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Comprehensive Assessment of the Potential for Efficient Heating and Cooling

Report for Point F - Analysis of the Economic Potential of Different High Efficiency Technologies for Heating and Cooling

Report for Ministry of Energy, Commerce and Industry (MECI) of the Republic of Cyprus

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1 Introduction

Annex X of the Energy Efficiency Directive (EU) 2023/1791 requires that the comprehensive assessment of national heating and cooling potentials includes an analysis of the economic potential for efficiency in heating and cooling. This Point F report satisfies this requirement by setting out the methodological approach to carrying out this assessment for the Republic of Cyprus, the results thereby returned and the conclusions arising from the analysis.

Specifically, this report is structured as follows:

Section 2 explains how the baseline technologies, against which high efficiency heating and cooling options are evaluated, are established. This is explained separately for the four distinct sectors of the economy analysed: Residential, Service, Industry and Agriculture. This section also explains how the baseline consumption for heating and cooling is established[1] and how this is adjusted to reflect already projected changes in heating and cooling demand out to 2030.

Section 3 sets out some of the detail of how the national demand for heating and cooling is represented in the modelling. It explains that, in order to manage the scope and complexity of the modelling, the heating and cooling demand is resolved into demand by a number of "architypes", which are defined to represent the diversity of demand across and within the different economic sectors.

Section 4 details the nature and characteristics of the high efficiency solutions evaluated. It splits these solutions into type generic types: District Heating and Cooling (DHC) solutions and individual building/site level solutions. Within each generic type of solution are a range of specific technologies. The operational nature of these is explained.

Section 0 explains the approach taken to the Cost Benefit Analysis (CBA) modelling, including the approach to establishing which technologies are applicable for satisfying demand in the different sectors, the costs and benefits captured in the analysis and the approach to capturing externalities (both costs and benefits) in the CBA. The main variables affecting the results are also listed in this section, and the effect of these is discussed in Sections 0 and 8.

Section 6 lists the variables used in the CBA which have the greatest potential to influence the results and points to where in the Appendices the values of these variables can be found.

Section 0 presents the results of the analysis, split by sector and technology. The sensitivity of the results for the cost effectiveness of DHC to key variables is discussed.

Section 8 discusses and caveats what the results presented in Section 0 mean, including uncertainties and areas where further work is needed to be more definitive about what the analysis indicates at this stage.

Section 9 sets out the salient conclusions that can be drawn from the CBA.

2 Establishing the Baseline

2.1 Baseline Energy Consumption

The economic potential for efficient heating and cooling technologies has been evaluated for four sectors, as follows:

- Residential
- Service
- Industry
- Agriculture

Baseline consumption of heat and cooling in these sectors has been determined for 2022. The methodology used to do this is set out in the Point A section of the Point A&B report. The geographic

[1] See Point A report for how this is done.

distribution of these demands has been established as presented in the Point C report. The resulting distribution of demand for space heating (Residential and Service), process heating (Industry and Agriculture), space cooling (Residential and Service), process cooling (Industry) and sanitary hot water (Residential and Service) are shown in the heat map for the Republic of Cyprus. This heat map and the underlying data layers are now hosted on MECI's ArcGIS Online account.

2.2 Baseline Technologies for the Provision of Heating and Cooling

Baseline technologies for the provision of heating and cooling across the four sectors have been defined. The economic and financial case for supplanting these with a range of high efficiency solutions, both District Heating and Cooling (DHC) and individual building level solutions using proven technologies, has been evaluated by a Cost Benefit Analysis (CBA) Excel spreadsheet model developed for this work. The high efficiency solutions evaluated are presented in Table 4-1 and

Table 4-2.

2.2.1 Residential

For the Residential sector, the model assumes a probability that the Space Heating (SH), Space Cooling (SC) and Sanitary Hot Water (SHW) demand is met by a combination of technologies. The probabilities of these combinations depend on the Residential architype under consideration. The technologies considered to be capable of providing SH, SC and SHW in the Residential sector are presented in Table 2-1, together with the probabilities considered to apply in 2022 for the three Residential architypes[2]. All architypes are listed in Section 3.

The mix of technologies for the Residential sector was constructed from the previous NCA for Cyprus completed in 2021, as per Fig 1.1 (a)-(c), where the projected proportions of space heating, SHW and space cooling delivered by different technologies in the residential sector are calculated for various years. The proportions in 2022 only are shown.[3]

Table 2-1 Technologies considered to be providing baseline SH, SC and SHW in the Residential sector

Space Heating (SH) Technology	Space Cooling (SC) Technology	Sanitary Hot Water (SHW) Technology	%of Apartment	Row House and Single House
Heat Pumps (split units)	Heat Pumps (split units)	Solar Panels	53.1%	24.0%
Electric Resistive Heating	Heat Pumps (split units)	Solar Panels	38.5%	17.4%
LPG Boiler	Heat Pumps (split units)	Solar Panels	2.0%	-
LPG Stoves	Heat Pumps (split units)	Solar Panels	6.0%	-
Oil Boiler	Heat Pumps (split units)	Solar Panels	0.5%	10.9%
Oil Stove	Heat Pumps (split units)	Solar Panels	-	39.3%
Solar Panels	Heat Pumps (split units)	Solar Panels	-	8.5%

2.2.2 Service

For the Service sector, with the exception of the Hotel architype, the same probability approach is taken to estimating the technology mix providing SH, SC and SHW in the baseline in 2021. The same technology mix is considered to apply across these seven Service sector architypes. The applicable technologies and their probabilities are presented in Table 2-2. The mix of technologies for the Service sector was taken from the previous NCA for Cyprus completed in 2021, as per Fig 1.2 (a)-(c), where the

[2] The three Residential architypes are: Apartments, Row Houses and Single Houses
[3] See tables A4.1-4.3 of Cost Benefit Analysis for the Potential of High-Efficiency Cogeneration in Cyprus
https://ec.europa.eu/energy/sites/default/files/documents/D%20I.4.1%20%20ReportCyprusen.pdf

proportions of space heating, SHW and space cooling delivered by different technologies in the service sector are presented.[4]

In the case of the Hotel architype, it is assumed that the baseline in 2022 is comprised of oil boilers for SH and SHW demand and heat pumps (split units) for SC.

Table 2-2 Technologies considered to be providing baseline SH, SC and SHW in the Service sector (all architypes except Hotels)

Space Heating (SH) Technology	Space Cooling (SC) Technology	Sanitary Hot Water (SHW) Technology	All Nine Service Architypes
Heat Pumps (split units)	Heat Pumps (split units)	Solar Panels	73.2%
Heat Pumps and wet systems	Heat Pumps and wet systems	Solar Panels	6.4%
Solar panels	Heat Pumps (split units)	Solar Panels	4.0%
Oil Stoves	Heat Pumps (split units)	Solar Panels	13.0%
Oil Boiler	Heat Pumps (split units)	Solar Panels	3.4%

2.2.3 Industry (Non-EU ETS)

In the absence of disaggregated fuel consumption data for industrial sites not covered by EU ETS, the mix of technologies and fuels used for the Industrial sector was taken from the previous NCA for Cyprus completed in 2021, as per Fig 1.3 (a)-(c), where the proportions of low, medium and high temperature heat delivered by different technologies in the industry sector are presented.[5] The applicable technologies and their probabilities for 2022 are presented in Table 2-3.

[4] See tables A4.4-4.6 of Cost Benefit Analysis for the Potential of High-Efficiency Cogeneration in Cyprus
https://ec.europa.eu/energy/sites/default/files/documents/D%20I.4.1%20%20ReportCyprusen.pdf

[5] See tables A4.7-4.9 of Cost Benefit Analysis for the Potential of High-Efficiency Cogeneration in Cyprus
https://ec.europa.eu/energy/sites/default/files/documents/D%20I.4.1%20%20ReportCyprusen.pdf

Table 2-3 Technologies considered to be providing baseline PH, PC and SHW in the Industrial sector (all non-EU ETS architypes)

Process Heating (PH) Technology	Process Cooling (PC) Technology	Sanitary Hot Water (SHW) Technology	All Non-EU ETS Industrial Architypes
Oil boiler	Electric chiller and wet system	Oil boiler	65.0%
Electric resistance heating	Electric chiller and wet system	Electric resistance heating	16.5%
LPG boiler	Electric chiller and wet system	LPG boiler	15.4%
Solar panels	Electric chiller and wet system	Solar Panels	2.3%
Biomass boiler	Electric chiller and wet system	Biomass boiler	0.8%

2.2.4 Industry (EU ETS)

There are seven EU ETS industrial installations, 1 x cement and 6 x ceramics sites (6 ceramics sites were operational in 2022). The fuel consumption data for these were available and so the baseline technologies reflect the fuel types consumed by these sites.

2.2.5 Agriculture

The mix of technologies and fuels used for the agriculture sector was taken from the previous NCA for Cyprus completed in 2021, as per Fig 1.4, where the proportions of heating delivered by different technologies in the agriculture sector are presented.[6] The applicable technologies and their probabilities for 2022 are presented in Table 2-4.

Table 2-4 Technologies considered to be providing baseline PH, PC and SHW in the Agricultural sector (all architypes)

Process Heating (PH) Technology	Process Cooling (PC) Technology	Sanitary Hot Water (SHW) Technology	All Agricultural Architypes
Oil boiler	Electric chiller and wet system	Oil boiler	95.4%
Biomass boiler	Electric chiller and wet system	Biomass boiler	3.5%
LPG boiler	Electric chiller and wet system	LPG boiler	1.1%

[6] See tables A4.10 of Cost Benefit Analysis for the Potential of High-Efficiency Cogeneration in Cyprus https://ec.europa.eu/energy/sites/default/files/documents/D%20I.4.1%20%20ReportCyprusen.pdf

2.3 Baseline Adjustments for Existing Policies Related to Heating and Cooling

For the purposes of the Cost Benefit Analysis (CBA) of efficient heating and cooling, two versions of the baseline are used, the baseline in 2022 as well as the baseline estimated in 2030 based on planned policies and measures both described below. CBA results using these two baselines are presented in Section 0.

The rationale for using two baselines to see if there is a material impact on the potential for efficient heating and cooling as a result of projected evolutions in demand to 2030 driven by Government policy in Cyprus.

2.3.1 Heating and Cooling Demand in 2022

This is the demand for heating and cooling in 2022, as set out in the Point A section of the Point A&B report. This demand is assumed to pertain in each year for which the CBA is carried out. The CBA is carried out over a period of 28 years (2025-2053) via a Discounted Cash Flow (DCF), for the balance of costs and benefits listed in Section 5.1[7]. Economic Net Present Value (ENPV) and Financial Net Present Value (FNPV) are calculated for each technology solution in terms of 2023 money.

2.3.2 Heating and Cooling Demand in 2030

In order to capture the impact of existing policies in Cyprus relating to heating and cooling, the 2022 heating and cooling demand is adjusted. The existing definitive analysis of the effect of existing policies on demand for heating and cooling is the analysis presented in Table 5.4 of the National Energy and Climate Plan (NECP)[8]. This shows an absolute predicted increase in final energy consumption associated with the provision of heating and cooling in Cyprus to be 12.1% between 2022 and 2030. During this time, according to the NECP, the population of Cyprus is projected to increase by 6.4% and the real GDP is projected to increase by 21.4%.

This absolute increase in final energy demand is considered to have the following components:

1. New demand at new sites, due to population increase, and
2. New demand at existing sites because of greater comfort expectations, especially in regard to cooling (air conditioning), as a result of higher incomes. It should be noted that projected increases in temperature due to climate change have not been taken into account explicitly in this analysis. However, over the period 1979-2020 the cooling degree days in Cyprus have increased on average by 12.5 CDDs per year while over the same period Heating Degree Days (HDDs) have decreased by 6.0 HDDs per year. Should this trend continue, it is reasonable to expect an increase in the demand for cooling that goes beyond that explained by greater comfort expectations.

In respect of point 1 above, the effect of population growth is considered to increase the heating and cooling demand in the residential and service sectors, but the increase in industrial and agricultural sectors is assumed to be at site level only. Consequently, for the purposes of the CBA, between 2022 and 2030, the useful heating and cooling demand in residential and service sector are both projected to increase by 21.7% in the residential sector and 20.4% in the service sector, and their building stocks are projected to increase at the same rate. But in the industry and agriculture sectors, the stock is assumed to remain constant with a decrease in heating and cooling demand of 5.2% for industry and an increase of 8.9% for agriculture at site level.

For this expanded demand, the CBA is carried out over a period of 28 years (2030-2058), using 2030 energy prices, CO_2 costs and other costs which change over time (see Appendices) and a NET Present Value (NPV) is calculated in terms of 2023 money. Both Economic Net Present Value (ENPV) and Financial Net Present Value (FNPV) are evaluated.

[7] Full cost assumptions are detailed in Appendices 2-9.
[8] Preliminary Draft Update: Cyprus NECP report 2023

3 The Use of Architypes

There are approximately 617 thousand buildings in Cyprus. In order for the CBA to be computed without undue complexity and with optimal speed, architypes have been established to reflect the range of diversity of heating and cooling demand seen across Cyprus. Each defined architype has a specific demand for heating and cooling. The heating or cooling demand within a particular geographical boundary (i.e. Post Code) is then the number of each architype in the Post Code of interest multiplied by the heating or cooling demand of that architype, summed across all architypes found in the Post Code.

Table 3-1 shows the number and description of the different architypes defined for each sector. For the avoidance of doubt, large industrial sites participating in EU ETS are included in the heat map but excluded from modelling as a large proportion of heat demand at these sites is high grade (>400C) which is unsuitable for high efficiency solutions and lower grade demands at these sites is likely to be provided either by the same existing plant or waste heat recovered from the high temperature processes.

Table 3-1 Architypes observed in the analysis

Sector	Architypes Observed
Residential	Apartment Row house Single house
Service	Airports Restaurant Health Hotels Offices Schools Shopping Other Services
Industrial (not EU ETS)	Chemicals (Non-EU ETS) Food and Drink (Non-EU ETS) Other Minerals (Non-EU ETS) Other industry (Non-EU ETS)
Agricultural	Greenhouses Other Agriculture

The heating and cooling consumption for each of the above listed architypes is produced in Appendix 1.

In the CBA modelling, the most economic individual building level solution is evaluated for each architype and this solution is assumed to apply for each incidence of that architype across Cyprus, irrespective of where it is located (i.e. irrespective of Post Code).

4 Solutions Evaluated

Efficient heating and cooling solutions have been evaluated for District Heating and Cooling (DHC) and for individual building level heating and cooling solutions. The results of the economic modelling are presented in this report after being aggregated up to the Post Code level.[9]

When evaluating a particular DHC solution in a Post Code, the solution under evaluation is modelled to serve all susceptible heating and cooling demand in that Post Code.

When evaluating building level solutions, the solution under evaluation is modelled to serve all of the susceptible heating and cooling demand in each building architype under consideration.

The susceptibility of heating and cooling demand to technology is discussed in Section 5.2.

For each high efficiency solution, the Economic Net Present Value (ENPV), Financial NPV (FNPV), CO2 savings, and Primary Energy Savings (PES) are all calculated relative to the baseline and summed for each postcode in the same way. The model then allows any of these 4 parameters to be selected as the measure of the merit of each solution. Unless otherwise stated, ENPV is the selected measure.

The ENPV for building level solutions in a Post Code is given by:

Equation 1

$$\begin{aligned} &ENPV\ for\ Post\ Code\ A \\ &\quad = \sum_{Architype\ 1}^{Architype\ N} ENPV\ for\ Best\ Individual\ Solution\ for\ Architype\ 1 \\ &\quad \times Number\ of\ Incidences\ of\ Architype\ 1\ in\ Post\ Post\ Code\ A \end{aligned}$$

The DHC solutions are evaluated at the Post Code level and are modelled to supply all susceptible heating and cooling for all architypes in the Post Code in question.

The CBA model presents results which may be expressed according to two preferences, as follows:

1. Where any of the DHC solutions is found to be beneficial (i.e. has a positive EPNV), the most economical (most positive) DHC solution for a particular Post Code, is counted as the best solution for that Post Code, regardless of the how economic individual level building solutions are. If no DHC solution is proved to be positive, then the most economic individual solutions for each architype are selected (where positive). If no DHC or high efficiency individual solutions are economic (i.e., have a positive NPV), then the baseline is reported as being best.
2. The most economical solution (greatest NPV) is counted as the best solution. Under this preference even if a DHC solution is found to be economic, if the total NPV of the most economic individual building level solutions in the postcode are found to be more economic (i.e. have a higher total NPV), the latter solution is counted as the best solution for the Post Code. This is the basis for the results presented and discussed.

4.1 District Heating and Cooling Solutions (DHC) Evaluated

The cost effectiveness, primary energy and CO_2 savings of several "Types" of DHC solutions are evaluated in the model. Each type was modelled to supply all of the domestic and service sector buildings in each Post Code. In the case of industrial and agricultural architypes (both EU ETS and non-EU ETS) the heat demand of these sites is excluded from the DHC solution evaluated on the grounds

[9] There are also two sub-post code areas for which solutions have been evaluated, in order to gauge the impact of evaluating DHC solutions at a more detailed level. These two sub-post code areas are tourist areas known to have concentrated heating and cooling demand.

that the grade of heat needed by industrial sites is incompatible with that which can be supplied by DHC, and the spatial density of agricultural sites is likely to be too low for DHC to be suitable.

Each DHC solution is evaluated to supply demands of Space Cooling (SC), Space Heating (SH) and Sanitary Hot Water (SHW), where the last is not currently supplied using solar thermal. Where SHW is assumed to be currently supplied using solar thermal, it is assumed that this arrangement will continue, even though SH and SC are supplied via the DHC scheme.

There are three basic "Types" of DHC solution evaluated, defined according to the approach taken to meeting the demands for cooling and heat in the buildings served by the solution. These are summarised below:

Type 1 – This is a 2-pipe solution, whereby the same flow and return pipes are used to supply hot water (for SH and SHW) and chilled water (for SC). This means that, at any one time, only heating or cooling can be supplied via the DHC network. Therefore, only hot water will flow in the DHC pipework in the winter/heating season (assumed to be November to April) and only chilled water will flow in the DHC pipework during the summer/cooling season (assumed to be May to October). A consequence of this supply arrangement is that the demand for SHW, which occurs throughout the year, cannot be met by the DHC network in the summer months when the network is dedicated to supplying chilled water for cooling. At these times, heat customers on the network will have to use their own local plant to meet all of their SHW demand. It is assumed that the existing technology for supplying SHW locally is retained and used for this purpose.

Type 2 – This is a 4-pipe solution, whereby there are separate flow and return pipes for hot water and chilled water. This means that at any one time both heating and cooling can be supplied by the DHC network, as required by the customers on the network. In contrast to the situation for Type 1, there is no need for local SHW heating plant (unless the end user is modelled to be currently using solar thermal for SHW, in which case the modelling assumes that particular arrangement continues).

Type 3 – This is a 2-pipe solution whereby the flow and return pipes are used only to supply hot water. No chilled water is carried by the DHC network. Instead, cooling is achieved locally using localised absorption chillers, but only where the building requiring cooling is a service sector building. Where the building in question is residential, it is assumed that the installation of localised absorption chillers to meet residential cooling demand would be prohibitively expensive, and in these cases the cooling demand is met by local heat pumps.

There are variations of each of the three Types of DHC solution mentioned above, with each variation relying on different primary, central heat generating plant. There are six types of primary, central heat generating plant. These are: Biomethane CHP, Oil CHP, LPG CHP, RDF CHP, Water Source Heat Pumps (WSHP) and waste heat recovered from power stations or industrial plant with a thermal input capacity >20 MWth. WSHPs are only applicable for coastal post codes. As discussed in the Point A & B report, only waste heat from two sources (one power station and one cement works) are considered suitable for modelling.

Taking the three different types of DHC solutions and the six primary, central heat generation technologies means that we have investigated eighteen combinations of DHC solution type and primary, central heat generating technology. Depending upon the type of solution, heat and cooling top-up plant, used to supplement the primary plant heat and cooling outputs, may or may not be necessary. Table 4-1 sets out in detail the primary plant, top-up plant and DHC pipework arrangements associated with each of the eighteen combinations (also known as "solutions").

The solutions evaluated are summarised in Table 4-1.

Table 4-1 Detailed characteristics of 18 combinations of DHC evaluated in this study

Combination No.	DHC Solution Type	No. Pipes (2 or 4)	Primary, Central Heating Plant	Top-up Central Heating Plant	Primary Central Cooling Plant	Top-up Central Cooling Plant	Localised Top-up SHW	Localised Top-up Cooling Plant
1	Type 1	2 pipe	Biomethane CHP	Biomass boiler	Absorption chiller	Electric chiller	As per baseline	Not required
2	Type 2	4 pipe	Biomethane CHP	Biomass boiler	Absorption chiller	Electric chiller	As per baseline	Not required
3	Type 3	2 pipe	Biomethane CHP	Biomass boiler	N/A (Cooling generated locally)	N/A	As per baseline	Local Absorption chiller + Reversible heat pump (for residential buildings)
4	Type 1	2 pipe	Oil CHP	Oil boiler	Absorption chiller	Electric chiller	As per baseline	Not required
5	Type 2	4 pipe	Oil CHP	Oil boiler	Absorption chiller	Electric chiller	As per baseline	Not required
6	Type 3	2 pipe	Oil CHP	Oil boiler	N/A (Cooling generated locally)	N/A	As per baseline	Local Absorption chiller + Reversible heat pump (for residential buildings)
7	Type 1	2 pipe	LPG CHP	LPG boiler	Absorption chiller	Electric chiller	As per baseline	Not required
8	Type 2	4 pipe	LPG CHP	LPG boiler	Absorption chiller	Electric chiller	As per baseline	Not required
9	Type 3	2 pipe	LPG CHP	LPG boiler	N/A (Cooling generated locally)	N/A	As per baseline	Local Absorption chiller + Reversible heat pump (for residential buildings)
10	Type 1	2 pipe	WSHP	Not required	WSHP	Not required	As per baseline	Not required
11	Type 2	4 pipe	WSHP	Not required	WSHP	Not required	As per baseline	Not required
12	Type 3	2 pipe	WSHP	Not required	WSHP	Not required	As per baseline	Not required
13	Type 1	2 pipe	RDF CHP	RDF boiler	Absorption chiller	Electric chiller	As per baseline	Not required
14	Type 2	4 pipe	RDF CHP	RDF boiler	Absorption chiller	Electric chiller	As per baseline	Not required

15	Type 3	2 pipe	RDF CHP	RDF boiler	N/A (Cooling generated locally)	N/A	As per baseline	Local Absorption chiller + Reversible heat pump (for residential buildings)
16	Type 1	2 pipe	Industrial/Power Station Waste Heat	Not required	Absorption chiller	Electric chiller	As per baseline	Not required
17	Type 2	4 pipe	Industrial/Power Station Waste Heat	Not required	Absorption chiller	Electric chiller	As per baseline	Not required
18	Type 3	2 pipe	Industrial/Power Station Waste Heat	Not required	N/A (Cooling generated locally)	N/A	As per baseline	Local Absorption chiller + Reversible heat pump (for residential buildings)

4.2 Individual Site/Building Level Solutions Evaluated

For each Post Code the potential for Space Heating (SH), Process Heating (PH), Space Cooling (SC), Process Cooling (PC) and Sanitary Hot Water (SHW) to be satisfied using individual, site/building level high efficiency solutions was evaluated. These high efficiency solutions are:

1-3. CHP (biomethane, oil and LPG fired), with individual building level absorption chillers and appropriate top up for heating and cooling. (Note: CHP solutions are only modelled for industrial and agricultural sites and non-residential buildings.[10])

4. Individual heat pumps for SH and SC, with solar for SHW generation. (Note: This solution is not evaluated for industrial sites, as it is assumed that the grade of heat required by these sites cannot be supplied by heat pumps).
5. Solar SH, SC (using absorption chillers) and SWH. (Note: This solution is only evaluated for the residential and service sectors, only where the information available indicates that they are not currently used (i.e. it is not in the baseline) and where there is deemed to be enough roof space for its installation.
6. Heat Pump plus PV for SH, SC and SHW generation. (Consistent with the approach taken for other technologies, this solution is modelled to deliver SHW only where the baseline SHW is assumed not to be provided by solar thermal. Where the baseline SHW is supplied by solar thermal, this assumed to continue in the solution). Under this solution, the PV system is sized such that all of the electricity consumed by the heat pump in a year to meet heating and cooling demand can be generated by the PV system. Also, it is assumed that each system uses net metering, that excess generation is exported and that this offsets imports at times where electricity demand from the heating and cooling system exceeds generation by the PV system. In other words, there is no net import of electricity to supply the heating and cooling system. Additional Capex for a net meter is included in the Capex for this solution to reflect this way of operating.

[10] Also, RDF fired CHP is not considered an appropriate solution at the individual building level and so is not modelled here

Table 4-2 Detailed characteristics of the individual building level solutions evaluated

Combination No.	Primary Heating Plant	Top-up Space Heating Plant	Primary Cooling Plant	Top-up Cooling Plant	Primary SHW Plant	Top-up SHW Plant
1	Biomethane CHP	Biomethane boiler	Absorption chiller	Electric chiller	Where not solar thermal, Biomass CHP/biomethane boiler	Where not solar thermal, biomethane CHP/biomethane boiler
2	Oil CHP	Oil boiler	Absorption chiller	Electric chiller	Where not solar thermal, Oil CHP/Oil boiler	Where not solar thermal, Oil CHP/Oil boiler
3	LPG CHP	LPG boiler	Absorption chiller	Electric chiller	Where not solar thermal, LPG CHP/LPG boiler	Where not solar thermal, LPG CHP/LPG boiler
4	Heat pump	None	Heat pump	None	Solar thermal	Oil boilers (for hotels and hospitals) Electric resistance (for other non-domestic buildings) Baseline (for domestic buildings)
5	Solar thermal	Oil boiler (for hotels) Baseline (for other non-domestic and domestic buildings)	Absorption chillers	Electric chillers (for hotels) Baseline (for other non-domestic and domestic buildings	Solar thermal	Oil boiler (for hotels) Baseline (for other non-domestic and domestic buildings)
6	PV + Heat pump	None	PV + Heat pump	None	Solar thermal	Oil boilers (for hotels and hospitals) Electric resistance (for other non-domestic buildings) Baseline (for domestic buildings)

5 Approach to CBA

5.1 General Points

The cost effective economic and financial potential of the DHC and individual site/building level solutions set out in Sections 4.1 and 4.2 were evaluated for all Post Codes in the Republic of Cyprus. Economic potential represents the economic potential from the point of view of the public investor. The financial potential represents the potential from the point of view of the private investor. Cost effective economic potential is deemed to exist if the Economic Net Present Value (ENPV) is positive.[11] Cost effective financial potential is deemed to exist if the Financial Net Present Value (FNPV)[12] is positive.

In addition to this analysis at the Post Code level, more localised analysis was carried out for two areas where the demand for heating and cooling is known to be dense. These areas are:

- Poseidonos Avenue, Paphos, incorporating parts of three Post Codes (PC_{8041}, PC_{8042} and PC_{8204}). This area captures 25 hotels dispersed across Poseidonos Avenue.
- Kryo Avenue, Ayia Napa - This area captures 20 hotels dispersed across this avenue and is contained within one Post Code (PC_{5330}).

The rationale behind evaluating for these localised areas is to assess the impact on the relative cost effectiveness of DHC and individual level solutions of selecting areas where consumption of cooling and heating are known to be dense.

Cost effective potential was evaluated using Discounted Cash Flow (DCF) analysis of the costs and benefits relative to the baseline technology mix for each architype, as set out in Section 2.2.

The DCF analysis has included the following costs:

- Capital costs of plant and equipment
- Capital costs of the associated energy networks, i.e. the pipework for DHC networks and the heat network interface costs to allow buildings to take heating and cooling from the network
- Operating costs of the plant, equipment and energy networks (both fixed and variable)
- Energy costs
- Costs associated with the emission of CO_2 at installations covered by the EU ETS – considered only in the evaluation of financial potential.
- Societal costs associated with the emission of CO_2 considered only in the evaluation of economic potential.
- Environmental costs associated with the emission of pollutants arising from the combustion of fuels (specifically NOx, PM10 and SOx) - – considered only in the evaluation of economic potential.

[11] Using a Discount Rate of 4%.
[12] Using a Discount Rate of 12%.

The **economic potential** is evaluated using a Discount Rate (DR) of 4% and the financial potential was evaluated using a DR of 12%, these were used in the last NCA completed in 2021. The economic potential is evaluated including an external cost associated with the deployment of the different technologies, in order to reflect the cost to wider society of fuel use. The external costs included here are two-fold:

(1) The costs of CO_2 arising from the combustion of fuel. The projected CO_2 costs were equated with the traded ETS price projection in the NECP report July 2023 update[13] and inflated to 2023 real terms. These are much higher for most years than those assumed in the 2021 central forecast which was based on the European Investment Bank guidelines.

(2) The costs associated with emissions from NOx, PM10 and SO2. The extent of such emissions depends upon whether the fuel is fossil fuel solid, fossil fuel liquid, fossil fuel gaseous or biomass. These differences are observed in the analysis. The quantity of emissions (g/kWh) for the different fuel types are taken from the European Environment Agency Air Pollutant and Emission Inventory Guidebook[14], The marginal costs of damage per tonne of each of the three pollutants is taken from the Cyprus NECP, 2023[15]. This results in a marginal pollution cost per kWh, as per Appendix 4. The damage costs associated with the consumption of generated electricity changes for each year of the analysis in response to the changing fuel mix for generation projected in the NECP. The damage costs for fuels consumed on site are assumed to remain constant.

The **financial potentia**l is evaluated excluding the above-mentioned external costs, but including the traded ETS cost of CO_2 where the combustion capacity of the plant would mean that it was covered under ETS1 and where this is not the case, under ETS2 from 2027 onwards. ETS1 only becomes relevant for the larger DHC solutions and larger industrial and agricultural sites and ETS2 applies elsewhere. As stated above, the assumed prices of ETS1 emission allowances are taken from the traded ETS price projection in the NECP report July 2023 update[16] and inflated to 2023 real terms. Meanwhile ETS2 prices for 2027-2030 are taken from the report ‘Recommended parameters for reporting on GHG projections in 2025, Update of June 2024’ and assumed to remain the same after 2030. These prices are set out in Appendix 3. The cost of taxes levied on fuel is excluded from the economic analysis but included in the financial analyses.

The projected electricity generating cost calculated in the NECP for the WEM scenario including distributed generation was inflated to 2023 real terms and used in the ENPV analysis. Meanwhile the ratio of the domestic and non-domestic electricity retail prices including taxes in 2023 to the cost prices calculated in the NECP was multiplied by the NECP cost price forecast to estimate the projected retail prices used in the FNPV analysis. Solutions involving the generation of electricity via PV for supplying heat pump driven heating and cooling solutions are sized such that there is no net increase in the demand of electricity from the grid, do not incur an electricity cost or a system upgrade cost.

The cost benefit analysis carried out here is consistent with the requirements of Article 15, paragraph 7 of Directive (EU) 2018/2001 (Renewable Energy Directive II). The renewable heating and cooling technologies evaluated (see Section 4) are either inherently low ecological risk (e.g. heat pumps and solar thermal) or, where not, the analysis includes appropriate external costs to reflect any ecological risk (e.g. biomass CHP). The water source heat pumps

[13] See Cyprus Draft Updated NECP 2021 - 2030, July 2023, Table 4.1. Projections for fossil fuel prices, ETS prices.
[14] European Environment Agency Air Pollutant and Emission Inventory Guidebook, Combustion in Manufacturing Industry, Tables 3.2-3.5 https://www.eea.europa.eu/publications/emep-eea-guidebook-2019
[15] See Cyprus Draft Updated NECP 2021 2030, July 2023, footnote 86, p. 180.
[16] See Cyprus Draft Updated NECP 2021 2030, July 2023, Table 4.1. Projections for fossil fuel prices, ETS prices.

evaluated here do not use land-based water bodies as the heat source/sink, but instead use the sea and, as such, do not entail ecological risks that cannot be appropriately mitigated. In so far as the potential for renewable heating and cooling technologies have been evaluated for three distinct residential architypes, including a separate architype for detached houses, the potential for small-scale household projects has been evaluated. As discussed above this analysis has been spatial in nature.

5.2 Applicability of Solutions Across Sectors and Sites

As discussed above, the technology solutions evaluated in the CBA are presented in Table 4-1 and

Table 4-2. For technical reasons not all of the heat demand is susceptible to all these solutions. The following principles have been adopted in the analysis to reflect this reality and should be kept in mind when interpreting the CBA results:

- A quantity of heat consumed at industrial EU ETS sites is high grade heat (i.e. heat with a temperature >400°C). This is the case at the cement and ceramics sites. Only CHP is considered to be suitable for high temperature processes but this would depend on natural gas being available for such sites, none of the other high efficiency solutions evaluated is capable of generating heat of this grade. To reflect this reality, this high-grade heat demand is not addressed in the CBA. In the future, should natural gas become available for these sites then CHP viability at these sites should be considered.
- It is assumed that all heat required by industry is of a grade (above 100°C) that cannot be supplied by DHC solutions. Consequently, only individual site level solutions are evaluated for industry. Of the individual site level solutions, only CHP solutions are considered applicable, since the grade of heat demanded by industry is predominantly steam and the other individual site solutions cannot generate steam. Furthermore, the EUETS sites are the Cement works and ceramics factories where much of the heat demand is high grade (> 400°C). We have assumed that where these sites have medium and low-grade heat this is provided by the same existing heat source either directly or from recovery of high-grade waste heat and therefore there is no opportunity to provide by a high efficiency solution.
- In the Residential sector, it is assumed that CHP is only a solution in the context of DHC, i.e. that individual, building level CHP solutions are not applicable in the Residential sector.

5.3 Sensitivity

There are a number of factors which, to a greater or lesser degree, have an impact upon the economic and financial potential of the solution being considered, relative to the baseline. The inherent uncertainties associated with the assumptions mean that it is important to understand which assumptions have the greatest impact on the result. As such, the modelling allows for an examination of the sensitivity of the economic and financial potential of a solution to a range of factors. The factors which can be explored in this way are:

- Electricity price
- Fossil fuel prices
- Renewable fuel prices (this applies to biomass and RDF)
- Environmental (external) and CO_2 costs (note this sensitivity is applied to both the external CO_2 cost (relevant to the Economic analysis) and the EU ETS CO_2 cost (relevant to the financial analysis)
- Primary Capex of DHC network
- Capex of connection to the DHC network and (where applicable) installation of a wet system[17]
- Capex and Opex of individual thermal plant
- Opex expressed as a % of Capex

[17] To receive heating and cooling from DHC, a building will have to have a hydronic system. Some buildings are modelled as not having such a system in the baseline. Where this is the case, a cost to install a hydronic system is incurred.

- Thermal energy demand

Unless otherwise stated, the results presented in and discussed in Section 7.4 below are for these factors set at 100% of the applicable value set out in the Appendices.

6 Key Assumptions

The results of the CBA are determined to a large extent by technical and economic assumptions made. The main assumptions are provided in the Appendices, as follows:

Appendix 1 Heating, cooling and SHW demand for modelled architypes

Appendix 2 External Costs of CO_2 (Economic Analysis only)

Appendix 3 Assumed CO_2 Prices for EU ETS 1 and 2 (Financial analysis only and solutions projected to exceed input threshold for EU ETS combustion)

Appendix 4 Marginal Damage Costs for NOx, PM10 and SOx per MWh of solid, liquid, gaseous and biomass fuels

Appendix 5 Assumed Hours of Occupancy of Different Building Types

Appendix 6 Energy Prices (Set 1 only – see model for Sets 2 and 3)

Appendix 7 CO_2 emissions associated with delivered grid electricity and primary energy input to delivered electricity output, over time

Appendix 8 Heating and Cooling Technology Assumptions

Appendix 9 District Heating and Cooling Pipework Assumptions

7 Results

7.1 Best High Efficiency Heating and Cooling Solutions for Modelled Architypes

For the avoidance of doubt, unless explicitly stated otherwise, the results presented in Section 0 and discussed in Section 8 relate to the cost effective potential as measured against the demand for heating and cooling in 2022 with the cash flows beginning in 2025. Cost effective potential measured against 2030 demand (with cash flows starting in 2030) is only discussed to make the point that the merit order of high efficiency technologies is unchanged when evaluating against the two baselines, which is an important finding in itself.

As detailed in Section 3, architypes are used to reflect the range of diversity of heating and cooling demand seen across Cyprus. Architypes are used for all points of heating and cooling demand except for sites that are covered by EU ETS. For these sites the actual fuel consumption is known, allowing heating demand to be deduced.

All technically suitable high efficiency solutions evaluated for these architypes have been evaluated and the detailed results are presented in Appendix 10. For the avoidance of doubt, these results are assuming plant is installed in 2025, and begins operating in 2026, with an annual heating and cooling demand as in 2022.[18] As can be seen in Appendix 10, the best individual solution in the Residential, service and agriculture sectors includes heat pumps. For single houses, apartments in coastal and low land areas and all service sectors, the best solution also includes PV but in row houses, apartments in mountainous and semi mountainous, and agriculture, it is better to omit PV. For the hotels and shops, the best solution is individual biomethane CHP in semi-mountainous areas but heat pumps including PV in other climatic regions. For industry, heat pumps are not suitable, and biomethane CHP is the best solution for all subsectors and climate regions. In this analysis it was assumed that compressed biomethane supply chain is likely to be developed soon. Although, the modelling work identified biomethane CHP solution for shops in semi-mountainous areas to be the best cost effective solution, it is not considered as the best particular solution due to the lack of available space for the CHP engine and the biomethane storage, and should not be considered further.

The NPV of the best solution for each architype is used to calculate the NPV for all individual building level solutions in each Post Code and detailed area evaluated. The NPV for a post code or detailed area, associated with these individual building level solutions, is calculated as set out in Equation 1.

7.2 Best High Efficiency Heating and Cooling Solutions at Post Code Level for 2022 and 2030

Table 7-1 and Table 7-2 show the high efficiency heating and cooling solutions with the greatest Economic Net Present Value (ENPV) relative to the baselines presented in Section 2.2 at the Post Code level. Table 7-1 shows this relative to the 2022 baseline and Table 7-2 relative to the 2030 baseline. These tables summarise the results for all four sectors evaluated. The salient points to take from these tables are:

[18] When using demand forecast for 2030, there are only very subtle differences in the best solutions within the industry sector and no change to the best solutions in the residential, service and agriculture sectors.

- There is only one Post Code for which District Heating and Cooling (DHC) is the best solution. This is Solution 16, which is waste heat recovery from the reciprocating engines at Dhekelia power station. This solution involves the centralised generation of cooling via absorption chillers and the supply of heating and cooling, via a DHC network, to satisfy the demand for heating and cooling in the same Post Code as the power station (7502). However, there are caveats associated with this finding which are discussed further in Section 8.4. This accounts for 0.3% of national cooling demand and 0.2% of space heating demand.
- For 2022 demand, overall, individual heat pumps powered by PV is the option with the best ENPV in the large majority of cases, accounting for 90.8% of space cooling and 62.5% of space heating demand.
- The second most prevalent "best" solution for the provision of heating and cooling (in overall energy terms) is individual heat pumps without PV, accounting for 7.1% of space cooling and 19.1% of space heating demand.
- For the remaining cooling and heating, individual biomethane CHP is the best solution accounting for 1.8% of cooling demand and 18.2% of heating demand.
- We assume existing solar thermal will continue to provide the majority of SHW, accounting for 91.6%. Where there is no existing solar thermal, the remaining 8.4% would be provided by PV+heat pumps + new solar thermal where it is the best solution.

- Assuming the solutions are not installed until 2029 with 2030 useful heating and cooling demands makes no difference to the ranking of best solutions but the share with PV+heat pumps does reduce from 90.8% to 76.2% of cooling and from 62.5% to 52.2% of space heating with the decrease essentially being taken up by heat pumps without PV. This may be possibly due to the following:
    i. The projected reduction in electricity generating cost, falling from €124/MWh in 2026 to €105/MWh in 2040 (2023 real) making it cheaper to run heat pumps and reducing the savings from PV.
    ii. The predicted reduction in external carbon and environmental damage costs associated with electricity as generation moves away from polluting oil towards natural gas and renewables.
- The increase in heating and cooling demand projected between 2022 and 2030 within Post Code 7502 has improved the ENPV from +€84m to +€106m. However, for all other post codes, the increase in heating and cooling demand by 2030 has not resulted in the promotion of DHC above the best individual building solution mix in terms of ENPV In fact, no other DHC has a positive ENPV relative to the baseline.
- Note, in the two detailed tourist areas, DHC produces a positive ENPV and FNPV relative to baseline, though less positive than the best mix of individual high efficiency solutions.

Table 7-1 Best high efficiency heating and cooling solutions (all Post Codes and sectors) – Baseline 2022

Solution	DHC / individual solution number	Total ENPV relative to baseline where best solution (€m)	Total FNPV relative to baseline where best solution (€m)	Total lifetime CO2 savings relative to baseline where best solution (kTCO2)	Total lifetime PES relative to baseline where best solution (GWh)	Total lifetime electricity consumption reduction relative to baseline where best solution (GWh)	Total lifetime electricity generation relative to baseline where best solution (GWh)	Annual space cooling delivered (GWh/Yr)	Annual space heating delivered (GWh/Yr)	Annual water heating delivered (GWh/Yr)
DHC Solutions*		84.1	24.6	43.6	361.7	217.9	0.0	16.0	5.5	0.0
Individual solutions*										
Individual Biomethane CHP	1	1,156.3	432.0	6,448.6	1,226.1	4,762.4	12,981.4	86.7	560.0	3.6
Individual oil CHP	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Individual LPG CHP	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Individual heat pumps and solar thermal hot water	4	911.4	233.7	2,614.6	9,327.9	-1,786.1	0.0	346.0	588.9	0.0
Solar thermal space, heating, cooling and hot water (hotels only)	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PV+individual heat pumps and solar hot water	6	4,526.9	3,104.4	17,370.6	55,534.8	70,529.5	0.0	4,407.8	1,921.6	86.5
Baseline*	-	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	982.9
TOTAL	-	**6,678.7**	**3,794.7**	**26,477.4**	**66,450.5**	**73,723.7**	**12,981.4**	**4,856.4**	**3,076.0**	**1,073.0**

Table 7-2 Best high efficiency heating and cooling solutions (all Post Codes and sectors) – Baseline 2030

Solution	DHC / individual solution number	Total ENPV relative to baseline where best solution (€m)	Total FNPV relative to baseline where best solution (€m)	Total lifetime CO2 savings relative to baseline where best solution (kTCO2)	Total lifetime PES relative to baseline where best solution (GWh)	Total lifetime electricity consumption reduction relative to baseline where best solution (GWh)	Total lifetime electricity generation relative to baseline where best solution (GWh)	Annual space cooling delivered (GWh/Yr)	Annual space heating delivered (GWh/Yr)	Annual water heating delivered (GWh/Yr)
DHC Solutions*		106.3	35.0	42.8	413.4	263.6	0.0	19.3	6.7	0.0
Individual solutions*										
Individual Biomethane CHP	1	1,132.5	439.0	5,656.4	-687.3	4,893.3	13,070.5	100.1	536.7	4.3
Individual oil CHP	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Individual LPG CHP	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Individual heat pumps and solar thermal hot water	4	1,596.0	593.8	3,747.4	14,753.3	-1,275.0	0.0	1,279.2	1,158.1	0.0
Solar thermal space, heating, cooling and hot water (hotels only)	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PV+individual heat pumps and solar hot water	6	4,712.9	3,213.7	14,633.9	47,628.0	68,862.1	0.0	4,471.0	1,856.8	104.2
Baseline*		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,194.6
TOTAL		**7,547.7**	**4,281.6**	**24,080.5**	**62,107.5**	**72,744.0**	**13,070.5**	**5,869.6**	**3,558.3**	**1,303.1**

7.2.1 Share of Renewables in Heating and Cooling Resulting from Best High Efficiency Heating and Cooling Solutions

It is possible to estimate the proportion of energy associated with heating and cooling that would be renewable in 2030 if the best solutions identified in Table 7-2 were implemented.

In arriving at this estimate it is necessary to take into account the fact that a proportion of the Final Energy Demand (FED) and Primary Energy Supply (PES) is associated with the supply of heating and cooling that is not susceptible to the high efficiency solutions that have been evaluated here. This is mainly due to the fact that the high efficiency solutions evaluated cannot meet very high grades of heat in industry.

Moreover, in arriving at the overall proportion of renewable energy for **all** heating and cooling **after** implementation of the best high efficiency measures, it is necessary to estimate the proportion of this non-susceptible heat that is supplied by renewable energy. For the purposes of simplicity, the proportion of renewable energy used in the supply of all heating and cooling in the "With Existing Measures (WEM)" projection presented in Point D (i.e. before the implementation of the best high efficiency technologies evaluated here) is assumed to apply to this non-susceptible heating and cooling.

Taking the results from Table 7-2 above, and the WEM projection presented in Point D, Table 7-3 below summarises the key inputs to the calculation of the proportion of all energy associated with the provision of heating and cooling in 2030 that would be renewable, if the best cost effective solutions are implemented. The Key inputs are as follows:

Col A – This is the FED and PES associated with the provision of heating and cooling in the WEM projection for 2030.

Col B – This is the % of FED and PES in Col A that is renewable.

Col C – This is the FED and PES associated with heating and cooling that is susceptible to the high efficiency solutions evaluated here.

Col D – This is the non-susceptible energy. By definition it is Col A minus Col C.

Col E – This is the % of FED and PES associated with non-susceptible energy that is projected to be renewable in 2030.

Col F – This the renewable non-susceptible energy. By definition it is Col D X Col E.

Col G – This is the quantity of energy associated with the best high efficiency solutions that is renewable.

Col H – This is the total energy associated with heating and cooling that is renewable, assuming that the best solutions are implemented. By definition it is Col F + Col G.

Col I – This is the overall proportion of energy associated with heating and cooling that is renewable if the best high efficiency solutions are implemented. By definition it is Col H/Col A.

As can be seen from the table, if the best high efficiency solutions were implemented by 2030, the proportion of FED associated with heating and cooling that is renewable would increase from 34% to 72% and for PES this would increase from 28% to 58%.

Table 7-3 Increase in renewable share of Final Energy Demand (FED) and Primary Energy Supply (PES) for Heating and Cooling that is renewable, if cost effective potential for high efficiency solutions is implemented

	Col A WEM Energy	Col B WEM % Renewable	Col C Susceptible Energy (GWh)	Col D Non-Susceptible Energy	COL E % Renewable Non-Susceptible Energy	Col F Renewable Non-Susceptible Energy	Col G Renewable Cost Effective Potential for Susceptible Energy	Col H Total Renewable (Non-susceptible + CEP Susceptible Energy)	Col I % Renewable
Final Energy Demand	7,813 GWh	34%	4,922 GWh	2,891 GWh	33.66%	973 GWh	4,660 GWh	5,633 GWh	**72%**
Primary Energy Supply	9,836 GWh	28%	4,829 GWh	5,007 GWh	28.47%	1,425 GWh	4,281 GWh	5,706 GWh	**58%**

Table 7-4 and Table 7-5 show the high efficiency heating and cooling solutions with the greatest Economic Net Present Value (ENPV) relative to the baselines for the Residential and Service sectors for 2022 and 2030 demand. The salient points to take form these tables are as follows:

- There is only one Post Code for which District Heating and Cooling (DHC) is the best solution. This is the aforementioned Solution 16, recovering waste heat from the Dhekelia power station. Since DHC is modelled to only serve residential and service sector buildings, this solution shows up as the best solution for one Post Code for the residential and service sectors.
- Individual heat pumps are the best solution for all of the heating and cooling demand in all residential and most service sectors, accompanied by PV for most of the demand. Biomethane CHP is best for hotels and shops in semi-mountainous areas. Although, the modelling work identified biomethane CHP solution for shops in semi-mountainous areas to be the best cost effective solution, it is not considered as the best particular solution due to the lack of available space for the CHP engine and the biomethane storage, and should not be considered further.
- With the 2030 baseline, the overall result is broadly similar but single houses in semi-mountainous areas and apartments in coastal regions would no longer benefit from having PV.

Table 7-4 Best high efficiency heating and cooling solutions (all Post Codes, Residential and Service Sectors, only) – Baseline 2022

Solution	DHC / individual solution number	Total ENPV relative to baseline where best solution (€m)	Total FNPV relative to baseline where best solution (€m)	Total lifetime CO2 savings relative to baseline where best solution (kTCO2)	Total lifetime PES relative to baseline where best solution (GWh)	Total lifetime electricity consumption reduction relative to baseline where best solution (GWh)	Total lifetime electricity generation relative to baseline where best solution (GWh)	Annual space cooling delivered (GWh/Yr)	Annual space heating delivered (GWh/Yr)	Annual water heating delivered (GWh/Yr)
DHC Solutions*		84.1	24.6	43.6	361.7	217.9	0.0	16.0	5.5	0.0
Individual solutions*										
Individual Biomethane CHP	1	130.0	51.8	782.8	-1,706.6	938.6	2,973.3	69.9	22.5	3.6
Individual oil CHP	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Individual LPG CHP	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Individual heat pumps and solar thermal hot water	4	553.9	256.6	1,088.5	4,705.9	103.4	0.0	346.0	361.8	0.0
Solar thermal space, heating, cooling and hot water (hotels only)	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PV+individual heat pumps and solar hot water	6	4,526.9	3,104.4	17,370.6	55,534.8	70,529.5	0.0	4,407.8	1,921.6	86.5
Baseline*		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	982.9
TOTAL		**5,295.0**	**3,437.4**	**19,285.5**	**58,895.8**	**71,789.3**	**2,973.3**	**4,839.6**	**2,311.5**	**1,073.0**

Table 7-5 Best high efficiency heating and cooling solutions (all Post Codes, Residential and Service Sectors, only) – Baseline 2030

Solution	DHC / individual solution number	Total ENPV relative to baseline where best solution (€m)	Total FNPV relative to baseline where best solution (€m)	Total lifetime CO2 savings relative to baseline where best solution (kTCO2)	Total lifetime PES relative to baseline where best solution (GWh)	Total lifetime electricity consumption reduction relative to baseline where best solution (GWh)	Total lifetime electricity generation relative to baseline where best solution (GWh)	Annual space cooling delivered (GWh/Yr)	Annual space heating delivered (GWh/Yr)	Annual water heating delivered (GWh/Yr)
DHC Solutions*		106.3	35.0	42.8	413.4	263.6	0.0	19.3	6.7	0.0
Individual solutions*										
Individual Biomethane CHP	1	147.1	60.2	778.3	-2,444.6	1,133.2	3,580.7	84.2	27.1	4.3
Individual oil CHP	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Individual LPG CHP	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Individual heat pumps and solar thermal hot water	4	1,163.1	599.6	2,040.1	9,539.0	769.5	0.0	1,279.2	910.8	0.0
Solar thermal space, heating, cooling and hot water (hotels only)	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PV+individual heat pumps and solar hot water	6	4,712.9	3,213.7	14,633.9	47,628.0	68,862.1	0.0	4,471.0	1,856.8	104.2
Baseline*		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,194.6
TOTAL		**6,129.4**	**3,908.5**	**17,495.0**	**55,135.9**	**71,028.5**	**3,580.7**	**5,853.6**	**2,801.4**	**1,303.1**

Table 7-6 and Table 7-7 show the high efficiency heating and cooling solutions with the greatest Economic Net Present Value (ENPV) relative to the baselines for the Industrial and Agricultural sectors. Again, note that high grade industrial heat (>400°C) is omitted from this analysis, on account of the fact that it cannot be satisfied by any of the high efficiency solutions evaluated.

The salient points to take away from these tables are as follows:

- DHC is not modelled as being able to serve industrial and agricultural sites, so cannot appear as the best solution here. Heat pumps are not modelled as being able to serve industry, so are only assumed to be suitable for agriculture.

  For both the 2022 baseline and 2030 baseline the following is observed:
- Heat pumps and solar thermal without PV are the best solution for all agricultural sites.
- Biomethane CHP is the most cost-effective solution for all industrial sites, but this depends on compressed biomethane supply chain being developed in the near future.

Table 7-6 Best high efficiency heating and cooling solutions (all Post Codes, Industry[19] and Agricultural Sectors, only) – Baseline 2022

Solution	DHC / individual solution number	Total ENPV relative to baseline where best solution (€m)	Total FNPV relative to baseline where best solution (€m)	Total lifetime CO2 savings relative to baseline where best solution (kTCO2)	Total lifetime PES relative to baseline where best solution (GWh)	Total lifetime electricity consumption reduction relative to baseline where best solution (GWh)	Total lifetime electricity generation relative to baseline where best solution (GWh)	Total CHP Capacity where best solution (MWe)	Annual space cooling delivered (GWh/Yr)	Annual space heating delivered (GWh/Yr)	Annual water heating delivered (GWh/Yr)
Individual solutions*											
Individual Biomethane CHP	1	1,026.3	380.2	5,665.8	2,932.6	3,823.8	10,008.1	31.0	16.8	537.5	0.0
Individual oil CHP	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Individual LPG CHP	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Individual heat pumps and solar thermal hot water	4	357.4	-22.8	1,526.1	4,622.0	-1,889.4	0.0	0.0	0.0	227.1	0.0
Solar thermal space, heating, cooling and hot water (hotels only)	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PV+individual heat pumps and solar hot water	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baseline*		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		**1,383.7**	**357.3**	**7,191.9**	**7,554.7**	**1,934.4**	**10,008.1**	**31.0**	**16.8**	**764.6**	**0.0**

Table 7-7 Best high efficiency heating and cooling solutions (all Post Codes, Industry[20] and Agricultural Sectors, only) – Baseline 2030

Solution	DHC / individual solution number	Total ENPV relative to baseline where best solution (€m)	Total FNPV relative to baseline where best solution (€m)	Total lifetime CO2 savings relative to baseline where best solution (kTCO2)	Total lifetime PES relative to baseline where best solution (GWh)	Total lifetime electricity consumption reduction relative to baseline where best solution (GWh)	Total lifetime electricity generation relative to baseline where best solution (GWh)	Total CHP Capacity where best solution (MWe)	Annual space cooling delivered (GWh/Yr)	Annual space heating delivered (GWh/Yr)	Annual water heating delivered (GWh/Yr)
Individual solutions*											
Individual Biomethane CHP	1	985.4	378.8	4,878.2	1,757.2	3,760.1	9,489.8	29.4	15.9	509.6	0.0
Individual oil CHP	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Individual LPG CHP	3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Individual heat pumps and solar thermal hot water	4	432.9	-5.7	1,707.3	5,214.3	-2,044.5	0.0	0.0	0.0	247.3	0.0
Solar thermal space, heating, cooling and hot water (hotels only)	5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PV+individual heat pumps and solar hot water	6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Baseline*		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL		**1,418.4**	**373.1**	**6,585.5**	**6,971.5**	**1,715.6**	**9,489.8**	**29.4**	**15.9**	**756.9**	**0.0**

19 Excluding high grade (>400°C) heat.
20 Excluding high grade (>400°C) heat.

7.3 Best District Heating and Cooling Solutions

As discussed in Section 7.1, individual building/site level solutions are the most economically cost-effective solutions for all but one of the Post Codes. It is nevertheless instructive to investigate the most favourable DHC solutions despite not being cost effective.

When considering the economic potential, DHC is only economic (i.e. produces a positive ENPV relative to baseline) value in postcodes 7502 and 2234 and in the two detailed tourist areas. However, DHC is only the best solution in postcode 7502 (supplied by waste heat from the Dhekelia Power Station's ICEs). In the other postcodes, the best mix of individual solutions is more economic.

When evaluated from a financial point of view (i.e. considering the Financial Net Present Value, FNPV), again postcode 7502 and the two detailed tourist areas register a positive FNPV relative to baseline for RDF fired CHP, 4-pipe solution with heating and cooling distribution. Their FNPV is less positive than the FNPV for the best individual mix of solutions but positive nevertheless, i.e. better than the baseline.

Although only one postcode DHC solution is found to be to be the most cost effective from an economic point of view and only 2 postcodes and the 2 detailed tourist areas are found to be financially cost effective, it is nevertheless instructive to consider which DHC solutions are closest to being cost effective (i.e. have the least negative ENPV) and for how many Post Codes is this the case. Table 7-8 sets this out for the Post Codes evaluated, by climatic area and DHC solution type.

The salient points to take from these results are as follows:

- Three out of 18 DHC solution Types evaluated are found to be the <u>best DHC</u> solution (least negative ENPV) in 99% of all Post Codes and detailed tourist areas evaluated.
- The best DHC solutions in 56%, 26%, and 17% of Post Codes respectively are Type 1 (Biomethane CHP, 2 pipe DHC (DC in summer and DH in winter), Type 3 (Biomethane CHP, 2-pipe and individual absorption chillers for cooling), and Type 12 (Reversible Water Source Heat Pump, 2-pipe and individual absorption chillers for cooling).

  .

Table 7-8 Summary count of best DHC solution (highest ENPV even if negative) type across climatic regions

Climatic Region	Count. of Post Codes and Detailed Areas	Type 1 (Biomethane CHP)	Type 2 (Biomethane CHP)	Type 3 (Biomethane CHP)	Type 4 (Oil CHP)	Type 5 (Oil CHP)	Type 6 (Oil CHP)	Type 7 (LPG CHP)	Type 8 (LPG CHP)	Type 9 (LPG CHP)	Type 10 (Heat Pump)	Type 11 (Heat Pump)	Type 12 (Heat Pump)	Type 13 (RDF CHP	Type 14 (RDF CHP	Type 15 (RDF CHP	Type 16 (Waste Heat)	Type 17 (Waste Heat)	Type 18 (Waste Heat)
Coastal	340	129	0	57	0	0	0	0	0	0	4	0	148	0	0	0	1	0	1
Low Land	179	154	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mountainous	119	3	0	116	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Semi-Mountainous	243	210	0	33	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**881**	**496**	**0**	**231**	**0**	**0**	**0**	**0**	**0**	**0**	**4**	**0**	**148**	**0**	**0**	**0**	**1**	**0**	**1**

7.4 Sensitivity of Results

Given the finding that, when evaluated at the Post Code level, DHC is only socially cost effective (positive ENPV) in two whole postcodes and for the 2 detailed tourist areas and only financially cost effective for one whole postcode and the 2 detailed tourist areas, it is instructive to investigate the sensitivity of the results to certain key input parameters. This is useful analysis as there is an inherent uncertainty associated with the input values for these key inputs and, should relatively small changes in the value of inputs produce material impacts on the cost effectiveness of DHC solutions, the economic case is worth investigating further.

We have investigated the sensitivity of the results to 10 parameters, by varying their values by +- 20% about the central value. The central value is the value assumed in the results presented in Sections 7.3. The parameters investigated are:

1. Electricity price
2. Fossil fuel prices
3. Renewable fuel prices
4. Environmental and CO_2 costs
5. DHC primary network capex
6. DHC connection and wet system Capex
7. Individual thermal plant Capex and Opex
8. DHC central thermal plant capex and Opex
9. Opex as a percentage of Capex per year
10. Thermal energy demand

As discussed previously, solution Types 1 and 3, and 12 (biomethane CHP with the two different 2 pipe DHC solutions and Reversible Water Source Heat Pump with 2-pipe and individual absorption chillers for cooling), produce the best ENPV (i.e. most positive or least negative ENPV) for about 99% of Post Codes. As such, it is instructive to test the sensitivity of results for these solutions to the above listed input parameters, to see whether any changes are material to the solution cost effectiveness. DHC is more likely to be cost effective when serving large demands for heating and cooling, as the savings relative to the baseline tend to be maximised for a given level of Capex. As such, Post Codes with the 10 highest levels of heating and cooling demand, for which Types 1, 3, or 12 are the best DHC solutions, have been reviewed. For each of these the ratio of ENPV to heating and cooling demand was calculated and the postcode with the highest negative ENPV/MWh value was selected for sensitivity analysis. The rational for this approach is that the higher the ENPV to heating and cooling demand ratio, the closer is the solution to becoming cost effective in response to changes in the input parameters. From this analysis, sensitivity analysis has been carried out for the following Post Code/Solution combinations:

Post Code = 8852, for which DHC Solution 3 is the best.

Post Code = 5290, for which DHC Solution 12 is the best.

The results of this sensitivity analysis are summarised in Table 7-9 and presented graphically in

Figure 1 and

Figure 2.

Table 7-9 Characteristics of DHC solution/Post Code combinations chosen for sensitivity analysis

ost Code	Solution	ENPV/Total Heating and Cooling Demand (€/MWh)	ENPV (€m) (No Sensitivity)	ENPV (€m) (Max Value)	ENPV (€m) (Min Value)	FNPV (€m) No Sensitivity)	FNPV (€m) (Max Value)	FNPV (€m) (Min Value)
8852	3	-629	-49	3	-101	-57	-22	-93
5290	12	-3,601	-91	-55	-127	-90	-63	-116

Figure 1 Sensitivity of ENPV and FNPV to changes in key input parameters to the CBA (Post Code 8852, Solution 3, Biomethane CHP with 2 pipe heat with distributed absorption chillers)

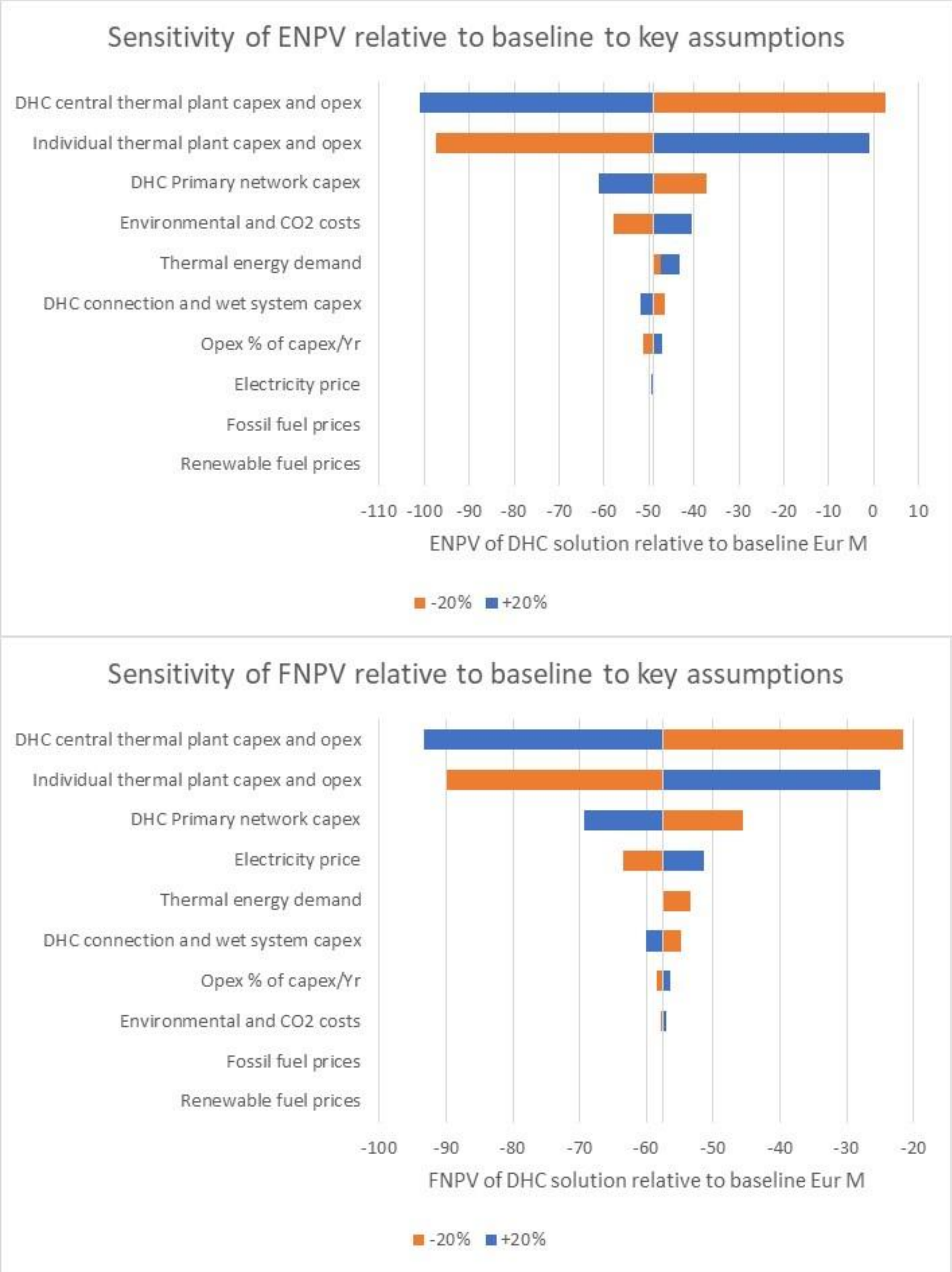
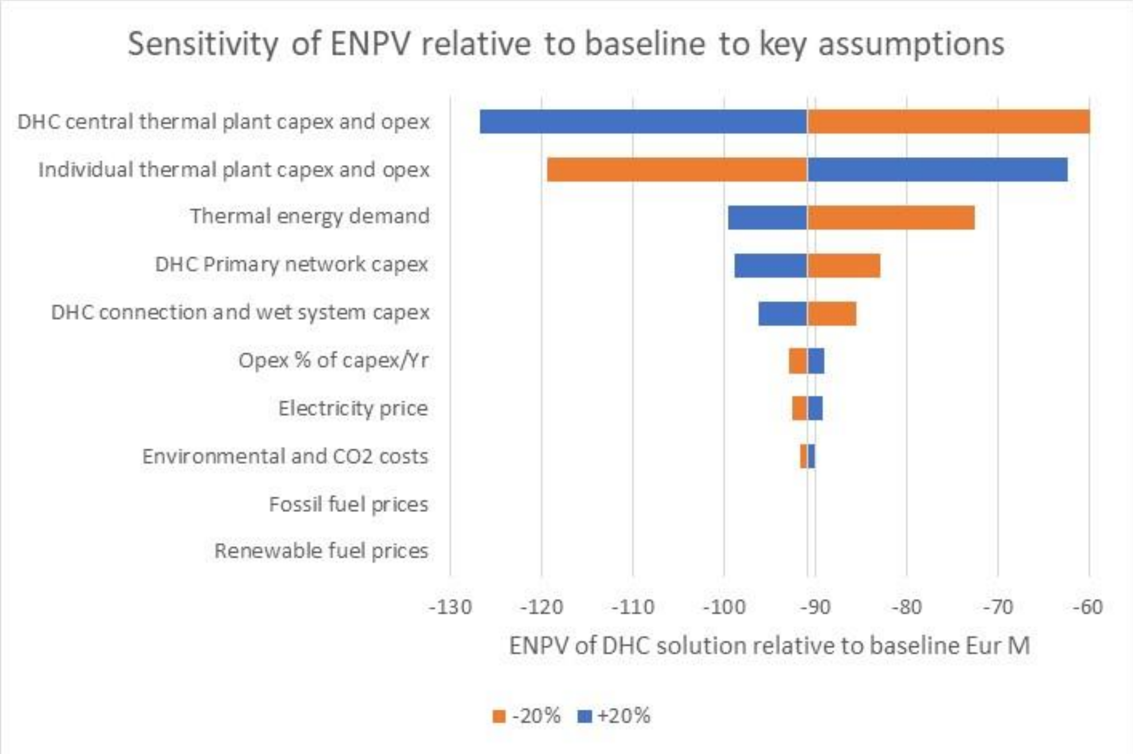
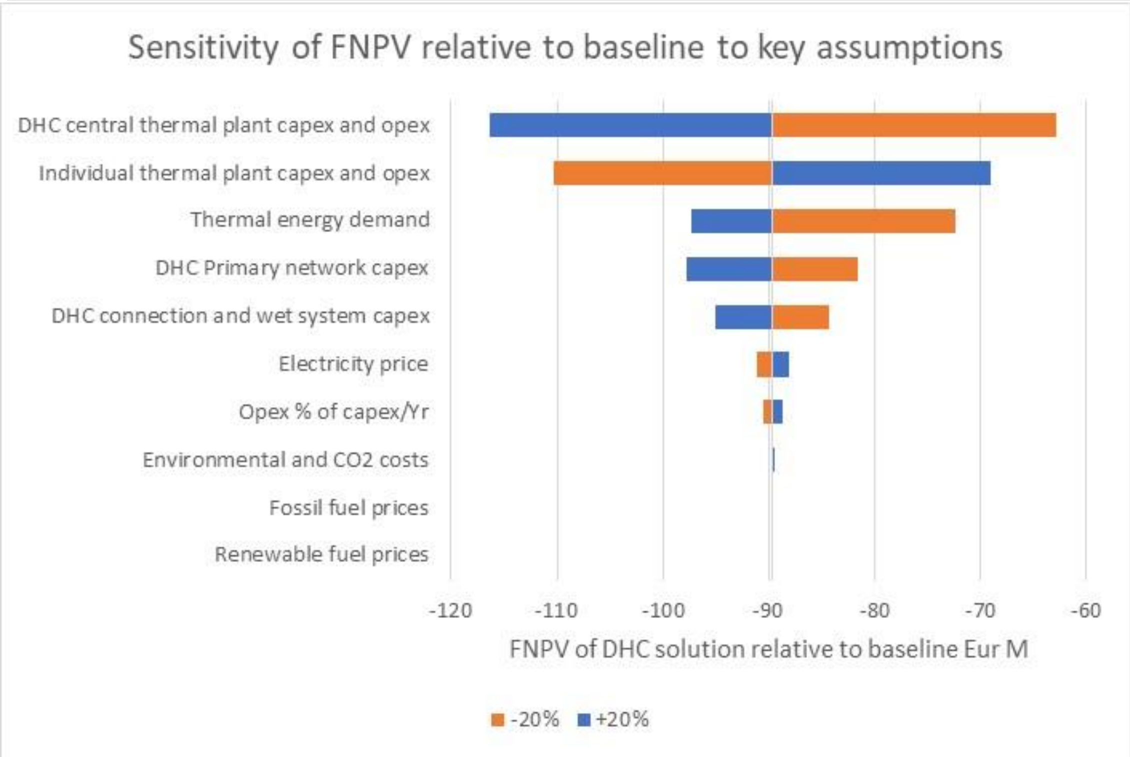


Figure 2 Sensitivity of ENPV and FNPV to changes in key input parameters to the CBA (Post Code 5290, Solution 12, water source heat pump with 2 pipe heat with distributed absorption chillers.





For postcode 8852 with solution 3 (Biomethane CHP with 2 pipe heat with distributed absorption chillers), the input parameter with the greatest influence on the value of the ENPV is the capital and maintenance cost of the main plant (biomethane CHP plant, backup boilers, and distributed absorption chillers). Next in order of impact is the capital and maintenance costs of the competing individual baseline technologies. Third in order of impact is the capital costs of the DHC network, which have a much lower impact than that of the above parameters. If the capital cost of the main plant were to reduce by 20%, the scheme would be economic from a social perspective but not a financial perspective.

For postcode 5290 with solution 12 (reversible water source heat pump with 2 pipe heat with distributed absorption chillers), again the most significant 2 parameters are the capital and maintenance costs of the main plant (water source heat pumps) followed by the capital and maintenance costs of the competing baseline technologies. However, the parameter with the third largest impact is the thermal demand. If the capital cost of the main plant were to reduce by 20%, the DHC scheme would still not be economic from a social or financial perspective.

8 Discussion

8.1 Relative Economic, CO_2 and Energy Performance of District Heating and Cooling (DHC) and Individual Building Solutions

As seen above, when modelling at the Post Code level, with the DHC solution modelled to supply all of the susceptible heating and cooling demand in the Post Code, with the exception of one DHC solution in one post code, DHC is not cost effective relative to the existing baseline from a social point of view. High efficiency individual building level solutions are found to be cost effective, relative to the baseline, for the large majority of the heating and cooling demand modelled here.

For all building architypes modelled (i.e. all residential and service sector buildings), the most cost-effective solution is heat pumps driven by PV supplying heating, cooling and solar thermal providing sanitary hot water, where the last is not already modelled as being satisfied by solar thermal. Compared against the baseline technologies, deployment of PV driven heat pumps will save both CO_2 and primary energy.

For the industry architypes, the only practical high efficiency solutions are CHP fuelled by biomass, biomethane, oil, or LPG. The grade of heat demand modelled for industry is such that DHC and heat pump heating driven solutions are naturally discounted[21]. A compressed biomethane supply chain is under development, this gives the best and only potentially widespread socially cost-effective solution. The results show biomethane CHP is cost effective in all industrial archıtypes modelled (sites not currently in the ETS with low grade hot water or steam requirements) and in some service sectors (hotels and shops). None of the other options provide a positive ENPV or FNPV. Biomass CHP would save CO_2 but have high damage costs associated with emissions. Neither oil nor LPG CHP solutions is found to save CO_2 relative to the baseline for the period of the analysis. We understand that natural gas may soon become available which will be less polluting than oil and is predicted to be cheaper than oil or LPG. But this would be earmarked for use in power generation in the foreseeable future which is one reason the carbon intensity of electricity is predicted to fall, making heat pumps an increasingly attractive option. However, in the longer term, natural gas fired CHP may also be economic for industry if gas becomes more widely available. For a Natural Gas fired CHP to meet the carbon intensity limit of 270 gCO2e/kWh of useful energy, would have to deliver an annual efficiency of 75%.

For agriculture architypes, which are modelled as not requiring cooling or high-grade heat, heat pumps without PV are the most cost-effective solution for providing heating. This produces both CO_2 and primary energy savings relative to the baseline.

8.2 The Effect of future changes in energy demands and costs.

The main impact of modelling the heating and cooling strategy with plant installed in 2030 rather than 2025 is that PV becomes less economically attractive, likely due to decreases in electricity and associated environmental costs. The impact of increased demand is likely to be less significant cause of this shift. However, the modelling shows heat pumps providing heating and cooling and solar thermal providing hot water will still be the best solution in most cases aside from industry where not suitable.

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[21] Heat pumps can be deployed at industrial sites to supply high grade heat at acceptable levels of efficiency if high grade waste heat is available for recovery and upgrading via a heat pump. However, the availability of high-grade waste heat presupposes the existing of combustion on the site and there is insufficient information available about the availability and grade of waste heat to model this possibility. Consequently, all heat demand is modelled as requiring fuel combustion.

8.3 What is Hampering DHC Solutions?

DHC solutions, in the vast majority of cases, fail to register positive NPV values because the net cash flows, relative to the baseline, are insufficient to balance the additional investment costs that have to be made. This may in part be because of the necessary approach taken to model DHC schemes, whereby each DHC scheme is modelled to supply all post code heating and cooling demand and not specifically selected densely populated sub-sets of this. Under this approach, the size of the central DHC thermal plant and pipe network will not be optimised for the quantity of heat and cooling demand and so operational savings per unit Capex will tend to be lower than they could be if specific heating and cooling demand areas were selected to be served by the DHC scheme.

The two sub post code tourist areas evaluated produce a positive ENPV and FNPV, though less positive than the best mix of individual high efficiency solutions. These areas have many hotels and were defined so as to capture specific zones known to be heating and cooling dense, thereby improving the optimisation of the scale of DHC plant and network for the demand. It is also likely that the economic case is improved in these areas because they have no residential demand in them. In the residential sector in Cyprus the heating and cooling demand is essentially zero for up to four months of the year and so there is a significant proportion of the year when savings are not generated to offset the Capex of the DHC serving residential properties.

From this finding it can be concluded that there is likely to be little socially economic cost-effective potential for DHC (at post code level or financially cost effective potential when compared with individual high efficiency solutions. However, there may be a small amount of potential which is financially cost effective when compared with the baseline only. Further investigation would require that smaller areas of dense non-domestic heating and cooling demand be investigated on a case-by-case basis. It is recommended to carry out further localised studies on the cost effectiveness of DHC solutions in tourist areas with a high density of hotels at the sub-postcode level. In addition, it is recommended to evaluate the viability of biomethane CHP with DHC for these areas, and other similar areas with concentration of hotels and or large commercial buildings.

8.4 Waste Heat DHC Solutions

The only sources of significant waste heat (suitable for DHC) are from power stations and cement. Cement works are unsuitable for waste heat in DHC as this site type would typically use their own waste heat in the process, furthermore the cement site in Cyprus is remote from areas of population density. There are three power stations in Cyprus, Moni and Vasilikos power stations are unsuitable for waste heat recovery due to their locations remote from populous areas.

The cost-effective waste heat DHC solution is found in Post Code 7502 and relates to the recovery of waste heat from the ICEs operating at Dhekelia power station. The power generated by these ICEs is known and from this the quantity of waste heat has been calculated[22]. While this calculated heat is sufficient to meet the heating and cooling demand of Post Code = 7502, it is unclear from the data available whether the availability of this waste heat coincides with heating and cooling demand. Since this is unlikely to be the case, thermal storage has been modelled. This thermal store has been sized to be as large as it can be whilst still being the best solution of this Post Code. The size of this “cost effective” thermal store is sufficient to meet a heat demand for cooling (via an absorption chiller) of 103 MW for 4 hours.

Whether this thermal store is large enough to cover the deficit of supply would have to be examined further by analysing data on the coincidence of waste heat from the ICEs and demand for heating and cooling.

[22] The heat that can be recovered from ICEs is genuine waste heat, because if not recovered would just be released to the atmosphere. This can be contrasted with the heat that “might” be extracted for a steam turbine. In the case of the latter a price is paid in terms of power generation being given up in exchange for the extracted heat and so, in that respect, the heat in question is not waste heat.

9 Conclusions

The CBA for efficient heating and cooling for the Republic of Cyprus has shown that there is very little to no socially economic potential for District Heating and Cooling (DHC), when evaluated at the Post Code level, which is necessary to obtain an estimate of potential at the national level.

The CBA has also evaluated the economic potential for DHC at a more detailed scale than the Post Code level for two specifically defined tourist areas known to have high density of demand. These two areas are found to be cost effective from both a financial and economic point of view. Further detailed studies will be needed to determine whether this holds true when more detailed analysis is undertaken into economic, practical and technical feasibility.

Overwhelmingly, heat pumps with solar thermal are found to be the high efficiency solution with the highest economic potential in the residential, agricultural and most service sectors. In all of the service sectors and for single houses and apartments in low land and coastal areas, incorporating solar PV alongside heat pumps will improve the economics. This result would have to be refined with more local data about the suitability of residential and service buildings for the installation of PV. However, for cases where PV was found not to be practical, the most economical solution would revert to heat pumps powered by grid electricity for the overwhelming majority of buildings.

For hotels and shops, biomethane CHP appears to be the most socially cost-effective option. Although, the modelling work identified biomethane CHP solution for shops in semi-mountainous areas to be the best cost-effective solution, it is not considered as the best particular solution due to the lack of available space for the CHP engine and the biomethane storage, and should not be considered further.

Within the Industry sector, the only suitable high efficiency solutions modelled are CHP fired by biomass, biomethane, oil and LPG. In all cases modelled, biomethane has the best economic solution. So, biomethane CHP has potential to decarbonise industrial heat demand provided the supply chain can supply this demand.

Appendices

Appendix 1 - Heating and Cooling Consumption for the Modelled Architypes

Appendix 2 - External Costs of CO_2 (Economic Analysis only)

Appendix 3 - CO_2 Traded Prices for EU ETS Installations (Financial Analysis Only)

Appendix 4 - Marginal Damage Costs for NOx, PM10 and SOx Associated with Fuel Combustion

Appendix 5 - Assumed Hours of Occupancy of Different Building Types

Appendix 6 - Energy Prices Set 1

Appendix 7 – CO_2 Emissions Associated with Grid Electricity Over Time and Overall Efficiency of Generation

Appendix 8 - Energy Technology Assumptions

Appendix 9 - District Heating and Cooling Pipework Assumptions

Appendix 10 - Best Individual Solutions for Evaluated Architypes

A1 Heating and Cooling Consumption for the Modelled Architypes

Table 9-1 Heating and Cooling Consumption for Modelled Architypes (Coastal Areas)

Sector	Architype	Space/Process Heating Demand (MWh)	Cooling Demand (MWh)	SHW Demand (MWh)
Residential	Apartment	1,808	4,781	1,408
	Row house	2,538	3,341	1,682
	Single house	2,893	4,834	2,063
Service	Airports	4,218,255	12,938,006	560
	Restaurant	45,260	104,942	17,828
	Hospitals	695,206	1,525,936	667,115
	Hotels	301,785	1,683,353	159,905
	Offices	28,074	63,915	-
	Schools	52,274	146,797	11,847
	Shopping	5,768	29,899	21
	Other Services	70,431	225,457	24,326
Industrial (Non-EU ETS)	Chemicals	93,247	52,946	-
	Food and Drink	94,803	14,452	-
	Other Minerals	14,752	0	-
	Other Industry	14,527	0	-
Agriculture	Greenhouses	2,978	0	-
	Other Agriculture	2,978	0	-

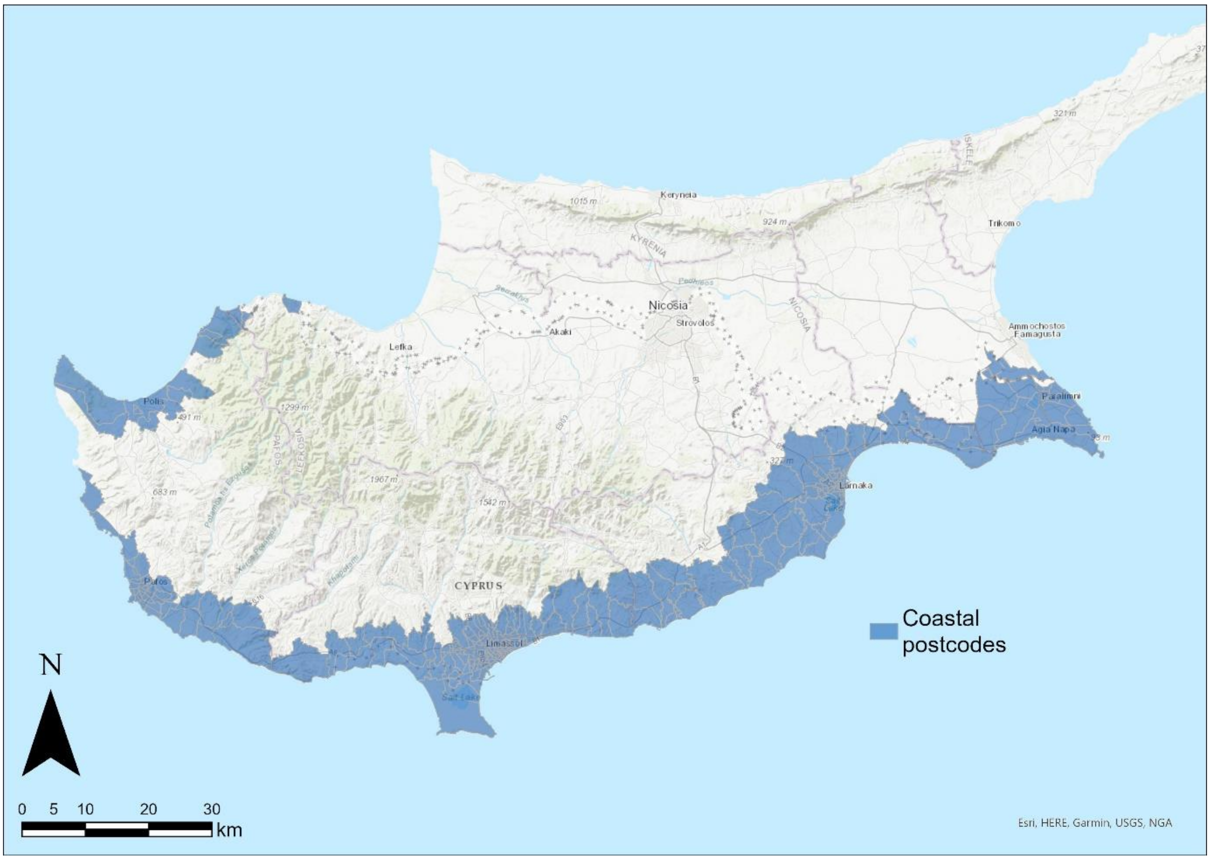

Coastal postcodes
N
0 5 10 20 30 km
Nicosia
Kyrenia
Famagusta
Larnaka
Limassol
Pafos
Polis
Lefka
Akaki
Strovolos
Trikomo
Paralimni
Agia Napa
CYPRUS
Esri, HERE, Garmin, USGS, NGA

Table 9-2 Heating and Cooling Consumption for Modelled Architypes (Low Land Areas)

Sector	Architype	Space/Process Heating Demand (MWh)	Cooling Demand (MWh)	SHW Demand (MWh)
Residential	Apartment	1,815	4,799	1,413
	Row house	2,581	3,398	1,710
	Single house	2,893	4,834	2,063
Service	Airports	0	0	-
	Restaurant	45,260	104,942	17,828
	Hospitals	914,201	2,006,618	877,261
	Hotels	175,768	980,434	93,134
	Offices	28,074	63,915	-
	Schools	59,547	167,221	13,495
	Shopping	5,110	26,486	19
	Other Services	70,415	225,408	24,320
Industrial (Non-EU ETS)	Chemicals	130,238	73,950	-
	Food and Drink	58,614	8,935	-
	Other Minerals	6,883	0	-
	Other Industry	11,947	0	-
Agriculture	Greenhouses	2,248	0	-
	Other Agriculture	2,248	0	-

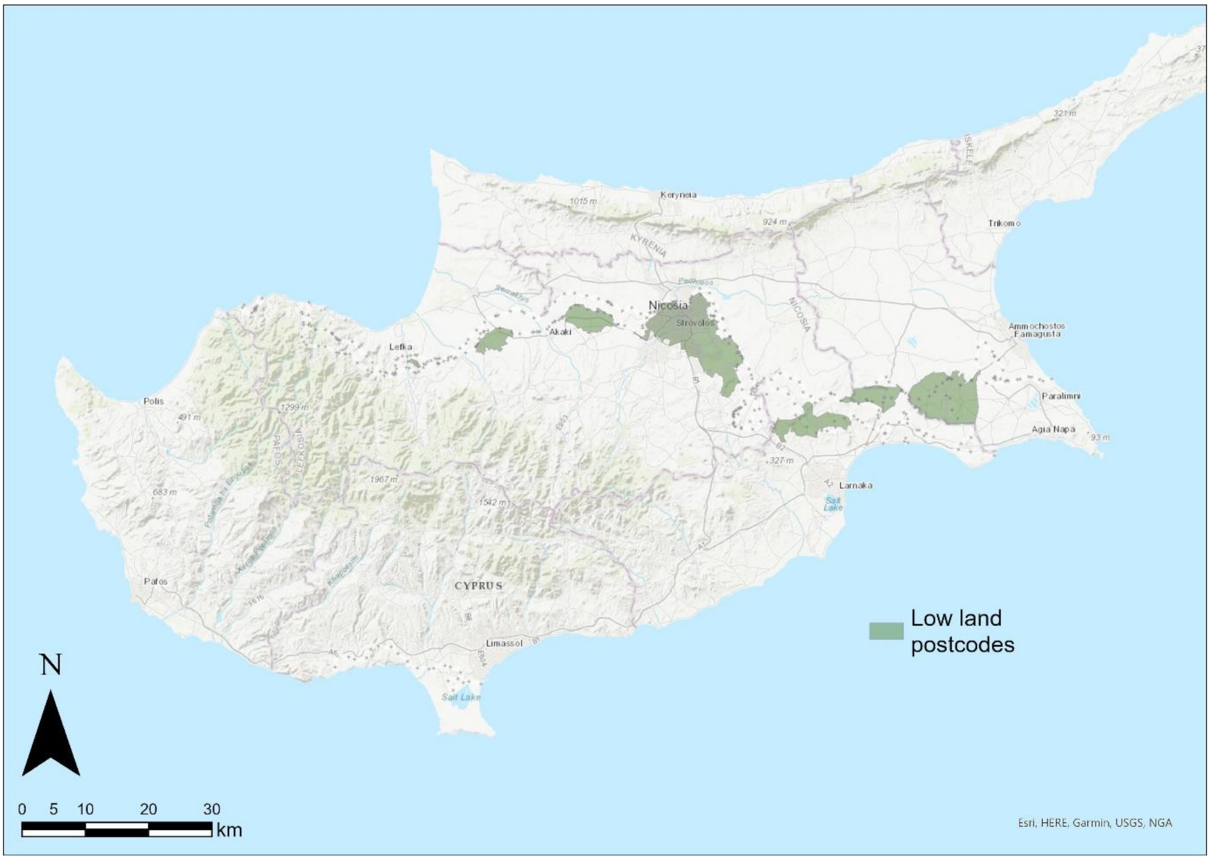

Kyrenia
Nicosia
Strovolos
Akaki
Lefka
Polis
Trikomo
Ammochostos
Famagusta
Paralimni
Agia Napa
Larnaka
CYPRUS
Pafos
Limassol
Low land postcodes
N
0 5 10 20 30
km
Esri, HERE, Garmin, USGS, NGA

Table 9-3 Heating and Cooling Consumption for Modelled Architypes (Mountainous Areas)

Sector	Architype	Space/Process Heating Demand (MWh)	Cooling Demand (MWh)	SHW Demand (MWh)
Residential	Apartment	5,431	0	1,410
	Row house	7,226	0	1,596
	Single house	8,679	0	2,063
Service	Airports	0	0	-
	Restaurant	135,780	0	17,828
	Hospitals	2,431,754	0	777,832
	Hotels	152,575	0	26,948
	Offices	84,221	0	-
	Schools	68,578	0	5,181
	Shopping	16,694	0	21
	Other Services	206,514	0	23,776
Industrial (Non-EU ETS)	Chemicals	0	0	-
	Food and Drink	35,335	0	-
	Other Minerals	3,528	0	-
	Other Industry	8,766	0	-
Agriculture	Greenhouses	2,398	0	-
	Other Agriculture	2,398	0	-

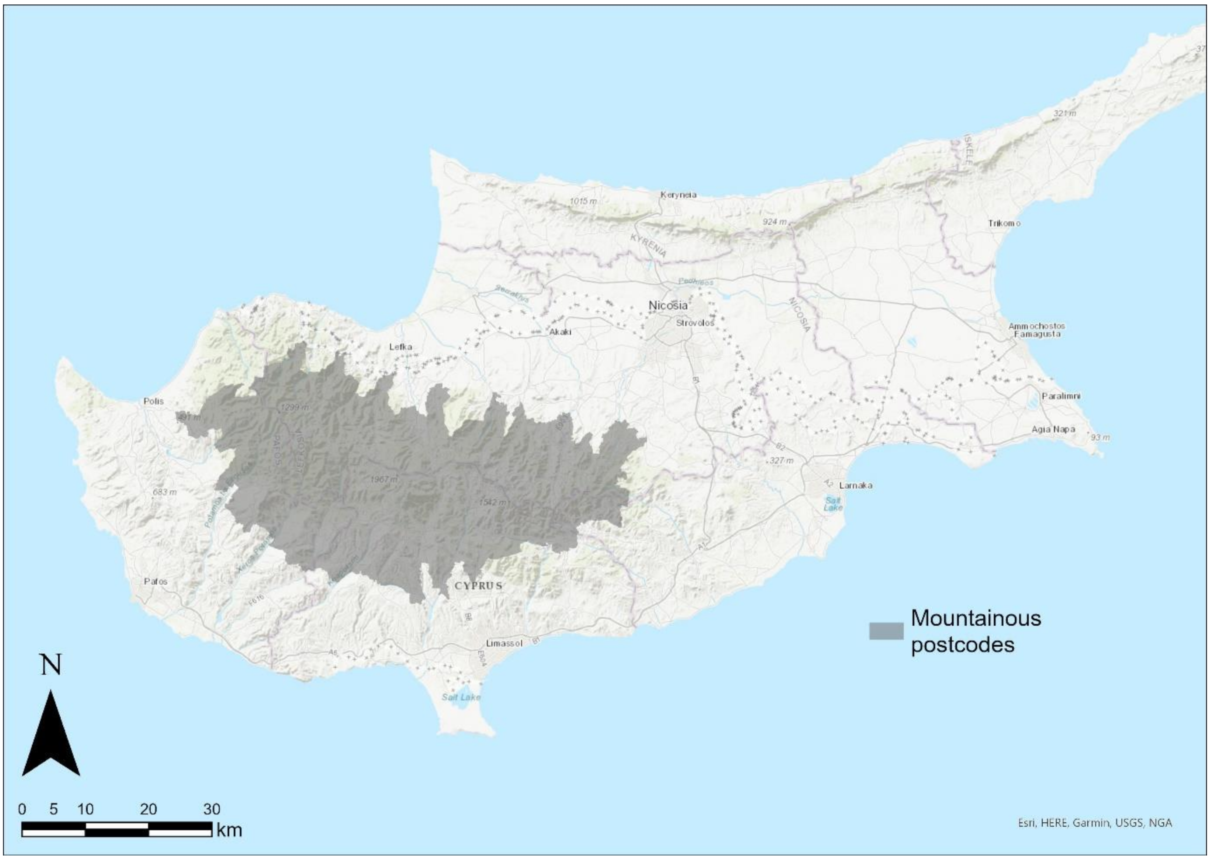
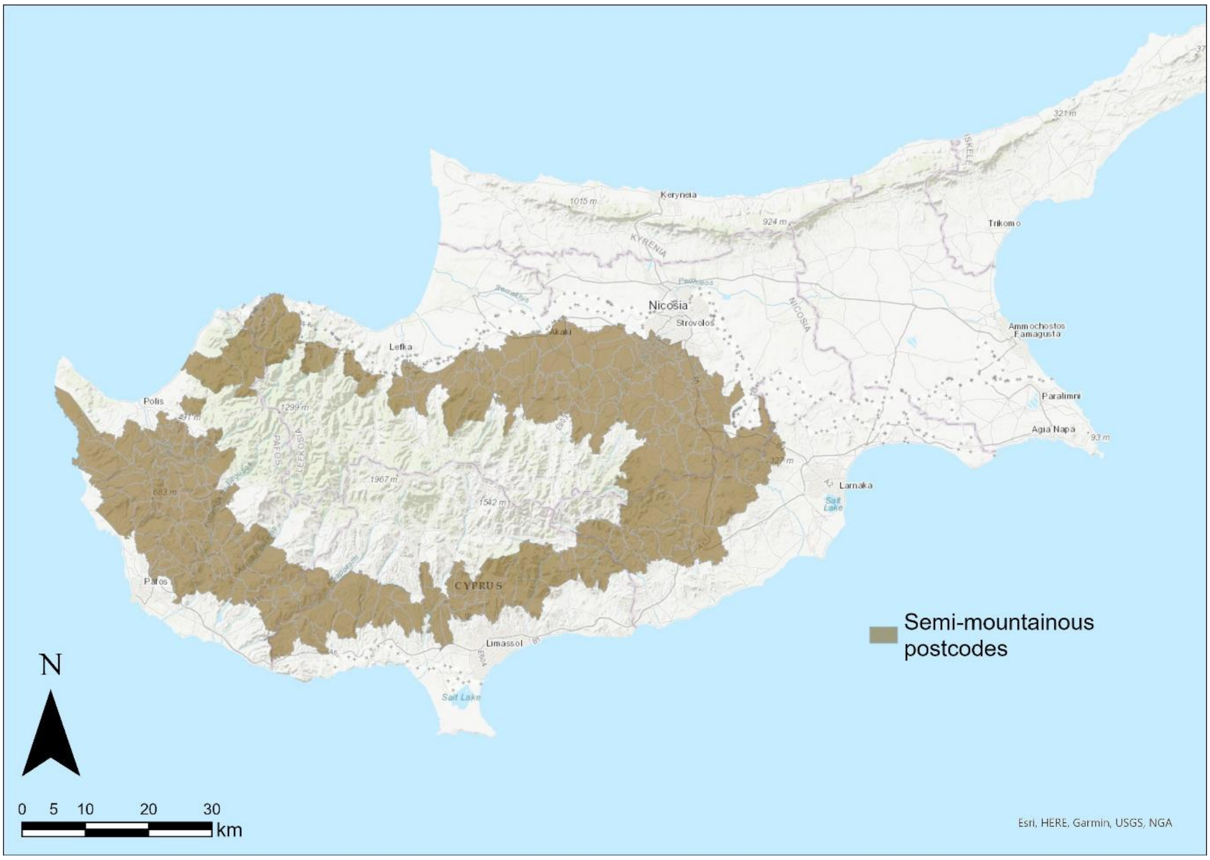

Nicosia
Mountainous postcodes
N
0 5 10 20 30
km
Esri, HERE, Garmin, USGS, NGA

Table 9-4 Heating and Cooling Consumption for Modelled Architypes (Semi--Mountainous Areas)

Sector	Architype	Space/Process Heating Demand (MWh)	Cooling Demand (MWh)	SHW Demand (MWh)
Residential	Apartment	2,159	3,330	1,401
	Row house	2,979	2,288	1,645
	Single house	3,472	3,383	2,063
Service	Airports	0	0	-
	Restaurant	54,312	73,459	17,828
	Hospitals	1,393,115	1,783,720	1,114,020
	Hotels	92,742	301,768	40,951
	Offices	33,688	44,740	-
	Schools	47,391	77,632	8,950
	Shopping	5,673	17,154	17
	Other Services	82,948	154,890	23,874
Industrial (Non-EU ETS)	Chemicals	108,940	43,300	-
	Food and Drink	104,388	11,139	-
	Other Minerals	8,745	0	-
	Other Industry	20,077	0	-
Agriculture	Greenhouses	1,748	0	-
	Other Agriculture	1,748	0	-


Semi-mountainous postcodes
N
0 5 10 20 30
km
Kyrenia
Kyreneia
Nicosia
Strovolos
Lefka
Akaki
Trikomo
Ammochostos Famagusta
Paralimni
Agia Napa
Larnaka
Salt Lake
Polis
Pafos
Limassol
CYPRUS
1015 m
924 m
321 m
1299 m
491 m
1967 m
1542 m
683 m
327 m
93 m
Esri, HERE, Garmin, USGS, NGA

A2 External Costs of CO_2 (Economic Analysis only)

Table 9-5 External costs of CO_2 (€2023). Equated with traded prices which are generally higher than previous projection.

	Traded (EU-ETS) €/TCO2
2023	€ 88.46
2024	€ 90.18
2025	€ 91.90
2026	€ 91.90
2027	€ 91.90
2028	€ 91.90
2029	€ 91.90
2030	€ 91.90
2031	€ 92.36
2032	€ 92.82
2033	€ 93.28
2034	€ 93.74
2035	€ 94.20
2036	€ 94.89
2037	€ 95.58
2038	€ 96.27
2039	€ 96.96
2040	€ 97.65
2041	€ 97.65
2042	€ 97.65
2043	€ 97.65
2044	€ 97.65
2045	€ 97.65
2046	€ 97.65
2047	€ 97.65
2048	€ 97.65
2049	€ 97.65
2050	€ 97.65
2051	€ 97.65
2052	€ 97.65
2053	€ 97.65
2054	€ 97.65
2055	€ 97.65
2056	€ 97.65
2057	€ 97.65
2058	€ 97.65

A3 CO_2 Prices for ETS1 and 2 (Financial Analysis Only)

Table 9-6 Traded costs of CO_2 (€2023). Traded costs used only in financial analysis where relevant.

	ETS1 €/TCO2	ETS2 €/TCO2
2023	€ 88.46	€ 0.00
2024	€ 90.18	€ 0.00
2025	€ 91.90	€ 0.00
2026	€ 91.90	€ 0.00
2027	€ 91.90	€ 30.00
2028	€ 91.90	€ 50.00
2029	€ 91.90	€ 55.00
2030	€ 91.90	€ 60.00
2031	€ 92.36	€ 60.00
2032	€ 92.82	€ 60.00
2033	€ 93.28	€ 60.00
2034	€ 93.74	€ 60.00
2035	€ 94.20	€ 60.00
2036	€ 94.89	€ 60.00
2037	€ 95.58	€ 60.00
2038	€ 96.27	€ 60.00
2039	€ 96.96	€ 60.00
2040	€ 97.65	€ 60.00
2041	€ 97.65	€ 60.00
2042	€ 97.65	€ 60.00
2043	€ 97.65	€ 60.00
2044	€ 97.65	€ 60.00
2045	€ 97.65	€ 60.00
2046	€ 97.65	€ 60.00
2047	€ 97.65	€ 60.00
2048	€ 97.65	€ 60.00
2049	€ 97.65	€ 60.00
2050	€ 97.65	€ 60.00
2051	€ 97.65	€ 60.00
2052	€ 97.65	€ 60.00
2053	€ 97.65	€ 60.00
2054	€ 97.65	€ 60.00
2055	€ 97.65	€ 60.00
2056	€ 97.65	€ 60.00
2057	€ 97.65	€ 60.00
2058	€ 97.65	€ 60.00

A4 Marginal Damage Costs for NOx, PM10 and SOx Associated with Fuel Combustion

Used in economic analysis only.

Appendix_4_MDC_Electricity_2024.xlsx

Fuel Type	NOx €2020/MWh	PM10 €2020/MWh	SOx €2020/MWh	Total Cost €2020/MWh	Comments
Electricity	**Varies each year is response to changing electricity generation mix. See attached spreadsheet for in year values.**				
Solid	7.40	77.83	73.22	**158.46**	**Applies all years**
Liquid	21.95	13.30	3.82	**39.08**	**Applies all years**
Gaseous	3.17	0.52	0.05	**3.74**	**Applies all years**
Biomass	3.89	95.13	0.89	**99.92**	**Applies all years**

A5 Assumed Hours of Occupancy of Different Building Types

Table 9-7 Hours of occupancy assumed for heating, cooling and SHW for a range of different building and end user types

Sub_Sector_no	Sub_Sector_list	Average weekly cooling hours in summer e.g. 8-5PM x 5 days per week = 45	Average weekly heating hours in winter e.g. 8-5PM x 5 days per week = 45	Average weekly water heating hours e.g. 8-5PM x 5 days per week = 45	Heating and cooling affected by degree days 1/0	Occupancy factor space cooling	Occupancy factor space heating	Occupancy factor water heating
1	Hotel_3star+	168.00	168.00	168.00	1	100.0%	100.0%	100.0%
2	Hotel_Other	168.00	168.00	168.00	1	100.0%	100.0%	100.0%
3	Education_1-2_Public	90.00	90.00	168.00	1	53.6%	53.6%	100.0%
4	Education_1-2_Private	90.00	90.00	168.00	1	53.6%	53.6%	100.0%
5	Education_Tertiary	90.00	90.00	168.00	1	53.6%	53.6%	100.0%
6	Public_Electric_Heating	90.00	90.00	168.00	1	53.6%	53.6%	100.0%
7	Public_Oil_Heating	90.00	90.00	168.00	1	53.6%	53.6%	100.0%
8	Supermarket	90.00	90.00	168.00	1	53.6%	53.6%	100.0%
9	Shopping_Malls	90.00	90.00	168.00	1	53.6%	53.6%	100.0%
10	Hospital_Public	168.00	168.00	168.00	1	100.0%	100.0%	100.0%
11	Health_Private	168.00	168.00	168.00	1	100.0%	100.0%	100.0%
12	Restaurant	90.00	90.00	168.00	1	53.6%	53.6%	100.0%
13	Office__Electric_Heating	45.00	45.00	168.00	1	26.8%	26.8%	100.0%
14	Office_Oil_Heating	45.00	45.00	168.00	1	26.8%	26.8%	100.0%
15	Retail	90.00	90.00	168.00	1	53.6%	53.6%	100.0%
16	House	90.00	90.00	168.00	1	53.6%	53.6%	100.0%
17	Apartment	90.00	90.00	168.00	1	53.6%	53.6%	100.0%
18	Airport	168.00	168.00	168.00	1	100.0%	100.0%	100.0%
19	Other_Services	168.00	168.00	168.00	1	100.0%	100.0%	100.0%
20	Cement	117.60	117.60	117.60	0	70.0%	70.0%	70.0%
21	Chemicals	117.60	117.60	117.60	0	70.0%	70.0%	70.0%
22	Food, tobacco and beverage	117.60	117.60	117.60	0	70.0%	70.0%	70.0%
23	Other minerals	117.60	117.60	117.60	0	70.0%	70.0%	70.0%
24	Other industry	117.60	117.60	117.60	0	70.0%	70.0%	70.0%
25	Greenhouses	10.50	10.50	10.50	0	6.3%	6.3%	6.3%
26	Other agriculture	90.00	90.00	168.00	1	53.6%	53.6%	100.0%
27	All	168.00	168.00	168.00	1	100.0%	100.0%	100.0%
28	Derelict/outbuilding	168.00	168.00	168.00	1	100.0%	100.0%	100.0%

A6 Energy Prices Set 1

Table 9-8 Fuel Prices – Economic analysis 2023-2040 (EURO2023/MWh GCV)

Sector	Subsector	Fuel	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Service	All	Electricity	149.65	156.60	149.18	123.91	99.96	100.67	103.13	107.01	105.89	104.76	103.63	102.51	101.38	102.19	102.99	103.80	104.61	105.41
Service	All	Diesel fuel oil	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75
Service	All	Gas oil_CHP	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86
Service	All	Gas oil_non_CHP	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86
Service	All	Light fuel oil	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90
Service	All	Kerosene	93.99	94.14	94.29	95.12	95.94	96.76	97.59	98.41	99.01	99.60	100.19	100.78	101.37	102.79	104.21	105.62	107.04	108.46
Service	All	LPG	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55
Service	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Service	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Service	All	RDF	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
Service	All	Natural gas	90.53	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	19.12	20.54	21.95	23.37	24.79
Service	All	Biomethane	0.00	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13
Industry	All	Electricity	149.65	156.60	149.18	123.91	99.96	100.67	103.13	107.01	105.89	104.76	103.63	102.51	101.38	102.19	102.99	103.80	104.61	105.41
Industry	All	Diesel fuel oil	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75
Industry	All	Gas oil_CHP	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86
Industry	All	Gas oil_non_CHP	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86
Industry	All	Light fuel oil	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90
Industry	All	Kerosene	93.99	94.14	94.29	95.12	95.94	96.76	97.59	98.41	99.01	99.60	100.19	100.78	101.37	102.79	104.21	105.62	107.04	108.46
Industry	All	LPG	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55
Industry	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industry	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Industry	All	RDF	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
Industry	All	Natural gas	90.53	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	19.12	20.54	21.95	23.37	24.79
Industry	All	Biomethane	0.00	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13
Agriculture	All	Electricity	149.65	156.60	149.18	123.91	99.96	100.67	103.13	107.01	105.89	104.76	103.63	102.51	101.38	102.19	102.99	103.80	104.61	105.41
Agriculture	All	Diesel fuel oil	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75	86.75
Agriculture	All	Gas oil_CHP	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86
Agriculture	All	Gas oil_non_CHP	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86
Agriculture	All	Light fuel oil	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90
Agriculture	All	Kerosene	93.99	94.14	94.29	95.12	95.94	96.76	97.59	98.41	99.01	99.60	100.19	100.78	101.37	102.79	104.21	105.62	107.04	108.46
Agriculture	All	LPG	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55
Agriculture	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Agriculture	All	RDF	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
Agriculture	All	Natural gas	90.53	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	19.12	20.54	21.95	23.37	24.79
Agriculture	All	Biomethane	0.00	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13
Residential	All	Electricity	149.65	156.60	149.18	123.91	99.96	100.67	103.13	107.01	105.89	104.76	103.63	102.51	101.38	102.19	102.99	103.80	104.61	105.41
Residential	All	Gas oil_non_CHP	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86	83.86
Residential	All	Light fuel oil	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90	73.90
Residential	All	Kerosene	93.99	94.14	94.29	95.12	95.94	96.76	97.59	98.41	99.01	99.60	100.19	100.78	101.37	102.79	104.21	105.62	107.04	108.46
Residential	All	LPG	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55	86.55
Residential	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residential	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Residential	All	Natural gas	90.53	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	17.70	19.12	20.54	21.95	23.37	24.79
Residential	All	Biomethane	0.00	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13

Table 9-9 Fuel Prices - Economic analysis 2041-2058 (EURO2023/MWh GCV)

Sector	Subsector	Fuel	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058
Service	All	Electricity	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41
Service	All	Diesel fuel oil	97.43	108.05	118.61	129.13	139.60	142.49	145.37	148.26	151.14	154.01	154.01	154.01	154.01	154.01	154.01	154.01	154.01	154.01
Service	All	Gas oil_CHP	94.19	104.45	114.66	124.83	134.95	137.75	140.53	143.32	146.11	148.89	148.89	148.89	148.89	148.89	148.89	148.89	148.89	148.89
Service	All	Gas oil_non_CHP	94.19	104.45	114.66	124.83	134.95	137.75	140.53	143.32	146.11	148.89	148.89	148.89	148.89	148.89	148.89	148.89	148.89	148.89
Service	All	Light fuel oil	83.00	92.05	101.05	110.01	118.93	121.39	123.84	126.30	128.75	131.20	131.20	131.20	131.20	131.20	131.20	131.20	131.20	131.20
Service	All	Kerosene	109.09	109.72	110.36	110.99	111.63	112.58	113.53	114.48	115.43	116.38	116.38	116.38	116.38	116.38	116.38	116.38	116.38	116.38
Service	All	LPG	97.20	107.80	118.34	128.83	139.28	142.16	145.04	147.91	150.79	153.66	153.66	153.66	153.66	153.66	153.66	153.66	153.66	153.66
Service	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Service	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Service	All	RDF	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
Service	All	Natural gas	26.20	27.62	29.03	30.45	31.87	33.99	36.12	38.24	40.36	42.49	42.49	42.49	42.49	42.49	42.49	42.49	42.49	42.49
Service	All	Biomethane	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13
Industry	All	Electricity	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41
Industry	All	Diesel fuel oil	97.43	108.05	118.61	129.13	139.60	142.49	145.37	148.26	151.14	154.01	154.01	154.01	154.01	154.01	154.01	154.01	154.01	154.01
Industry	All	Gas oil_CHP	94.19	104.45	114.66	124.83	134.95	137.75	140.53	143.32	146.11	148.89	148.89	148.89	148.89	148.89	148.89	148.89	148.89	148.89
Industry	All	Gas oil_non_CHP	94.19	104.45	114.66	124.83	134.95	137.75	140.53	143.32	146.11	148.89	148.89	148.89	148.89	148.89	148.89	148.89	148.89	148.89
Industry	All	Light fuel oil	83.00	92.05	101.05	110.01	118.93	121.39	123.84	126.30	128.75	131.20	131.20	131.20	131.20	131.20	131.20	131.20	131.20	131.20
Industry	All	Kerosene	109.09	109.72	110.36	110.99	111.63	112.58	113.53	114.48	115.43	116.38	116.38	116.38	116.38	116.38	116.38	116.38	116.38	116.38
Industry	All	LPG	97.20	107.80	118.34	128.83	139.28	142.16	145.04	147.91	150.79	153.66	153.66	153.66	153.66	153.66	153.66	153.66	153.66	153.66
Industry	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industry	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Industry	All	RDF	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
Industry	All	Natural gas	26.20	27.62	29.03	30.45	31.87	33.99	36.12	38.24	40.36	42.49	42.49	42.49	42.49	42.49	42.49	42.49	42.49	42.49
Industry	All	Biomethane	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13
Agriculture	All	Electricity	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41
Agriculture	All	Diesel fuel oil	97.43	108.05	118.61	129.13	139.60	142.49	145.37	148.26	151.14	154.01	154.01	154.01	154.01	154.01	154.01	154.01	154.01	154.01
Agriculture	All	Gas oil_CHP	94.19	104.45	114.66	124.83	134.95	137.75	140.53	143.32	146.11	148.89	148.89	148.89	148.89	148.89	148.89	148.89	148.89	148.89
Agriculture	All	Gas oil_non_CHP	94.19	104.45	114.66	124.83	134.95	137.75	140.53	143.32	146.11	148.89	148.89	148.89	148.89	148.89	148.89	148.89	148.89	148.89
Agriculture	All	Light fuel oil	83.00	92.05	101.05	110.01	118.93	121.39	123.84	126.30	128.75	131.20	131.20	131.20	131.20	131.20	131.20	131.20	131.20	131.20
Agriculture	All	Kerosene	109.09	109.72	110.36	110.99	111.63	112.58	113.53	114.48	115.43	116.38	116.38	116.38	116.38	116.38	116.38	116.38	116.38	116.38
Agriculture	All	LPG	97.20	107.80	118.34	128.83	139.28	142.16	145.04	147.91	150.79	153.66	153.66	153.66	153.66	153.66	153.66	153.66	153.66	153.66
Agriculture	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Agriculture	All	RDF	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
Agriculture	All	Natural gas	26.20	27.62	29.03	30.45	31.87	33.99	36.12	38.24	40.36	42.49	42.49	42.49	42.49	42.49	42.49	42.49	42.49	42.49
Agriculture	All	Biomethane	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13
Residential	All	Electricity	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41	105.41
Residential	All	Gas oil_non_CHP	94.19	104.45	114.66	124.83	134.95	137.75	140.53	143.32	146.11	148.89	148.89	148.89	148.89	148.89	148.89	148.89	148.89	148.89
Residential	All	Light fuel oil	83.00	92.05	101.05	110.01	118.93	121.39	123.84	126.30	128.75	131.20	131.20	131.20	131.20	131.20	131.20	131.20	131.20	131.20
Residential	All	Kerosene	109.09	109.72	110.36	110.99	111.63	112.58	113.53	114.48	115.43	116.38	116.38	116.38	116.38	116.38	116.38	116.38	116.38	116.38
Residential	All	LPG	97.20	107.80	118.34	128.83	139.28	142.16	145.04	147.91	150.79	153.66	153.66	153.66	153.66	153.66	153.66	153.66	153.66	153.66
Residential	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residential	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Residential	All	Natural gas	26.20	27.62	29.03	30.45	31.87	33.99	36.12	38.24	40.36	42.49	42.49	42.49	42.49	42.49	42.49	42.49	42.49	42.49
Residential	All	Biomethane	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13	56.13

Table 9-10 Fuel Prices - Financial analysis 2023-2040 (EURO2023/MWh GCV)

Sector	Subsector	Fuel	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Service	All	Electricity	326.10	341.26	325.09	270.02	217.84	219.38	224.73	233.20	230.74	228.29	225.83	223.37	220.92	222.68	224.44	226.19	227.95	229.71
Service	All	Diesel fuel oil	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76
Service	All	Gas oil_CHP	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37
Service	All	Gas oil_non_CHP	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37
Service	All	Light fuel oil	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62
Service	All	Kerosene	106.37	106.54	106.70	107.64	108.57	109.50	110.44	111.37	112.04	112.71	113.38	114.05	114.72	116.32	117.93	119.53	121.13	122.73
Service	All	LPG	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63
Service	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Service	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Service	All	RDF	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
Service	All	Natural gas	114.77	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	33.40	35.02	36.63	38.25	39.86
Service	All	Biomethane	0.00	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80
Industry	All	Electricity	326.10	341.26	325.09	270.02	217.84	219.38	224.73	233.20	230.74	228.29	225.83	223.37	220.92	222.68	224.44	226.19	227.95	229.71
Industry	All	Diesel fuel oil	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76
Industry	All	Gas oil_CHP	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37
Industry	All	Gas oil_non_CHP	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37
Industry	All	Light fuel oil	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62
Industry	All	Kerosene	106.37	106.54	106.70	107.64	108.57	109.50	110.44	111.37	112.04	112.71	113.38	114.05	114.72	116.32	117.93	119.53	121.13	122.73
Industry	All	LPG	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63
Industry	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industry	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Industry	All	RDF	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
Industry	All	Natural gas	114.77	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	33.40	35.02	36.63	38.25	39.86
Industry	All	Biomethane	0.00	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80
Agriculture	All	Electricity	326.10	341.26	325.09	270.02	217.84	219.38	224.73	233.20	230.74	228.29	225.83	223.37	220.92	222.68	224.44	226.19	227.95	229.71
Agriculture	All	Diesel fuel oil	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76	160.76
Agriculture	All	Gas oil_CHP	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37
Agriculture	All	Gas oil_non_CHP	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37
Agriculture	All	Light fuel oil	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62
Agriculture	All	Kerosene	106.37	106.54	106.70	107.64	108.57	109.50	110.44	111.37	112.04	112.71	113.38	114.05	114.72	116.32	117.93	119.53	121.13	122.73
Agriculture	All	LPG	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63
Agriculture	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Agriculture	All	RDF	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
Agriculture	All	Natural gas	114.77	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	33.40	35.02	36.63	38.25	39.86
Agriculture	All	Biomethane	0.00	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80
Residential	All	Electricity	345.20	361.24	344.13	285.84	230.60	232.23	237.90	246.85	244.26	241.66	239.06	236.46	233.86	235.72	237.58	239.44	241.30	243.16
Residential	All	Gas oil_non_CHP	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37	109.37
Residential	All	Light fuel oil	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62	89.62
Residential	All	Kerosene	126.58	126.78	126.98	128.09	129.20	130.31	131.42	132.53	133.33	134.12	134.92	135.72	136.52	138.42	140.33	142.24	144.15	146.05
Residential	All	LPG	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63	104.63
Residential	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residential	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Residential	All	Natural gas	114.77	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	31.79	33.40	35.02	36.63	38.25	39.86
Residential	All	Biomethane	0.00	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80

Table 9-11 Fuel Prices - Financial analysis 2041-2058 (EURO2023/MWh GCV)

Sector	Subsector	Fuel	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058
Service	All	Electricity	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71
Service	All	Diesel fuel oil	173.99	187.15	200.24	213.27	226.25	229.82	233.40	236.97	240.54	244.10	244.10	244.10	244.10	244.10	244.10	244.10	244.10	244.10
Service	All	Gas oil_CHP	120.82	132.21	143.54	154.81	166.04	169.13	172.23	175.32	178.41	181.49	181.49	181.49	181.49	181.49	181.49	181.49	181.49	181.49
Service	All	Gas oil_non_CHP	120.82	132.21	143.54	154.81	166.04	169.13	172.23	175.32	178.41	181.49	181.49	181.49	181.49	181.49	181.49	181.49	181.49	181.49
Service	All	Light fuel oil	100.41	111.13	121.80	132.42	142.99	145.91	148.83	151.74	154.65	157.55	157.55	157.55	157.55	157.55	157.55	157.55	157.55	157.55
Service	All	Kerosene	123.45	124.17	124.89	125.61	126.32	127.40	128.48	129.55	130.63	131.71	131.71	131.71	131.71	131.71	131.71	131.71	131.71	131.71
Service	All	LPG	117.51	130.32	143.07	155.75	168.38	171.86	175.34	178.82	182.29	185.76	185.76	185.76	185.76	185.76	185.76	185.76	185.76	185.76
Service	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Service	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Service	All	RDF	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
Service	All	Natural gas	41.47	43.09	44.70	46.31	47.93	50.35	52.77	55.19	57.61	60.03	60.03	60.03	60.03	60.03	60.03	60.03	60.03	60.03
Service	All	Biomethane	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80
Industry	All	Electricity	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71
Industry	All	Diesel fuel oil	173.99	187.15	200.24	213.27	226.25	229.82	233.40	236.97	240.54	244.10	244.10	244.10	244.10	244.10	244.10	244.10	244.10	244.10
Industry	All	Gas oil_CHP	120.82	132.21	143.54	154.81	166.04	169.13	172.23	175.32	178.41	181.49	181.49	181.49	181.49	181.49	181.49	181.49	181.49	181.49
Industry	All	Gas oil_non_CHP	120.82	132.21	143.54	154.81	166.04	169.13	172.23	175.32	178.41	181.49	181.49	181.49	181.49	181.49	181.49	181.49	181.49	181.49
Industry	All	Light fuel oil	100.41	111.13	121.80	132.42	142.99	145.91	148.83	151.74	154.65	157.55	157.55	157.55	157.55	157.55	157.55	157.55	157.55	157.55
Industry	All	Kerosene	123.45	124.17	124.89	125.61	126.32	127.40	128.48	129.55	130.63	131.71	131.71	131.71	131.71	131.71	131.71	131.71	131.71	131.71
Industry	All	LPG	117.51	130.32	143.07	155.75	168.38	171.86	175.34	178.82	182.29	185.76	185.76	185.76	185.76	185.76	185.76	185.76	185.76	185.76
Industry	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Industry	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Industry	All	RDF	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
Industry	All	Natural gas	41.47	43.09	44.70	46.31	47.93	50.35	52.77	55.19	57.61	60.03	60.03	60.03	60.03	60.03	60.03	60.03	60.03	60.03
Industry	All	Biomethane	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80
Agriculture	All	Electricity	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71	229.71
Agriculture	All	Diesel fuel oil	173.99	187.15	200.24	213.27	226.25	229.82	233.40	236.97	240.54	244.10	244.10	244.10	244.10	244.10	244.10	244.10	244.10	244.10
Agriculture	All	Gas oil_CHP	120.82	132.21	143.54	154.81	166.04	169.13	172.23	175.32	178.41	181.49	181.49	181.49	181.49	181.49	181.49	181.49	181.49	181.49
Agriculture	All	Gas oil_non_CHP	120.82	132.21	143.54	154.81	166.04	169.13	172.23	175.32	178.41	181.49	181.49	181.49	181.49	181.49	181.49	181.49	181.49	181.49
Agriculture	All	Light fuel oil	100.41	111.13	121.80	132.42	142.99	145.91	148.83	151.74	154.65	157.55	157.55	157.55	157.55	157.55	157.55	157.55	157.55	157.55
Agriculture	All	Kerosene	123.45	124.17	124.89	125.61	126.32	127.40	128.48	129.55	130.63	131.71	131.71	131.71	131.71	131.71	131.71	131.71	131.71	131.71
Agriculture	All	LPG	117.51	130.32	143.07	155.75	168.38	171.86	175.34	178.82	182.29	185.76	185.76	185.76	185.76	185.76	185.76	185.76	185.76	185.76
Agriculture	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agriculture	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Agriculture	All	RDF	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32	2.32
Agriculture	All	Natural gas	41.47	43.09	44.70	46.31	47.93	50.35	52.77	55.19	57.61	60.03	60.03	60.03	60.03	60.03	60.03	60.03	60.03	60.03
Agriculture	All	Biomethane	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80
Residential	All	Electricity	243.16	243.16	243.16	243.16	243.16	243.16	243.16	243.16	243.16	243.16	243.16	243.16	243.16	243.16	243.16	243.16	243.16	243.16
Residential	All	Gas oil_non_CHP	120.82	132.21	143.54	154.81	166.04	169.13	172.23	175.32	178.41	181.49	181.49	181.49	181.49	181.49	181.49	181.49	181.49	181.49
Residential	All	Light fuel oil	100.41	111.13	121.80	132.42	142.99	145.91	148.83	151.74	154.65	157.55	157.55	157.55	157.55	157.55	157.55	157.55	157.55	157.55
Residential	All	Kerosene	146.91	147.76	148.62	149.47	150.32	151.61	152.89	154.17	155.45	156.73	156.73	156.73	156.73	156.73	156.73	156.73	156.73	156.73
Residential	All	LPG	117.51	130.32	143.07	155.75	168.38	171.86	175.34	178.82	182.29	185.76	185.76	185.76	185.76	185.76	185.76	185.76	185.76	185.76
Residential	All	Solar	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Residential	All	Wood Chip (20%)	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02	51.02
Residential	All	Natural gas	41.47	43.09	44.70	46.31	47.93	50.35	52.77	55.19	57.61	60.03	60.03	60.03	60.03	60.03	60.03	60.03	60.03	60.03
Residential	All	Biomethane	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80	100.80

A7 CO_2 Emissions Associated with Grid Electricity Over Time and Overall Efficiency of Generation

Table 9-9 Ratio of primary energy input to delivered electricity output and CO_2 intensity of delivered electricity

Year	Primary delivered power generation energy efficiency	Delivered electricity CO2 intensity
	%GCV	TCO2/MWh
2023	42.89%	0.597
2024	48.28%	0.427
2025	53.71%	0.330
2026	53.51%	0.321
2027	53.55%	0.321
2028	54.07%	0.317
2029	54.17%	0.309
2030	53.79%	0.308
2031	55.47%	0.285
2032	57.26%	0.262
2033	59.18%	0.239
2034	61.22%	0.217
2035	63.41%	0.194
2036	64.69%	0.181
2037	66.02%	0.169
2038	67.41%	0.156
2039	68.86%	0.144
2040	70.37%	0.131
2041	71.15%	0.125
2042	71.95%	0.119
2043	72.77%	0.113
2044	73.60%	0.106
2045	74.46%	0.100
2046	75.16%	0.095
2047	75.87%	0.090
2048	76.60%	0.085
2049	77.34%	0.080
2050	78.10%	0.075
2051	78.10%	0.075
2052	78.10%	0.075
2053	78.10%	0.075
2054	78.10%	0.075
2055	78.10%	0.075
2056	78.10%	0.075
2057	78.10%	0.075
2058	78.10%	0.075

A8 Energy Technology Assumptions

Technology_Assumptions.xlsx

A9 District Heating and Cooling Pipework Assumptions

DHC_Pipe_Assumptions.xlsx

A10 Best Individual Solutions for Evaluated Architypes

Sector	Subsector	Climatic Regions	Best Individual Solution	ENPV (€) Relative to Baseline (Range due to climatic region)	FNPV (€) Relative to Baseline (Range due to climatic region)	Saves CO_2 Relative to Baseline Over 2022 to 2050	Saves Primary Relative to Baseline Over 2022 to 2050
Residential	**Apartment**	**Mountainous + semi-mountainous.** **Low land and coastal**	**Heat pumps and solar hot water.** **PV+ heat pumps and solar hot water**	**1,300 to 1,400**	**1,100 to 2,100**	**Y**	**Y**
Residential	**Row House**	**All**	**Heat pumps and solar hot water**	**4,700 to 6,600**	**1,800 to 2,400**	**Y**	**Y**
Residential	**Single House**	**All**	**PV + Heat Pump + Solar Hot Water**	**5,700 to 8,100**	**3,300 to 4,100**	**Y**	**Y**

Sector	Subsector	Climatic Regions	Best Individual Solution	ENPV (€) Relative to Baseline (Range due to climatic region)	FNPV (€) Relative to Baseline (Range due to climatic region)	Saves CO_2 Relative to Baseline Over 2022 to 2050	Saves Primary Relative to Baseline Over 2022 to 2050
Service	Airports	Only one climatic region has airports.	PV + Heat Pump + Solar Hot Water	14,272,000	10,900,000	Y	Y
Service	Restaurant	All	PV + Heat Pump + Solar Hot Water	85,000 to 99,000	55,000 to 76,000	Y	Y
Service	Health (public)	All	PV + Heat Pump + Solar Hot Water	1,754,000 to 2,610,000	1,299,000 to 1,909,000	Y	Y
Service	Hotels	Semi-mountainous Other climatic regions	Individual Biomethane CHP PV + Heat Pump + Solar Hot Water	476,000 to 2,578,000	143,000 to 1,256,000	Y	Y
Service	Offices	All	PV + Heat Pump + Solar Hot Water	49,000 to 63,000	29,000 to 48,000	Y	Y
Service	Schools	All	PV + Heat Pump + Solar Hot Water	40,000 to 151,000	25,000 to 118,000	Y	Y
Service	Shopping	Semi-mountainous Other climatic regions	Individual Biomethane CHP PV + Heat Pump + Solar Hot Water	6,000 to 15,000	3,000 to 13,000	Y	Y
Service	Other	All	PV + Heat Pump + Solar Hot Water	145,000 to 194,000	91,000 to 154,000	Y	Y

Sector	Subsector	Climatic Regions	Best Individual Solution	ENPV (€) Relative to Baseline (Range due to climatic region)	FNPV (€) Relative to Baseline (Range due to climatic region)	Saves CO_2 Relative to Baseline Over 2022 to 2050	Saves Primary Relative to Baseline Over 2022 to 2050
Industry	Chemicals (Non-EU ETS)	All except mountainous where there are none	Individual Biomethane CHP	466,000 to 853,000	147,000 to 358,000	Y	Y
Industry	Food and Drink (Non-EU ETS)	All	Individual Biomethane CHP	192,000 to 664,000	67,000 to 262,000	Y	Y
Industry	Other Industry (Non-EU ETS)	All	Individual Biomethane CHP	58,000 to 134,000	20,000 to 45,000	Y	Y

Sector	Subsector	Climatic Regions	Best Individual Solution	ENPV (€) Relative to Baseline (Range due to climatic region)	FNPV (€) Relative to Baseline (Range due to climatic region)	Saves CO_2 Relative to Baseline Over 2022 to 2050	Saves Primary Relative to Baseline Over 2022 to 2050
Agriculture	**Greenhouses**	**All**	**Heat Pumps + Solar Hot Water**	**2,000 to 3,700**	**-1,100 to -700**	**Y**	**Y**
Agriculture	**Other agriculture**	**All**	**Heat Pumps + Solar Hot Water**	**3,900 to 6,700**	**700 to 1,200**	**Y**	**Y**

A10.1 Subsidy for Greenhouse Architypes

Subsector	Climatic region	Total support required where ENPV is positive and FNPV Negative (= -FNPV)	Annualised support requirement over 20-year lifetime at 12% discount rate €/Year	Total Heating + cooling + SHW provided (no SHW if baseline-solar) MWh	Support required €/MWh heat supplied
Greenhouses	Semi_Mountainous	€ 705	€ 94	1.7	€ 54
Greenhouses	Mountainous	€ 897	€ 120	2.4	€ 50
Greenhouses	Low_Land	€ 854	€ 114	2.2	€ 51
Greenhouses	Coastal	€ 1,056	€ 141	3.0	€ 47
Greenhouses	Average				€ 51

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