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Comprehensive Assessment of the Potential for Efficient Heating and Cooling

Report for Points A and B

Report for MECI, Cyprus

ED 14106 | Issue number 1 | Date 28th July 2021

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Customer:

Ministry of Energy, Commerce and Industry, Cyprus

Customer reference: YEEB/YE/01/2020

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Ref: ED14106]

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Glossary

Abbreviation	Definition
CCGT	Combined Cycle Gas Turbine
FEC	Final Energy Consumption
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

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, ambient heat 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.

In this work we refer to Eurostat Cyprus energy balance for 2018 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 grade of heat and cooling demanded. This is a key step underpinning later tasks analysing the technical and economic potential for efficient heat and cooling, since the grade of heat demanded determines the technical viability of a range of potential heating technologies. Therefore, we observe the following grades of heating and cooling:

- High heat – Heat which is consumed in industry at >400°C
- Medium heat - Heat which is consumed in industry in the range 100°C - 400°C
- Low 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.

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 2015 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 2018 the residential sector in Cyprus had a final energy consumption 14,117 TJ (3,921,388 MWh)[1], of which 43% was in the form of electricity. Solar thermal accounted for the second largest proportion of final energy consumed (18%) followed by gas oil (16%), LPG (9.5%), primary biofuels (5.0%), charcoal (1.8%), ambient heat (3.0%) and geothermal (0.5%).

As shown below, the FEC associated with heating and cooling in the residential sector has been estimated to be 2,713,124 MWh.

An additional source of information relating to final energy consumption for the residential sector was provided by MECI[2], which gives the final energy consumed for a number of end uses, including space heating, space cooling and water heating, by fuel. Space heating, space cooling and water heating are assumed to directly map to Heating, SHW and Cooling grades of demand given in section 1.1. The FEC given in this source is 14,124 TJ, which is within 0.05% of the Eurostat figure. Consequently, we have decided to use the FEC in Eurostat 2018 and apportion the fuels across end uses in the same proportions as those in the MECI source.

1.3.2 Residential Data Sources Used

JRC split of UE by sector, subsector, fuel and technology from: <input data and assumptions for NECP.xlsx>, worksheet 'H&C - historic estimates'

Table 5 Energy Conversion Factors (Final to Useful) from: <Report Households.pdf>

National Energy Balance for Cyprus, Eurostat 2013

Heat Pump data for residential and service sector deployment: <E_PaMs_030719_1500_EC template.xls>

Final energy consumption by end use in residential sector from: <Households Sector by type of end use_2018.xls>

National Energy Balance for Cyprus, Eurostat 2018

[1] 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.
[2] Households Sector by type of end use_2018

1.3.3 Residential Sector Methodology

The process for deriving the FEC and UE for heating, cooling and SHW for 2018 in the residential sector can be summarised as follows:

1. Take the UE split by subsector, end use, fuel and technology for 2013 which was an output of the 2015 NCA *(Use: JRC split of UE by sector, subsector, fuel and technology from: <input data and assumptions for NECP.xlsx>, worksheet 'H&C - historic estimates')*

2. Divide each element by the end use specific conversion factor turning UE into FE, thereby returning the FEC *(Use: Table 5 Energy Conversion Factors (Final to Useful) from: <Report Households.pdf>)*

3. Express each element as a percentage of the relevant FEC fuel consumed in the 2013 national balance

4. Calculate the quantity of each final FEC fuel consumed for H, C and SHW and express as a % of each FEC fuel *(Use: Final energy consumption by end use in residential sector from: <Households Sector by type of end use_2018.xls>)*

5. Adjust the element percentages in 3 to reflect the actual proportions calculated in 4.

6. Accept the adjusted percentages in 5 for all fuels other than electricity

7. For electricity, use the electricity consumption for heat pump operation in the residential sector given in MECI source "Heat Pumps" to deduce the quantity of electricity used for heating using heat pumps and heating using resistive heating *(Use <E_PaMs_030719_1500_EC template.xls>)*

8. Bring 6 and 7 together and use the resulting % of each FEC fuel for each subsector/technology/end use combination

9. Multiply the element percentages in 8 by the FEC for each fuel in the 2018 national balance to derive the quantity of each fuel used for each subsector/technology/end use combination.

10. Apply conversion factors to 9 to turn each FEC element into a corresponding UE value. The conversion factors used in this step have been updated from those presented in *Table 5 Energy Conversion Factors (Final to Useful) from: <Report Households.pdf>* to reflect improvements in efficiency deemed to have occurred since the 2015 NCA. Specifically, boiler efficiencies have been adjusted to those in the harmonised reference values for the separate production of heat[3]. In the case of heat pumps used for heating, the minimum space heating energy efficiency set out in Commission Regulation No 813/2013[4] has been used. 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[5].

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[3] 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

[4] See Annex II Ecodesign Requirements of Commission regulation (EU) No 813/2013 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0813&from=EN

[5] See Table 3 of Commission Regulation (EU) 2016/2281 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R2281&from=EN

1.3.4 Residential Sector Results

1.3.4.1 Useful Energy Consumption

Table 1-1 Residential UE by fuel

Fuel	Useful Energy Consumption (MWh/year)
Ambient heat (heat pumps)	Included in heat pump electric
Electricity (non-renewable)	1,997,091
Electricity (renewable)	207,934
Gas oil	553,719
Geothermal	18,032
Ambient heat (heat pumps)	117,007
Kerosene	98,430
LPG	161,293
Solar	580,511
Solid biomass	167,588
Total	**3,901,605**

Table 1-2 Residential UE by end use

End Use	Useful Energy Consumption (MWh/year)
Cooling	1,871,417
Heating	1,253,396
SHW	776,791
Total	**3,901,605**

Table 1-3 Residential UE by technology

Technology	Useful Energy Consumption (MWh/year)
Boilers	981,030
Heat pumps	2,083,622
Resistance heaters	256,442
Solar panels	580,511
Total	**3,901,605**

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 (MWh/year)
Ambient heat (heat pumps)	117,007
Electricity (non-renewable)	677,856
Electricity (renewable)	70,577
Gas oil	636,459
Geothermal	18,032
Kerosene	113,138
LPG	177,245
Solar	707,940
Solid biomass	194,870
Total	**2,713,124**

Table 1-5 Residential FEC by end use

End Use	Final Energy Consumption (MWh/year)
Cooling	413,573
Heating	1,384,408
SHW	915,143
Total	**2,713,124**

Table 1-6 Residential FEC by technology

Technology	Final Energy Consumption (MWh/year)
Boilers	1,121,711
Heat pumps	625,778
Resistance heaters	257,695
Solar panels	707,940
Total	**2,713,124**

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

According to Eurostat, in 2018 the service sector in Cyprus had a final energy consumption of 11,575 TJ (3,215,178 MWh). Of this, 68% was electricity, followed by ambient heat (13%), gas oil (6.0%), LPG (5.6%) and solar thermal (3.9%).

As shown below, the FEC associated with heating and cooling in the service sector has been estimated to be 1,887,166 MWh.

1.4.2 Service Sector Data Sources Used

JRC split of UE by sector, subsector, fuel and technology from: <input data and assumptions for NECP.xlsx>, worksheet 'H&C - historic estimates'

Table 1 Energy conversion factors (from final to useful) Report-ServiceSector-Final02.17.doc

National Energy Balance for Cyprus, Eurostat 2013

Heat Pump data for residential and service sector deployment: <E_PaMs_030719_1500_EC template.xls>

National Energy Balance for Cyprus, Eurostat 2018

Data on fuel consumed, electricity and heat generated by 14 CHP plant operating in Cyprus <On site generation.xls>

1.4.3 Service Sector Methodology

1. Take the UE split by subsector, end use, fuel and technology for 2013 for Sector = Services *(Source: JRC split of UE by sector, subsector, fuel and technology from: <input data and assumptions for NECP.xlsx>, worksheet 'H&C - historic estimates')*

2. Divide each element by the end use specific conversion factor turning UE into FE, thereby deriving the FEC for each element *(Use: Table 1 Energy conversion factors (from final to useful) Report-ServiceSector-Final02.17.doc*

3. Express the FEC for each element as a percentage of the FEC of the relevant fuel in 2013 *(Use: National Energy Balance for Cyprus, Eurostat 2013)*

4. Calculate the quantity of each final FEC fuel consumed for H, C and SHW and express as a % of each FEC fuel

5. Calculate the proportion of total of each FEC fuel consumed for Heating, Cooling and SHW

6. Adjust the element percentages in 3 to reflect the actual proportions calculated in 5.

7. Accept the adjusted percentages in 6 for all fuels other than electricity

8. For electricity, use the electricity consumption for heat pump operation in the service sector given in MECI source "Heat Pumps" to deduce the quantity of electricity used for heating using heat pumps and heating using resistive heating *(Use: <E_PaMs_030719_1500_EC template.xls>)*

9. Bring 7 and 8 together and use the resulting % of each FEC fuel for each subsector/technology/end use combination

10. Multiply the element percentages in 9 by the FEC for each fuel in the 2018 national balance to derive the quantity of each fuel used for each subsector/technology/end use combination. *(Use: National Energy Balance for Cyprus, Eurostat 2018)*

11. Apply conversion factors to 10 to turn each FEC element into a corresponding UE value. The conversion factors used in this step have been updated from those presented in *Table 5 Energy Conversion Factors (Final to Useful) from: <Report Households.pdf>)* to reflect improvements in efficiency deemed to have occurred since the 2015 NCA. Specifically, boiler efficiencies have been adjusted to those in the harmonised reference values for the separate production of heat[6]. In the case of heat pumps used for heating, the minimum space heating energy efficiency set out in Commission Regulation No 813/2013[7] has been used. 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[8].

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 (MWh/year)
Ambient heat (heat pumps)	419,053
Biogases	9,492
Electricity (non-renewable)	2,797,715
Electricity (renewable)	291,294
Gas oil	165,083
Kerosene	17,370
Light fuel oil	31,293

[6] 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

[7] See Annex II Ecodesign Requirements of Commission regulation (EU) No 813/2013 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0813&from=EN

[8] See Table 3 of Commission Regulation (EU) 2016/2281 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32016R2281&from=EN

LPG	97,734
Solar	89,647
Solid biomass	3,767
Total	**3,922,449**

Table 1-8 Service sector UE by end use

End Use	Useful Energy Consumption (MWh/year)
Cooling	2,783,370
Heating	905,005
SHW	234,073
Total	**3,922,449**

Table 1-9 Service sector UE by technology

Technology	Useful Energy Consumption (MWh/year)
Boilers	321,063
CHP[9]	3,677
Heat pumps	3,441,883
Resistance heaters	66,179
Solar panels	89,647
Total	**3,922,449**

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.

1.4.4.2 Final Energy Consumption

Table 1-10 Service sector FEC by fuel

Fuel	Final Energy Consumption (MWh/year)
Ambient heat (heat pumps)	419,053
Biogases	12,093
Electricity (non-renewable)	903,732
Electricity (renewable)	94,095
Gas oil	189,751
Kerosene	19,966
Light fuel oil	35,969
LPG	107,400
Solar	100,726
Solid biomass	4,380
Total	**1,887,166**

Table 1-11 Service sector FEC by end use

End Use	Final Energy Consumption (MWh/year)
Cooling	691,521
Heating	934,293

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

SHW	261,353
Total	**1,887,166**

Table 1-12 Service sector FEC by technology

Technology	Final Energy Consumption (MWh/year)
Boilers	365,220
CHP	4,339
Heat pumps	1,350,033
Resistance heaters	66,848
Solar panels	100,726
Total	**1,887,166**

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.

1.5 Industry Sector

1.5.1 Industry Sector Overview

According to Eurostat, in 2018 the industrial sector in Cyprus had a final energy consumption of 9,533 TJ (2,648,017 MWh). Of this, petroleum coke accounted for 25%, followed by electricity (20%), fuel oil (13%) renewable municipal waste (12%) and non-renewable municipal waste (8.4%) and gas oil (8.0%). The large consumption of petroleum coke and municipal waste 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 2,218,613 MWh.

1.5.2 Industry Sector Data Sources Used

JRC 2015 split of UE by sector, subsector, fuel, technology, and thermal end use from: <input data and assumptions for NECP.xlsx>, worksheet 'H&C - historic estimates'.

Proportion of final energy used for thermal end uses by industrial subsector and fuel from: <Copy of IndAnalysis_1015f-FINAL.xlsx>, worksheet ‘Final E by end-use’ table in cells C24:E34 but as overridden in various places in formulae embedded in application in cells X5:Z19.

Also indicated in energy rather than % terms in <CY Industry sector-FINAL-revised.doc>, Figure 3 but %s taken from above spreadsheet.

Energy conversion factors from final to useful (i.e. heating efficiencies) from: <Copy of IndAnalysis_1015f-FINAL.xlsx>, worksheet ‘Useful E by end-user’

Same also displayed in <CY Industry sector-FINAL-revised.doc>, Appendix Table 2.

2013 final energy per fuel type per industry subsector from National Energy Balance for Cyprus, Eurostat 2013 <Energy balance 2013_v4.xls>, Worksheet ‘eurostat’

2018 final energy per fuel type per industry subsector from National Energy Balance for Cyprus, Eurostat 2018 <CY-Energy-Balances-2018.xls>

1.5.3 Industry Sector Methodology

1. Split the 2018 national final energy consumption given for the non-metallic minerals subsector into that used by the cement and other non-metallic minerals subsectors using the same ratio as assumed in 2013 by the author of <Copy of IndAnalysis_1015f-FINAL.xlsx>, in worksheet 'Final E by end-use'.
2. Tabulate the final energy proportion consumed in 2013 for each fuel category in <Copy of IndAnalysis_1015f-FINAL.xlsx>, worksheet 'Final E by end-use' deduced from cells C24:E34 as overridden by the author in cells X5:Z19. In most cases this entailed substituting the proportions for fossil fuels in the 'other industry' subsector for sectors where the source table in cells C24:E34 had no data.

3. Manually map the subsector and fuel categories in the Eurostat national balance to those in the <Copy of IndAnalysis_1015f-FINAL.xlsx>, in worksheet 'Final E by end-use' cells C24:E34. Where fuels are not contained in <Copy of IndAnalysis_1015f-FINAL.xlsx>, they are still included as new fuel categories.

4. Use the above mapping to tabulate the fuel for heat proportions in line with Eurostat national balance (with non-metallic minerals split into cement and other as above) and revise where necessary. We have only made one revision. In the case of electricity in the chemicals sector which the author had assumed to be 0% which we believe is likely in error, so we have applied the 54% factor stated in the original source table. Proportions for new fossil fuels categories are similarly mapped to the fossil fuel proportion category, proportions for the new renewable solids category (only present in cement) to the biomass category, and we assumed 100% for the new solar thermal category (only present in chemicals).

5. Calculate the final energy consumed for heat in 2018 for each fuel in each Eurostat subsector (with non-metallic minerals split into cement and other as above) by combining the CY national energy balance for 2018 with the proportions of each fuel used to generate heat.

6. Manually map the subsector and fuel categories in the Eurostat national balance to those in the JRC split of UE <input data and assumptions for NECP.xlsx>, worksheet 'H&C - historic estimates')

7. Aggregate the final energy consumed for heat in 2018 for each fuel in each Eurostat subsector (with non-metallic minerals split into cement and other as above) JRC split of UE

8. Tabulate the heat efficiencies for each combination of industry subsector (as classified in JRC 2013 split of UE <input data and assumptions for NECP.xlsx>, worksheet 'H&C - historic estimates') and fuel as classified in the Eurostat 2018 national energy balance, based on the energy conversion factors from final to useful (i.e. heating efficiencies) from: <Copy of IndAnalysis_1015f-FINAL.xlsx>, worksheet 'Useful E by end-user' and assumed mapping to the JRC and Eurostat subsector and fuel classifications. We have assumed attributed the aggregate efficiency for fossil fuels in the 2015 data set to new fossil fuels, the efficiency for biomass to new renewable solid fuels and assumed 100% for solar thermal.

9. Estimate the final energy for heat in 2013 for each combination of industry subsector, fuel, technology and end use (high, med and low temperature) by dividing the same division of useful heat in <input data and assumptions for NECP.xlsx>, worksheet 'H&C - historic estimates' by the heat efficiencies for each subsector/fuel combination.

10. Aggregate the final energy consumed for heat in 2013 for each fuel in each Eurostat subsector (with non-metallic minerals split into cement and other as above) JRC split of UE

11. Calculate the proportion of final energy consumed for heat in 2013 by each technology for each end use within each subsector for each fuel type in 2013 by combining the output of steps 9 and 10.

12. Assume the same proportion of final energy was consumed for heat in 2018 by each technology for each end use within each subsector for each fuel type as for 2013. For new fossil fuels, assume the same proportion as the aggregate for all fossil fuels in 2013, for renewable solids (present in cement only), assume same proportions as for biomass and for solar thermal (present in chemicals only), assume 100% was consumed for low grade heat.

13. Apportion the final energy consumed for heat in 2018 calculated in step 7 above to each technology for each end use using the proportions calculated in step 12 above to result in the industry entries in the final energy table (Table A1 2020) i.e. industrial heating and cooling final energy split by industry subsector, fuel type, heating technology and end use (heat grade).

14. Multiply the final energy breakdown in step 13 above by the efficiencies derived in step 8 to result in the industry entries in the useful energy table (Table A2 2020) i.e. industrial heating and cooling useful energy split by industry subsector, fuel type, heating technology and end use (heat grade).

1.5.4 Industry Sector Results

1.5.4.1 Useful Energy Consumption

Table 1-13 Industry sector UE by fuel

Fuel	Useful Energy Consumption (MWh/year)
Biogases	12,869
Electricity (non-renewable)	53,467
Electricity (renewable)	5,567
Fuel oil	278,884
Gas oil	172,273
Industrial waste (non-renewable)	35,277
Kerosene	747
LPG	85,411
Non-renewable municipal waste	181,093
Other bituminous coal	131,413
Petroleum coke	537,994
Renewable municipal waste	260,266
Solar	4,667
Solid biomass	32,749
Total	**1,792,676**

Table 1-14 Industry sector UE by end use

End Use	Useful Energy Consumption (MWh/year)
High Heat	1,206,166
Low Heat	374,500
Medium Heat	195,910
Cooling	16,100
Total	**1,792,676**

Table 1-15 Industry sector UE by technology

Technology	Useful Energy Consumption (MWh/year)
Boilers	1,728,975
Chillers	16,100
Resistance heaters	42,934
Solar panels	4,667
Total	**1,792,676**

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.

1.5.4.2 Final Energy Consumption

Table 1-16 Industry sector FEC by fuel

Fuel	Final Energy Consumption (MWh/year)
Biogases	18,384
Electricity (non-renewable)	99,411
Electricity (renewable)	10,351
Fuel oil	340,102
Gas oil	210,089
Industrial waste (non-renewable)	43,552
Kerosene	911
LPG	99,315
Non-renewable municipal waste	223,572
Other bituminous coal	158,329
Petroleum coke	648,185
Renewable municipal waste	321,316
Solar	4,667
Solid biomass	40,430
Total	**2,218,613**

Table 1-17 Industry sector FEC by end use

End Use	Final Energy Consumption (MWh/year)
High Heat	1,476,308
Low Heat	474,214
Medium Heat	248,019
Cooling	20,072
Total	**2,218,613**

Table 1-18 Industry sector FEC by technology

Technology	Final Energy Consumption (MWh/year)
Boilers	2,104,185

Chillers	20,072
Resistance heaters	89,690
Solar panels	4,667
Total	**2,218,613**

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.

1.6 Agriculture Sector

1.6.1 Agriculture Sector Overview

According to Eurostat, in 2018 the agricultural sector in Cyprus had a final energy consumption of 1,776 TJ (493,307 MWh). Of this, gas oil accounted for 50%, followed by electricity (35%), LPG (6.7%), biogas (5.4%) and derived heat (3%).

As shown below, the FEC associated with heating and cooling in the agriculture sector has been estimated to be 277,894 MWh.

1.6.2 Agriculture Sector Data Sources Used

JRC split of UE by sector, subsector, fuel and technology from: <input data and assumptions for NECP.xlsx>, worksheet 'H&C - historic estimates'

<Report Agriculture.v3.doc> (specific assumption that efficiency of current heating equipment is 80%

National Energy Balance for Cyprus, Eurostat 2013

National Energy Balance for Cyprus, Eurostat 2018

Data on fuel consumed, electricity and heat generated by 14 CHP plant operating in Cyprus <On site generation.xls>

1.6.3 Agriculture Sector Methodology

1. Take the UE split by subsector, end use, fuel and technology for 2013 for Sector = Services *(Source: JRC split of UE by sector, subsector, fuel and technology from: <input data and assumptions for NECP.xlsx>, worksheet 'H&C - historic estimates')*
2. Divide each element by the end use specific conversion factor turning UE into FE, thereby deriving the FEC for each element *(Source: <Report Agriculture.v3.doc>, specifically assuming that current efficiency of heating equipment is 80%)*
3. Express the FEC for each element as a percentage of the FEC of the relevant fuel in 2013 *(Use: National Energy Balance for Cyprus, Eurostat 2013)*
4. Calculate the quantity of each final FEC fuel consumed for H, C and SHW and express as a % of each FEC fuel
5. Calculate the proportion of total of each FEC fuel consumed for Heating, Cooling and SHW
6. Multiply the element percentages in 5 by the FEC for each fuel in the 2018 national balance to derive the quantity of each fuel used for each subsector/technology/end use combination. *(Use: National Energy Balance for Cyprus, Eurostat 2018).*

1.6.4 Agriculture Sector Results

1.6.4.1 Useful Energy Consumption

Table 1-19 Agriculture sector UE by fuel

Fuel	Useful Energy Consumption (MWh/year)
Biogases	20,307
Gas oil	191,529
Heat	14,958
LPG	4,104
Total	**230,898**

Table 1-20 Agriculture sector UE by end use

End Use	Useful Energy Consumption (MWh/year)
Heating	230,898
Total	**230,898**

Table 1-21 Agriculture sector UE by technology

Technology	Useful Energy Consumption (MWh/year)
Boilers	199,947
CHP	30,951
Total	**230,898**

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.

1.6.4.2 Final Energy Consumption

Table 1-22 Agriculture sector FEC by fuel

Fuel	Final Energy Consumption (MWh/year)
Biogases	25,319
Gas oil	233,542
Heat	14,958
LPG	4,772
Total	**278,590**

Table 1-23 Agriculture sector FEC by end use

End Use	Useful Energy Consumption (MWh/year)
Heating	278,590
Total	**278,590**

Table 1-24 Agriculture sector FEC by technology

Technology	Useful Energy Consumption (MWh/year)
Boilers	244,692
CHP	33,899
Total	**278,590**

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 original analysis for the first CA and the NECP 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 2013. We have refreshed these splits to make consistent with the national energy balance for 2018. 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 2015 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 ehat pumps used for heating and cooling. It is also the case that additional fuel types are included in the 2018 national balance which were not included in the balance for 2015. This exercise has brought these additional fuel types in to the analysis.

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

Sector	Subsector	End Use	Fuel	Technology
Residential	Apartment buildings	Heating	Electricity (non-renewable)	Boilers
	Row	Cooling	Electricity (non-renewable)	Heat pumps
	Single houses	SHW	Gas Oil	Solar panels
Service	Airports	High temperature heat	Solar	Resistance heaters
	Shopping	Medium temperature heat	Petroleum Coke	CHP
	Schools	Low temperature heat	Ambient heat (heat pumos)	Chillers
	Hotels		LPG	
	Other		Fuel oil	
	Healthcare		Renewable municipal waste	
	Catering		Solid biomass	

Agriculture	Offices		Non-renewable municipal waste	
	Greenhouses		Renewable electricity	
	Other		Other bituminous coal	
Industry	Cement		Kerosene	
	Other Minerals		Biogases	
	Food, tobacco and beverages		Industrial waste (non-renewable)	
	Chemicals		Light fuel oil	
	Other industry		Geothermal	
			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	1,302,093	177,170	1,124,923
CHP	Heating	3,677	3,677	-
Heat pumps	Heating	870,717	583,950	286,767
Resistance heaters	Heating	322,621	30,423	292,198
Solar panels	Heating	670,157	670,157	-
Heat pumps	Cooling	4,654,788	438,947	4,215,841
Total		**7,824,053**	**1,904,325**	**5,919,728**

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 2018 and in this year, according to Eurostat, 9.43% of the electricity generated was renewable[10], 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.

[10] Out of a total gross electricity production of 435.1 ktoe, 41.1 ktoe came from renewable sources.

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	1,928,922	311,079	1,617,843
CHP	Heating	30,951	29,243	1,707
Resistance heaters	Heating	42,934	4,049	38,886
Solar panels	Heating	4,667	4,667	-
Heat pumps	Cooling	16,100	1,518	14,582
Total		**2,023,574**	**350,556**	**1,673,018**

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 underlying data used here relate to 2018 and in this year, according to Eurostat, 9.43% of the electricity generated was renewable[11], and this is the proportion of electricity consumption considered renewable.

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.

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

[11] Out of a total gross electricity production of 435.1 ktoe, 41.1 ktoe came from renewable sources.

stations listed above) has revealed 1 x cement installation and 8 x ceramics installations. 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 a 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, at present it is unclear whether the vaporisation process will be open loop or closed loop and, consequently, whether there will be any waste cold available.

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 six 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 Reciprocating Engine (RE).

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 RE 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.

For RE 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

A bottom up assessment of heat available for recovery from cement clinker producing installations was carried out for UK installations[12].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 same study of potential heat recovery from UK industrial installations mentioned above[2] 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.

[12] 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

Sector	Site and Plant	Prime Mover	Electrical Capacity (MWe)	Annual Fuel Consumption (MWh HHV)	Power Efficiency (% HHV)	Annual Electricity Generation (MWh)	Full Load Hours (hrs)	Steam Extraction Potential (MWh/year)	Steam Extraction Potential (MWt)
Power (EAC)	Vasilikos ST	ST	390	4,031,869	37.6%	1,517,331	3,891	1,952,187	501.8
Power (EAC)	Vasilikos GT	OCGT	38.00	10,730	26.5%	2,838	75	5,745	76.9
Power (EAC)	Vasilikos CCGT 4	CCGT	220.00	1,728,095	45.3%	782,848	3,558	685,289	192.6
Power (EAC)	Vasilikos CCGT 5	CCGT	220.00	1,389,152	45.3%	629,302	2,860	550,879	192.6
Power (EAC)	Dhekeleia ST	ST	360.00	4,666,893	29.4%	1,371,257	3,809	2,699,723	708.8
Power (EAC)	Dhekeleia ICE 1	ICE	51.00	398,822	39.4%	157,133	3,081	161,925	52.6
Power (EAC)	Dhekeleia ICE 2	ICE	51.00	321,409	40.2%	129,174	2,533	127,953	50.5
Power (EAC)	Moni GT	OCGT	150.00	195,034	26.5%	51,594	344	104,433	303.6

A comprehensive worksheet setting out the calculations leading to the above values is provided in Appendix 6.

Note: As explained in the Point F report, opportunities to extract waste heat from the above power generating stations have only been pursued in respect of the ICEs at Dhekeleia. 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 LHV)	Full Load Hours (hrs)	Industrial Waste Heat Potential (MWh/MWh fuel input LHV)	Industrial Waste Heat Potential (MWht)
Cement	Vasiliko - non biomass	1,441,624	8,000	0.113	162,990
Cement	- biomass	401,778	8,000	0.113	45,425
Ceramics	United Brickworks	Not available	4,000	0.117	-
Ceramics	KAPA	9,537	4,000	0.117	1,111
Ceramics	Chrysafis	11,700	4,000	0.117	1,363
Ceramics	Kakogiannis	13,045	4,000	0.117	1,520
Ceramics	Melios & Pafitis	15,399	4,000	0.117	1,794
Ceramics	Gigas Tiles	Not available	4,000	0.117	-
Ceramics	Gigas Bricks	Not available	4,000	0.117	-
Ceramics	Ledra	13,934	4,000	0.117	1,623

Note: As explained in the Point F report, opportunities to extract waste heat have only been pursued in respect of the Vasilikos cement works. Feedback from the operators of the ceramics 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.

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

Appendix
1_Useful_Energy_Co

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

Appendix
2_Final_Energy_Con

A3 Power Station Waste Heat Potential

Appendix 3
Power_Station_Was

A4 Industrial Installation Waste Heat Potential

Appendix 4
Industrial_Installatic

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