, health, ecosystems, etc.

The tables below present the results of the cost-benefit analysis per climate zone, as well as the minimum rate of financial aid that may be granted either in the form of grants or under subsidised loans, so that the investments are economically viable.

Table 12: Economic viability under Scenario 2

Climate Zone A		Population							
		500	1 000	2 000	5 000	10 000	20 000	50 000	100 000
Distance (km)	1	86 %	80 %	74 %	63 %	52 %	41 %	22 %	6 %
	5	B/C<1	87 %	82 %	72 %	61 %	49 %	30 %	13 %
	10	B/C<1	B/C<1	87 %	78 %	68 %	57 %	38 %	21 %
	15	B/C<1	B/C<1	B/C<1	82 %	73 %	62 %	44 %	28 %
	20	B/C<1	B/C<1	B/C<1	85 %	77 %	67 %	49 %	33 %
	30	B/C<1	B/C<1	B/C<1	B/C<1	82 %	73 %	57 %	42 %
	40	B/C<1	B/C<1	B/C<1	B/C<1	85 %	77 %	63 %	49 %
	50	B/C<1	B/C<1	B/C<1	B/C<1	B/C<1	80 %	67 %	54 %

Climate Zone B		Population							
		500	1 000	2 000	5 000	10 000	20 000	50 000	100 000
Distance (km)	1	86 %	80 %	74 %	63 %	52 %	40 %	21 %	5 %
	5	B/C<1	86 %	81 %	70 %	59 %	47 %	29 %	12 %
	10	B/C<1	B/C<1	86 %	76 %	66 %	55 %	36 %	19 %
	15	B/C<1	B/C<1	89 %	80 %	71 %	60 %	42 %	25 %
	20	B/C<1	B/C<1	B/C<1	83 %	75 %	64 %	46 %	30 %
	30	B/C<1	B/C<1	B/C<1	B/C<1	80 %	71 %	54 %	38 %
	40	B/C<1	B/C<1	B/C<1	B/C<1	83 %	75 %	60 %	45 %
	50	B/C<1	B/C<1	B/C<1	B/C<1	85 %	78 %	64 %	50 %

Climate Zone C		Population							
		500	1 000	2 000	5 000	10 000	20 000	50 000	100 000
Distance (km)	1	85 %	79 %	73 %	62 %	51 %	39 %	20 %	4 %
	5	B/C<1	85 %	79 %	69 %	57 %	45 %	26 %	9 %
	10	B/C<1	B/C<1	84 %	74 %	64 %	52 %	33 %	16 %
	15	B/C<1	B/C<1	87 %	78 %	68 %	57 %	38 %	21 %
	20	B/C<1	B/C<1	B/C<1	81 %	72 %	60 %	43 %	26 %
	30	B/C<1	B/C<1	B/C<1	85 %	77 %	67 %	50 %	34 %
	40	B/C<1	B/C<1	B/C<1	B/C<1	81 %	71 %	56 %	40 %
	50	B/C<1	B/C<1	B/C<1	B/C<1	83 %	75 %	60 %	45 %

Climate Zone D		Population							
		500	1 000	2 000	5 000	10 000	20 000	50 000	100 000
Distance (km)	1	85 %	81 %	73 %	62 %	50 %	38 %	20 %	3 %
	5	90 %	79 %	79 %	68 %	57 %	44 %	25 %	9 %
	10	B/C<1	84 %	83 %	73 %	63 %	51 %	31 %	14 %
	15	B/C<1	88 %	86 %	77 %	67 %	55 %	36 %	19 %

	20	B/C<1	B/C<1	B/C<1	80 %	71 %	59 %	41 %	24 %
	30	B/C<1	B/C<1	B/C<1	84 %	76 %	66 %	48 %	31 %
	40	B/C<1	B/C<1	B/C<1	B/C<1	79 %	70 %	54 %	37 %
	50	50	B/C<1	B/C<1	B/C<1	B/C<1	82 %	74 %	58 %

As shown in the above tables, the benefit-to-cost ratio falls below one as the thermal demands of the region decrease, either due to climate zone or due to the small number of the residents of the settlements, and as the distance of the thermal source from the settlement increases.

In any case, where the benefit-to-cost ratio is higher than one, the maximum rate of financial aid needed for the implementation of investments in district heating networks is 90 %.

In addition, financial aid for the same settlement varies between climate zones. For the same type of settlement and distance from the thermal source, the rate of necessary financing increases when moving from climate zone D (maximum thermal demands) to climate zone A (minimum thermal demands).

5.3. Scenario 3: Heat supply from new HECHP plants via district heating networks

For an investment to be designated as economically viable and for economic potential to be deemed to exist, the economic indicators must record the values cited in Table 10 of section 5.1.

This section addresses the substitution of conventional heat-generating systems in settlements for each climate zone separately by use of heat produced by 75 % from high-efficiency co-generation (HECHP) systems and by 25 % from natural gas-fired boilers and transmission of the energy generated via district heating networks to settlements, with a view to covering their thermal needs.

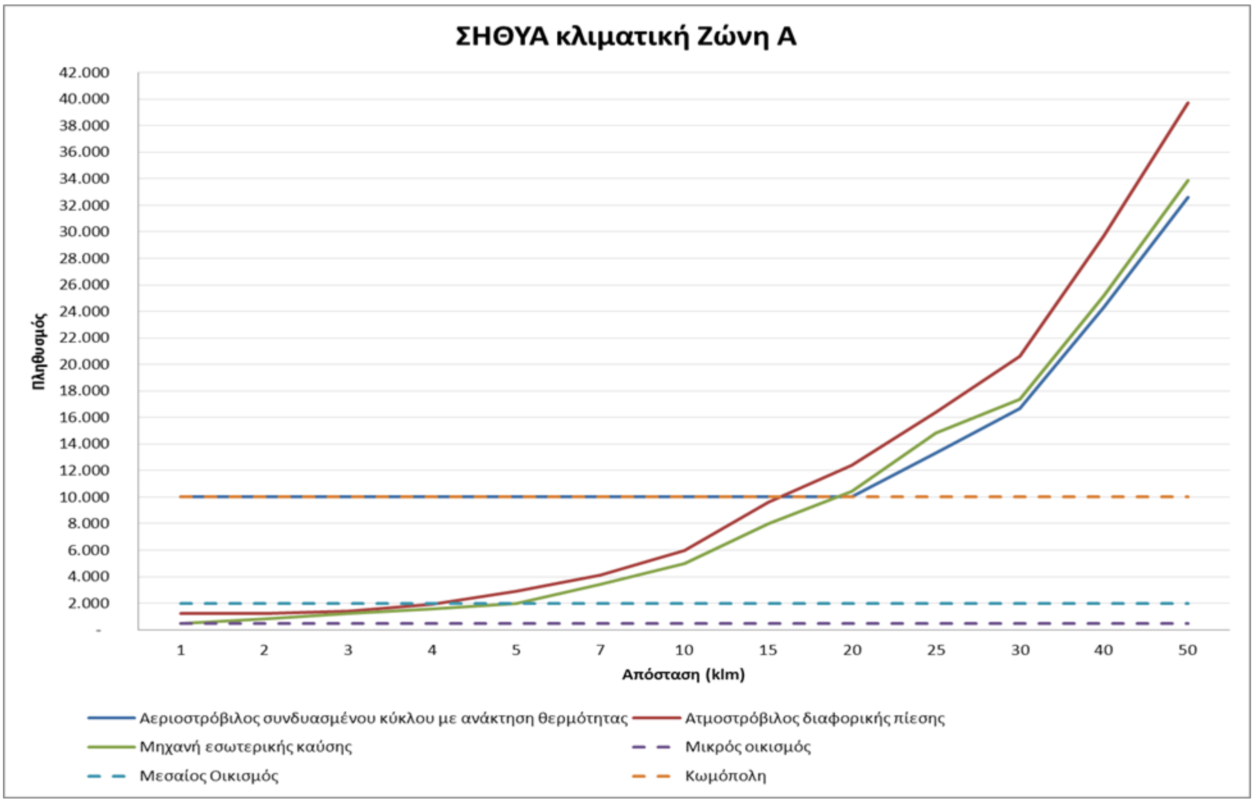
The analysis performed takes into account the co-generation technology that may be used, the potential distance of the settlement from the thermal source, the population of the settlement, as well as the climate zone where the settlement is located.

More specifically, the following HECHP technologies are examined:

- Combined cycle gas turbine with heat recovery
- Differential pressure steam turbine
- Steam extracting-condensing turbine with heat recovery
- Gas turbine with heat recovery
- Internal combustion engine

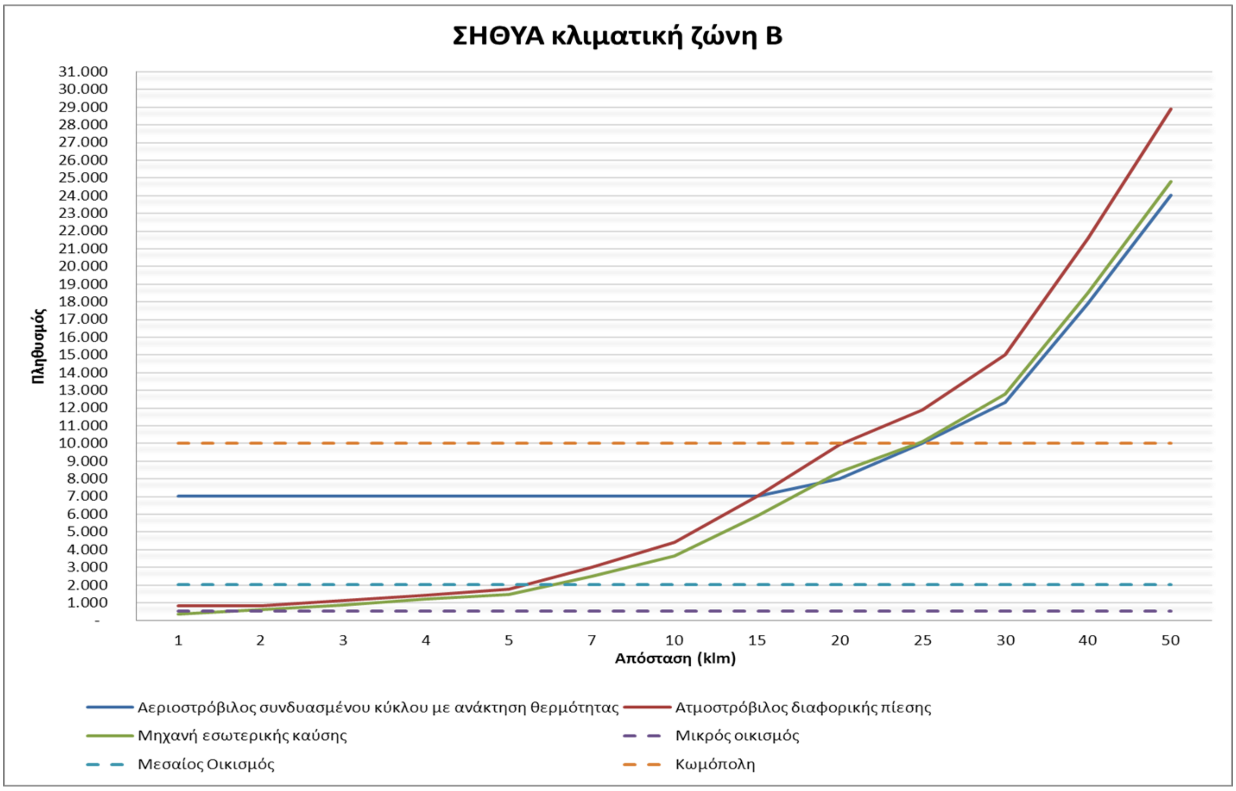
The results of the economic analysis are presented in the graphs below per climate zone and HECHP technology examined.

Graph 14 – HECHP Climate Zone A



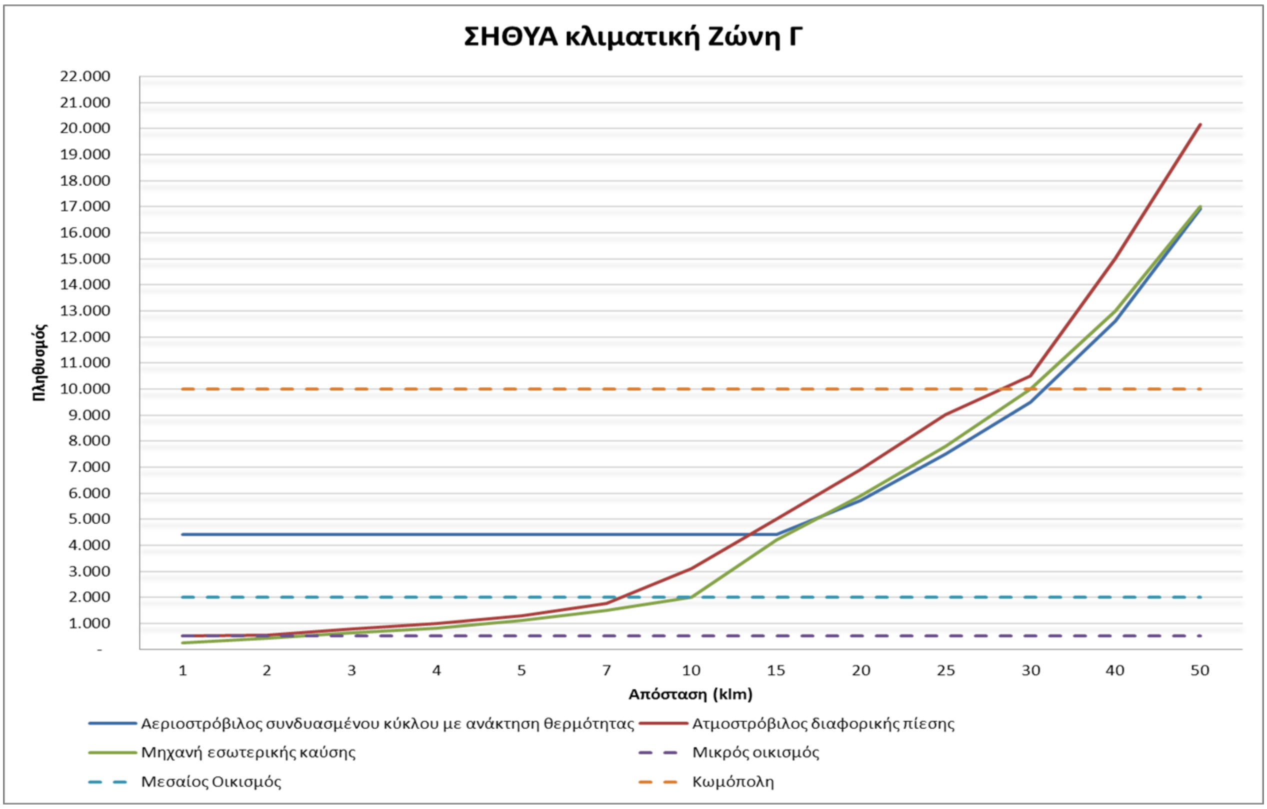
	HECHP Climate Zone A
	Population
	Distance (km)
	Combined cycle gas turbine with heat recovery
	Internal combustion engine
	Medium-sized settlement
	Differential pressure steam turbine
	Small-sized settlement
	Town

Graph 15 - HECHP Climate Zone B



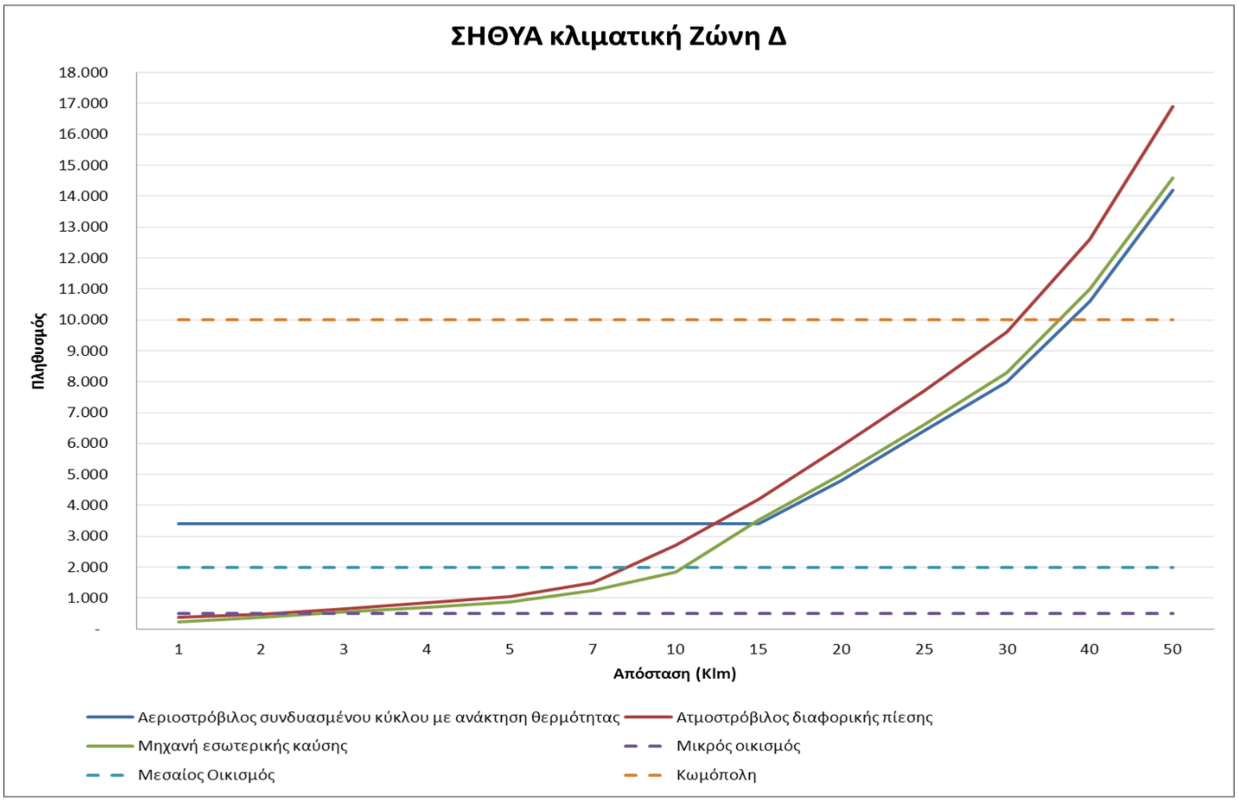
	HECHP Climate Zone B
	Population
	Distance (km)
	Combined cycle gas turbine with heat recovery
	Internal combustion engine
	Medium-sized settlement
	Differential pressure steam turbine
	Small-sized settlement
	Town

Graph 16 – HECHP Climate Zone C



	HECHP Climate Zone C
	Population
	Distance (km)
	Combined cycle gas turbine with heat recovery
	Internal combustion engine
	Medium-sized settlement
	Differential pressure steam turbine
	Small-sized settlement
	Town

Graph 17 – HECHP Climate Zone D



	HECHP Climate Zone D
	Population
	Distance (km)
	Combined cycle gas turbine with heat recovery
	Internal combustion engine
	Medium-sized settlement
	Differential pressure steam turbine
	Small-sized settlement
	Town

The curves on the graph represent the points where the economic indicators of the investments record the values cited in Table 10 (section 5.1) for the given population and distance between the waste heat source and the point of demand for energy.

The points under the curves represent points where the internal rate of return (IRR) of the investments is less than 10 % and, therefore, there is no economic potential for the penetration of HECHP technologies via district heating networks. Accordingly, investments are economically viable at the points over the curves. The dotted curves on the graph represent the population ceilings of the categories of settlements examined.

As shown in the graph above, for each climate zone, where an installed capacity of HECHP system higher than 4 MWe is needed for covering the thermal demands for the settlements (technical potential), the combined cycle gas turbine with heat recovery (the installed capacity of combined cycle gas turbine with heat recovery system ranging from 4 to 300 MWe) is the prevailing technology, since, for a given distance from the settlement, investments in that technology are economically viable for settlements with a smaller population.

In all other cases, internal combustion engines prevail over the other HECHP technologies.

In any event, efficient heating is economically viable in towns at a distance from the heat generation point ranging from 15 km (climate zone A) to 30 km (climate zone D).

In addition, economic potential for heat generation from HECHP plants exists also for very small settlements (with no less than 230 residents in climate zone D) at a short distance from the heat-generating plant (1 km).

Lastly, the economic potential increases in all cases where the population and the thermal demand per climate zone increase while the distance from the thermal source decreases.

5.4. Scenario 4: Penetration of various technologies for individual installations

This section examines the viability of replacing existing conventional systems for heating, cooling and domestic hot water at the level of installation per activity sector, with usage of energy generated from various technologies. More specifically, the following are examined:

- Heat pumps (air-to-air and air-to-water) (Scenario 4.1)
- Geothermal heat pumps (Scenario 4.2)
- Stand-alone biomass-fired boilers (Scenario 4.3)
- Solar water heaters (Scenario 4.4)
- Co-generation system using natural gas as fuel (Scenario 4.5)

5.4.1. Scenario 4.1: Penetration of heat pumps

This specific scenario relates to the substitution of thermal energy for space heating, generated from a heating oil-fired boiler, with thermal energy generated from heat pumps in residential and tertiary sector buildings. The analysis below examines the substitution of conventional heat generation systems in typical buildings for each building category.

An economic analysis of investments and a cost-benefit analysis at community level are carried out.

The cost and benefit components that are taken into account in the cost-benefit analysis, are as follows:

(-) Operating costs of air-heated heat pumps: They include the cost of electricity consumed and the maintenance costs for air-heated heat pumps.

(+) Operating benefit from the substitution of heating oil: It includes the heating oil costs and the maintenance costs for the heating oil boiler that are avoided.

(-) External cost of air-heated heat pumps: It includes the external cost of the electricity consumed and relates to the impact on climate change, health, ecosystems, etc.

(+) External benefit from the substitution of heating oil: It includes the external benefit from the substitution of heating oil and relates to the impact on climate change, health, ecosystems, etc.

The results of the economic and cost-benefit analyses are presented in the following tables.

The assumptions of the specific analysis are cited in **Annex IV**.

The results of the economic and cost-benefit analyses are presented in the following tables, and the amount of the existing funding gap that has to be covered for the investments to be economically viable is determined.

Table 13 – Results for air-to-air heat pumps

Heat Pumps Air-to-air	**Economic analysis**		**Cost-benefit analysis**			**B/C variation**	**Economic aid rate**
	FNPV (€)	**FIRR (%)**	**ENPV (€)**	**EIRR (%)**	**B/C**		**%**
Residence	€9 836	29 %	€4 156	20 %	1.26	1.21–1.52	N/A
Private office buildings	€5 797	19 %	€2 290	12 %	1.05	1.05–1.27	N/A
Public office buildings	-€2 454	3 %	€4 289	8 %	0.95	0.95–1.16	6 %
Hospitals	€3 222 273	97 %	€1 572 984	69 %	1.72	1.72–2.11	N/A
Hotels	€34 335	28 %	€17 018	19 %	1.18	1.18–1.44	N/A
Schools	€54 186	40 %	€22 679	27 %	1.32	1.32–1.61	N/A

Table 14 – Results for air-to-water heat pumps

Heat Pumps Air-to-water	Economic analysis		Cost-benefit analysis			B/C variation	Economic aid rate
	FNPV (€)	FIRR (%)	ENPV (€)	EIRR (%)	B/C		%
Residence	€6 707	17 %	€1 697	10 %	1.00	0.97–1.26	N/A
Private office buildings	€1 950	8 %	-€1 381	2 %	0.82	0.82–1.02	6 %
Public office buildings	-€27 968	-6 %	-€15 903	-2 %	0.74	0.74–0.93	55 %
Hospitals	€2 959 947	64 %	€1 371 061	45 %	1.54	1.54–1.89	N/A
Hotels	€6 219	8 %	€4 168	8 %	0.95	0.95–1.17	9 %
Schools	€41 069	24 %	€12 582	14 %	1.09	1.09–1.33	N/A

The variation in the benefit/cost indicator arises from the sensitivity analysis conducted regarding critical parameters for the purpose of obtaining more reliable results. Specifically, the parameters examined in the residential sector are as follows:

- **Sensitivity Analysis 1**: Higher price of heating oil (€0.75/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2025, EU Reference Scenario)
- **Sensitivity Analysis 2**: Higher price of heating oil (€0.85/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2030, EU Reference Scenario)
- **Sensitivity Analysis 3**: Higher price of electricity (15 % increase in the price of electricity relative to the baseline scenario)
- **Sensitivity Analysis 4**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 5**: Lower system cost (30 % reduction of purchase cost relative to the baseline scenario cost)

Respectively, a sensitivity analysis was conducted for the tertiary sector with respect to the following parameters:

- **Sensitivity Analysis 1**: Higher price of heating oil (€0.75/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2025, EU Reference Scenario)
- **Sensitivity Analysis 2**: Higher price of heating oil (€0.85/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2030, EU Reference Scenario)
- **Sensitivity Analysis 3**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 4**: Lower system cost (30 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 5**: Higher system efficiency (COP 5 instead of the COP 4.3 of the baseline scenario)

It is observed, taking into account the results of the analysis, that penetration of air-to-air heat pumps is recommended for all buildings in the residential and tertiary sectors, considering all economic and societal cost and benefit components, as reflected in the benefit/cost indicator, which is higher than one.

The penetration of air-to-water heat pumps is recommended primarily for buildings such as hospitals, hotels and schools, while in certain cases and depending on how the critical parameters considered in the sensitivity analysis are shaped, the benefit/cost indicator may be higher than one for other categories of buildings as well.

Finally, in some cases, such as hotels, schools and offices, economic aid is necessary for the technical solution to be economically viable.

5.4.2. Scenario 4.2: Penetration of geothermal heat pumps

This specific scenario relates to the substitution of thermal energy for space heating, generated from a heating oil-fired boiler, with thermal energy generated from geothermal heat pumps with closed-loop geoexchange. The analysis below examines the substitution of conventional heat generation systems in typical buildings of each category.

An economic analysis of investments and a cost-benefit analysis at community level are carried out.

The cost and benefit components that are taken into account in the cost-benefit analysis, are as follows:

(-) Operating costs of geothermal heat pumps: It includes the cost of electricity consumed and the maintenance costs for geothermal heat pumps.
(+) Operating benefit from the substitution of heating oil: It includes the heating oil costs and the maintenance costs for the heating oil boiler that are avoided.
(-) External cost of geothermal heat pumps: It includes the external cost of the electricity consumed and relates to the impact on climate change, health, ecosystems, etc.

(+) External benefit from the substitution of heating oil: It includes the external benefit from the substitution of heating oil and relates to the impact on climate change, health, ecosystems, etc.

The assumptions of the specific analysis are cited in Annex II.

The results of the economic and cost-benefit analyses are presented in the following tables, and the amount of the existing funding gap that has to be covered for the investments to be economically viable is determined.

Table 15 – Results for geothermal heat pumps

Geothermal Heat Pumps	Economic analysis		Cost-benefit analysis			B/C variation	Economic aid rate
	FNPV (€)	FIRR (%)	ENPV (€)	EIRR (%)	B/C		%
Household	-€1 160	3 %	-€5 047	1 %	0.83	0.81–1.04	39 %
Private office buildings	-€11 155	-2 %	-€10 181	-2 %	0.71	0.71–0.88	64 %
Public office buildings	-€51 040	-1 %	-€64 521	-3 %	0.65	0.65–0.81	58 %
Hospitals	€2 587 833	22 %	€1 010 693	15 %	1.43	1.43–1.73	N/A
Hotels	-€6 176	3 %	-€25 641	0 %	0.83	0.83–1.01	39 %
Schools	€28 803	10 %	-€10 101	3 %	0.95	0.95–1.15	19 %

The variation in the benefit/cost indicator arises from the sensitivity analysis conducted regarding critical parameters for the purpose of obtaining more reliable results. Specifically, the parameters examined in the residential sector are as follows:

- **Sensitivity Analysis 1**: Higher price of heating oil (€0.75/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2025, EU Reference Scenario)
- **Sensitivity Analysis 2**: Higher price of heating oil (€0.85/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2030, EU Reference Scenario)
- **Sensitivity Analysis 3**: Higher price of electricity (15 % increase in the price of electricity relative to the baseline scenario)
- **Sensitivity Analysis 4**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 5**: Lower system cost (30 % reduction of purchase cost relative to the baseline scenario cost)

Respectively, a sensitivity analysis was conducted for the tertiary sector with respect to the following parameters:

- **Sensitivity Analysis 1**: Higher price of heating oil (€0.75/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2025, EU Reference Scenario)
- **Sensitivity Analysis 2**: Higher price of heating oil (€0.85/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2030, EU Reference Scenario)
- **Sensitivity Analysis 3**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 4**: Lower system cost (30 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 5**: Higher system efficiency (COP 6 instead of the COP 5 of the baseline scenario)

It is observed, taking into account the results of the analysis, that penetration of geothermal heat pumps is not recommended for buildings in the residential sector, as it has a benefit/cost indicator lower than one. However, in certain cases and depending on how the critical parameters assessed in the sensitivity analysis are shaped, the benefit/cost indicator may be higher than one.

In the tertiary sector, the penetration of geothermal pumps is recommended primarily for buildings such as hospitals, whereas for hotels and schools, in certain cases and depending on how the critical parameters considered in the sensitivity analysis are shaped, the benefit/cost indicator may be higher than one.

5.4.3. Scenario 4.3: Penetration of solar water heaters

This specific scenario relates to the substitution of thermal energy for domestic hot water (DHW) generated by electricity-powered water heaters, by thermal energy generated by solar water heaters in residential and tertiary sector buildings. The analysis below examines the substitution of electric water heaters in typical buildings of each building category.

An economic analysis of investments and a cost-benefit analysis at community level are carried out.

The cost and benefit components that are taken into account in the cost-benefit analysis, are as follows:

(-) Operating costs of solar water heater: They include the cost of maintenance
(+) Operating benefit from the substitution of electricity for DHW: It includes the cost of electricity and the maintenance costs for the conventional electricity-fired heating system for DHW that are avoided
(-) External costs of solar water heater: They include the external costs of the electricity consumed (the amount that was not substituted) and relate to the impact on climate change, health, ecosystems, etc.

(+) External benefit from the substitution of electricity: It includes the external benefit from the substitution of electricity and relates to the impact on climate change, health, ecosystems, etc.

The assumptions of the specific analysis are cited in Annex II.

The results of the economic and cost-benefit analyses are presented in the following tables, and the amount of the existing funding gap that has to be covered for the investments to be economically viable is determined.

Table 16 – Results for solar water heating systems for DHW

Solar water heating for DHW	Economic analysis		Cost-benefit analysis			B/C variation	Economic aid rate
	FNPV (€)	FIRR (%)	ENPV (€)	EIRR (%)	B/C		%
Residence	€401	8 %	€123	7 %	1.10	1.10–1.24	9 %
Hospitals	€205 932	11 %	€192 944	12 %	1.63	1.63–1.88	N/A
Hotels	€16 996	9 %	€4 388	6 %	1.11	1.11–1.29	6 %

The variation in the benefit/cost indicator arises from the sensitivity analysis conducted regarding critical parameters for the purpose of obtaining more reliable results. Specifically, the parameters examined in the residential and tertiary sectors are as follows:

- **Sensitivity Analysis 1**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 2**: Higher price of electricity (15 % increase in the price of electricity relative to the baseline scenario)

It is observed, taking into account the results of the analysis, that penetration of solar water heaters is recommended for buildings in the residential sector, hotels and hospitals, as it has a benefit/cost indicator higher than one. It is also observed that the benefit/cost indicator is consistently higher than one for all critical parameters and relevant scenarios examined in the sensitivity analysis.

5.4.4. Scenario 4.4: Penetration of stand-alone biomass-fired boilers

This specific scenario relates to the substitution of thermal energy for heating, generated from conventional oil-fired boilers, with thermal energy for heating generated from biomass-fired boiler systems. The analysis below examines the substitution of conventional heating systems for each type of building.

An economic analysis of investments and a cost-benefit analysis at community level are carried out.

The cost and benefit components that are taken into account in the cost-benefit analysis, are as follows:

(-) Operating costs of biomass-fired boiler system: They include the cost of maintenance and the cost of fuel.
(+) Operating benefit from the substitution of heating oil: It includes the heating oil costs and the maintenance costs for the heating oil boiler that are avoided.
(-) External costs of biomass-fired boiler system: They include the external cost of the biomass consumed and relate to the impact on climate change, health, ecosystems, etc.
(+) External benefit from the substitution of heating oil: It includes the external benefit from the substitution of heating oil and relates to the impact on climate change, health, ecosystems, etc.

The assumptions of the specific analysis are cited in Annex II.

The results of the economic and cost-benefit analyses are presented in the following tables, and the amount of the existing funding gap that has to be covered for the investments to be economically viable is determined.

Table 17 – Results for biomass-fired boilers

Biomass-fired boilers	Economic analysis		Cost-benefit analysis			B/C variation	Economic aid rate
	FNPV (€)	**FIRR (%)**	**ENPV (€)**	**EIRR (%)**	**B/C**		**%**
Residence	€10 222	22 %	€3 588	14 %	1.34	1.25–1.63	N/A
Private office buildings	€8 528	18 %	€3 105	11 %	1.24	1.16–1.51	N/A
Public office buildings	€48 756	16 %	€11 593	9 %	1.17	1.10–1.43	N/A
Hospitals	€3 595 095	80 %	€1 641 431	53 %	1.86	1.68–2.28	N/A
Hotels	€47 892	26 %	€21 347	16 %	1.39	1.29–1.70	N/A
Schools	€64 941	34 %	€25 887	22 %	1.52	1.40–1.86	N/A

The variation in the benefit/cost indicator arises from the sensitivity analysis conducted regarding critical parameters for the purpose of obtaining more reliable results. Specifically, the parameters examined in the residential and tertiary sectors are as follows:

- **Sensitivity Analysis 1**: Higher price of heating oil (€0.75/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2025, EU Reference Scenario)
- **Sensitivity Analysis 2**: Higher price of heating oil (€0.85/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2030, EU Reference Scenario)
- **Sensitivity Analysis 3**: Higher biomass market price (€130/t compared to €110/t of the baseline scenario)
- **Sensitivity Analysis 4**: Lower biomass calorific value (3 200 kcal/kg compared to 3 500 kcal/kg)
- **Sensitivity Analysis 5**: Higher biomass calorific value (4 000 kcal/kg compared to 3 500 kcal/kg)
- **Sensitivity Analysis 6**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 7**: Lower system cost (30 % reduction of purchase cost relative to the baseline scenario cost)

It is observed, taking into account the results of the analysis, that penetration of biomass-fired boilers is recommended for all buildings in the residential and tertiary sectors, considering all economic and societal cost and benefit components, as reflected in the benefit/cost indicator, which is higher than one.

5.4.5. Scenario 4.5: Penetration of natural gas-fired co-generation

This scenario examines tertiary sector buildings. In that case, the operating benefit from the installation of a CHP system also includes the cost avoided through the termination of the existing conventional systems.

Furthermore, the size of the existing funding gap – for investments to become economically viable – is indicated.

The cost and benefit components that are taken into account in the cost-benefit analysis, are as follows:

(+) Income: Includes revenues from the sale of the electricity generated from the co-generation plant.

(-) Operating costs: They include the purchase cost of fuel and the co-generation plant maintenance cost.

(+) Operating benefit from the substitution of heating oil and electricity for the generation of DHW: Includes the cost of heating oil and electricity that is avoided.

(-) External costs of co-generation plant: They include the external cost of the co-generation plant and relate to the impact on climate change, health, ecosystems, etc.

The following tables summarise the results of the economic analysis and the cost-benefit analysis for the deployment, in the tertiary sector, of small- and medium-scale co-generation systems with an Internal Combustion Engine (IC engine) using natural gas as fuel.

Table 18 – Results for HECHP using natural gas as fuel

HECHP (IC engine fuelled with natural gas)	Economic analysis		Cost-benefit analysis			B/C variation	Economic aid rate
	FNPV (€)	FIRR (%)	ENPV (€)	EIRR (%)	B/C		%
Tertiary sector	-€12,567	8 %	€88 782	14 %	2.98	2.95–3.03	15 %

Industry

The study on the viability of replacing existing conventional systems for heating and domestic hot water with co-generation systems was carried out at the level of the individual installation and complex.

In that case, the operating benefit from the installation of a CHP system also includes the cost avoided through the termination of the existing conventional systems.

The study examined the economic viability of investments, taking into account the annual operating hours of the system, as well as the fuel used by the conventional systems and the co-generation systems.

The economic potential of CHP at the level of the individual installation is identified in the replacement of an existing heat-generation system fired with heating oil with a co-generation system fired with natural gas.

The table below presents the results relating to the economic potential of CHP in the industrial sector.

Table 19 – Results for HECHP in the industrial sector

Operating hours	Indicator	Internal combustion engine	Micro-turbines	Fuel cells	Other types of technology
6 500	FNPV	X	X	X	√
	FIRR	X	X	X	X
	BC	X	X	X	√
	DPB	X	X	X	X
7 000	FNPV	√	X	X	√
	FIRR	X	X	X	√
	BC	X	X	X	√
	DPB	X	X	X	√
7 500	FNPV	√	X	X	√
	FIRR	√	X	X	√
	BC	√	X	X	√
	DPB	√	X	X	√
8 000	FNPV	√	X	X	√
	FIRR	√	X	X	√
	BC	√	X	X	√
	DPB	√	X	X	√

5.5. Scenario 5: Penetration of heat pumps compared to NG-fired boilers for stand-alone facilities

This specific scenario relates to the substitution of thermal energy both for space heating (Scenario 5.1) and for combining space heating and DHW (Scenario 5.2), generated from an NG-fired boiler, with thermal energy generated from heat pumps in residential and tertiary sector buildings.

- **Scenario 5.1:** Substitution of NG-fired boiler with air-to-water heat pump for space heating
- **Scenario 5.2:** Substitution of NG-fired boiler with air-to-water heat pump for space heating and DHW

The analysis below examines the substitution of NG-fired boilers in typical buildings for each building category. An economic analysis of investments and a cost-benefit analysis at community level are carried out.

The cost and benefit components that are taken into account in the cost-benefit analysis, are as follows:

(-) Operating costs of heat pumps: They include the cost of electricity consumed and the maintenance costs for air-heated heat pumps.

(+) Operating benefit from the substitution of natural gas: It includes the natural gas costs and NG-fired boiler maintenance costs which are avoided.

(-) External cost of heat pumps: It includes the external cost of the electricity consumed and relates to the impact on climate change, health, ecosystems, etc.

(+) External benefit from the substitution of natural gas: It includes the external benefit from the substitution of natural gas and relates to the impact on climate change, health, ecosystems, etc.

The assumptions of the specific analysis are cited in Annex IV. The results of the economic and cost-benefit analyses are presented in the following tables, and the amount of the existing funding gap that has to be covered for the investments to be economically viable is determined.

Table 20 – Results regarding the substitution of NG-fired boiler with air-to-air heat pumps for space heating

Heat Pumps Air-to-air	Economic analysis		Cost-benefit analysis			B/C variation	Economic aid rate
	FNPV (€)	FIRR (%)	ENPV (€)	EIRR (%)	B/C		%
Residence	-€2 323	-5 %	-€545	2 %	0.86	0.86–1.54	46 %
Private office buildings	-€4 557	-16 %	-€3 052	-7 %	0.71	0.71–1.27	67 %
Public office buildings	-€32 655	N/A	-€23 406	-15 %	0.63	0.63–1.15	6 %
Hospitals	€11 545	5 %	€331 417	22 %	1.12	1.12–1.98	N/A
Hotels	-€16 600	N/A	-€9 265	-5 %	0.78	0.78–1.41	N/A
Schools	-€13 849	-13 %	-€3 630	0 %	0.87	0.87–1.56	N/A

Table 21 – Results regarding the substitution of NG-fired boiler with air-to-water heat pumps for space heating

Heat Pumps Air-to-water	Economic analysis		Cost-benefit analysis			B/C variation	Economic aid rate
	FNPV (€)	**FIRR (%)**	**ENPV (€)**	**EIRR (%)**	**B/C**		**%**
Residence	-€5 542	-13 %	-€3 064	-6 %	0.68	0.68–1.22	60 %
Private office buildings	-€8 403	N/A	-€6 724	N/A	0.56	0.56–1.01	6 %
Public office buildings	-€58 170	N/A	-€43 598	N/A	0.49	0.49–0.90	55 %
Hospitals	-€250 781	-5 %	€129 494	10 %	1.00	1.00–1.79	0 %
Hotels	-€22 443	-14 %	-€22 114	-14 %	0.63	0.63–1.15	9 %
Schools	-€26 965	N/A	-€13 726	-9 %	0.72	0.72–1.30	0 %

Table 22 – Results regarding the substitution of NG-fired boiler with air-to-water heat pumps for space heating and DHW

Air-to-water heat pumps	Economic analysis		Cost-benefit analysis			B/C variation	Economic aid rate
	FNPV (€)	FIRR (%)	ENPV (€)	EIRR (%)	B/C		%
Residence	-€3 245	-2 %	-€1 264	2 %	0.91	0.91–1.61	54 %
Private office buildings	-€6 912	-12 %	-€5 536	-6 %	0.68	0.68–1.22	78 %
Public office buildings	-€56 111	N/A	-€37 105	-10 %	0.60	0.60–1.10	87 %
Hospitals	-€72 638	2 %	€298 981	12 %	1.13	1.13–2.00	0 %
Hotels	-€19 148	-6 %	-€8 552	1 %	0.90	0.90–1.63	0 %
Schools	-€9 677	0 %	-€1 953	4 %	0.97	0.97–1.54	73 %

The variation in the benefit/cost indicator arises from the sensitivity analysis conducted regarding critical parameters for the purpose of obtaining more reliable results. Specifically, the parameters examined in the residential and tertiary sectors are as follows:

- **Sensitivity Analysis 1:** Higher price of natural gas (€0.69/m3, in contrast with the €0.53/m3 of the baseline scenario – Projected increase in NG price for 2025, EU Reference Scenario)
- **Sensitivity Analysis 2**: Higher price of natural gas (€0.80/m3, in contrast with the €0.53/m3 of the baseline scenario – Projected increase in NG price for 2030, EU Reference Scenario)
- **Sensitivity Analysis 3**: Higher system efficiency (COP 6 instead of the COP 4.3 of the baseline scenario)
- **Sensitivity Analysis 4**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 5**: Lower system cost (30 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 6**: Combination of parameters from Sensitivity Analyses 2, 3 & 5 (NG price: €0.80/m3, 30 % reduction in purchase cost and COP 6)

Taking into account the results of the analysis, it is observed that, at the moment, the penetration of heat pumps compared to NG-fired boilers is not recommended for any type of building other than hospitals, considering all economic and societal cost and benefit components, as it has a benefit/cost indicator lower than one.

However, in certain cases, and in light of the results of the sensitivity analysis – more specifically, combined Scenario 6 of the sensitivity analysis, wherein the cost of heat pumps decreases at the same time that their efficiency increases; furthermore, the price of natural gas increases, in line with the EU Reference scenario's projection for a price increase in 2030 –, the benefit/cost indicator is higher than one. Therefore, it is understood that from 2030 onwards the benefit/cost indicator will be higher than one, making the substitution under consideration advantageous at community level. However, for certain types of buildings, such as schools, office buildings and residences, economic aid will be required for the technical solution to be economically viable.

5.6. Scenario 6: Penetration of heat pumps compared to biomass-fired boilers for stand-alone facilities

This specific scenario relates to the substitution of thermal energy for space heating, generated from a biomass-fired boiler, with thermal energy generated from heat pumps in residential sector buildings.

The analysis below examines the substitution of biomass-fired boilers for residential buildings. An economic analysis of investments and a cost-benefit analysis at community level are carried out.

The cost and benefit components that are taken into account in the cost-benefit analysis, are as follows:

(-) Operating costs of heat pumps: They include the cost of electricity consumed and the maintenance costs for air-heated heat pumps.

(+) Operating benefit from the substitution of biomass: It includes the biomass costs and biomass-fired boiler maintenance costs which are avoided.

(-) External cost of heat pumps: It includes the external cost of the electricity consumed and relates to the impact on climate change, health, ecosystems, etc.

(+) External benefit from the substitution of biomass: It includes the external benefit from the substitution of biomass and relates to the impact on climate change, health, ecosystems, etc.

The results of the economic and cost-benefit analyses are presented in the following tables.

The assumptions of the specific analysis are cited in Annex IV.

The results of the economic and cost-benefit analyses are presented in the following tables, and the amount of the existing funding gap that has to be covered for the investments to be economically viable is determined.

Table 23 – Results regarding the substitution of biomass-fired boiler with air-to-water heat pumps for space heating

Air-to-water heat pumps	Economic analysis		Cost-benefit analysis			B/C variation	Economic aid rate
	FNPV (€)	FIRR (%)	ENPV (€)	EIRR (%)	B/C		%
Residence	-€5 698	N/A	-€3 904	-11 %	0.62	0.62–1.03	86 %

The variation in the benefit/cost indicator arises from the sensitivity analysis conducted regarding critical parameters for the purpose of obtaining more reliable results. Specifically, the parameters examined in the residential sector are as follows:

- **Sensitivity Analysis 1:** Higher biomass price (€130/t compared to the €110/t of the baseline scenario)

- **Sensitivity Analysis 2**: Higher biomass price (€150/t compared to the €110/t of the baseline scenario)
- **Sensitivity Analysis 3**: Higher system efficiency (COP 6 instead of the COP 4.3 of the baseline scenario)
- **Sensitivity Analysis 4**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 5**: Lower system cost (30 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 6**: Combination of parameters from Sensitivity Analyses 2, 3 & 5 (biomass price: €150/t, 30 % reduction in purchase cost and COP 6)

Taking into account the results of the analysis, it is observed that, at the moment, the penetration of heat pumps compared to biomass-fired boilers is not recommended for residences, considering all economic and societal cost and benefit components, as it has a benefit/cost indicator lower than one.

However, in certain cases, and in light of the results of the sensitivity analysis – more specifically, combined Scenario 6 of the sensitivity analysis, wherein the cost of heat pumps decreases at the same time that their efficiency increases; furthermore, the price of biomass follows an upward trend –, the benefit/cost indicator is higher than one. Therefore, it is understood that from 2035 onwards the benefit/cost indicator will be higher than one, making the substitution under consideration advantageous at community level. However, economic aid will be required for the technical solution to be economically viable.

6. Economic potential

This section calculates, for each technology, the economic potential for efficient space heating and DHW generation. The additional policies and measures scenario (WAM) of the NECP is used as the baseline scenario for the evolution of the demand for useful energy through 2050, as well as covering such demand using various fuels and technologies, and an alternative scenario is elaborated for meeting such demand using various technologies, taking into account the results of the cost-benefit analysis of Chapter 5. Please note that the WAM scenario takes into account the energy-efficient upgrading of building shells and the replacement of existing systems by new, more energy-efficient, ones; as a result, this study focuses only on the substitution of the systems.

The economic potential is calculated for space heating and DHW generation for the residential and tertiary sectors. Below is a description of the main assumptions used in developing the alternative scenario.

Alternative scenario – Main assumptions:

- **The share of oil in space heating in the residential and tertiary sectors begins to decrease from 2025 onwards and is reduced to zero in 2050**.

This decision is taken based on the fact that the cost-benefit analysis for stand-alone systems, in particular the substitution of oil-fired boilers for space heating with air-to-air and air-to-water heat pumps (Scenario 4.1) and the substitution of oil-fired boilers with biomass-fired boilers (Scenario 4.4), has a cost/benefit ratio higher than one. Indeed the sensitivity analysis shows that as the cost of oil increases (price projection from the EU reference scenario 2020), the cost of acquiring new systems decreases and their efficiency increases, the B/C indicator value is consistently higher than one.

- **The share of natural gas in space heating begins to decrease as of 2030 and is reduced to zero by 2050.**

This decision is compatible with the results of the cost-benefit analysis of Scenario 5.1 regarding the substitution of NG-fired boilers with heat pumps for space heating. Although the results show that, at the present time (2020), the penetration of heat pumps compared to NG-fired boilers is not recommended for any type of building other than hospitals, it seems that, in certain cases, and in light of the results of the sensitivity analysis – more specifically, combined Scenario 6 of the sensitivity analysis, wherein the cost of heat pumps decreases at the same time that their efficiency increases; furthermore, the price of natural gas increases, in line with the EU Reference scenario’s projection for a price increase in 2030 –, the benefit/cost indicator is higher than one. Therefore, it is understood that from 2030 onwards the benefit/cost indicator will be higher than one, making the substitution under consideration advantageous at community level. However, for certain types of buildings, such as schools, office buildings and residences, economic aid will be required for the technical solution to be economically viable.

- **The share of electricity in DHW begins to decrease as of 2025, as it is replaced by solar water heaters, and in 2050 it is limited to approximately 55 % compared to WAM.**

This decision is compatible with the results of the cost-benefit analysis of Scenario 4.3, concerning the substitution of electric water heaters with solar ones, as their cost/benefit indicator is higher than one.

- **In the tertiary sector, the share of natural gas in DHW begins to decrease as of 2030 and is reduced to zero by 2050.**

This decision is compatible with the results of the cost-benefit analysis of Scenario 5.2 regarding the substitution of NG-fired boilers with heat pumps for space heating and DHW generation. Although the results show that, at the present time (2020), the penetration of heat pumps compared to NG-fired boilers is not recommended for any type of building other than hospitals, it seems that, in certain cases, and in light of the results of the sensitivity analysis – more specifically, combined Scenario 6 of the sensitivity analysis, wherein the cost of heat pumps decreases at the same time that their efficiency increases; furthermore, the price of natural gas increases, in line with the EU Reference scenario's projection for a price increase in 2030 –, the benefit/cost indicator is higher than one. Therefore, it is understood that from 2030 onwards the benefit/cost indicator will be higher than one, making the substitution under consideration advantageous at community level.

- **In the residential sector, with regard to space heating with the use of biomass, there is a progressive transition from inefficient systems (e.g. space heaters, open fireplaces) toward efficient biomass-fired systems (e.g. biomass-fired boilers, energy-efficient fireplaces).**

The following sections present the economic potential results in the residential and tertiary sectors.

6.1 Residential sector

Table 24 – Baseline Scenario[5] – Final energy consumption (GWh) – Residential sector – Space heating

	2020	2025	2030	2035	2040	2045	2050
Heat pumps	1 317	3 020	3 749	3 786	3 710	3 517	3 146
Bioenergy	9 482	9 772	9 981	8 688	9 628	8 877	8 341
Bioenergy - boilers	906	1 736	2 086	1 947	2 176	2 428	2 572
Bioenergy - other systems	8 576	8 036	7 895	6 741	7 451	6 449	5 769
Electricity	4 215	4 502	4 043	3 608	3 051	2 943	2 678
Electricity - heat pumps	1 138	2 130	1 768	1 838	1 624	1 543	1 334
Electricity - other systems	3 062	2 372	2 275	1 770	1 427	1 400	1 344
Natural gas	4 015	5 694	5 760	6 397	6 071	5 967	5 583
Geothermal energy	46	0	0	0	0	0	0
District heating	498	479	457	433	410	384	357
Oil	14 225	7 360	5 022	3 991	2 338	1 172	421
Solar	0	0	0	0	0	0	0
TOTAL	**33 811**	**30 827**	**29 011**	**26 902**	**25 207**	**22 858**	**20 526**

Table 25 – Baseline Scenario – Final energy consumption (GWh) – Residential sector – DHW

	2020	2025	2030	2035	2040	2045	2050
Heat pumps	0	0	0	0	0	0	0
Bioenergy	2	30	19	0	0	0	0
Electricity	711	815	850	644	646	640	559
Natural gas	53	110	275	215	128	33	0
Geothermal energy	0	0	0	0	0	0	0
District heating	0	1	0	0	0	0	0
Oil	29	11	10	3	0	0	0
Solar	3 271	3 351	4 382	3 951	4 292	4 654	5 033
TOTAL	**4 065**	**4 318**	**5 537**	**4 813**	**5 066**	**5 327**	**5 592**

[5] NECP scenario of additional measures and policies (WAM).

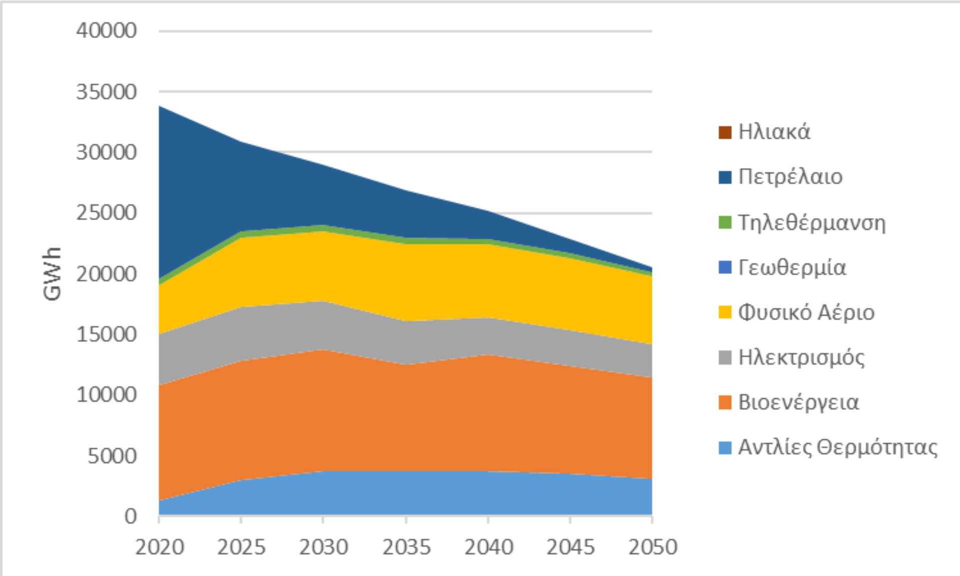
Table 26 – Alternative Scenario – Final energy consumption (GWh) – Residential sector – Space heating

	2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heat pumps	1 317	3 718	5 013	5 958	6 312	6 678	6 321
Bioenergy	9 482	9 937	9 798	8 126	6 692	5 749	5 372
Bioenergy - boilers	906	2 140	2 637	2 604	2 638	2 672	2 665
Bioenergy - other systems	8 576	7 796	7 161	5 521	4 054	3 077	2 707
Electricity	4 215	4 968	4 745	4 643	4 223	4 260	4 001
Electricity - heat pumps	1 138	2 595	2 470	2 873	2 796	2 860	2 657
Electricity - other systems	3 077	2 391	1 767	1 647	1 291	1 402	1 324
Natural gas	4 015	5 694	5 184	4 478	2 732	895	0
Geothermal energy	46	0	0	0	0	0	0
District heating	498	479	457	433	410	384	357
Oil	14 225	5 520	2 511	998	234	59	0
Solar	0	0	0	0	0	0	0
TOTAL	**33 811**	**30 315**	**27 707**	**24 634**	**20 602**	**18 024**	**16 051**

Table 27 – Alternative Scenario – Final energy consumption (GWh) – Residential sector – DHW

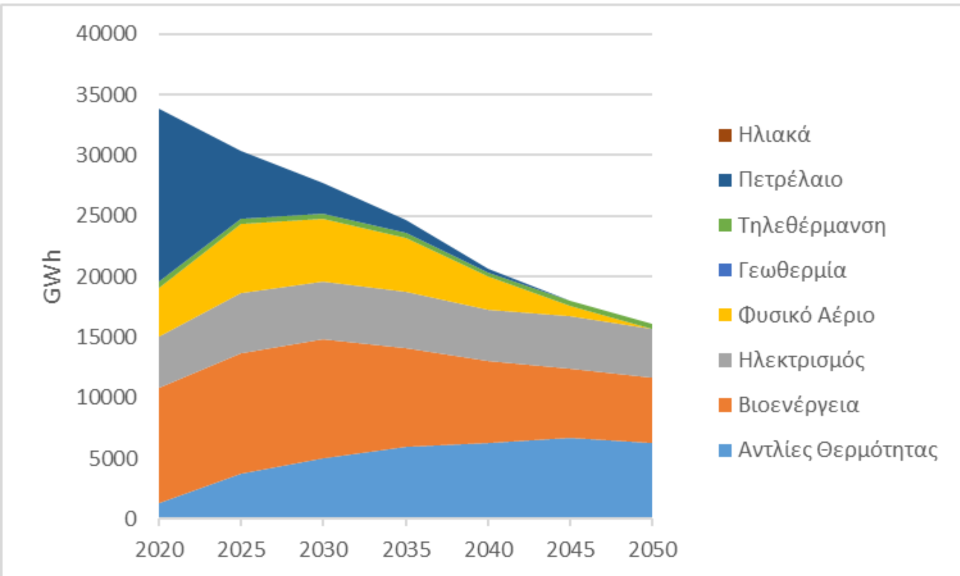
	2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heat pumps	0	0	0	0	0	0	0
Bioenergy	2	30	19	0	0	0	0
Electricity	711	652	595	419	387	365	308
Natural gas	53	110	275	215	128	33	0
Geothermal energy	0	0	0	0	0	0	0
District heating	0	1	0	0	0	0	0
Oil	29	11	10	3	0	0	0
Solar	3 271	3 514	4 637	4 177	4 550	4 929	5 284
TOTAL	**4 065**	**4 318**	**5 537**	**4 813**	**5 066**	**5 327**	**5 592**

Graph 18 – NECP Scenario (WAM) – Final energy consumption in the residential sector – Space heating



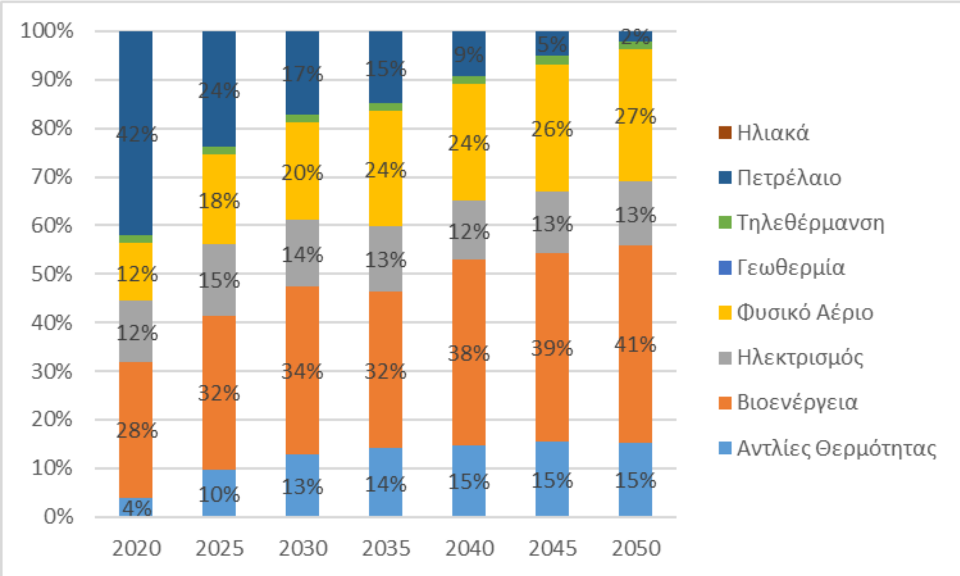
	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

Graph 19 – Alternative scenario – Final energy consumption in the residential sector – Space heating



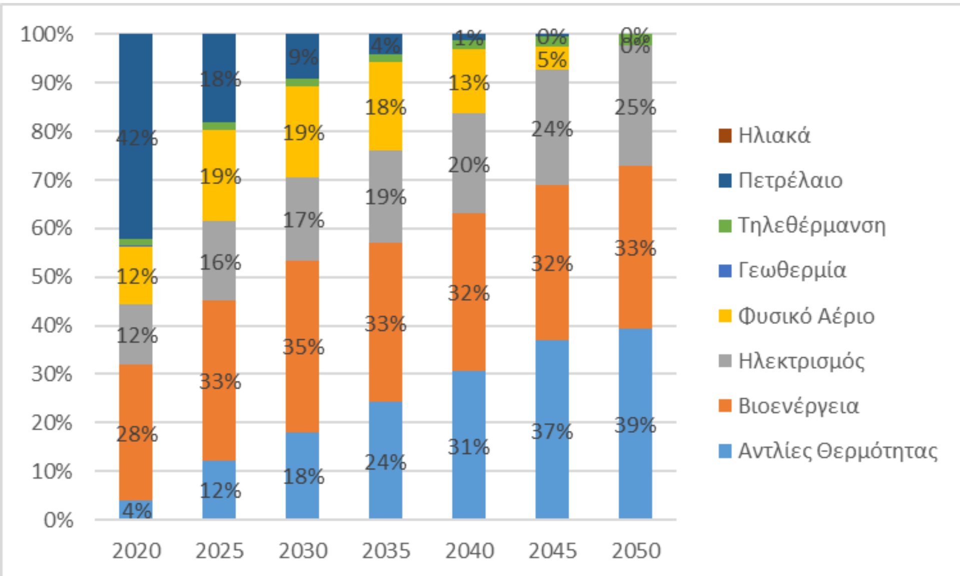
	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

Graph 20 – NECP Scenario (WAM) – Percentage of final energy consumption in the residential sector – Space heating



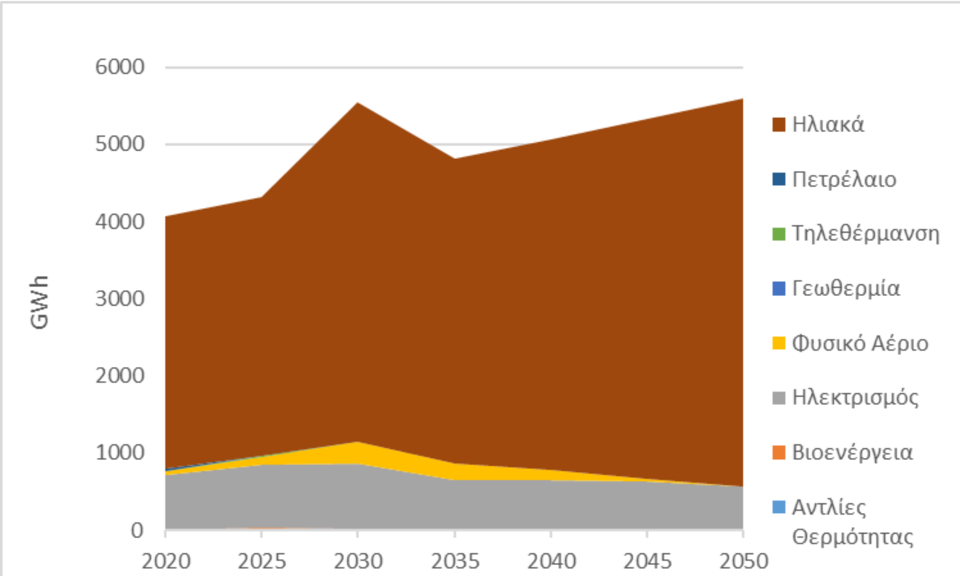
	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

Graph 21 – Alternative scenario – Percentage of final energy consumption in the residential sector – Space heating



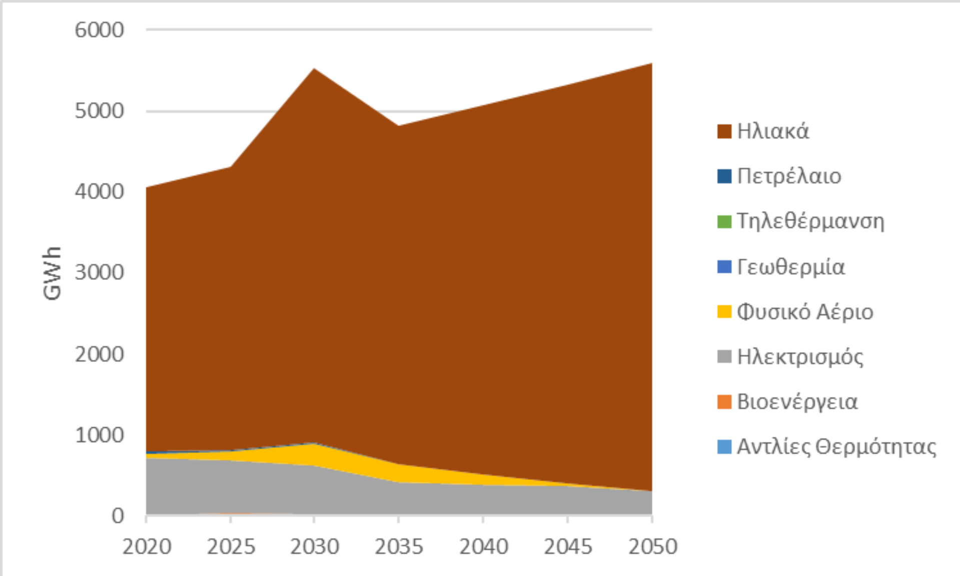
	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

Graph 22 – NECP Scenario (WAM) – Final energy consumption in the residential sector – DHW



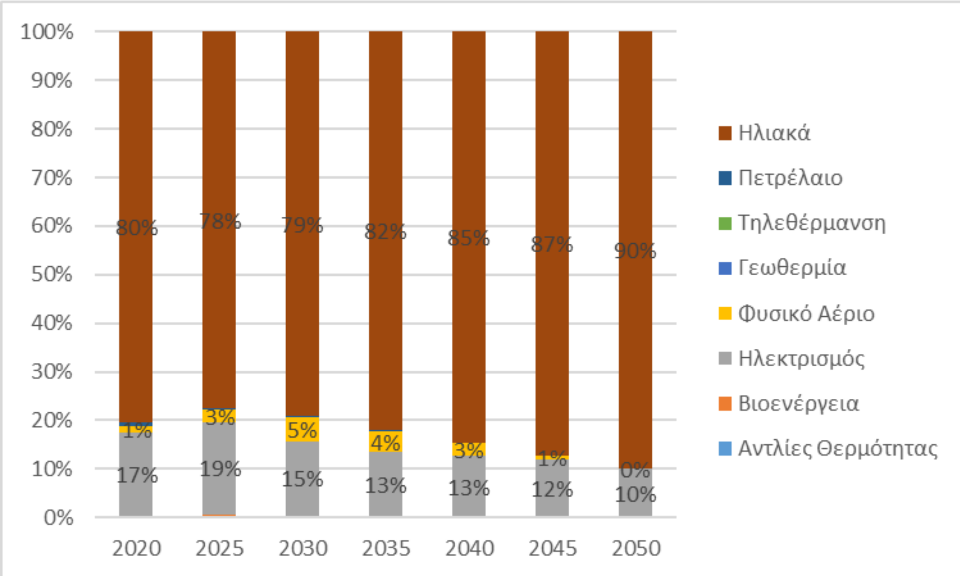
	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

Graph 23 – Alternative scenario – Final energy consumption in the residential sector – DHW



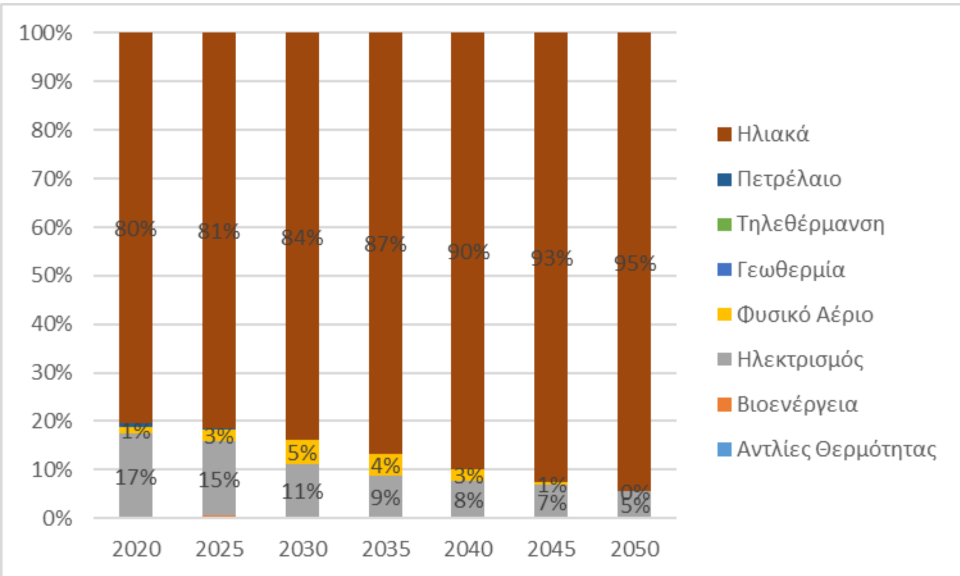
	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

Graph 24 – NECP Scenario (WAM) – Percentage of final energy consumption in the residential sector – DHW



	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

Graph 25 – Alternative scenario – Percentage of final energy consumption in the residential sector – DHW



	■ Solar
	■ Oil
	■ District heating
	■ Geothermal energy
	■ Natural gas
	■ Electricity
	■ Bioenergy
	■ Heat pumps

6.2 Tertiary sector

Table 28 – Baseline Scenario[6] – Final energy consumption (GWh) – Space heating

	2020	2025	2030	2035	2040	2045	2050
Heat pumps	3 175	4 829	6 323	7 062	7 822	8 592	9 716
Bioenergy	100	94	94	75	66	44	26
Electricity	5 227	5 313	5 387	5 480	5 569	5 660	5 925
Natural gas	1 437	1 198	1 029	896	788	703	622
Geothermal energy	0	0	0	0	0	0	0
District heating	0	0	0	0	0	0	0
Oil	1 836	1 572	1 296	1 084	863	630	376
Solar	0	0	0	0	0	0	0
TOTAL	**11 775**	**13 006**	**14 129**	**14 597**	**15 109**	**15 629**	**16 665**

Table 29 – Baseline Scenario – Final energy consumption (GWh) – DHW

	2020	2025	2030	2035	2040	2045	2050
Heat pumps	0	0	0	0	0	0	0
Bioenergy	0	0	28	0	0	0	0
Electricity	1 584	916	833	699	594	424	209
Natural gas	339	1 214	1 325	1 512	1 647	1 858	2 135
Geothermal energy	0	0	0	0	0	0	0
District heating	0	0	0	0	0	0	0
Oil	15	15	7	3	0	0	0
Solar	170	283	397	510	623	737	850
TOTAL	**2 109**	**2 428**	**2 589**	**2 724**	**2 864**	**3 019**	**3 193**

[6] NECP scenario of additional measures and policies (WAM).

Alternative scenario

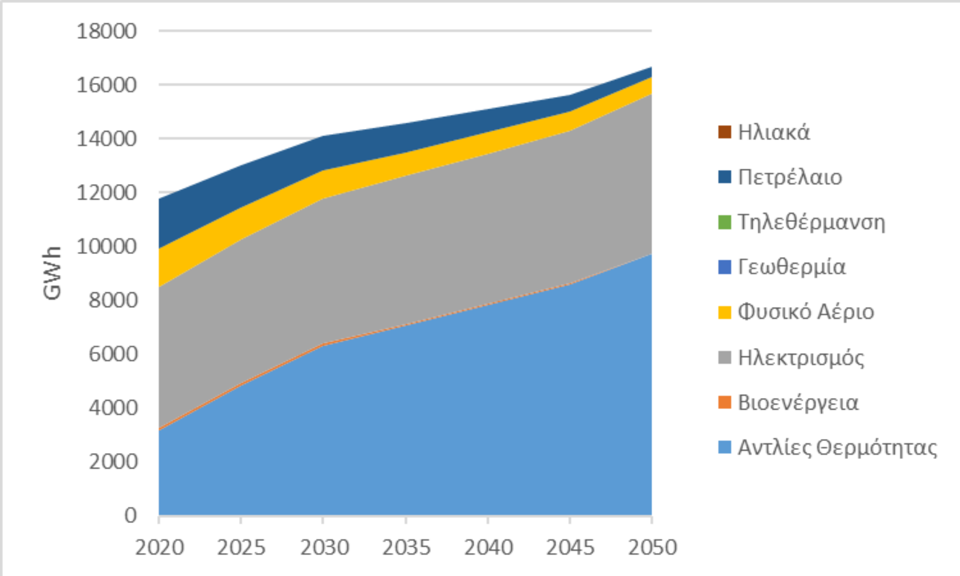
Table 30 – Alternative Scenario – Final energy consumption (GWh) – Space heating

	2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heat pumps	3 175	5 032	6 714	7 605	8 419	9 153	10 219
Bioenergy	100	94	94	75	66	44	26
Electricity	5 227	5 448	5 604	5 738	5 838	5 894	6 134
Natural gas	1 437	1 198	926	672	433	246	62
Geothermal energy	0	0	0	0	0	0	0
District heating	0	0	0	0	0	0	0
Oil	1 836	1 179	648	271	86	31	0
Solar	0	0	0	0	0	0	0
	11 775	**12 951**	**13 987**	**14 362**	**14 843**	**15 368**	**16 442**

Table 31 – Alternative Scenario – Final energy consumption (GWh) – DHW

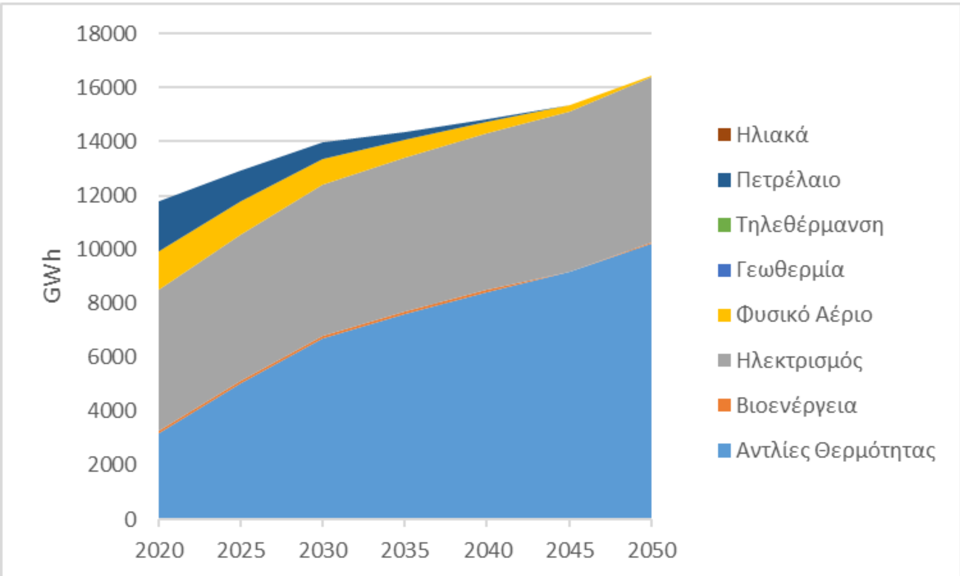
	2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Heat pumps	0	0	73	334	545	821	1 178
Bioenergy	0	0	28	0	0	0	0
Electricity	1 584	732	623	613	602	584	606
Natural gas	339	1 214	1 193	907	659	372	0
Geothermal energy	0	0	0	0	0	0	0
District heating	0	0	0	0	0	0	0
Oil	15	15	7	3	0	0	0
Solar	170	466	646	755	861	919	944
	2 109	**2 428**	**2 570**	**2 612**	**2 667**	**2 695**	**2 728**

Graph 26 – NECP Scenario (WAM) – Final energy consumption in the tertiary sector – Space heating



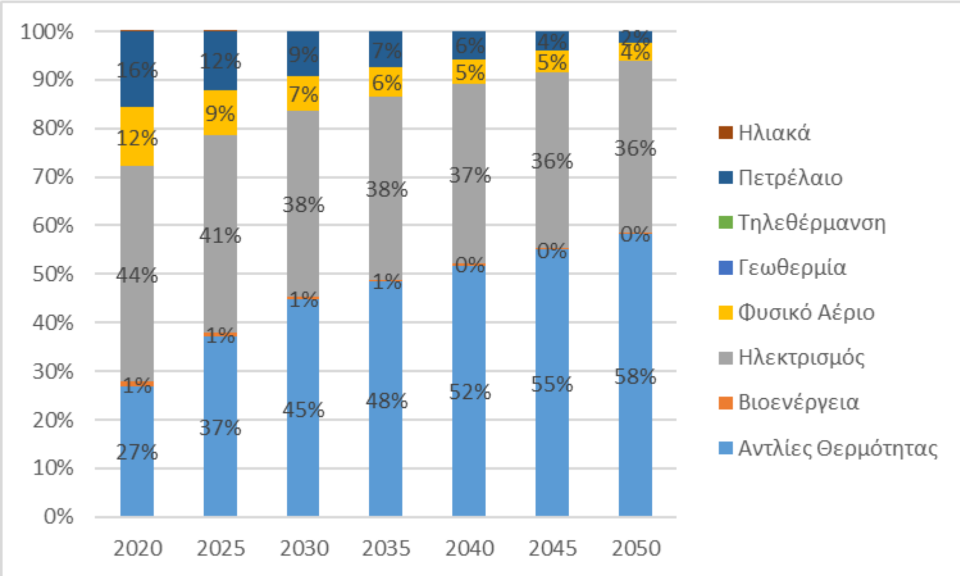
	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

Graph 27 – Alternative scenario – Final energy consumption in the tertiary sector – Space heating



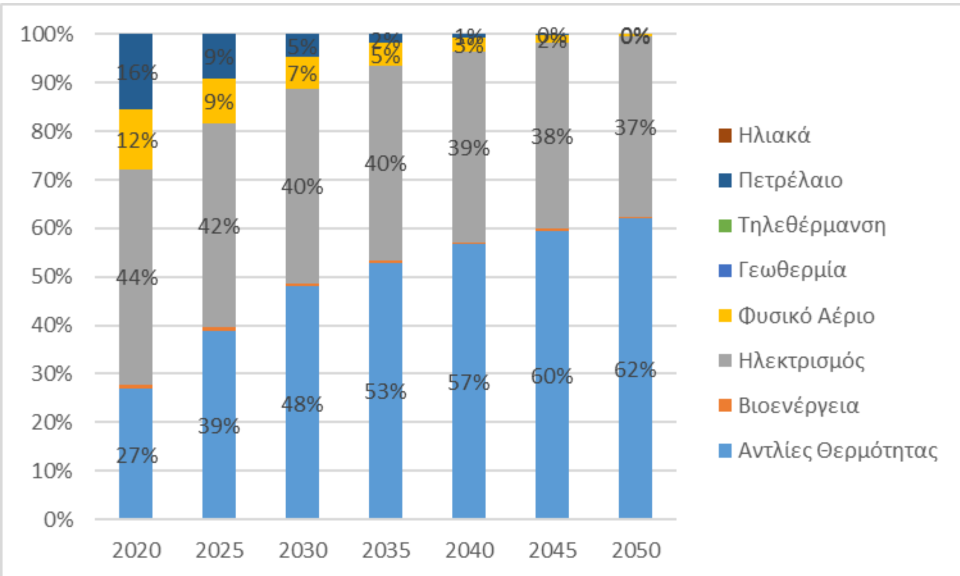
	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

Graph 28 – NECP Scenario (WAM) – Percentage of final energy consumption in the tertiary sector – Space heating



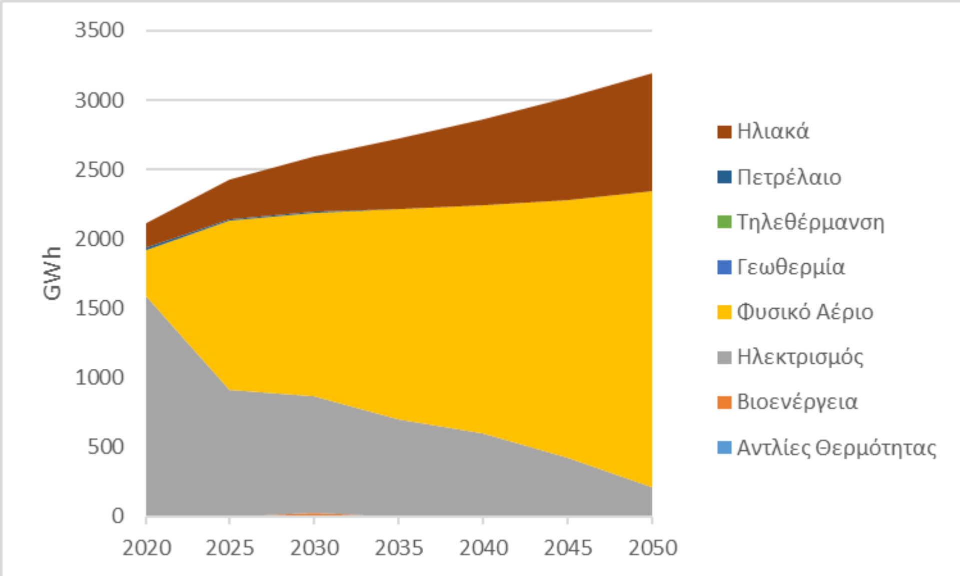
	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

Graph 29 – Alternative scenario – Percentage of final energy consumption in the tertiary sector – Space heating



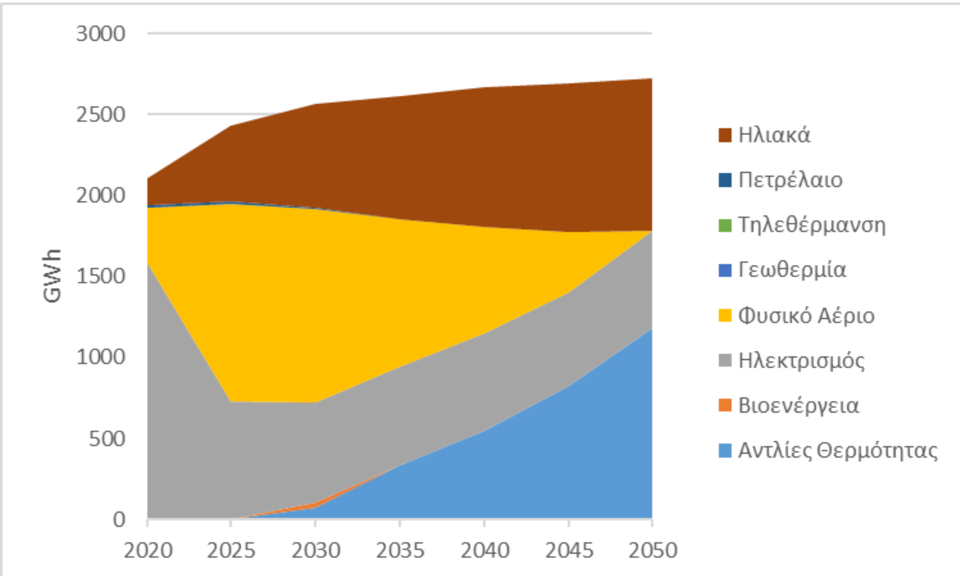
	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

Graph 30 – NECP Scenario (WAM) – Final energy consumption in the tertiary sector – DHW



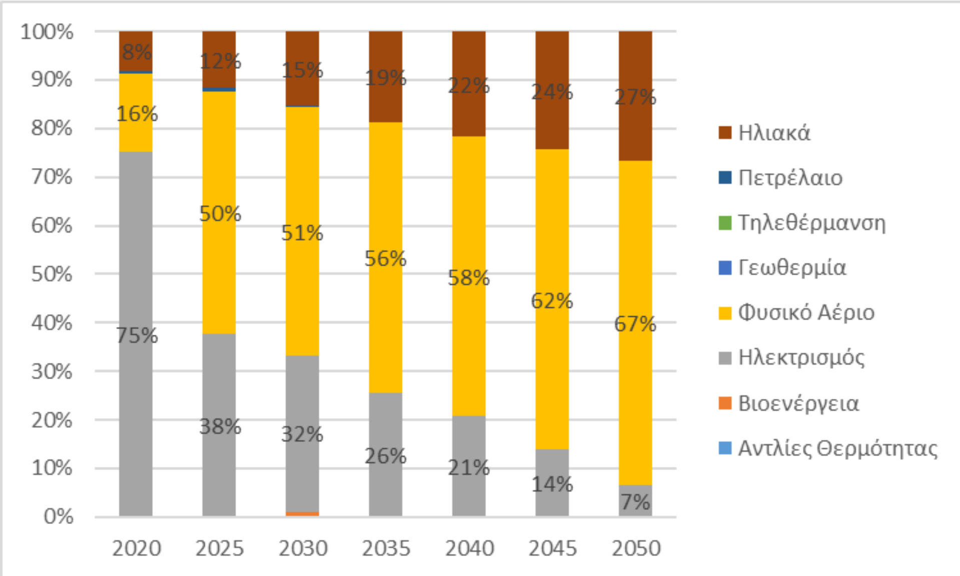
	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

Graph 31 – Alternative scenario – Final energy consumption in the tertiary sector – DHW



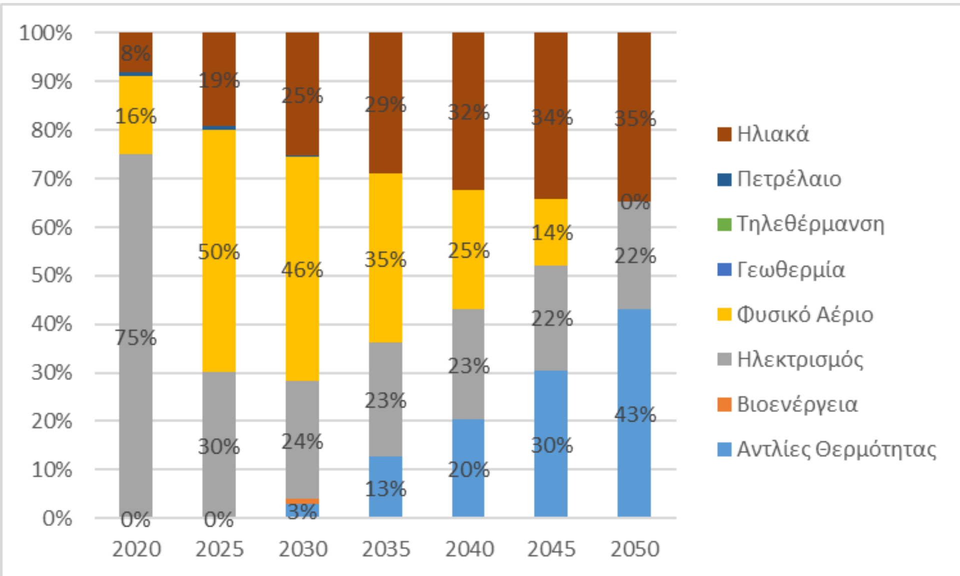
	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

Graph 32 – NECP Scenario (WAM) – Percentage of final energy consumption in the tertiary sector – DHW



	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

Graph 33 – Alternative scenario – Percentage of final energy consumption in the tertiary sector – DHW



	Solar
	Oil
	District heating
	Geothermal energy
	Natural gas
	Electricity
	Bioenergy
	Heat pumps

7. Potential new strategies and policy measures

This chapter describes new measures and strategies that must be implemented for heating and cooling, at a reasonable cost, to benefit society. However, it is worth mentioning that the difficulty in finding data regarding the cooling sector, including district cooling (as it has not been implemented in Greece yet) makes it hard to identify the cooling and district cooling potential and limits the ability to identify and implement additional policy measures.

Furthermore, the need for cooling and district cooling in Greece is relatively small compared to the need for heating and district heating. Therefore, this subchapter focuses on initiatives for a better approach regarding the socioeconomic potential for efficient heating and district heating.

The following is necessary for establishing new strategies concerning heating/cooling and district heating / district cooling:

- They must be based on a thorough assessment of the characteristics of the existing building stock.
- The decisions regarding the establishment of new infrastructure must be clear and they must include unambiguous timetables for promoting new infrastructure and gradually phasing out fossil fuels in heating.
- Communication and awareness-raising activities must be included in the duty to update consumers regarding imminent changes and what those mean for them.
- Incentives and funding mechanisms must be established to support the transition to heating and cooling with a low carbon footprint.
- Special aid for low- and middle-range income must be provided for.
- It must be ensured that consumers have access to a specialised workforce of installers and advisers, who will be able to provide them with reliable advice on which system is the best, and that they can have it installed as appropriate.
- **Clearer legislation concerning cooling / district cooling:** Clearer regulations must be adopted regarding official approval, by the competent authorities, for cooling / district cooling projects. These regulations must be adapted as appropriate to prove that a cooling / district cooling project is more energy-efficient, according to the definition of efficient cooling / district cooling of the Energy Efficiency Directive. This specific arrangement is expected to equip municipalities with an important tool for handling approvals for cooling / district cooling projects.
- **Data collection regarding cooling / district cooling:** As mentioned above, in Greece there is limited knowledge on and development of the cooling / district cooling sector. The companies engaged in cooling / district cooling projects across Greece must collect and publish more extensively any data regarding their projects, including turnover, fuel consumption, emissions, coverage of cooling / district cooling needs, etc. Such data is considered necessary so that additional measures and policies may be suggested subsequently for the further development of the domestic cooling / district cooling sector.

The proposed new policy measures regarding heating / district heating are summarised as follows:

Table 32 – Envisaged policy measures for the period 2021–2030 concerning heating and cooling

Policy measure	Key objective of policy	Relevant Energy Union dimension	Implementation period	Implementation status
M11	Measures to reduce emissions in the tourism sector	Decarbonisation	2021–2030	Envisaged
M12	Development of smart networks and promotion of smart models and sustainable cities	Decarbonisation	2021–2030	Envisaged
M12	Support for the development of RES energy projects by energy communities *inter alia* through specialised funding tools	Decarbonisation, RES generation	2020–2030	Envisaged
M13	Reform of electricity market regulatory framework to allow for participation of decentralised energy ventures	Decarbonisation, RES generation	2020–2030	Envisaged
M17	New Regulation on the Energy Performance of Buildings	Decarbonisation, RES generation	2019–2030	Envisaged
M19	Financial tools in the context of the new programming period	Decarbonisation, RES generation	2021–2027	Envisaged
M21	Use of tax incentives for installations in the residential and tertiary sectors	Decarbonisation, RES generation	2020–2030	Envisaged
M22	Development of regulatory framework for the generation of thermal energy from RES and for biomethane injection into the NG network	Decarbonisation, RES generation	2020–2030	Envisaged
M23	Development of supply chains for residual biomass / biodegradable materials and support for the development and implementation of optimum environmental and energy-efficient bioenergy applications	Decarbonisation, RES generation	2020–2030	Envisaged
M24	Utilisation of power generation from RES for heating/cooling and transport, and for operating storage systems	Decarbonisation, RES generation	2020–2030	Envisaged
M29	Funding programmes to promote HECHP, district heating / district cooling in the framework of the new programming period	Energy efficiency	2016–2030	Envisaged
M31	Promotion of innovative smart city models using advanced technologies	Energy efficiency	2021–2030	Envisaged
M35	Promotion of centralised systems for heat generation and distribution at the level of Industrial and Business Areas (IBA)	Energy efficiency	2021–2030	Envisaged
M17	Energy upgrade of residential buildings housing energy-vulnerable households, and promoting the establishment of RES plants to cover their energy needs	Internal energy market	2021–2030	Envisaged

Source: NECP, December 2019

- **Measures to reduce emissions in the tourism sector**

This measure includes all measures for achieving an energy transition in the tourism sector, both regarding sustainable tourism development and plans for destination management, and promoting the use of RES and actions to improve energy efficiency in tourist accommodation establishments.

- **Development of smart networks and promotion of smart models and sustainable cities**

This measure aims to promote the ‘smart and sustainable cities’ models based on a high penetration of clean energy technologies combined with the use of advanced information and communication technologies. Smart meters and smart networks will constitute a key part of such plans, allowing for monitoring and managing the large volume of information required for their harmonious operation, which will significantly help final consumers, at city level, to use energy rationally. In combination with the new regulatory framework for the demand response mechanism and energy communities, the role of cities and citizens in the transition, and ultimately the restructuring of the energy sector, is expected to be promoted significantly. Additionally, the use of ‘smart’ applications is also intertwined with urban regeneration, aiming primarily to improve the residents’ standard of living and the conditions in which businesses operate.

- **Support for the development of RES energy projects by energy communities *inter alia* through specialised funding tools**

This measure aims to strengthen the role of local communities and consumers; therefore, these ventures will operate with the support of specific tools.

- **Reform of electricity market regulatory framework to allow for participation of decentralised energy ventures**

This measure aims to initiate necessary adjustments to allow for participation of decentralised energy ventures from energy communities.

- **New Regulation on the Energy Performance of Buildings**

This measure aims to ensure greater penetration of RES applications in the building sector by incorporating in the New Regulation on the Energy Performance of Buildings the relevant projections for nearly zero-energy buildings, taking into account techno-economic viability criteria.

- **Financial tools in the context of the new programming period**

This measure aims to utilise the financial tools available in the context of the new programming period and the corresponding Operational Programmes so as to promote the economically optimal RES systems per final consumer category, also taking into account contribution to attaining the corresponding objective.

- **Use of tax incentives for installations in the residential and tertiary sectors**

This measure aims to develop a special tax incentive scheme for the installation of RES systems for heating and cooling in the residential and tertiary sectors.

- **Development of a regulatory framework for the generation of thermal energy from RES and for biomethane injection into the NG network**

This measure aims to establish the regulatory framework necessary for the production of specific fuels; for instance, biomethane generated from organic waste and injected into the natural gas network or used as transport fuel. Additionally, environmental licensing for biogas upgrading technologies will be established to initiate the smooth implementation of the required investments.

- **Development of supply chains for residual biomass / biodegradable materials and support for the development and implementation of optimum environmental and energy-efficient bioenergy applications**

This measure relates to planning specialised programmes to support the development of efficient supply chains of residual biomass and biodegradable materials, and to support and implement optimum environmental and energy-efficient bioenergy applications.

- **Utilisation of power generation from RES for heating/cooling and transport, and for operating storage systems**

This measure aims to utilise excess RES-generated electricity to cover the demand for heating and cooling, and load dispatching, by developing and implementing an integrated framework for response to demand and building storage facilities.

- **Funding programmes to promote HECHP, district heating / district cooling in the framework of the new programming period**

This measure provides for planning and implementing funding programmes in the context of the new programming period for the development of HECHP plants and district heating / district cooling systems, thereby promoting efficient heating and cooling.

- **Promotion of innovative smart city models using advanced technologies**

This measure focuses on promoting innovative smart city models.

- **Promotion of centralised systems for heat generation and distribution at the level of Industrial and Business Areas (IBA)**

This measure focuses on the installation of centralised systems for heat generation and distribution.

- **Energy upgrade of residential buildings housing energy-vulnerable households, and promoting the establishment of RES plants to cover their energy needs**

This measure relates to planning targeted funding programmes aiming to improve the energy efficiency of residential buildings housing energy-vulnerable households.

According to the NECP, a significant part of the funding for the implementation of the proposed measures originates from EU resources and relates to infrastructure and programmes to be implemented within the current (2021–2027) programming period, by means of the corresponding Partnership Agreement for the Development Framework (PA) and Agricultural Development Programme.

In addition, particular emphasis is given to funding development activities in Greek regions where the economy depends to a large extent on the use of lignite in power generation, particularly in the Region of Western Macedonia and the Municipality of Megalopoli, to support the just transition of these regions by setting up the 'Special Account for the just transition of lignite regions'. As discussed in detail in the NECP, the development activities to be funded on the basis of an annual cycle of revenue distribution from the auction of emission allowances, are decided through open public consultation governed by the following axes:

The use of RES systems for heating and cooling (mainly heat pumps and solar water heating systems) will be supported through combined use of various policy measures. Initially, the financial tools available in the context of the new programming period and the corresponding Operational Programmes will be planned to promote the economically optimal RES systems per final consumer category, also taking into account contribution to attaining the corresponding objective. The financial tools are expected to be supplemented with a special tax incentive scheme for installing RES systems for heating and cooling in the residential and tertiary sectors.

To promote bioenergy further, specialised programmes will be planned to support the development of efficient supply chains of residual biomass and biodegradable materials, and to support and implement optimum environmental and energy-efficient bioenergy applications.

Another priority is the connection of energy sectors to enhance optimum RES penetration, as it contributes to the utilisation of excess RES-generated electricity to cover the demand for heating and cooling, and load dispatching.

There is also reference to the NECP on assessing the necessity of building new infrastructure for district heating and district cooling generated by RES.

The acknowledged technical and economic potential of RES to be used toward the development of district heating applications is identified in certain regions in the Greek territory, and relates mainly to the utilisation of geothermal low-enthalpy fields and of residual solid biomass.

Interest in such infrastructure is expressed mainly in regions of northern Greece and/or semi-mountainous/mountainous regions, as well as in specific islands of the North Aegean, where there are both RES potential for district heating and year-round thermal needs at local level. There is also noteworthy interest in utilising existing district heating infrastructure by substituting lignite and using locally-available RES, in particular biomass; natural gas may be used on a transitional or supplementary basis.

The key objective is to develop, by means of financial tools, RES district heating networks with the use of solid biomass and geothermal energy (30–40 MW_{th}).

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Annex I – Methodology for assessing demand for heating & cooling at municipality level

Residential sector

This section presents the overall thermal demand for space heating and domestic hot water, as well as the total demand for cooling. The demand for heating and cooling determines the overall heat market for the specific sector and is calculated at the level of municipalities nationwide.

Assessment of demand for heating for residential sector buildings at the level of settlements and administrative units

The demand for heating includes space heating (SH) and domestic hot water (DHW) in the residential sector.

The demand for heating in the residential sector is calculated by using the results of the census of the number of permanent residences carried out in 2011 by ELSTAT and the average surface area of permanent residences as revealed by the ELSTAT Household Budget Survey for 2018.

In addition, the average primary energy consumption for space heating and domestic hot water (kWh/m2) per climate zone (zones A, B, C, D, as laid down in the 'Regulation on the Energy Performance of Buildings' (REPB) is determined by processing the energy certificates. Primary energy consumption is converted into final energy consumption by use of a conversion factor based on the conversion factors laid down in Technical Guidelines of the Technical Chamber of Greece (TEE-TCG) 20701-1/2017 (Government Gazette, Series II, No 4003/17.11.2017), taking into account the share of each fuel in space heating and DHW generation, in accordance with information from Eurostat for 2018.

Primary energy consumption, as resulting from the processing of available results about the energy performance of residential sector buildings, involves a degree of uncertainty.

A correction factor is applied in determining the thermal demand in order to eliminate such uncertainty. This factor is set by taking into account the total energy consumption in the residential sector for 2020 (data entered in the TIMES model), as well as the allocation of energy consumption per end use in the sector (project entitled 'National information system for measuring energy efficiency, pursuant to Directive 2006/32/EC', CRES(2015)).

The equations applied for determining the total thermal demand at the level of municipalities are as follows:

TDMi =TDSHi + TDDHWi

In particular:

TDSHi= Ai*AA*PESHi*CFSH*CF

TDDHWi = Ai*PEDHWi*AA*CFDHW*CF

Where:

i: the municipality

TDMi: the total thermal demand in the municipality

TDSHi: the thermal demand for space heating

TDDHWi: the thermal demand for domestic hot water

Ai: the number of permanent residences

AA: the average surface area of a permanent residence

PESHi: the primary energy consumption for space heating

PEDHWi: the primary energy consumption for domestic hot water

CFSH: the primary-to-final fuel energy conversion factor for space heating

CFDHW: the primary-to-final fuel energy conversion factor for domestic hot water

CF: the correction factor

Assessment of demand for cooling for residential sector buildings at the level of settlements and administrative units

The demand for cooling in the residential sector is calculated in line with the calculation of the demand for heating, by using the results of the census of the number of permanent residences at a nationwide level, which was carried out in 2011 by ELSTAT, and the average surface area of permanent residences (Household Budget Survey 2018).

The average primary energy consumption for space cooling (kWh/m2) per climate zone (zones A, B, C and D, as laid down in the Regulation on the Energy Performance of Buildings (REPB)) is determined by processing energy certificates. Primary energy consumption is converted into final energy consumption by use of a conversion factor based on the conversion factors laid down in Technical Guidelines of the Technical Chamber of Greece (TEE-TCG) 20701-1/2017 (Government Gazette, Series II, No 4003/17.11.2017), taking into account the share of each fuel in space cooling, in accordance with information from Eurostat for 2018.

The equation applied for determining the demand for cooling at the level of municipalities is as follows:

DCi= Ai*AA*PESCi*FCFSC*CF

Where:

i: the municipality

DCi: the demand for cooling in the municipality

Ai: the number of permanent residences

AA: the average surface area of a permanent residence

PESCi: the primary energy consumption for space cooling

FCFSC: the primary-to-final fuel energy conversion factor for space cooling

CF: the correction factor

Tertiary sector

To assess demand for heating and cooling in the tertiary sector, the total energy consumption in the tertiary sector is used, as resulting from the energy balance of Greece every year.

Energy demand for space heating and cooling and domestic hot water is determined for the following sub-sectors of final consumption:

- School buildings
- Office buildings – trade establishments – Private sector
- Office buildings – Public sector
- Hospitals
- Hotels – tourist accommodation establishments

Assessment of demand for heating for tertiary sector buildings at the level of settlements and administrative units

The demand for space heating and domestic hot water is allocated per local community taking into account the following:

- the total number of installations/buildings,
- the average area per type of building (for the sub-sectors under consideration),
- the consumption of primary energy for heating and DHW for each sub-sector of final consumption.

The data for calculating the demand for heating per final consumption sub-sector are obtained from the overall energy balance of Greece for 2018, the TIMES model for 2020, the last census of buildings performed in 2011 by the Hellenic Statistical Authority (ELSTAT), the geographical and climatic location and the processing of available results relating to the energy performance of buildings in the tertiary sector.

Additionally, the results of the project entitled 'National information system for measuring energy efficiency, pursuant to Directive 32/2006/EC' [1] are used to determine the average surface area of heated spaces of buildings per final energy sub-sector of the tertiary sector.

The average primary energy consumption for space heating and domestic hot water (kWh/m2) is determined by processing energy certificates. Primary energy consumption is converted into final energy consumption by use of conversion factors laid down in Technical Guidelines of the Technical Chamber of Greece (TEE-TCG) 20701-1/2017 (Government Gazette, Series II, No 4003/17.11.2017),

DHMij=DSH**ij** + DDHW**ij**

DSHij= Aij*AAj*PESHij*CFSH*CF

DDHWij = Aij*PEDHWij*AAj*CFDHW*CF

Where:

i: the municipality

j: the final consumption sub-sector of the tertiary sector

DHMij: the demand for heating in the municipality

DSHij: the demand for space heating in the municipality

DDHWij: the demand for domestic hot water in the municipality

and

Aij: the number of buildings in the final consumption sub-sector

AAij: the average surface area of the heated spaces of the building

PESHij: the primary energy consumption for space heating in the sub-sector

PEDHWij: the primary energy consumption for domestic hot water in the sub-sector

CFSH: the primary-to-final fuel energy conversion factor for space heating

CFDHW: the primary-to-final fuel energy conversion factor for domestic hot water

CF: the correction factor

Assessment of demand for cooling for tertiary sector buildings at the level of settlements and administrative units

The demand for cooling in the tertiary sector is determined in line with the determination of the demand for space cooling in the residential sector. The data for calculating the demand for cooling per final consumption sub-sector are obtained from the overall energy balance of Greece for 2018, the TIMES model for 2020, the last census of buildings performed in 2011 by the Hellenic Statistical Authority (ELSTAT), the geographical and climatic location and the processing of available results relating to the energy performance of buildings in the tertiary sector.

Additionally, the results of the project entitled 'National information system for measuring energy efficiency, pursuant to Directive 32/2006/EC' [1] are used to determine the average surface area of cooled spaces of the buildings per final energy sub-sector of the tertiary sector.

The average primary energy consumption for space cooling (kWh/m2) is determined by processing the energy certificates. Primary energy consumption is converted into final energy consumption by use of conversion factors laid down in Technical Guidelines of the Technical

Chamber of Greece (TEE-TCG) 20701-1/2017 (Government Gazette, Series II, No 4003/17.11.2017),

The equation applied for determining the demand for cooling at the level of municipalities is as follows:

DCij= Aij*AAij*PESCij*FCFSC*CF

Where:

i: the municipality

j: the final consumption sub-sector of the tertiary sector

DCij: the demand for cooling in the municipality

Aij: the number of buildings in the final consumption sub-sector

AAij: the average surface area of the cooled spaces of the building

PESCij: the primary energy consumption for space cooling in the sub-sector

FCFSC: the primary-to-final fuel energy conversion factor for space cooling

CF: the correction factor

Annex II – Technical Potential of Biomass

The quantities of biomass that can be utilised by potential facilities and fall into the category of agricultural residue, as well as forest biomass, were calculated. These quantities are close to potential facilities (maximum distance of 50 km) and are either exclusive fuel, in cases where there are no industrial residues, or additional fuel, in cases where there are such residues.

Given the spatial allocation of the potential, the geographical database of biomass potential, organised by the CRES, has been used. The biomass potential database of the CRES includes statistical data at municipal district level, as well as estimates of:

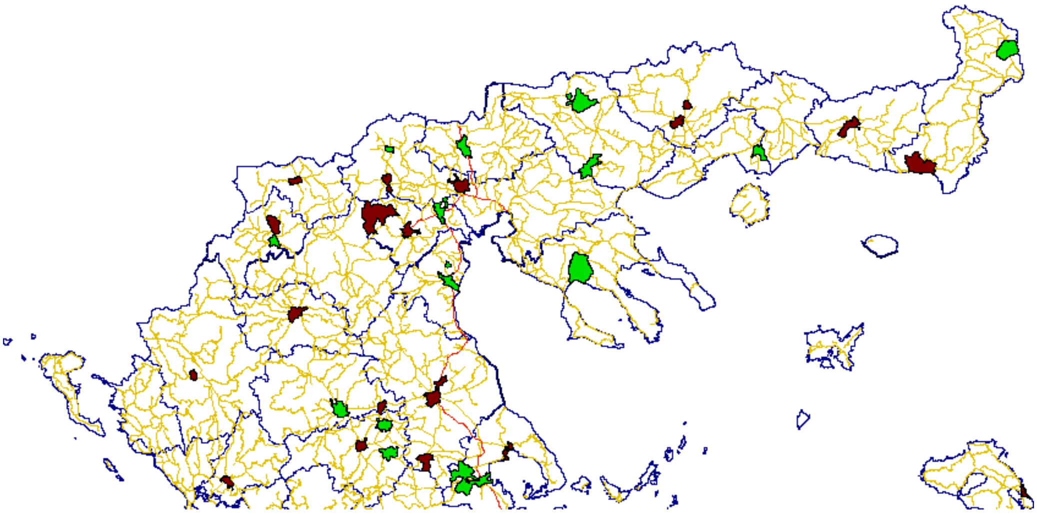
- the quantities of biomass left on the field on the basis of the annual agricultural statistical survey;
- the available quantities of biomass, taking into account relevant availability factors;
- the physical characteristics of the residues of each category (calorific value, relative moisture), as well as their disposal and transport costs;
- the wood fuels available based on the applicable management studies.

On the basis of the geographical information system where the information about the potential has been entered, it is possible to calculate the relevant distance between extraction sites and combustion sites for each category of potential, in order to assess the relevant transport costs.

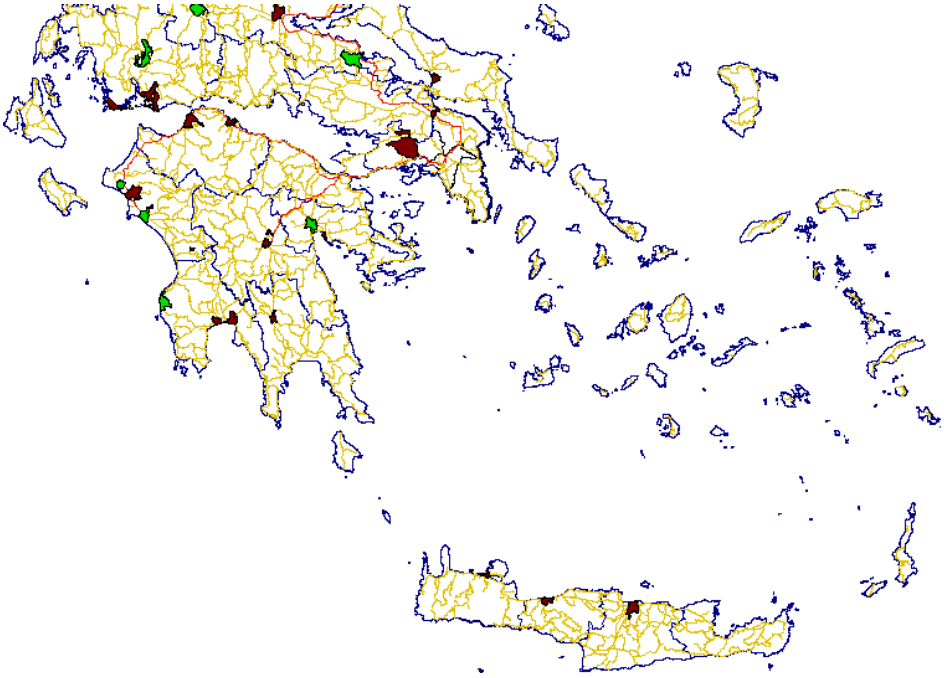
The exploitable biomass potential may be defined as the maximum quantity of biomass that can be utilised for energy production in each area, so that a positive balance of income and expenses results from its sale.

The maps below present the areas with exploitable biomass potential.

Map 4 – Allocation of estimated sites of facilities for heat production from biomass – North Greece



Map 5 – Allocation of estimated sites of facilities for heat production from biomass – South Greece



Annex III – Assumptions regarding District Heating

Determination of the nominal thermal demand of the settlement

The nominal heat output (q_{ov}) of the facility that covers the typical demand for heating and domestic hot water of a settlement may be calculated in relation to the actual population of the settlement according to the following equation:

$$q_{ov} = 0.001 * \pi * 51\,398 * \pi^{(-0.2671)}, \qquad MW_{th}$$

Where:

π is the actual population of the settlement.

The above empirical equation refers to settlements of Western Macedonia; therefore, for the other areas in Greece, the equation is adjusted on the basis of the specific consumption per climate zone and end use in accordance with the REPB.

Determination of thermal output of thermal energy transmission

The thermal output of transmission is determined by the nominal output according to the following equation:

$$Q_{\mu\varepsilon\tau} = v * q_{ov}$$

Where: **v** is the percentage rate of the thermal output transmitted

The percentage rate of the nominal output **v** of the settlement in our calculations is equal to 70 % of the nominal output, since that is the prevailing coverage rate according to existing implementation studies in Greece. More specifically, when thermal energy is transmitted over a distance via a transmission network, usually from a low-cost thermal source, the best practice is not to design the transmission network for 100 % of the demands of the settlement but for a part of the nominal output.

Calculation of district heating / district cooling network costs:

Data from studies on the district heating networks that are operating in Greece or that have been already tendered and are under construction, have been used to determine the cost of the district heating distribution network (main distribution network, building interconnection costs and district heating substation costs). The above-mentioned district heating distribution networks are, specifically, those of Kozani, Ptolemaida, Amyntaio, Florina and Megalopoli. Using data from these studies, it was possible to roughly determine the cost of the distribution networks.

The following basic assumptions have been made for the described cost estimate:

- The thermal energy transmission medium is hot/superheated water, with a maximum temperature of 130 °C and ΔT=50 °C.

- The thermal energy transmission and distribution networks are underground and consist of pre-insulated steel pipes with insulation made of polyurethane and a protective enclosure of polyethylene, which are placed directly under the ground.

- The thermal energy transmission - distribution system is a closed two-pipe system.

For district cooling, even though there are no data from actual projects available, we can extrapolate based on both the ΔT and the cooling potential: More specifically, the cost of the district cooling network $C_{\tau\psi}$ can be approximately calculated in this case on the basis of the cost of the district heating network of $\Delta T_{\tau\psi}$ and the ratio of the cooling potential to the heating potential of the settlement; the approximate formula is as follows:

$$C_{\tau\psi} = C_{\tau\theta}\sqrt{\frac{50}{\Delta T_{\tau\psi}}} \cdot \frac{Q_{\tau\psi}}{Q\tau\theta}$$

$\Delta T_{\tau\psi}$ for district cooling is approximately 10 °C.

In any case, the cost of the district cooling pipes is lower than the cost of the district heating pipes and, for that reason, the installation in the analysis performed is based on the district heating pipe costs.

Cost of thermal power plants and pumping equipment

- District heating plant generating thermal energy from natural gas-fired boilers: 0.05-0.15 M€/MWth
- District heating plant generating thermal energy from biomass-fired boilers: 0.4–0.6 M€/MWth
- Small-scale district heating plant generating thermal energy through HECHP and biomass fuel: 1.5–1.9 M€/MWth
- Medium-scale district heating plant generating thermal energy through HECHP and biomass fuel: 1.2–1.4 M€/MWth
- District heating plant with thermal energy recovery from the industry (e.g. PPC steam-driven power plants): 0.05–0.12 M€/MWth

The cost of the pumping equipment, as well as of the thermal energy storage infrastructure, is approximately determined by the following table:

Table 33 – Cost of pumping equipment

Type of settlement	Cost as a percentage of the network (transmission and distribution) costs
Towns with 2 000 to 10 000 residents	10 %
Urban areas with more than 10 000 residents	5 %

Cost of thermal energy transmission network

The transmission cost of thermal energy **K** is calculated in conjunction with the transmission distance L (Km) as follows:

$$K = \kappa * L * Q_{\mu\varepsilon\tau}$$

Where:

κ is the specific cost of thermal energy transmission as calculated by the following equation:

$$\kappa = 155764 * Q_{\mu\varepsilon\tau}^{(-0.5199)}, \qquad €/MW/Km$$

$Q_{\mu\varepsilon\tau}$: the thermal output of transmission, as calculated above in MW_{th}.

Cost of thermal energy distribution network

The cost of the distribution network **K** is related to the size of the settlement and is determined by the following equation:

$$K = \kappa * \pi \ (€)$$

Where:

$\kappa = 7000 * \pi^{\wedge(-0.1889)}$ €/resident: the specific cost and

π: the actual population of the settlement.

The climate data for Western Macedonia are taken into account for calculation purposes; therefore, the result must be accordingly reduced for the other regions in Greece.

Energy selling price to consumer

The selling price of the energy generated must not exceed 80 % of the energy cost already incurred by consumers for covering their energy needs with conventional technologies, so that an economic incentive is given to the consumer to choose the energy supply from the district heating and cooling network.

Thus, the selling price of the energy available from district heating networks is determined taking into account the energy demand per end use, the efficiency of the conventional technologies, as well as the selling price of conventional fuels.

The specific method of calculating the selling price of the available energy disconnects the analysis made from the potential impact of the selling price of conventional fuels to the final consumer, under the baseline scenario, on the cash flows of the investment. A potential change to the fuel price of conventional systems is directly reflected in the selling price of the energy made available from the district heating systems.

Annex IV – Assumptions on cost-benefit analysis for stand-alone systems

Table 34 - Unit cost per technology (excl. VAT)

Technologies		
Air-to-air heat pumps	204	€/kW
Air-to-water heat pumps	304	€/kW
Closed-loop geothermal heat pumps	880	€/kW
Open-loop geothermal heat pumps	800	€/kW
Stand-alone biomass-fired boilers	267	€/kW
Solar water heating systems in residential sector buildings for DHW	310	€/m2
Air-to-water heat pumps + DHW generation	404	€/kW

Table 35 – Cost of heating oil

Refinery price	0.4951	€/l
Duty paid to Regulatory Authority for Energy (RAE)	0.0002	€/l
Special Account Levy	0.0059	€/l
Special customs services duty (DETE)	0.0045	€/l
Special consumption tax (EFK)	0.4100	€/l
VAT	0.2528	€/l
Company profit	0.1374	€/l
Final price	1.3059	€/l
Direct taxes	0.6628	€/l
Direct tax percentage	51 %	%
Price cost-benefit analysis	0.6432	€/l
Price without VAT	1.0532	€/l

Source: Liquid Fuels Observatory

Table 36 – Cost of natural gas

Supply Price	0.0297	€/kWh
Transmission Charge	0.0023	€/kWh
Distribution Charge	0.0142	€/kWh
Taxes & Duties	0.0058	€/kWh
VAT	0.0067	€/kWh

Final price (incl. VAT)	0.0588	€/kWh
Direct taxes	0.0125	€/kWh
Direct tax percentage	21 %	%
Price cost-benefit analysis	0.0463	€/kWh
Price without VAT	0.0521	€/kWh

Source: Attica Gas

Table 37 – Electricity price

	Final price (incl. VAT)	Price cost-benefit analysis	Price without VAT	
Household Invoice	0.15	0.11		€/kWh
C21 (Commercial)	0.21	0.15	0.19	€/kWh

Table 38 – Biomass characteristics

Biomass purchase cost	110	**€/t**
Biomass calorific value	3 500	**kcal/kg**

Table 39 – Consumption per building type

Residence	Space heating	111.9	kWh/m2
	Space cooling	28.7	kWh/m2
	DHW	27.5	kWh/m2
	Households	4 122	thousand
	Average surface area	90	m2
	Formal system	15	kW
Private office space	Space heating	54	kWh/m2
	Space cooling	40	kWh/m2
	DHW	2	kWh/m2
	Buildings	174 770	
	Average surface area	212	m2
	Formal system	20	kW
Public office space	Space heating	54	kWh/m2
	Space cooling	40	kWh/m2
	DHW	2	kWh/m2
	Buildings	16 000	
	Average surface area	1 099	m2
	Formal system	110	kW
Hotel	Space heating	80	kWh/m2
	Space cooling	41	kWh/m2
	DHW	50	kWh/m2
	Buildings	46 000	
	Average surface area	704	m2
	Formal system	70	kW

Hospital	Space heating	228	kWh/m2
	Space cooling	216	kWh/m2
	DHW	34	kWh/m2
	Buildings	2 000	
	Average surface area	11 669	m2
	Formal system	1 100	kW
Educational buildings	Space heating	108	kWh/m2
	Space cooling	13	kWh/m2
	DHW	9	kWh/m2
	Buildings	22 000	
	Average surface area	522	m2
	Formal system	55	kW

Table 40 – External costs/benefits

External costs of oil-fired systems	27.2	€/MWh
External costs of heat pumps	12.5	€/MWh
External costs of biomass-fired boilers	11.2	€/MWh
External costs of NG-fired boilers	17.9	€/MWh
Cost of emissions	19	€/t
External costs of solar heating systems	10	€/MWh
External costs of NG-fired boiler	17.9	€/MWh

Table 41 – Price projections

Reference year 2020	2025	2030	2035	2040	2050
Percentage increase of oil	50 %	100 %	125 %	145 %	195 %
Percentage increase of natural gas	60 %	100 %	110 %	160 %	195 %

Source: EU reference scenario 2020, price projections.

Annex V – Sensitivity analysis of critical parameters in the cost-benefit analysis for stand-alone systems

Sensitivity analysis for Scenario 4.1

The sensitivity analysis for Scenario 4.1 was conducted as regards the following critical parameters. Residential sector

- **Sensitivity Analysis 1**: Higher price of heating oil (€0.75/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2025, EU Reference Scenario)
- **Sensitivity Analysis 2**: Higher price of heating oil (€0.85/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2030, EU Reference Scenario)
- **Sensitivity Analysis 3**: Higher price of electricity (15 % increase in the price of electricity relative to the baseline scenario)
- **Sensitivity Analysis 4**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 5**: Lower system cost (30 % reduction of purchase cost relative to the baseline scenario cost)

Tertiary sector:

- **Sensitivity Analysis 1**: Higher price of heating oil (€0.75/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2025, EU Reference Scenario)
- **Sensitivity Analysis 2**: Higher price of heating oil (€0.85/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2030, EU Reference Scenario)
- **Sensitivity Analysis 3**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 4**: Lower system cost (30 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 5**: Higher system efficiency (COP 5 instead of the COP 4.3 of the baseline scenario)

The aggregated results of the sensitivity analysis for Scenario 4.1 are provided in the table below.

Table 42 – Results of Sensitivity Analysis for Scenario 4.1

Air-to-air heat pump	Scenario 4.1	Sensitivity Analysis 1	Sensitivity Analysis 2	Sensitivity Analysis 3	Sensitivity Analysis 4	Sensitivity Analysis 5
Residence						
ENPV (€)	4 156	5 725	7 193	3 652	4 999	5 842
EIRR (%)	20 %	25 %	30 %	19 %	26 %	33 %
B/C	1.26	1.39	1.52	1.21	1.38	1.52
Private office buildings						
ENPV (€)	2 290	4 072	5 741	3 414	2 987	4 538

EIRR (%)	12 %	17 %	21 %	17 %	14 %	23 %
B/C	1.05	1.16	1.27	1.15	1.10	1.27
Public office buildings						
ENPV (€)	4 289	13 528	22 177	10 470	7 901	16 652
EIRR (%)	8 %	12 %	17 %	12 %	10 %	17 %
B/C	0.95	1.06	1.16	1.04	1.00	1.16
Hospitals						
ENPV (€)	1 572 984	1 987 187	2 374 932	1 634 797	1 734 910	1 696 610
EIRR (%)	69 %	84 %	97 %	81 %	75 %	99 %
B/C	1.72	1.92	2.11	1.79	1.87	1.85
Hotels						
ENPV (€)	17 018	25 786	33 994	20 951	20 445	24 885
EIRR (%)	19 %	25 %	30 %	24 %	21 %	31 %
B/C	1.18	1.32	1.44	1.27	1.25	1.38
Schools						
ENPV (€)	22 679	31 456	39 672	25 769	26 110	28 860
EIRR (%)	27 %	34 %	40 %	33 %	29 %	41 %
B/C	1.32	1.47	1.61	1.41	1.40	1.51
Air-to-water heat pump	Scenario 4.1	Sensitivity Analysis 1	Sensitivity Analysis 2	Sensitivity Analysis 3	Sensitivity Analysis 4	Sensitivity Analysis 5
Residence						
ENPV (€)	1 697	3 265	4 734	1 236	2 953	4 209
EIRR (%)	10 %	14 %	17 %	9 %	14 %	20 %
B/C	1.00	1.11	1.21	0.97	1.12	1.26
Private office buildings						
ENPV (€)	-1 381	401	2 069	293	-685	1 968
EIRR (%)	2 %	6 %	9 %	6 %	3 %	11 %
B/C	0.82	0.91	0.99	0.91	0.85	1.02
Public office buildings						
ENPV (€)	0	-6 664	1 985	-6 693	-12 291	2 517
EIRR (%)	0 %	2 %	6 %	2 %	0 %	6 %
B/C	0.00	0.83	0.91	0.82	0.77	0.93
Hospitals						
ENPV (€)	1 371 061	1 785 264	2 173 009	1 463 162	1 532 986	1 555 264
EIRR (%)	45 %	55 %	65 %	53 %	49 %	66 %
B/C	1.54	1.72	1.89	1.62	1.66	1.70
Hotels						
ENPV (€)	4 168	12 936	21 144	10 029	7 596	15 890
EIRR (%)	8 %	12 %	17 %	12 %	10 %	17 %
B/C	0.95	1.06	1.17	1.05	1.00	1.16
Schools						
ENPV (€)	12 582	21 359	29 576	17 188	16 014	21 793
EIRR (%)	14 %	20 %	24 %	19 %	16 %	25 %
B/C	1.09	1.22	1.33	1.19	1.15	1.30

Sensitivity analysis for Scenario 4.2

The sensitivity analysis for Scenario 4.2 was conducted as regards the following critical parameters.

Residential sector

- **Sensitivity Analysis 1**: Higher price of heating oil (€0.75/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2025, EU Reference Scenario)
- **Sensitivity Analysis 2**: Higher price of heating oil (€0.85/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2030, EU Reference Scenario)
- **Sensitivity Analysis 3**: Higher price of electricity (15 % increase in the price of electricity relative to the baseline scenario)
- **Sensitivity Analysis 4**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 5**: Lower system cost (30 % reduction of purchase cost relative to the baseline scenario cost)

Tertiary sector:

- **Sensitivity Analysis 1**: Higher price of heating oil (€0.75/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2025, EU Reference Scenario)
- **Sensitivity Analysis 2**: Higher price of heating oil (€0.85/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2030, EU Reference Scenario)
- **Sensitivity Analysis 3**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 4**: Lower system cost (30 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 5**: Higher system efficiency (COP 6 instead of the COP 5 of the baseline scenario)

Table 43 – Results of Sensitivity Analysis for Scenario 4.2

Geothermal heat pump	Scenario 4. 2	Sensitivity Analysis 1	Sensitivity Analysis 2	Sensitivity Analysis 3	Sensitivity Analysis 4	Sensitivity Analysis 5
Residence						
ENPV (€)	-5 047	-3 478	-2 010	-5 450	-2 723	-398
EIRR (%)	1 %	2 %	3 %	0 %	2 %	5 %
B/C	0.83	0.91	0.98	0.81	0.92	1.04
Private office buildings						
ENPV (€)	-10 181	-8 399	-6 730	-7 082	-9 468	-3 983
EIRR (%)	-2 %	-1 %	1 %	-1 %	-1 %	1 %
B/C	0.71	0.77	0.83	0.78	0.73	0.88
Public office buildings						
ENPV (€)	-64 521	-55 282	-46 633	-47 476	-60 823	-30 432

EIRR (%)	-3 %	-2 %	-1 %	-2 %	-3 %	0 %
B/C	0.65	0.71	0.77	0.72	0.67	0.81
Hospitals						
ENPV (€)	1 010 693	1 424 895	1 812 640	1 181 138	1 176 473	1 351 583
EIRR (%)	15 %	19 %	22 %	18 %	17 %	23 %
B/C	1.43	1.59	1.73	1.52	1.53	1.63
Hotels						
ENPV (€)	-25 641	-16 873	-8 665	-14 795	-22 132	-3 948
EIRR (%)	0 %	2 %	3 %	2 %	1 %	4 %
B/C	0.83	0.91	0.99	0.91	0.85	1.01
Schools						
ENPV (€)	-10 101	-1 324	6 892	-1 579	-6 588	6 944
EIRR (%)	3 %	5 %	7 %	5 %	3 %	7 %
B/C	0.95	1.05	1.14	1.04	0.99	1.15

Sensitivity analysis for Scenario 4.3

The sensitivity analysis for Scenario 4.3 was conducted as regards the following critical parameters, both for the residential and the tertiary sector.

- **Sensitivity Analysis 1**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 2**: Higher price of electricity (15 % increase in the price of electricity relative to the baseline scenario)

Table 44 – Results of Sensitivity Analysis for Scenario 4.3

Solar water heating	Scenario 4.3	Sensitivity Analysis 1	Sensitivity Analysis 2
Residence			
ENPV (€)	123	240	291
EIRR (%)	7 %	9 %	9 %
B/C	1.10	1.22	1.24
Hospital			
ENPV (€)	192 944	234 794	259 693
EIRR (%)	12 %	15 %	14 %
B/C	1.63	1.88	1.84
Hotels			
ENPV (€)	4 388	9 968	10 310
EIRR (%)	6 %	8 %	8 %
B/C	1.11	1.29	1.26

Sensitivity analysis for Scenario 4.4

The sensitivity analysis for Scenario 4.4 was conducted as regards the following critical parameters, both for the residential and the tertiary sector.

- **Sensitivity Analysis 1**: Higher price of heating oil (€0.75/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2025, EU Reference Scenario)
- **Sensitivity Analysis 2**: Higher price of heating oil (€0.85/l, in contrast with the €0.64/l of the baseline scenario – Projected increase in heating oil price for 2030, EU Reference Scenario)
- **Sensitivity Analysis 3**: Higher biomass market price (€130/t compared to the €110/t of the baseline scenario)
- **Sensitivity Analysis 4**: Lower biomass calorific value (3 200 kcal/kg compared to 3 500 kcal/kg)
- **Sensitivity Analysis 5**: Higher biomass calorific value (4 000 kcal/kg compared to 3 500 kcal/kg)
- **Sensitivity Analysis 6**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 7**: Lower system cost (30 % reduction of purchase cost relative to the baseline scenario cost)

Table 45 – Results of Sensitivity Analysis for Scenario 4.4

Biomass-fired boiler	Scenario 4. 4	Sensitivity Analysis 1	Sensitivity Analysis 2	Sensitivity Analysis 3	Sensitivity Analysis 4	Sensitivity Analysis 5	Sensitivity Analysis 6	Sensitivity Analysis 7
Residence								
ENPV (€)	3 588	5 156	5 156	5 156	5 156	5 156	5 156	5 156
EIRR (%)	14 %	18 %	18 %	18 %	18 %	18 %	18 %	18 %
B/C	1.34	1.49	1.49	1.49	1.49	1.49	1.49	1.49
Private office buildings								
ENPV (€)	3 105	4 887	6 556	2 229	2 653	3 707	4 005	4 904
EIRR (%)	11 %	14 %	17 %	10 %	10 %	12 %	14 %	18 %
B/C	1.24	1.38	1.51	1.16	1.20	1.30	1.34	1.45
Public office buildings								
ENPV (€)	11 593	20 832	29 481	7 050	9 251	14 716	16 541	21 489
EIRR (%)	9 %	12 %	15 %	8 %	8 %	10 %	12 %	16 %
B/C	1.17	1.30	1.43	1.10	1.13	1.23	1.26	1.37
Hospitals								
ENPV (€)	1 641 431	2 055 633	2 443 379	1 437 794	1 536 431	1 781 431	1 690 914	1 740 398
EIRR (%)	53 %	64 %	75 %	47 %	50 %	57 %	62 %	76 %
B/C	1.86	2.07	2.28	1.68	1.76	2.00	1.91	1.96
Hotels								
ENPV (€)	21 347	30 115	30 115	30 115	30 115	30 115	30 115	30 115
EIRR (%)	16 %	20 %	20 %	20 %	20 %	20 %	20 %	20 %

B/C	1.39	1.55	1.55	1.55	1.55	1.55	1.55	1.55
Schools								
ENPV (€)	25 887	34 664	42 880	21 572	23 662	28 854	28 361	30 836
EIRR (%)	22 %	27 %	31 %	19 %	20 %	23 %	26 %	32 %
B/C	1.52	1.69	1.86	1.40	1.45	1.61	1.60	1.68

Sensitivity analysis for Scenarios 5.1 and 5.2

The sensitivity analysis for Scenarios 5.1 and 5.2 was conducted as regards the following critical parameters, both for the residential and the tertiary sector.

- **Sensitivity Analysis 1:** Higher price of natural gas (€0.69/m3, in contrast with the €0.53/m3 of the baseline scenario – Projected increase in NG price for 2025, EU Reference Scenario)
- **Sensitivity Analysis 2**: Higher price of natural gas (€0.80/m3, in contrast with the €0.53/m3 of the baseline scenario – Projected increase in NG price for 2030, EU Reference Scenario)
- **Sensitivity Analysis 3**: Higher system efficiency (COP 6 instead of the COP 4.3 of the baseline scenario)
- **Sensitivity Analysis 4**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 5**: Lower system cost (30 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 6**: Combination of parameters from Sensitivity Analyses 2, 3 & 5 (NG price: €0.80/m3, 30 % reduction in purchase cost and COP 6)

Table 46 – Results of Sensitivity Analysis for Scenario 5.1

Air-to-air heat pump	Scenario 5.1	Sensitivity Analysis 1	Sensitivity Analysis 2	Sensitivity Analysis 3	Sensitivity Analysis 4	Sensitivity Analysis 5	Sensitivity Analysis 6
Residence							
ENPV (€)	-545	1 326	2 631	576	297	1 140	5 438
EIRR (%)	2 %	10 %	15 %	7 %	7 %	12 %	31 %
B/C	0.86	1.02	1.13	0.95	0.94	1.04	1.54
Private office buildings							
ENPV (€)	-3 052	-926	557	-1 642	-1 929	-805	4 215
EIRR (%)	-7 %	2 %	7 %	-1 %	-4 %	1 %	22 %
B/C	0.71	0.85	0.94	0.78	0.78	0.86	1.27
Public office buildings							
ENPV (€)	-23 406	-12 383	-4 694	-16 096	-17 224	-11 043	14 979
EIRR (%)	-15 %	-4 %	2 %	-7 %	-11 %	-7 %	16 %
B/C	0.63	0.76	0.85	0.68	0.69	0.76	1.15
Hospitals							
ENPV (€)	331 417	825 558	1 170 282	659 123	393 230	455 043	1 621 613
EIRR (%)	22 %	41 %	54 %	35 %	27 %	35 %	95 %
B/C	1.12	1.36	1.53	1.33	1.16	1.21	1.98
Hotels							
ENPV (€)	-9 265	1 196	8 493	-2 328	-5 331	-1 398	14 302

EIRR (%)	-5 %	6 %	12 %	3 %	-2 %	3 %	16 %
B/C	0.78	0.94	1.05	0.87	0.84	0.91	1.15
Schools							
ENPV (€)	-3 630	6 841	14 145	3 314	-539	2 551	27 271
EIRR (%)	0 %	13 %	19 %	9 %	4 %	9 %	39 %
B/C	0.87	1.05	1.17	0.98	0.93	0.99	1.56
Air-to-water heat pump	Scenario 5.1	Sensitivity Analysis 1	Sensitivity Analysis 2	Sensitivity Analysis 3	Sensitivity Analysis 4	Sensitivity Analysis 5	Sensitivity Analysis 6
Residence							
ENPV (€)	-3 064	-1 193	112	-469	-99	1 157	3 511
EIRR (%)	-6 %	1 %	5 %	4 %	5 %	10 %	18 %
B/C	0.68	0.81	0.89	0.85	0.88	1.00	1.22
Private office buildings							
ENPV (€)	-6 724	-4 597	-3 114	-685	-5 049	-3 375	1 645
EIRR (%)	#NUM!	-8 %	-3 %	3 %	-13 %	-8 %	10 %
B/C	0.56	0.66	0.73	0.85	0.62	0.69	1.01
Public office buildings							
ENPV (€)	-43 598	-32 576	-24 886	-36 288	-34 388	-25 178	844
EIRR (%)	#NUM!	-13 %	-7 %	-16 %	#NUM!	-15 %	5 %
B/C	0.49	0.59	0.66	0.52	0.54	0.61	0.90
Hospitals							
ENPV (€)	129 494	623 635	968 358	457 199	221 595	313 696	1 480 267
EIRR (%)	10 %	25 %	35 %	20 %	14 %	20 %	63 %
B/C	1.00	1.22	1.37	1.17	1.05	1.11	1.79
Hotels							
ENPV (€)	-22 114	-11 654	-4 357	-15 177	-16 253	-10 392	14 302
EIRR (%)	-14 %	-4 %	2 %	-7 %	-11 %	-6 %	16 %
B/C	0.63	0.76	0.85	0.69	0.69	0.76	1.15
Schools							
ENPV (€)	-13 726	-3 255	4 049	-6 782	-9 121	-4 516	20 203
EIRR (%)	-9 %	2 %	8 %	-1 %	-5 %	-1 %	24 %
B/C	0.72	0.87	0.97	0.80	0.78	0.85	1.30

Table 47 – Results of Sensitivity Analysis for Scenario 5.2

Air-to-water heat pump for heating and DHW	Scenario 5 .2	Sensitivity Analysis 1	Sensitivity Analysis 2	Sensitivity Analysis 3	Sensitivity Analysis 4	Sensitivity Analysis 5	Sensitivity Analysis 6
Residence							
ENPV (€)	-1 264	1 121	2 711	-160	-129	1 007	6 087
EIRR (%)	2 %	7 %	10 %	5 %	5 %	8 %	19 %
B/C	0.91	1.08	1.20	0.99	0.99	1.09	1.61
Private office buildings							

ENPV (€)	-5 536	-3 280	-1 776	-4 074	-4 022	-2 508	2 715
EIRR (%)	0 %	0 %	2 %	-2 %	-4 %	-1 %	10 %
B/C	0.81	0.81	0.90	0.74	0.74	0.82	1.22
Public office buildings							
ENPV (€)	-37 105	-25 408	-17 610	-29 524	-28 776	-20 448	6 627
EIRR (%)	-10 %	-3 %	0 %	-5 %	-8 %	-5 %	7 %
B/C	0.60	0.72	0.81	0.65	0.66	0.73	1.10
Hospitals							
ENPV (€)	298 981	880 030	1 267 396	675 556	382 263	465 544	1 810 532
EIRR (%)	12 %	24 %	31 %	20 %	15 %	19 %	55 %
B/C	1.13	1.37	1.54	1.34	1.17	1.21	2.00
Hotels							
ENPV (€)	-8 552	8 842	20 437	2 721	-3 253	2 047	42 310
EIRR (%)	1 %	8 %	13 %	6 %	3 %	6 %	25 %
B/C	0.90	1.10	1.23	1.03	0.96	1.03	1.63
Schools							
ENPV (€)	-1 953	2 132	9 870	-1 953	-5 311	-1 147	25 721
EIRR (%)	4 %	6 %	10 %	4 %	1 %	4 %	21 %
B/C	0.97	1.03	1.15	0.97	0.91	0.98	1.54

Sensitivity analysis for Scenario 6

The sensitivity analysis for Scenario 6 was conducted as regards the following critical parameters, for the residential sector.

- **Sensitivity Analysis 1:** Higher biomass price (€130/t compared to the €110/t of the baseline scenario)
- **Sensitivity Analysis 2**: Higher biomass price (€150/t compared to the €110/t of the baseline scenario)
- **Sensitivity Analysis 3**: Higher system efficiency (COP 6 instead of the COP 4.3 of the baseline scenario)
- **Sensitivity Analysis 4**: Lower system cost (15 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 5**: Lower system cost (30 % reduction of purchase cost relative to the baseline scenario cost)
- **Sensitivity Analysis 6**: Combination of parameters from Sensitivity Analyses 2, 3 & 5 (biomass price: €150/t, 30 % reduction in purchase cost and COP 6)

Table 48 – Results of Sensitivity Analysis for Scenario 6

Air-to-water heat pump from biomass-fired boiler	Scenario 6	Sensitivity Analysis 1	Sensitivity Analysis 2	Sensitivity Analysis 3	Sensitivity Analysis 4	Sensitivity Analysis 5	Sensitivity Analysis 6
Residence							
ENPV (€)	-3 904	-3 133	-2 362	-3 017	-3 048	-2 193	236
EIRR (%)	-11 %	-6 %	-2 %	-5 %	-9 %	-6 %	6 %
B/C	0.62	0.70	0.77	0.68	0.68	0.75	1.03