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Comprehensive Assessment of the Potential for Efficient Heating and Cooling

Report for Points A and B

Report for MECI, Cyprus

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Contact:

Aisling Crowley, Gemini Building, Fermi Avenue, Harwell, Didcot, OX11 0QR, UK

T: +44(0)7968707754

E: aisling.crowley@ricardo.com

Author:

Jeremy Stambaugh and Aisling Crowley

Approved by:

Mahmoud Abu Ebid

Signed

Date:

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Glossary

Abbreviation	Definition
CCGT	Combined Cycle Gas Turbine
FEC	Final Energy Consumption (input of electricity, fuels, or geothermal heat to the heating or cooling equipment)
HHV	Higher Heating Value
ICE	Internal Combustion Engine
LHV	Lower Heating Value
OCGT	Open Cycle Gas Turbine
RE	Reciprocating Engine
ST	Steam Turbine
UE	Useful energy (energy consumed by end users in the form of heat or cold)

1 Point A Determination of Annual Heating and Cooling Demand in Terms of Assessed Useful Energy and Quantified Final Energy Consumption

1.1 Introduction

Under Point A we determine the annual heating and cooling demand in terms of useful energy (UE) and quantified final energy consumption (FEC).

Consistent with the terms of the Technical Specifications set out by MECI, it is confirmed that useful energy means here the energy consumed by end users in the form of heat or cold after all steps have taken place to transform an input of electricity, fuel or primary heat, via a process of transformation taking place in heating or cooling equipment, into heat and cold.

The energy input to the transformation process is confirmed here as the quantified final energy consumption. This final energy consumption takes the form of input of electricity, fuels or geothermal heat to the heating or cooling equipment. As such it is the energy shown as “Final energy consumption” in the national energy balance for Cyprus by Eurostat, apart from ambient heat which we have excluded.

In this work we refer to Eurostat Cyprus energy balance for 2022 and our analysis is conducted so that there is consistency between the final energy consumption in the energy balance and the total final energy consumption derived here for the purposes of heating and cooling. However, agreement between final energy consumption of a particular fuel in the energy balance and the final energy consumption of the same fuel associated with heating and cooling should not be automatically expected, since a proportion of the fuel shown in the energy balance may be consumed for purposes other than providing heating and cooling. This is especially the case, for example, for electricity where a large proportion of the final electricity consumed is for providing motive power or lighting.

The UE and FEC are broken down by the sector consuming the heat or cold. Here we observe the following sectors of consumption:

- Residential
- Services
- Industry, and
- Agriculture

We do not include any other distinct sectors in our analysis since we do not believe that any other sector on its own accounts for more than 5% of total national useful heating or cooling demand.

Furthermore, we disaggregate demand according to the associated grade of heat and cooling. This is a key step underpinning further analysis on the technical and economic potential for efficient heat and cooling, since the grade of heat determines the technical viability of a range of potential heating technologies. Therefore, we classify the following grades of heating and cooling:

- High grade heat – Heat which is consumed in industry at >400°C
- Medium grade heat - Heat which is consumed in industry in the range 100°C - 400°C
- Low grade heat - Heat which is consumed in industry in the range <100°C
- Heating – Heat which is consumed for space heating in the Residential, Services or Agricultural sectors
- Sanitary Hot Water (SHW) – Heat for providing this service in the Residential and Service sectors
- Cooling – Cooling provided for the Residential and Service sectors, which can be provided by cooling fluids down to 4°C. Chilling below this temperature is excluded from this work on the grounds that it is difficult to achieve using absorption chilling – the efficient means of providing such cooling.
- For heating and cooling, where the input involves the consumption of electricity (i.e. resistance heaters and heat pumps for cooling) a proportion of this electricity input is considered renewable.

- The methodology is based on EUROSTAT 2022 data, 'Gross electricity production' for Renewables and biofuels is divided by the total to calculate renewable electricity share.
- According to Eurostat, in 2022, 16.78% of the electricity generated was renewable[1], and this is the proportion of electricity consumption considered renewable.

1.2 General Approach

Our general approach to establishing the UE and FEC associated with providing the above grades of heating and cooling across the relevant sectors can be summarised as follows:

- Build on the work done in 2021 in support of the NCA
- Make improvements to assumptions used in the previous work in response to new information received.
- Update the work to reflect changes to the official energy balance for Cyprus and utilise other data sources which have become available in the meantime.

The specific approach followed for each of the four sectors is detailed in the sections below.

1.3 Residential Sector

1.3.1 Residential Sector Overview

According to Eurostat, in 2022 the residential sector in Cyprus had a final energy consumption 360.542ktoe (4,193,103 MWh)[2], of which the largest share was electricity (42.4%). Solar thermal accounted for the second largest proportion (18.0%) followed by gas oil (15.5%), LPG (11.0%), primary solid biofuels (4.2%), ambient heat (3.5%), kerosene (3.4%), and charcoal (1.9%).

As shown below, the FEC associated with heating and cooling in the residential sector, excluding ambient heat, has been estimated to be 2,755,731 MWh.

1.3.2 Residential Data Sources Used

REE split of 2018 final energy by sector, subsector, end use, fuel and technology.

REE split of 2018 useful energy by sector, subsector, end use, fuel and technology.

National Energy Balance for Cyprus, Eurostat 2018

National Energy Balance for Cyprus, Eurostat 2022

Final consumption in households, MECI 2021[3]

Heat pump energy forecasts for 2022, MECI[4]

1.3.3 Residential Sector Methodology

The process for deriving the FEC and UE for heating, cooling and SHW for 2022 in the residential sector is summarised as follows:

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[1] Out of a total gross electricity production of 453.0 ktoe, 76.0 ktoe came from renewable sources.
[2] Note, this figure includes final energy consumed for all purposes, and so is larger than the final energy consumption figures derived for just heating and cooling.
[3] 2021 residential final energy split by thermal and non-thermal end uses provided by MECI residential <final cons in households 2021.xls>
[4] Heat pump final energy (electricity input) and useful energy (ambient heat) forecast for 2022 as supplied by MECI within workbook <Heat Pump Renewable energy.xlsx>

1. Using the 2021 residential final energy split by thermal and non-thermal end uses provided by MECI <final cons in households 2021.xls>
2. Calculate the 2021 % of total final energy for cooling, heating and SHW for each fuel type
3. Multiply the 2021 heating, cooling and SHW % by the final energy in the EUROSTAT 2022 energy balance for the residential sector for each fuel to calculate final energy for each fuel for cooling, heating and SHW.
4. Take EUROSTAT 2022 and divide 'Gross electricity production' for Renewables and biofuels by the total to calculate renewable electricity share.
5. Split electricity into renewable and non-renewable using renewable electricity share.
6. Take the heat pump residential final energy (electricity input) forecast for 2022 as supplied by MECI within workbook <Heat Pump Renewable energy.xlsx> and deduct from EUROSTAT (residential final electricity) to calculate final energy for non-heat pump technologies for each fuel type.
7. Aggregate 2018 final energy calculated in 2021 NCA to calculate final energy for non-heat pump technologies for each fuel type in 2018.
8. Calculate ratio of final energy in 2022 vs 2018 for each fuel type for heat pumps and separately for non-heat pump technologies.
9. Multiply the ratio of final energy for 2022 vs 2018 to the UE split by subsector, end use, fuel and technology for 2018, which was an output of the 2021 NCA, to calculate UE split for 2022. Split electricity into renewable and non-renewable as explained in introduction above.
10. Divide each element by the end use specific conversion factor turning UE into FE, thereby returning the FEC. The conversion factors used in this step are 99% for resistive electric heating as presented in *Table 5 Energy Conversion Factors (Final to Useful) from: <Report Households.pdf>*. In the case of heat pumps used for heating, the ambient heat reported in EUROSTAT has been added to the heat pump electricity consumption as supplied by MECI[5]. In the case of heat pumps used for cooling, the minimum space cooling energy efficiency set out in Commission Regulation (EU) 2016/2281 has been used[6]. Fossil fuel boiler efficiencies have been based on the harmonised EU reference values for the separate production of heat[7].

1.3.4 Residential Sector Results

1.3.4.1 Useful Energy Consumption

Table 1-1 Residential UE by fuel

Fuel	Useful Energy Consumption 2022 (MWh)
Ambient heat (heat pumps)	148,399
Electricity (non-renewable)	1,909,500
Electricity (renewable)	385,021
Gas oil	565,116
Geothermal	-
Kerosene	124,230

[5] Heat pump ambient heat should align with the data supplied by MECI. However, there is a small discrepancy so the ambient heat is equated with EUROSTAT.
[6] See Table 3 of Commission Regulation (EU) 2016/2281 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R2281&from=EN
[7] See Annex II of Commission Delegated Regulation (EU) 2015/2402 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2402&from=DE

LPG	218,725
Solar	619,841
Solid biomass	151,172
Total	**4,122,005**

Table 1-2 Residential UE by end use

End Use	Useful Energy Consumption 2022 (MWh)
Cooling	1,931,218
Heating	1,354,019
SHW	836,768
Total	**4,122,005**

Table 1-3 Residential UE by technology

Technology	Useful Energy Consumption 2022 (MWh)
Boilers	1,059,244
Heat pumps	2,141,843
Resistance heaters	301,078
Solar panels	619,841
Total	**4,122,005**

The full split of useful energy in the residential sector by subsector, end use, fuel and technology is given in the Excel file provided in Appendix 1.

1.3.4.2 Final Energy Consumption

Table 1-4 Residential FEC by fuel

Fuel	Final Energy Consumption 2022 (MWh)
Electricity (non-renewable)	658,550
Electricity (renewable)	132,787
Gas oil	649,559
Geothermal	-
Kerosene	142,793
LPG	240,358
Solar	755,903
Solid biomass	175,782
Total	**2,755,731**

Table 1-5 Residential FEC by end use

End Use	Final Energy Consumption 2022 (MWh)
Cooling	426,788
Heating	1,342,334
SHW	986,609
Total	**2,755,731**

Table 1-6 Residential FEC by technology

Technology	Final Energy Consumption 2022 (MWh)
Boilers	1,208,491
Heat pumps	489,015
Resistance heaters	302,322
Solar panels	755,903
Total	**2,755,731**

The full split of final energy consumption in the residential sector by subsector, end use, fuel and technology is given in the Excel file provided in Appendix 2.

1.4 Service Sector

1.4.1 Service Sector Overview

In 2022 the service sector in Cyprus had a final energy consumption of 288.779ktoe (3,358,500 MWh), according to Eurostat. Of this, electricity was the largest proportion (67.7%), followed by ambient heat (13.1%), gas oil (5.4%), LPG (4.5%), solar thermal (4.0%), charcoal (1.6%), solid biofuels (1.4%), fuel oil (1.3%), kerosene (0.8%), biogas (0.2%), and blended biodiesels (0.02%).

As shown below, the FEC associated with heating and cooling in the service sector, excluding ambient heat, has been estimated to be 1,537,521 MWh.

1.4.2 Service Sector Data Sources Used

REE split of 2018 final energy by sector, subsector, end use, fuel and technology.

REE split of 2018 useful energy by sector, subsector, end use, fuel and technology.

National Energy Balance for Cyprus, Eurostat 2018

National Energy Balance for Cyprus, Eurostat 2022

Heat Pump Energy Forecast for 2022, MECI[8]

CHP operating data provided by MECI < CHP 2022.xlsx>

1.4.3 Service Sector Methodology

1. Using CHP data provided by MECI <CHP 2022.xlsx>, each scheme was allocated to appropriate service, industry or agriculture subsector[9].

[8] Heat pump final energy (electricity input) and useful energy (ambient heat) forecast for 2022 as supplied by MECI within workbook <Heat Pump Renewable energy.xlsx>

[9] According to MECI, 7 of the CHP schemes are animal production (NACE code 0146), 3 are sewage treatment works (NACE code 3700), 3 are waste materials recovery sites (NACE code 3821) and one is in the food industry (NACE 1011). These 4 groups are attributed to the agriculture (other agriculture), services (other services), and industry (Food, tobacco and beverages) subsectors respectively. The third group might have been expected to be attributed to services but was attributed to agriculture in 2021 and the fuel consumption of these 3 sites coupled with that of the sewage treatment sites greatly exceeds the EUROSTAT 2022 final energy totals for the service sector. Therefore, these have been attributed to agriculture as in 2021.

2. 'Fuel for heat' for each service sector CHP scheme was calculated based on fuel consumption and operating efficiency.
3. We have taken the heat pump service sector final energy (electricity input) forecast for 2022 as supplied by MECI within workbook <Heat Pump Renewable energy.xlsx>.
4. The total CHP fuel for heat, and heat pump final energy (electricity) were subtracted from the final energy totals (EUROSTAT data) for each fuel, apart from biogas[10], to calculate final energy for non-heat pump and non-CHP technologies for each fuel type.[11]
5. The 2018 final energy calculated in 2021 NCA was aggregated to calculate final energy for non-heat pump and non-CHP technologies for each fuel type in 2018.
6. The ratio of final energy in 2022 vs 2018 was calculated for each fuel type for heat pumps and separately for non-heat pump and non-CHP technologies.
7. To calculate UE split for 2022; The fuel for CHP heat was extracted from data provided from MECI. For other technology types, the ratios of final energy for 2022 vs 2018 for heat pumps and other technologies were multiplied by the UE split for each subsector, end use, fuel and technology for 2018 (an output of the 2021 NCA).
8. In 2018 no blended biodiesel consumption was reported but some was reported in 2022. Therefore, the split by subsector and end use was based on the 2018 FE split for gasoil.
9. Electricity has been split into renewable and non-renewable as explained in introduction above.
10. For CHP, the UE (heat output) and the service subsector is informed directly by the CHP data and all attributed to heating as all sewage treatment works. Each non CHP element was divided by the end use specific conversion factor turning UE into FE, thereby returning the FEC. The conversion factors used in this step are 99% for resistive electric heating as presented in *Table 5 Energy Conversion Factors (Final to Useful) from: <Report Households.pdf>*. In the case of heat pumps used for heating, the ambient heat reported in EUROSTAT has been added to the heat pump electricity consumption as supplied by MECI[12]. In the case of heat pumps used for cooling, the minimum space cooling energy efficiency set out in Commission Regulation (EU) 2016/2281 has been used[13]. Fossil fuel boiler efficiencies have been based on the harmonised EU reference values for the separate production of heat[14].

1.4.4 Service Sector Results

1.4.4.1 Useful Energy Consumption

Table 1-7 Service sector UE by fuel

Fuel	Useful Energy Consumption 2022 (MWh)
Ambient heat (heat pumps)	438,381
Biogases	3,473
Blended biodiesels	1,244
Electricity (non-renewable)	2,687,343

[10] In the case of biogas it is understood that no biogas is consumed other than in CHP and the difference between CHP consumption and EUROSTAT was assumed to be an error

[12] Heat pump ambient heat should align with the data supplied by MECI. However, there is a small discrepancy so the ambient heat is equated with EUROSTAT.
[13] See Table 3 of Commission Regulation (EU) 2016/2281 *https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R2281&from=EN*
[14] See Annex II of Commission Delegated Regulation (EU) 2015/2402 *https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2402&from=DE*

Electricity (renewable)	541,862
Gas oil	154,187
Kerosene	21,926
Light fuel oil	39,106
LPG	82,036
Solar	95,667
Solid biomass	36,851
Total	**4,102,077**

Table 1-8 Service sector UE by end use

End Use	Useful Energy Consumption 2022 (MWh)
Cooling	2,908,397
Heating	957,448
SHW	236,231
Total	**4,102,077**

Table 1-9 Service sector UE by technology

Technology	Useful Energy Consumption 2022 (MWh)
Boilers	335,351
CHP[15]	3,473
Heat pumps	3,598,434
Resistance heaters	69,152
Solar panels	95,667
Total	**4,102,077**

The full split of useful energy in the service sector by subsector, end use, fuel and technology is given in the Excel file provided in Appendix 1.

[15] CHP in the Service sector is used exclusively in the waste management industry (STW and MSW processing sites).

1.4.4.2 Final Energy Consumption

Table 1-10 Service sector FEC by fuel

Fuel	Final Energy Consumption 2022 (MWh)
Biogases	4,099
Blended biodiesels	1,464
Electricity (non-renewable)	868,891
Electricity (renewable)	175,199
Gas oil	177,226
Kerosene	25,202
Light fuel oil	44,950
LPG	90,150
Solar	107,491
Solid biomass	42,850
Total	**1,537,521**

Table 1-11 Service sector FEC by end use

End Use	Final Energy Consumption 2022 (MWh)
Cooling	722,583
Heating	551,820
SHW	263,118
Total	**1,537,521**

Table 1-12 Service sector FEC by technology

Technology	Final Energy Consumption 2022 (MWh)
Boilers	381,842
CHP	4,099
Heat pumps	974,239
Resistance heaters	69,850
Solar panels	107,491
Total	**1,537,521**

The full split of final energy consumption in the service sector by subsector, end use, fuel and technology is given in the Excel file provided in Appendix 2.

Industry Sector

1.4.5 Industry Sector Overview

In 2022 the industrial sector in Cyprus had a final energy consumption of 248.447ktoe (2,889,439 MWh), according to Eurostat. Of this electricity accounted for the largest share (20.2%), followed by Non-renewable municipal waste (16.6%), other bituminous coal (12.3%), gas oil (12.3%), fuel oil (11.8%) renewable municipal waste (10.8%), primary solid biofuels (4.9%), petroleum coke (4.7%), LPG (3,4%), industrial waste (non-renewable) (2.1%), biogas (0.6%), blended biofuels (0.2%), solar thermal (0.2%), and kerosene (0.01%).

The municipal waste and petroleum coke consumption is driven by the demand of the cement clinker producing process at Vasilikos. This plant and the ceramics producing installations are the most significant industrial undertakings in the Republic of Cyprus. Together, cement and ceramics production account for a little over two thirds of the final energy consumed in industry.

As shown below, the FEC associated with heating and cooling in the industry sector has been estimated to be 2,403,409 MWh.

1.4.6 Industry Sector Data Sources Used

REE split of 2018 final energy by sector, subsector, end use, fuel and technology.

REE split of 2018 useful energy by sector, subsector, end use, fuel and technology.

National Energy Balance for Cyprus, Eurostat 2018

National Energy Balance for Cyprus, Eurostat 2022

Industrial information supplied by MECI <Copy of IndAnalysis_1015f-FINAL.xlsx>

CHP operating data provided by MECI <CHP 2022.xlsx>

ETS fuel data provided by MECI <ETS 2022.xlsx>

1.4.7 Industry Sector Methodology

1. The ETS fuel data provided by MECI <ETS 2022.xlsx> was aggregated for industry subsectors ‘Cement and other minerals’ for each fuel type.
2. The ETS fuel for cement is equated to the cement subsector as there is only one cement site and the ETS fuel for ceramics to the ‘other minerals ETS’ subsector.
3. The ETS fuel was subtracted from final energy for the industry non-metallic minerals (EUROSTAT 2022) and the remainder was attributed to the ‘other minerals NETS’ subsector.[16]
4. CHP data provided by MECI <CHP 2022.xlsx> was attributed to appropriate service, industry or agriculture subsector[17].
5. ‘Fuel for heat’ for industrial CHP schemes was calculated based on fuel consumption and operating efficiency.
6. Total CHP fuel for heat was subtracted from the final energy totals (EUROSTAT data) for the appropriate industrial subsectors for each fuel, apart from biogas,[18] to calculate final energy for non-CHP technologies for each industry subsector and fuel type.

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[16] The ETS dataset reports petroleum coke was consumed at the Vasiliko cement site and only one of the ceramics sites (Antreas Kasapis), but the total fuel reported greatly exceeds the petroleum coke final energy reported for petroleum coke in the non-metallic mineral’s subsector. The amount reported in the ETS dataset for the cement site alone is very similar to the total reported in EUROSTAT 2022. We have therefore assumed the consumption at Antreas Kasapis was omitted from EUROSTAT 2022 and included this in this report.
[17] According to MECI, only one CHP scheme is in the food industry (NACE 1011).
[18] In the case of biogas it is understood that no biogas is consumed other than in CHP and the difference between CHP consumption and EUROSTAT was assumed to be an error. In the case of fuel oil, the split between light and heavy fuel oil is known for ETS sites but not the national total (obtained from EUROSTAT) so the balance is simply shown as Fuel Oil.

7. Final energy for 2018 calculated in 2021 NCA was aggregated to calculate final energy for non-ETS and non CHP technologies for each subsector and fuel type in 2018.
8. The ratio of final energy in 2022 vs 2018 was calculated for each fuel type for heat pumps and separately for non-heat pump and non-CHP technologies.
9. In 2018 no blended biodiesel consumption was reported but some was reported in 2022. Therefore, the split by subsector and end use was based on the 2018 FE split for gasoil.
10. In 2021 the other minerals subsector was not split between ETS and NETS, so these subsectors were split separately into low, medium and high grade heat according to the 2021 split.
11. Electricity was split into renewable and non-renewable as explained in introduction above.
12. For CHP, the UE (heat output) and the service subsector is informed directly by the CHP data and assumed to be exclusively for heating as in 2021. Each non-CHP element was divided by the end use specific conversion factor turning UE into FE, thereby returning the FEC. The conversion factors used in this step for electric heating and cooling are as implied in Industrial information supplied by MECI <Copy of IndAnalysis_1015f-FINAL.xlsx>. Fossil fuel boiler efficiencies have been based on the harmonised EU reference values for the separate production of heat[19].

1.4.8 Industry Sector Results

1.4.8.1 Useful Energy Consumption

Table 1-13 Industry sector UE by fuel

Fuel	Useful Energy Consumption 2022 (MWh)
Biogases	3,539
Blended biodiesels	4,326
Electricity (non-renewable)	52,564
Electricity (renewable)	10,599
Fuel oil	187,253
Light Fuel Oil	17,730
Heavy Fuel Oil	72,709
Gas oil	287,761
Industrial waste (non-renewable)	49,325
Kerosene	150
LPG	85,095
Non-renewable municipal waste	388,917

[19] See Annex II of Commission Delegated Regulation (EU) 2015/2402 *https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2402&from=DE*

Other bituminous coal	295,311
Petroleum coke	115,084
Renewable municipal waste	252,219
Solar	4,664
Solid biomass	111,131
Grand Total	**1,937,876**

Table 1-14 Industry sector UE by end use

End Use	Useful Energy Consumption 2022 (MWh)
High Heat	1,235,020
Medium Heat	232,877
Low Heat	453,176
Cooling	16,802
Grand Total	**1,937,876**

Table 1-15 Industry sector UE by technology

Technology	Useful Energy Consumption 2022 (MWh)
Boilers	425,046
Boilers & direct heat[20]	220,540
Direct heat	1,220,489
Chillers	16,802
CHP	3,974
Resistance heaters	46,360
Solar panels	4,664
Grand Total	**1,937,876**

The full split of useful energy in the industry sector by subsector, end use, fuel and technology is given in the Excel file provided in Appendix 1.

[20] Note, the end uses 'low, medium and high heat' are either produced by boilers (low and medium heat), or direct heating (medium and high heat). Hence these end uses are grouped into the first three technology types of Table 1-15.

1.4.8.2 Final Energy Consumption

Table 1-16 Industry sector FEC by fuel

Fuel	Final Energy Consumption 2022 (MWh)
Biogases	4,386
Blended biodiesel	5,208
Electricity (non-renewable)	97,345
Electricity (renewable)	19,628
Fuel oil	228,357
Light Fuel Oil	21,622
Heavy Fuel Oil	88,059
Gas oil	350,937
Industrial waste (non-renewable)	60,895
Kerosene	183
LPG	98,948
Non-renewable municipal waste	480,145
Other bituminous coal	355,797
Petroleum coke	138,656
Renewable municipal waste	311,382
Solar	4,664
Solid biomass	137,199
Grand Total	**2,403,409**

Table 1-17 Industry sector FEC by end use

End Use	Final Energy Consumption 2022 (MWh)
High Heat	1,519,481
Medium Heat	293,572
Low Heat	569,461
Cooling	20,894
Grand Total	**2,403,409**

Table 1-18 Industry sector FEC by technology

Technology	Final Energy Consumption 2022 (MWh)
Boilers	526,775
Boilers & direct heat	270,839
Direct heat	1,492,781
Chillers	20,894
CHP	4,925
Resistance heaters	96,079
Solar panels	4,664
Grand Total	**2,403,409**

The full split of final energy consumption in the industry sector by subsector, end use, fuel and technology is given in the Excel file provided in Appendix 2.

1.5 Agriculture Sector

1.5.1 Agriculture Sector Overview

According to Eurostat, in 2022 the agricultural sector in Cyprus had a final energy consumption of 42.252ktoe (491,391 MWh). Of this, the largest share was gas oil (51.1%), followed by electricity (32.2%), LPG (7.5%), biogas (6.3%), derived heat (2.3%), and primary solid biomass (0.7%).

As shown below, the FEC associated with heating and cooling in the agriculture sector has been estimated to be 273,692 MWh.

1.5.2 Agriculture Sector Data Sources Used

REE split of 2018 final energy by sector, subsector, end use, fuel and technology.

REE split of 2018 useful energy by sector, subsector, end use, fuel and technology.

National Energy Balance for Cyprus, Eurostat 2018

National Energy Balance for Cyprus, Eurostat 2022

1.5.3 Agriculture Sector Methodology

Multiply the final and useful energy for each agriculture subsector, end use, fuel and technology segment as derived by REE in 2021, by the 2022 national residential final energy total divided by the 2018 national residential final energy total.

1. Using CHP data provided by MECI <CHP 2022.xlsx>, each scheme was attributed to appropriate agriculture subsector[21].
2. 'Fuel for heat' for each service sector CHP scheme was calculated taking account of heat sold for agriculture as reported in EUROSTAT based on fuel consumption and operating efficiency.
3. The total CHP fuel for heat and sold heat were subtracted from the final energy totals (EUROSTAT data) for each fuel, apart from biogas,[22] to calculate final energy for non-heat pump and non-CHP technologies for each fuel type.
4. The ratio of final energy in 2022 vs 2018 was calculated for each fuel type for non-CHP technologies (in the case of agriculture this is only boilers).
5. To calculate UE split for 2022; The CHP useful heat was extracted directly from the CHP data. For useful heat from boilers, the ratios of final energy for 2022 vs 2018 for boilers were multiplied by the UE split by subsector, end use, fuel and technology for 2018 (which was an output of the 2021 NCA).
6. For CHP, the UE (heat output) and the service subsector is informed directly by the CHP data, and all assumed to be for heating as in 2021. Each non CHP element was divided by the end use specific conversion factor turning UE into FE, thereby returning the FEC. The conversion factors used in this step are based on the harmonised EU reference values for the separate production of heat[23].

1.5.4 Agriculture Sector Results

1.5.4.1 Useful Energy Consumption

Table 1-19 Agriculture sector UE by fuel

Fuel	Useful Energy Consumption 2022 (MWh)
Biogases	14,931
Gas oil	196,493
LPG	4,535
Renewable Heat	10,306
Non-renewable Heat	847
Total	**227,112**

[21] According to MECI, 7 of the CHP schemes are animal production (NACE code 0146), 3 are sewage treatment works (NACE code 3700), 3 are waste materials recovery sites (NACE code 3821) and one is in the food industry (NACE 1011), These 4 groups are attributed to the agriculture (other agriculture), services (other services), and industry (Food, tobacco and beverages) subsectors respectively. The third group might have been expected to be attributed to services but was attributed to agriculture in 2021 and the fuel consumption of these 3 sites coupled with that of the sewage treatment sites greatly exceeds the EUROSTAT 2022 final energy totals for the service sector. Therefore, these have been attributed to agriculture as in 2021.
[22] In the case of biogas it is understood that no biogas is consumed other than in CHP and the difference between CHP consumption and EUROSTAT was assumed to be an error.
[23] See Annex II of Commission Delegated Regulation (EU) 2015/2402 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32015R2402&from=DE

Table 1-20 Agriculture sector UE by end use

End Use	Useful Energy Consumption 2022 (MWh)
Heating	227,112
Total	**227,112**

Table 1-21 Agriculture sector UE by technology

Technology	Useful Energy Consumption 2022 (MWh)
Boilers	199,801
CHP	27,311
Total	**227,112**

The full split of useful energy in the agriculture sector by subsector, end use, fuel and technology is given in the Excel file provided in Appendix 1.

1.5.4.2 Final Energy Consumption

Table 1-22 Agriculture sector FEC by fuel

Fuel	Final Energy Consumption 2022 (MWh)
Biogases	17,683
Gas oil	239,582
LPG	5,274
Renewable Heat	10,306
Non-renewable Heat	847
Total	**273,692**

Table 1-23 Agriculture sector FEC by end use

End Use	Useful Energy Consumption 2022 (MWh)
Heating	273,692
Total	**273,692**

Table 1-24 Agriculture sector FEC by technology

Technology	Useful Energy Consumption 2022 (MWh)
Boilers	243,402
CHP	30,290

Total	273,692

The full split of final energy consumption in the agriculture sector by subsector, end use, fuel and technology is given in the Excel file provided in Appendix 2.

2 Point B Identification/Estimation of Current Heating and Cooling Supply by Technology and Potential Supply from Waste Heat and Cold

2.1 Current Heating and Cooling Supply by Technology

2.1.1 The Analysis

The analysis underpinning the first Comprehensive Assessment (CA) and the Integrated National Energy and Climate Plan (NECP) for the Republic of Cyprus has been utilised to derive updated splits for the technologies providing heating and cooling supply.

The analysis for the second NCA in 2021 derived quantities of heating and cooling supplied across a comprehensive range of sectors and subsectors, split by technology and type of fuel. This analysis was anchored in the national energy balances for 2018. We have refreshed these splits to make consistent with the national energy balance for 2022. The methodology employed for doing that is explained above in Section 1, where the steps for deriving the splits for UE and FEC for each sector are set out in detail.

As previously stated, the results presented below carry forward the main assumptions used in 2021 for the split of heating and cooling technologies across sectors and subsectors but reflect changes in share of final energy consumption taken by the sectors of interest, changes in the same for the different fuel types and assumed improvements in the efficiency of boilers and heat pumps used for heating and cooling.

The analysis discussed above distinguishes between the sectors and subsectors, heating and cooling end uses fuel type and technology type shown in Table 2-1.

Table 2-1 Summary of attributes used to characterise a unit of UE or FEC

Sectors	Subsectors	End Uses	Fuels	Technologies
Residential	Apartment buildings	Heating	Electricity (non-renewable)	Boilers
	Row	Cooling	Electricity (non-renewable)	Boilers & direct heat
	Single houses	SHW	Gas Oil	Direct Heat
Service	Airports	High temperature heat	Solar	CHP
	Shopping	Medium temperature heat	Petroleum Coke	Chillers
	Schools	Low temperature heat	Ambient heat (heat pumps)	Heat pumps
	Hotels		LPG	Resistance heaters
	Other		Fuel oil[24]	Solar panels

[24] Where it is not known if the fuel oil is light or heavy, the fuel type is simply labelled as; 'Fuel Oil'.

	Healthcare		Light Fuel Oil	
	Catering		Heavy Fuel Oil	
	Offices		Renewable municipal waste	
Agriculture	Greenhouses		Solid biomass	
	Other		Non-renewable municipal waste	
	Cement[25]		Renewable electricity	
	Other Minerals ETS[26]		Other bituminous coal	
Industry	Other Minerals NETS		Kerosene	
	Food, tobacco and beverages		Biogases	
	Chemicals		Industrial waste (non-renewable)	
			Geothermal	
	Other industry		Blended Biodiesel	
			Renewable heat	
			Non-renewable heat	

2.1.2 Results

2.1.2.1 On-site Heating and Cooling Supply

Table 2-2 Technologies used to supply **heating (space heating and SHW) and cooling** at residential and service sites

Technology	End Use	Quantity Supplied (MWh)	Of which Renewable	Of which Non-renewable
Heat only boilers	Heating	1,394,595	189,268	1,205,327
CHP	Heating	3,473	3,473	
Heat pumps	Heating	900,662	639,449	261,212
Resistance heaters	Heating	370,229	62,125	308,105

[25] There is only one cement site, and this is in the ETS.
[26] Since 2021, we have subdivided the ‘other minerals subsector into ETS and NETS to facilitate the division of reporting and modelling.

Solar panels	Heating	715,508	715,508	
Heat pumps	Cooling	4,839,615	812,089	4,027,526
Total		**8,224,082**	**2,421,911**	**5,802,170**

For heating and cooling, where the input involves the consumption of electricity (i.e. heat pumps for heating, resistance heaters and heat pumps for cooling) a proportion of this electricity input is considered renewable. The underlying data used here relate to 2022 and in this year, according to Eurostat 16.78% of the electricity generated was renewable[27], and this is the proportion of electricity consumption considered renewable.

All CHP heat shown in Table 2-2 is consumed at two sewage treatment works and one municipal solid waste processing facility. None of the CHP heat generated is supplied to a District Heating and Cooling (DHC) network.

Table 2-3 Technologies used to supply **heating and cooling** at non-residential and non-service sites

Technology	End Use	Quantity Supplied (MWh)	Of which Renewable	Of which Non-renewable
Heat only boilers	Heating	624,847	46,926	577,920
Boiler & direct heat	Heating	220,540	34,857	185,684
Direct heat	Heating	1,220,489	285,891	934,598
CHP	Heating	31,286	28,777	2,509
Resistance heaters	Heating	46,360	7,779	38,581
Solar panels	Heating	4,664	4,664	
Chillers	Cooling	16,802	2,819	13,983
Total		**2,164,988**	**411,714**	**1,753,275**

All CHP heat shown in Table 2-3 is consumed at agricultural sites. None of the CHP heat generated is supplied to a District Heating and Cooling (DHC) network.

2.1.2.2 Off-site Heating and Cooling Supply

There are no District Heating and Cooling (DHC) networks presently operating in Cyprus.

[27] Out of a total gross electricity production of 453.0 ktoe, 76.0 ktoe came from renewable sources.

2.2 Identification of Installations that Generate Waste Heat or Cold and their Potential for Heating and Cooling Supply, GWh per Year

2.2.1 Introduction

We have considered existing locations which could present themselves as sources of waste heat. Consistent with the requirements of the Technical Specification, we have considered the following types of installation:

- Thermal power generating installations with thermal input exceeding 50MW. There are three separate power station locations comprised of six distinct generating units, each of which have thermal input capacities exceeding 50MW. These are located at Vasilikos, Dhekelia and Moni.
- Heat and power cogeneration installations with total thermal input exceeding 20MW. There are no such installations in Cyprus.
- Waste incineration plants. There are no waste incineration plants in Cyprus. According to Eurostat, all in-country waste generated and consumed for energy purposes and waste imported for the same purpose is finally consumed within the non-metallic minerals sector as a fuel. This means the cement plant at Vasilikos, which is covered below.
- Renewable energy installations with a total thermal input exceed 20MW (if not already included in the categories above). There are no such installations in Cyprus.
- Industrial installations with a total thermal input exceeding 20MW. Such installations would be covered by EU ETS. Consulting data on EU ETS installations in Cyprus (excluding the power stations listed above) has revealed 1 x cement installation and 9 x ceramics installations, of which 3 consumed no fuel in 2022 so unclear if these are still operating. These are listed in the table in section 2.2.3 below.
- Large cooling systems may dump significant quantities of low grade heat which could conceivably feed a DHC scheme. In line with the Directive requirement for power stations of more than 20 GWh per year of electricity generation to be shown on the heat map as potential points of heat supply, we have adopted a similar philosophy for large cooling systems, i.e. we have considered whether there are any large cooling systems with the potential to dump more than 20 GWh of heat. For a cooling system with a COP of 3, this means a system serving a building or buildings with a cooling load of about 13 GWh. Such buildings or buildings are most likely to be located in tourist areas or central commercial areas in Nicosia. Therefore, we have carried out an assessment of building footprints in tourist areas and dense commercial areas in Nicosia and estimate that the largest cooling demand are in the region of 4-5 GWh per year at some hotel complexes in Paphos. Based on this, we conclude that there are no sufficiently large point sources of waste heat arising from cooling systems which could serve DHC.
- Large points of waste cold could also serve as potential point sources for cooling delivered via DHC. At present there are no large sources of waste cold in Cyprus. The Liquid Natural Gas (LNG) plant currently being constructed at Vassiliko will vaporise LNG delivered already in the liquid form. However, we believe LNG is not a suitable waste cold source in Mediterranean countries as seawater is of sufficient temperature to provide vaporisation all year round and this is likely to be a more cost effective solution than connecting DHC to the LNG terminal to supply vaporisation heat to the LNG and cooling to the DHC.

2.2.2 The Analysis

As discussed above, there are three power generating installations and nine industrial installations falling within scope for the evaluation of waste heat potential. Below we explain the methodology used for estimating a quantity of waste heat potentially available for exploitation from these installations.

2.2.2.1 Power Stations

There are four power generating technologies employed at the nine generating units at the three power station installations listed above in section 2.2.1: Steam Turbine (ST), Combined Cycle Gas Turbine, Open Cycle Gas Turbine (OCGT) and Internal Combustion Engine (ICE).

The following data sets were used to derive fuel input and electrical power generation at each unit.

Electrical capacity, generator type, 2017 fuel input (NCV), electrical power generation and electrical efficiency (NCV) for each of 8 units across the 3 power stations provided by MECI in 2020 <input data and assumptions for NECP.xlsx>, worksheet ‘PM10’.

ETS fuel data for each of the 3 power stations provided by MECI <ETS 2022.xlsx>

Electrical capacity, generator type, and retirement dates for each of 9 generating units provided by MECI <EAC Decommissioning.xlsx>. The unit list is the same as <input data and assumptions for NECP.xlsx>, worksheet ‘PM10’, except Vasilikos steam turbine is split into 2 units.

The capacity and scheduled retirement data for each of the 9 units was taken from <EAC Decommissioning.xlsx>

The 2022 fuel input for each of the 3 power stations was taken from <ETS 2022.xlsx> and divided by the 2017 fuel consumption aggregated for each of the 3 stations from <input data and assumptions for NECP.xlsx>, worksheet ‘PM10’.

The 2022/2017 ratio was then applied to the 2017 fuel consumption for each of the 8 units listed in <input data and assumptions for NECP.xlsx>, worksheet ‘PM10’ and for Vasilikos ST, split in proportion to capacity.

The 2017 electrical efficiency of each unit was taken from <input data and assumptions for NECP.xlsx>, worksheet ‘PM10’ and multiplied by the 2022 fuel input for each of the 9 units to calculate 2022 electrical output. Waste heat can be extracted from all of these technologies, in effect turning each into CHP. When heat is extracted from ST and CCGT technologies, this is extracted as steam, which in effect deprives the ST of some of the steam energy which it would otherwise convert into power. Therefore, there is a power penalty associated with heat extraction from ST and CCGT technologies, which must be taken into consideration when evaluating the economics of heat recovery. In the case of ICE and OCGT waste heat is available which, if extracted, has no effect on power generated.

For each technology we have assumed that it is possible to extract heat to convert the generating unit into a CHP with an efficiency of 80% (HHV). This allows the heat efficiency and, therefore, the quantity of heat that could be extracted to be quantified. The approaches to doing this are explained below. For the reasons given below, two different approaches are taken, depending on the power generating technology.

Some of these generating stations are due to be decommissioned in the next 10 years. We do not know if this capacity is likely to be replaced with similar technology and thus whether waste heat availability is likely to remain or not.

For ICE and OCGT,

$$Heat\ Efficiency\ (\%) = 80\% - Power\ Efficiency\ (\%)$$

$$Power\ Efficiency\ (\%) = \frac{Annual\ Power\ Generation\ (MWh)}{Annual\ Fuel\ Input\ (MWh)}$$

$$Annual\ Heat\ Available\ for\ Recovery\ (MWh) = Heat\ Efficiency(\%) \times AnnualFuel\ Input\ (MWh)$$

For ST and CCGT,

$$Heat\ Efficiency\ (\%) = 80\% - Revised\ Power\ Efficiency\ (\%)$$

$$Revised\ Power\ Efficiency\ (\%) = \frac{Revised\ Power\ Output\ (MWh)}{Annual\ Fuel\ Input\ (MWh)}$$

$$Revised\ Power\ Output\ (MWh) = Original\ Power\ Output\ (MWh) - Power\ Loss\ via\ Heat\ Extraction\ (MWh)$$

$$Power\ Loss\ via\ Heat\ Extraction\ (MWh) = \frac{Annual\ Heat\ Available\ for\ Recovery\ (MWh)}{Z - Ratio}$$

$$Z - Ratio = \frac{Heat\ Gained\ from\ Steam\ Extraction\ (MWh)}{Power\ Lost\ (MWh)}$$

For the purposes of this analysis, we have assumed a Z-ratio of 8 which is consistent with previous analysis carried out for the UK NCA.

2.2.2.2 Cement Installation at Vasilikos

The 2022 fuel input was taken from <ETS 2022.xlsx>

A bottom-up assessment of heat available for recovery from cement clinker producing installations was carried out for UK installations[28].In all, primary data relating to waste heat available for district heating from this study was gathered for six different UK clinker producing installations.

For these installations, waste heat is assumed to be available from the separate streams of kiln preheater and precalciner. This available heat for each installation was plotted against the fuel input for each installation in order to obtain a characteristic of waste heat available per unit of fuel input. This plot produced a linear fit with a very good correlation ($R^2 = 0.92$) with a gradient of 0.113, implying that 11.3% of the energy content for the fuel inputs to the kiln is available as waste heat for district heating.

By default, we have assumed that the kiln technology used at Vasilikos uses multiple cyclone preheaters and a precalciner and, therefore, the characteristics of waste heat availability from the UK study is applicable in this case. Accordingly, we assume that 11.3% of the energy content of the fuel input to the kiln system at Vasilikos is available for recovery and reuse.

2.2.2.3 Ceramics Installations.

The 2022 fuel input for each site was taken from <ETS 2022.xlsx>

The same study of potential heat recovery from UK industrial installations mentioned above[28] quantified the waste heat available for district heating from three brickworks with continuous tunnel kilns. The fuel input for these kilns was obtained and plotted against the waste heat available for district heating. A good linear correlation was obtained with R2 = 0.99 with a gradient of 0.117, implying that 11.7% of the energy content of the fuel is available as waste heat for district heating.

We have made an assumption that the ceramics installations in EU ETS are similar to the UK installations (i.e. making bricks and using continuous tunnel kilns and have the same green product drying requirements). Accordingly, we assume that 11.7% of the fuel input at the ceramics installations is available as heat for district heating

[28] The potential for recovering and using surplus heat from industry, Final Report for DECC by Element Energy (2014)

2.2.3 Results

Table 2-4 Summary of main attributes of thermal power generation installations and the potential for heat to be recovered from them

Industry Sector	Site and plant	Prime Mover	Electrical Capacity 2022 MWe	Annual fuel consumption MWh GCV 2022	Power efficiency %GCV 2017	Annual electrical generation MWh 2022	Full load hours 2022	Waste Heat/steam extraction Potential MWht/year 2022	Waste Heat/steam extraction Potential MWt 2022	Scheduled retirement Date
Power (EAC)	Vasilikos ST 1	ST	260.00	2,865,672	37.6%	1,078,451	4,148	1,387,527	334.5	31/12/2032
Power (EAC)	Vasilikos ST 2	ST	130.00	1,432,836	37.6%	539,226	4,148	693,764	167.3	31/12/2037
Power (EAC)	Vasilikos GT	OCGT	38.00	11,439	26.5%	3,026	80	6,125	76.9	31/12/2035
Power (EAC)	Vasilikos CCGT 4	CCGT	220.00	1,842,379	45.3%	834,620	3,794	730,609	192.6	31/12/2035
Power (EAC)	Vasilikos CCGT 5	CCGT	220.00	1,481,020	45.3%	670,920	3,050	587,310	192.6	31/12/2038
Power (EAC)	Dhekeleia ST	ST	360.00	3,714,465	29.4%	1,091,408	3,032	2,148,758	708.8	31/12/2028
Power (EAC)	Dhekeleia ICE 1	ICE	51.00	317,429	39.4%	125,065	2,452	128,879	52.6	31/12/2035
Power (EAC)	Dhekeleia ICE 2	ICE	51.00	255,815	40.2%	102,812	2,016	101,840	50.5	31/12/2036
Power (EAC)	Moni GT	OCGT	150.00	102,165	26.5%	28,752	192	58,197	303.6	31/12/2031

Note: As explained in the Point F report 2021, opportunities to extract waste heat from the above power generating stations were only pursued in respect of the ICEs at Dhekeleia. A similar approach is anticipated in this year's NCA. There are two reasons for this:

- The OCGT stations at Vasilikos and Moni are peaking plant (as evidenced by their very low full load hours) and consequently would not be a reliable source of waste heat for DHC
- The other generating stations use steam turbines (STs) which are assumed to be condensing. In order for heat extraction to be possible, the condensing ST would have to be replaced with a pass out condensing steam turbine. From our experience of evaluating the economics of this in the UK, this would not be economically viable. Instead, it is recommended that new power stations are required to be "CHP ready", i.e. have the necessary steam turbine configurations to allow heat to be extracted without expensive replacement of the existing ST.

Table 2-5 Summary of main attributes of industrial installations with thermal input >20MWth and the potential for heat to be recovered from them

Sector	Site and plant	Annual fuel consumption MWh NCV 2022	Full load hours 2022	Industrial waste Heat Potential MWh/MWh fuel input (NCV) 2022	Waste Heat/steam extraction Potential MWht/year 2022
Cement	Vasiliko - non biomass	1,056,424	8,000	0.113	119,439
Cement	Vasiliko - biomass	398,572	8,000	0.113	45,063
Ceramics	United	-	8,000	0.117	-
Ceramics	KAPA	16,243	8,000	0.117	1,892
Ceramics	Chrysafis	13,442	8,000	0.117	1,566
Ceramics	Kakogiannis	15,077	8,000	0.117	1,757
Ceramics	Melios & Pafitis	15,345	8,000	0.117	1,788
Ceramics	Gigas Tiles	-	8,000	0.117	-
Ceramics	Antreas Kasapis	18,095	8,000	0.117	2,108
Ceramics	Gigas Bricks	-	8,000	0.117	-
Ceramics	Ledra	14,109	8,000	0.117	1,644

Note: As explained in the Point F report 2021, opportunities to extract waste heat were only pursued in respect of the Vasilikos cement works. Feedback from the operators of the ceramic sites listed in Table 2-5 indicates that all surplus heat from the firing kiln is consumed for drying green product prior to the firing stage. Given this feedback, it is assumed that surplus heat is not available to supply DHC. Same approach anticipated in this NCA.

Appendices

Appendix 1 – Detailed split of Useful Energy (UE) by sector, subsector, fuel, end use and technology.

Appendix 2 – Detailed split of Final Energy Consumption (FEC) by sector, subsector, fuel, end use and technology.

Appendix 3 - Power generation installations and the potential for heat to be recovered from them.

Appendix 4 -Industrial installations with thermal input >20MWth and the potential for heat to be recovered from them.

A1 Detailed split of Useful Energy (UE) by sector, subsector, fuel, end use and technology

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A2 Detailed split of Final Energy Consumption (FEC) by sector, subsector, fuel, end use and technology

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A3 Power Station Waste Heat Potential

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A4 Industrial Installation Waste Heat Potential

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T: +44 (0) 1235 753000

E: enquiry@ricardo.com

W: ee.ricardo.com