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Energy efficiency potential

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Abstract
Energy efficiency potential
This report contains the results from the activities related to describing the heating and cooling demand that could be satisfied by high-efficiency cogeneration and by district heating and cooling, the potential for additional high-efficiency co- and tri-generation, the identification of energy efficiency potentials of district heating and cooling infrastructure with a separate analysis of district cooling potentials supplied from waste heat and renewable energy sources.

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- Marta Santamaria
- Kostas Kavvadias
- Mindaugas Jakubcionis
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1 Introduction

As described by the CSWD (see point 18.4), *´based on the identified heat demand and heat demand forecast, the next step consists of identifying those elements of the heat demand that technically could be satisfied by the applicable efficient solutions, including high efficiency cogeneration, micro-cogeneration and efficient district-heating and cooling. This means establishing the maximum or technical potential´*. The technical potential is assessed as the theoretical maximum amount of energy that could be produced with efficient heating and cooling solutions, disregarding all non-engineering constraints such as economic or market barriers. So, the technical potential of a solution could be defined as: ''*the amount of demand (measured in terms of useful energy, MWh/a) that could be covered by the technology or energy resource being evaluated, considering its maximum achievable penetration within the considered timeframe, considering technical or practical limitations, including topographic limitations, environmental, and land-use constraints, without taking into consideration economic criteria.*''

Thus, the followings aspects have to be taken into account to determine the technical potential:

- Resource availability. This factor is a limiting factor for some efficient solutions but not for all. It will be a restricting element in the case of solutions based in renewable resources and in the case of recovered resources, e.g., waste heat from existing power plants.
- Technical considerations that intervene in the energy conversion and/or use processes (efficiencies, temperature ranges, etc.).
- Demand size. This parameter is taken into account in order to determine the maximum amount of useful energy that is required. In those cases where the availability of the resource is higher than the demand, the demand delimits the amount that will be evaluated or considered within the technical potential of a solution. Similarly, in those cases where there is no relevant restriction on the availability of the resource, e.g., air heat pumps or micro-cogeneration, the technical potential will be sized as a function of the demand.

The identification of the technical potential is conducted at a system boundary level. As was mentioned before, the technical potential of centralised solutions will be assessed in the two high demand system boundaries identified in section 3. The technical potential of individual solutions is assessed considering the entire Cyprus as one system boundary.

The assessment of the technical potential is based on technical aspects. The aim of the assessment is to obtain the theoretical maximum amount of energy that could be produced with efficient heating and cooling solutions. In the next step of the analysis (see section 6), the economic evaluation will be conducted in order to identify which part of that technical potential can economically be met by efficient heating and cooling solutions. The output of the cost-benefit analysis will allow determining the economic potential of efficient heating and cooling options.

This section provides firstly, an identification of technical solutions that are considered within the frame of Art.14 of the EED. The second part of the section is focused on the assessment of the technical potential of those solutions.

2 Identification of technical solutions

A wide range of high efficiency heating and cooling solutions could satisfy the heating and cooling demand of different sub-sectors identified previously. A '**solution**' is a 'combination of three elements named:

- a resource that is used as a source of energy (e.g. waste heat, biomass or electricity);
- a technology that is used to convert the source of energy into a useful form of energy (e.g. efficient boilers or heat pumps) and,
- a distribution system that allows providing the useful energy to consumers (centralized or decentralized).

Table 2.1 summarizes the technical solutions analysed within this study. As can be seen, **14 technical efficient solutions** have been identified. Some of these solutions will present in both the baseline and alternative scenarios that will be built in order to conduct the CBA. All solutions considered for any end use (heat; SHW and cooling), could add absorption chillers whenever that is required. Regarding the type of resource, the technological solutions can be grouped in the following categories:

- Solutions using **recovered resources**, which encompass the use of waste heat from power generation. Within this category, different technologies can be used.
- Solutions using **renewable resources**, which encompasses solar; biomass and waste to energy. Within this category, different technologies can be used.
- Solutions using **conventional resources**, which encompass fossil fuels and electricity, similarly. Within this category, different technologies can be used (CHP, boilers, etc.).

Table 2.1 Efficient technical solutions analysed on this study

* analysed only for centralised energy supply options

Type	Resource	Technology	Present in the baseline	Present in alternative scenario
Conventional resources	Electricity	Heat pumps	√	√
	Electricity	Resistance heaters	√	√
	Gas oil	CHP	√	√
	Light fuel oil	CHP		√
	Natural gas	CHP		√
	Natural gas	Efficient boilers		√
Renewable resources	Solar	Solar panels	√	√
	Solid biomass	Efficient boilers	√	√
	Solid biomass	CHP		√
	Municipal waste	CHP		√
	Municipal waste	Efficient boilers		√
	Livestock/Industrial waste	CHP		√
	Livestock/Industrial waste	Efficient boilers		√
Recovered resources	Waste heat from power generation			√*

* analysed only for centralised energy supply options

The centralized systems are used to supply heating and cooling to system boundaries that were characterised as high demand density. Within this study, the only solution considered applicable to centralized systems (which means, using district heating/cooling systems to distribute thermal energy from a central heat source to consumers) is waste heat from power plants. Some other solutions identified could technically be implemented through centralized systems. Nevertheless, the cost of building the distribution system could harm their competitiveness. It was decided to analyse firstly the centralised system only with waste heat (as the fuel cost in that case is zero) and depending on the profitability of this option, determining if it would be worthy evaluating centralised system for other solutions.

The rest of the technical solutions identified and presented in Table 2.1 are considered for decentralized or individual systems, which means producing heat and cold *in situ,* so each consumer produces its own energy. As cogeneration is evaluated as an individual solution, micro-CHP is considered as part as CHP options because it is not a different technical solution, just a different size. The different size has an impact on the capital cost and this fact is reflected on the techno-economic parameters of the solutions.

3 Definition of geographical and system boundaries

The data collection exercise resulted in heat demand data for different uses by different subsectors, expressed in energy units (MWh/a). In this report the geographical boundary is the territory of the Republic of Cyprus. Further subdivision within geographical boundaries is achieved by using postal code areas as so called *base heat demand areas*.

One of the purposes of incorporating the geographical dimension into the analysis is to identify areas potentially suitable for implementation of efficient district heating and cooling solutions. The heat demand density (kWh/m² of land area) has been used as criteria for this identification.

Figure 3.1 shows the results of the baseline scenario in terms of energy density per base heat demand area. It is evident that 4 clusters of high energy density area can be identified. As a minimum threshold for a first screening the value of 5 kWh/m^2 was used based on the clustering classification done by "Jenkins natural breaks" algorithm. The four high demand density systems were identified, in the wider urban areas of:

- Nicossia
- Paphos
- Limassol
- Larnaca

These boundaries were further optimized based on a simple prefeasibility techno-economic model that estimates the optimum size of a district heating based on the energy density. The results are presented in Table 3.1. Figures 3.2 – 3.5 show the four high energy density boundaries applicable for the installation of district heating/cooling networks. After an early analysis it was decided that Famagusta could be disregarded due to less economically interesting heat demand characteristics than the other four high density areas.

Postal codes that do not belong to these four wider city areas are grouped in another single system boundary that encompasses the postal codes of the rest of Cyprus, thus forming a part of one *low demand density system*. In this system boundary, only individual solutions will be examined.

Table 3.1 Definition of system boundaries

	Energy density (kWh/m^2)
Paphos	23.3
Limassol	33.3
Larnaca	30.9
Nicosia	29.8
Rest of country	0.53

Within the four high demand density system boundaries, Limassol and Larnaca have a nearby exploitable waste heat source (see section 4.2.1).

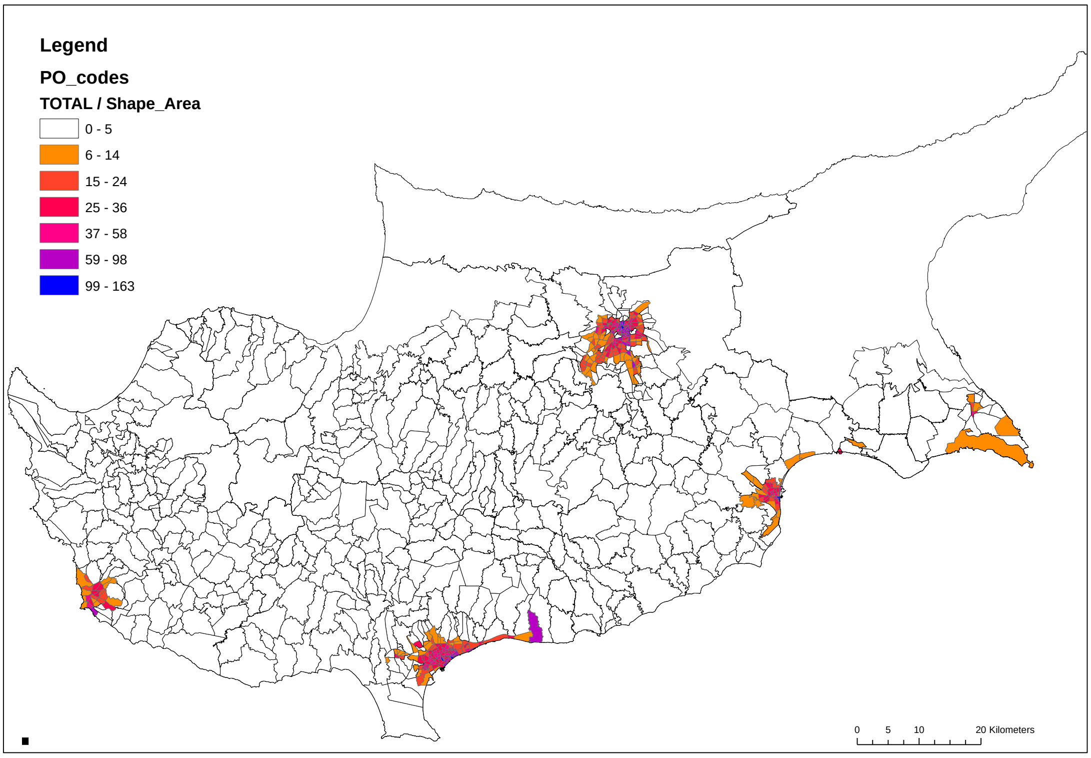

Figure 3.1 Heating and cooling demand per postal code

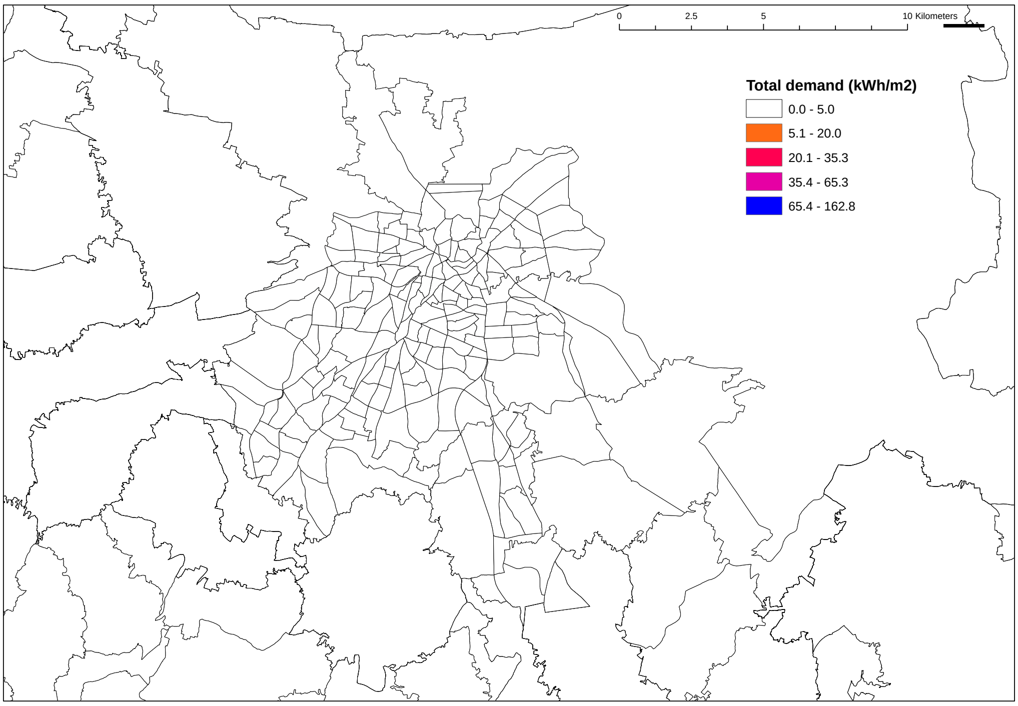

Figure 3.2 Specific heat demand per postal code in Nicosia (kWh/m^2)

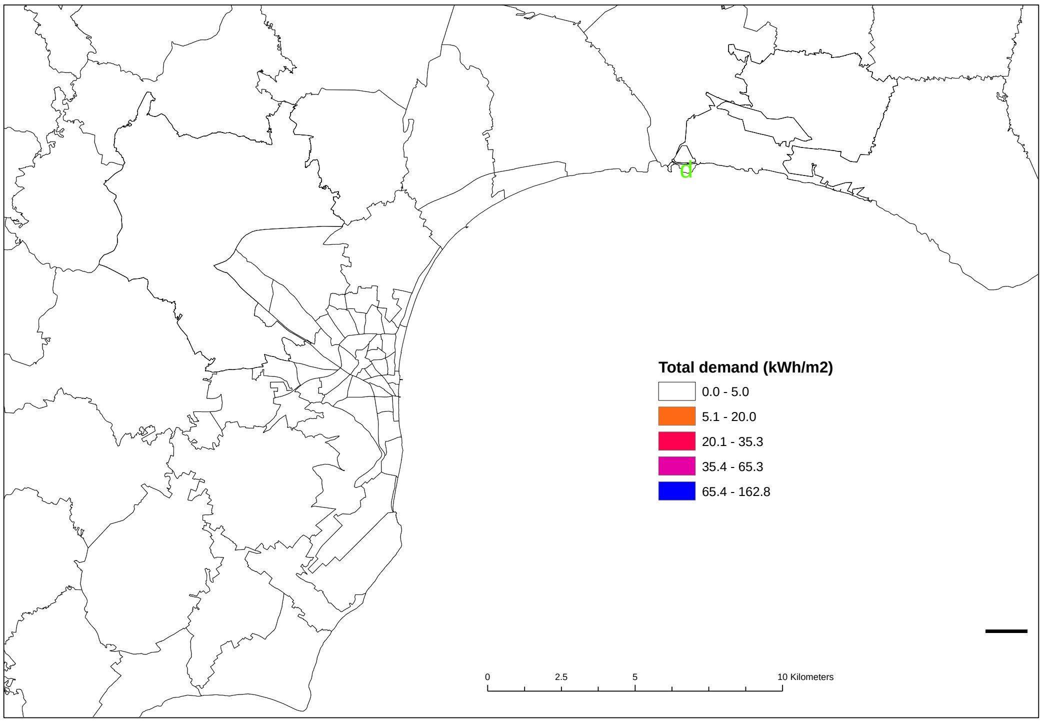

Figure3.3. Specific heat demand per postal code in Larnaca (kWh/m^2)

Figure 3.4 Specific heat demand per postal code in Paphos (kWh/m^2)

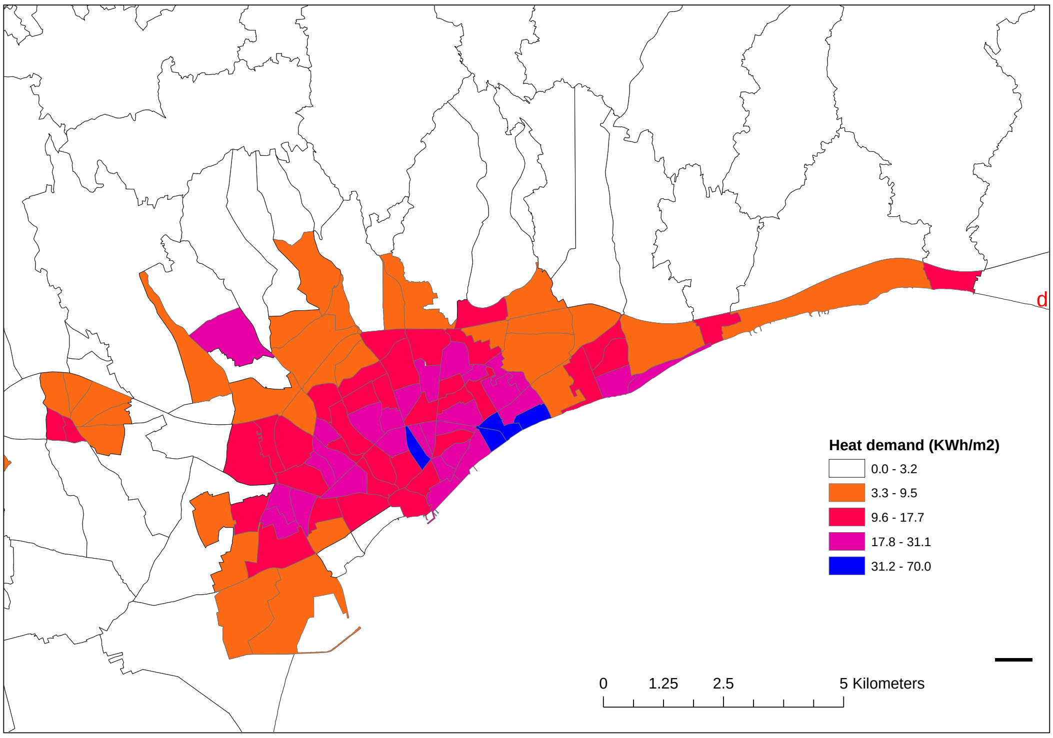

Figure 3.5 Specific heat demand per postal code in Limassol (kWh/m^2)

4 Identification of technical potential of efficient heating and cooling solutions

As described by the CSWD (see point 18.4), ´*based on the identified heat demand and heat demand forecast, the next step consists of identifying those elements of the heat demand that technically could be satisfied by the applicable efficient solutions, including high efficiency cogeneration, micro-cogeneration and efficient district-heating and cooling. This means establishing the maximum or technical potential*´. The technical potential is assessed as the theoretical maximum amount of energy that could be produced with efficient heating and cooling solutions, disregarding all non-engineering constraints such as economic or market barriers (NAPEE, 2007). So, the technical potential of a solution could be defined as: ''*the amount of demand (measured in terms of useful energy, MWh/a) that could be covered by the technology or energy resource being evaluated, considering its maximum achievable penetration within the considered timeframe, considering technical or practical limitations, including topographic limitations, environmental, and land-use constraints, without taking into consideration economic criteria.*''

Thus, the followings aspects have to be taken into account to determine the technical potential:

- Resource availability. This factor is a limiting factor for some efficient solutions but not for all. It will be a restricting element in the case of solutions based in renewable resources and in the case of recovered resources, e.g., waste heat from existing power plants.
- Technical considerations that intervene in the energy conversion and/or use processes (efficiencies, temperature ranges, etc.).
- Demand size. This parameter is taken into account in order to determine the maximum amount of useful energy that is required. In those cases where the availability of the resource is higher than the demand, the demand delimits the amount that will be evaluated or considered within the technical potential of a solution. Similarly, in those cases where there is no relevant restriction on the availability of the resource, e.g., air heat pumps or micro-cogeneration, the technical potential will be sized as a function of the demand (considering the demand as a cap).

The identification of the technical potential is conducted at a system boundary level.

The assessment of the technical potential is based on technical aspects. The aim of the assessment is to obtain the theoretical maximum amount of energy that could be produced with efficient heating and cooling solutions. In next steps of the analysis (see Section 6), the economic evaluation will be conducted in order to identify which part of the technical potential can economically be met by efficient heating and cooling solutions. The output of the cost-benefit analysis will allow identifying the economic potential of efficient heating and cooling options.

This section provides firstly, an identification of technical solutions that are considered within the frame of Art.14 of the EED and are applicable in Cyprus. The second part of the section is focused on estimation of resources availability and the third part presents the results of the technical potential of the solutions identified.

4.1 Identification of technical solutions

A wide range of high efficiency heating and cooling solutions could satisfy the heating and cooling demand of different sub-sectors identified previously. A 'solution' is a 'combination of three elements named:

- A resource that is used as a source of energy (e.g. waste heat or biomass);
- A technology used to convert a source into useful energy (e.g. efficient boilers);
- A distribution system that allows providing useful energy to consumers (centralized or decentralized).

Table 4.1 summarizes the technical solutions analysed within this study. As can be seen, **14 technical efficient solutions** have been identified. Some of these solutions will be present in both the baseline and alternative scenarios that will be built in order to conduct the CBA. All solutions are considered for any end use (including heat; SHW and cooling). In the case of cooling, absorption chillers are added whenever is required. Regarding the type of resource, the technological solutions can be grouped in the following categories:

- Solutions using **recovered resources**, which encompass heat recovery from power generation.
- Solutions using **renewable resources**, which encompasses solar and biomass (including solid biomass, municipal waste and livestock/industrial waste). Within the biomass category, different technologies can be used (e.g. efficient boilers or CHP).
- Solutions using **conventional resources**, which encompass fossil fuels and electricity, similarly. Within this category, different technologies can be used (CHP, boilers, heat pumps or resistance heaters).

Table 4.1 Efficient technical solutions analysed on this study

Solution type	Resource	Technology	Present in the baseline	Present in alternative scenario
Recovered resources	Heat recovery from power generation			√*
Renewable resources	Solar	Solar panels	√	√
	Solid biomass	CHP	√	√
	Solid biomass	Efficient boilers		√
	Municipal waste	CHP		√

	Municipal waste	Efficient boilers		√
	Livestock/Industrial waste	CHP		√
	Livestock/Industrial waste	Efficient boilers		√
Conventional resources	Electricity	Heat pumps[1]	√	√
	Electricity	Split unit– heat pumps	√	√
	Electricity	Resistance heaters	√	√
	Gas oil	CHP	√	√
	Light fuel oil	CHP		√
	LPG	CHP		√

* analysed only for centralised energy supply options

The centralized systems are used to supply heating and cooling to system boundaries that are characterised as high demand density. Within this study, any solution has been considered applicable for centralized systems (which means, using district heating/cooling systems to distribute thermal energy from a central heat source to consumers). Heat recovery from power plants is analysed only for centralised energy supply options. The rest of the technical solutions presented in Table 4.1 are also considered for individual systems (which means producing heat and cold *in situ,* so each consumer produces its own energy). When cogeneration is evaluated as an individual solution, micro-CHP is considered as part as CHP options because it is not a different technical solution, just a different size. The different size has an impact on the capital cost of this solution and this fact is reflected on the techno-economic parameters of the solutions that are presented on Section 6.

4.2 Estimation of the resources availability

Once the technical solutions have been identified, the next step consists of identifying their technical potential. The following sub-sections describes the assessment of the resource availability for those solutions whose technical potential is highly dependent in the availability of resources. These solutions are mainly solutions based on recovered resources (e.g., waste heat from power generation) and solutions based on renewable resources (solar and biomass). When the resource is scarce, as is the case of solutions based on renewable resources and recovered resources, the resource has to be allocated to specific consumers to avoid a double allocation of a resource that could generate wrong results. The approach used for the allocation of resources will also be described below.

For solutions based on conventional resources, such as different types of fossil fuel, it was assumed that the availability of such resources is infinite, i.e. such solutions could

[1] The analytical model has been developed assuming that this solution ('Heat pumps') is a water based system. Conversely, the solution called 'Split unit – heat pump' is not a heat water based system.

potentially cover all the heating and cooling demand in Cyprus during all the period. In the case of natural gas, there is no gas distribution network in Cyprus yet but the construction of the infrastructure will be considered as a potential efficient heating and cooling solution.

4.2.1 Identification of waste heat recovery potential from power generation

In 2013 the Electricity Authority of Cyprus (EAC) has three power stations with a total installed capacity of 1258 MW as follows (Electricity Authority of Cyprus, 2013) as presented in Table 4.2:

Table 4.2 Power plant capacity installed (MW)

Vasilikos PowerStation		
Steam Units	3 x 130 MW	390 MW
Gas Turbine	1 x 38 MW	38 MW
Combine Cycle Units	2 x 220 MW	220 MW
Dhekelia PowerStation		
Steam Units	6 x 60 MW	360 MW
Internal Combustion Engines	2 x 50 MW	100 MW
Moni PowerStation		
Gas Turbines	4 x 37.5 MW	150 MW
Total Installed Capacity		**1258 MW**

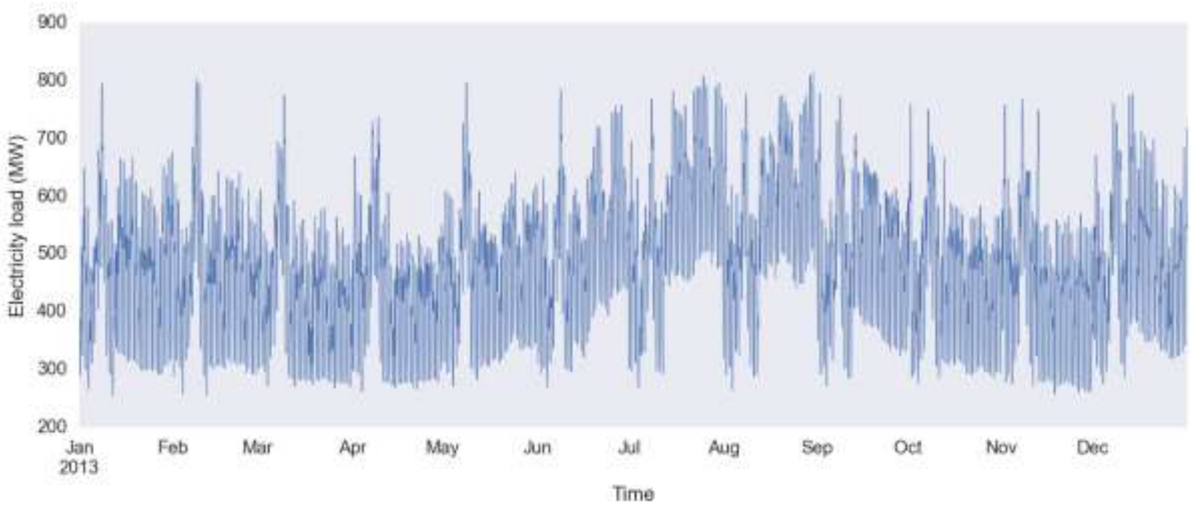

Figure 4.1 Electricity load of Cyprus for 2013 (ENTSOE)

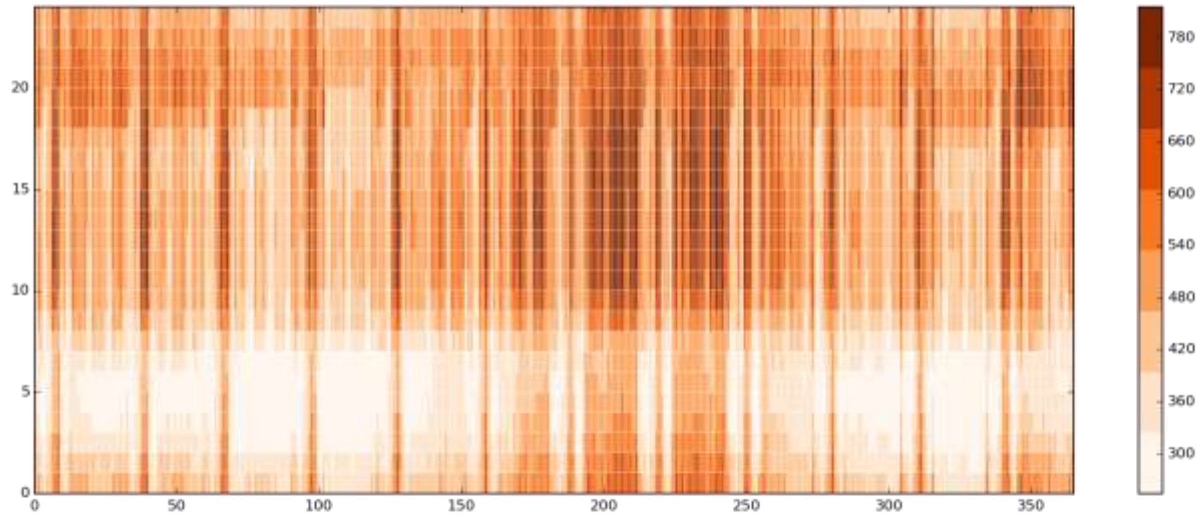

Figure 4.2 Heat map of electricity load per day of year and time of day (MW)

As can be seen in Figure 4.1, the Minimum load in 2013 is 254 MW, peak load is 815 MW and average is 488 MW. It can be observed that the peak (and average) load is much lower than the total installed capacity (1258 MW) and that the higher peaks are noticed during the summer months (Fig. 4.2).

Table 4.3 presents the power plant operational data for 2013 as reported by EAC.

Table 4.3 Power plant operational data (2013)

	Capacity (MW)	Electricity Production (GWh)	Peak efficiency (%)	Capacity Factor (%)
Vassilikos	648	2 243	46%	40%
Dhekelia	460	1 690	41%	42%
Moni	150	7.5	10%	1%

The total fuel burnt was 883,071 tonnes having an average heat rate of 42,751 kJ/kg. According to that the average efficiency was 35.88%. Assuming that 10% are irreversible heat losses, the rest of the fuel energy content is dissipated in the environment via the condenser (Table 4.4).

Table 4.4 Heat losses

	Capacity (MW)	Electricity Production (GWh)	Condenser Waste heat (GWh)
Vassilikos	648	2 243	3 607
Dhekelia	460	1 690	2 719
Moni	150	7.5	61.1

If the steam based plant could be converted to backpressure turbines all this steam could be available for other uses. This would have an effect on the performance on the power plant reducing the electricity production from 15–25% depending on the extraction temperature of the steam. Internal combustion engines and gas turbines can utilize this heat without a penalty on the thermodynamic cycle.

However such a big retrofit of the current power plants is unrealistic because that would require a redesign of the power plant and utilization of these amounts of heat. A more realistic way of harnessing the waste heat is to convert the existing condensing turbines to extraction/condensing turbines by extracting some steam. In previous reports (MECIT, 2009) it was mentioned that (given their manufacture consent) 23 MWth of heat could be potentially extracted for each 100 MWe produced. In that case, the electricity production would be lowered by 22 % (assuming that the required heat falls into the range of 120–130°C). According to the above, Table 4.5 shows the waste heat potential in terms of capacity.

Table 4.5 Waste heat capacity potential

	Capacity (MWe)	Maximum waste heat capacity potential (MWth)	Realisable waste heat capacity potential (MWth)
Vassilikos	648	681	151
Dhekelia	460	605	107
Moni	150	241	35

For 2013, given the capacity factors of these plants, this potential would correspond to the following waste heat production as described in Table 4.6.

Table 4.6 Waste heat potential (2013)

	Theoretical waste heat potential (GWh)	Realisable waste heat potential (GWh)
Vassilikos	2 361	523
Dhekelia	2 226	395
Moni	12	1.8

4.2.2 Identification of availability of renewable resources

4.2.2.1 Biomass

Within this study, the availability of biomass has been assessed based on information provided by previous studies and reports. The main sources of this information used are:

- *Assessment of national potential for cogeneration in Cyprus* (MCIT, 2009). Section on 'Technical Potential for CHP from Biomass' provides figures for: [i] solid biomass from agricultural residues and [ii] manure and industrial waste.
- *Atlas of EU biomass potentials* (Elbersen *et al*., 2012), which provides EU biomass potential from different sources for 2010; 2020 and 2030.

The availability of Municipal Solid Waste is the only category that has been estimated *ex profeso,* based on the amount of biodegradable fraction from municipal waste[2] and the calorific value of municipal solid wastes (EC, 2006).

Table 4.7 indicates the sources of data used to determine the availability of biomass in Cyprus, as well as a summary of the information shown in those sources. Figure 4.3 summarizes the availability of biomass in Cyprus (in ktoe), for the period 2010-2030. As can be seen the main sources of biomass are:

i. the biodegradable fraction of Municipal wastes;
ii. the solid biomass residues from agriculture;
iii. the manure from livestock.

[2] This information has been taken from the 'GENERATION AND TREATMENT OF MUNICIPAL SOLID WASTE' published by the Statistical Office of CYPRUS. The production of 'Organic Material' disposed in landfill in 2010 was 211.000 tonnes. To make long term forecasts, it has been assumed that this fraction will increase 1.5% per year (during the years before the economic crisis, the rates of production were growing with rhythm between 2% and 5% so the assumption done could be considered conservative, taking also into account that there are some targets to reduce the production of wastes at the EU).

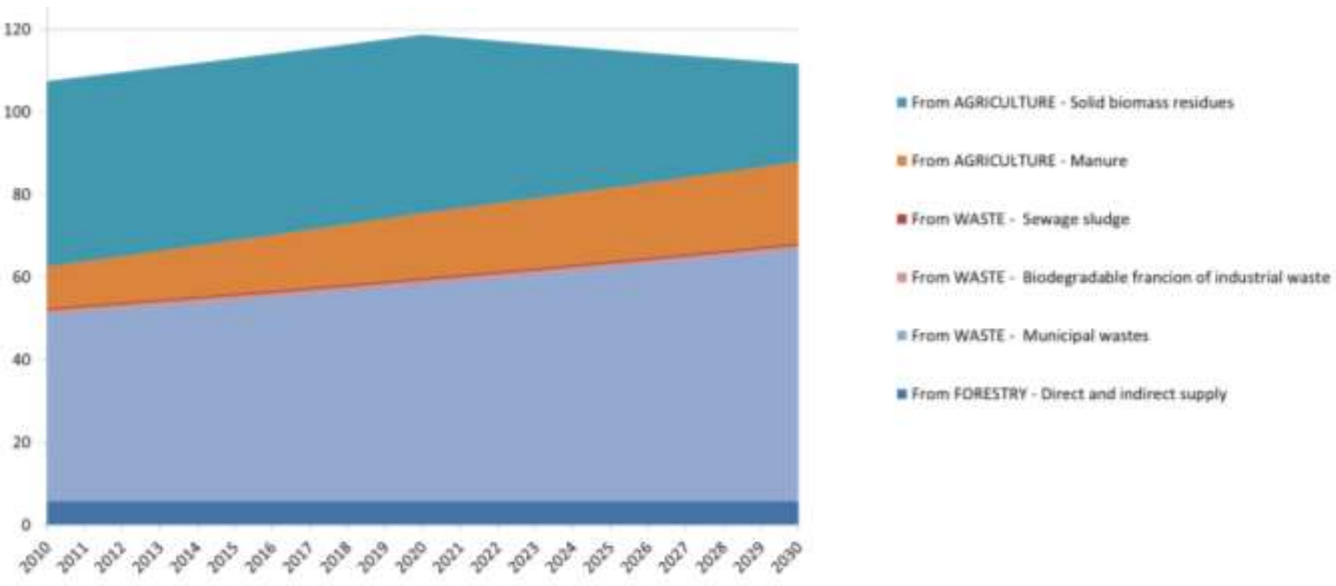

Figure 4.3 Biomass availability from different sources in Cyprus (ktoe), 2010-2030

Table 4.7 Sources of information used to determine biomass availability in Cyprus

Type of biomass source	SOURCE of information	POTENTIAL, as presented in the original source	POTENTIAL, energy content considered in this study
Biomass from FORESTRY			
Direct and indirect supply	*Atlas of EU biomass potentials* (Elbersen *et al.*, 2012).	- 2010: 5.7 ktoe - 2020: 5.7 ktoe - 2030: 5.7 ktoe	- 2010: 5.7 ktoe - 2020: 5.7 ktoe - 2030: 5.7 ktoe
Biomass from AGRICULTURE			
Solid biomass	For the current: *Assessment of national potential for cogeneration in Cyprus* (MCIT, 2009). For the evolution: *Atlas of EU biomass potentials* (Elbersen *et al.*, 2012).	Current: 1880 TJ - 2010: 32.25 ktoe - 2020: 31.00 ktoe - 2030: 17.00 ktoe	- 2010: 44.9 ktoe - 2020: 43.2 ktoe - 2030: 23.7 ktoe
Manure	For the current: *Assessment of national potential for cogeneration in Cyprus* (MCIT, 2009). For the evolution: *Atlas of EU biomass potentials* (Elbersen *et al.*, 2012).	Current: 750.000 tn - 2010: 152.38 ktoe - 2020: 238.00 ktoe - 2030: 298.00 ktoe	- 2010: 10.1 ktoe - 2020: 15.8 ktoe - 2030: 19.8 ktoe
Biomass from WASTES			
Municipal waste	Own estimates based on: - Organic fraction of municipal waste in 2010: 211,000 tn - Annual increase: 1.5% -Calorific value of MSW: 9		- 2010: 45.4 ktoe - 2020: 52.6 ktoe - 2030: 61.1 ktoe

	GJ/tn		
Biodegradable fraction of industrial waste	For the current: *Assessment of national potential for cogeneration in Cyprus* (MCIT, 2009). For the evolution: There is NO INFORMATION – Assumption: constant production	Current: 65.000 tn	- 2010: 0.9 ktoe - 2020: 0.9 ktoe - 2030: 0.9 ktoe
Sewage sludge	For the current: Kythreotou *et al. (*2012) For the evolution: There is NO INFORMATION – Assumption: constant production	Current: 1,103,896 m3 of biogas	- 2010: 0.5 ktoe - 2020: 0.5 ktoe - 2030: 0.5 ktoe

The second task has consisted of collecting data on current and expected **use of biomass** for energy production, to identify the expected consumption of resources in the baseline scenario. These data have been taken from the National Renewable Action Plan (NREAP)[3] that provides figures on consumption of biomass sources in 2006 as well as forecasts for 2015 and 2020[4]. The results are shown in Figure 4.4. The difference between the potential and the expected use of biomass is significant in the case of: solid biomass from agriculture; manure from livestock; municipal wastes and industrial waste (although in this case, it is decreasing along the time). In the case of biomass from forestry, the expected use of resources is close to the total available resources. In the case of sewage sludge, the expected use is even higher than the figures found in other literature sources.

[3] The National Renewable Action Plan was published in 2010 and it is available in: https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans

[4] The document provides ranges of energy production. The medium value has been the one considered for the assessment.

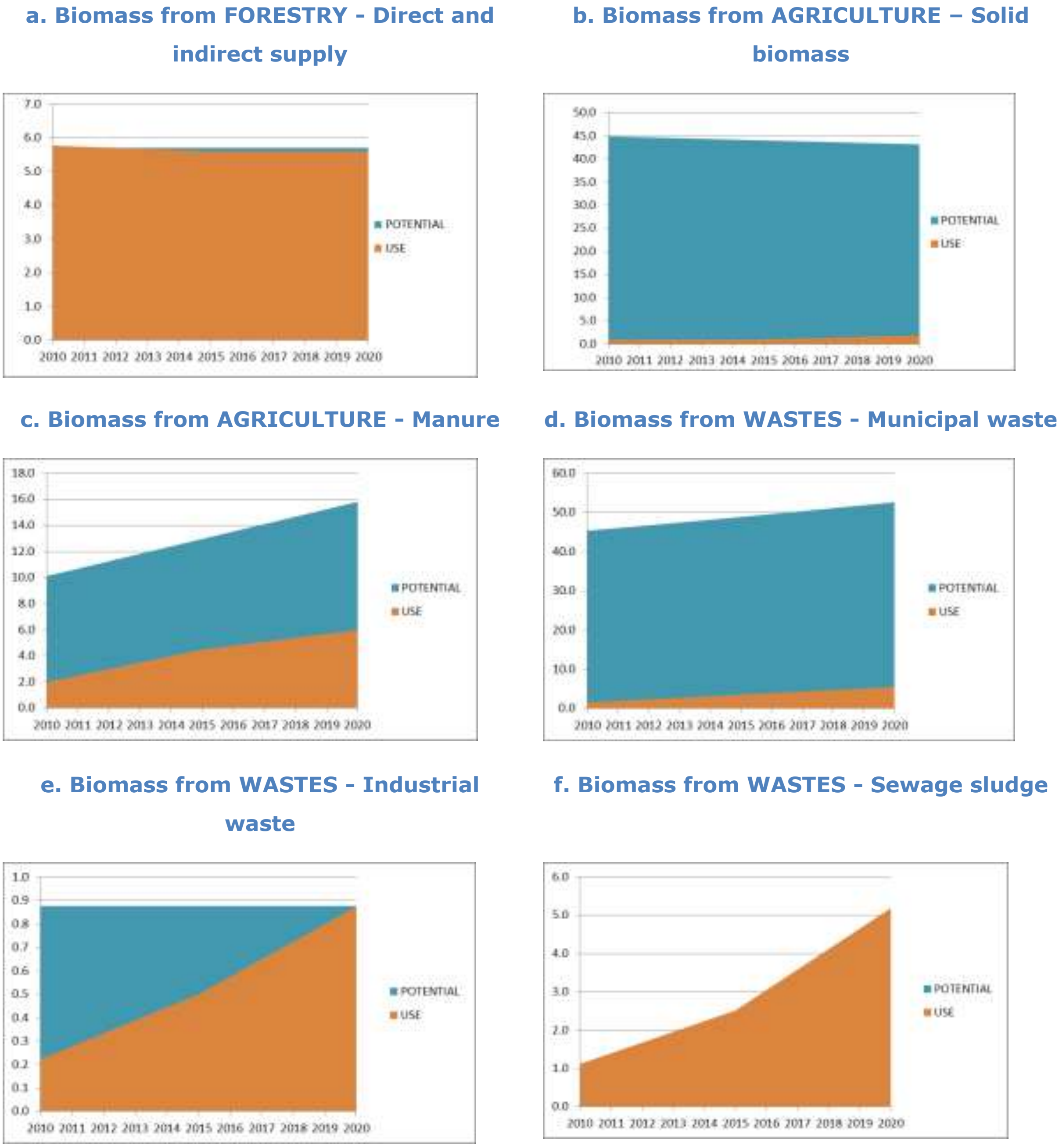

Figure 4.4 Comparison between POTENTIAL and USE of biomass resources in Cyprus (ktoe), 2010-2020

The last step consists of allocating the finite resources to different consumer types. The allocation was based on a simplified optimization model designed to maximize the use of available resources covering as much end-use energy demand as possible subject to sectorial applicability constraints. The results are presented in Figure 4.5.

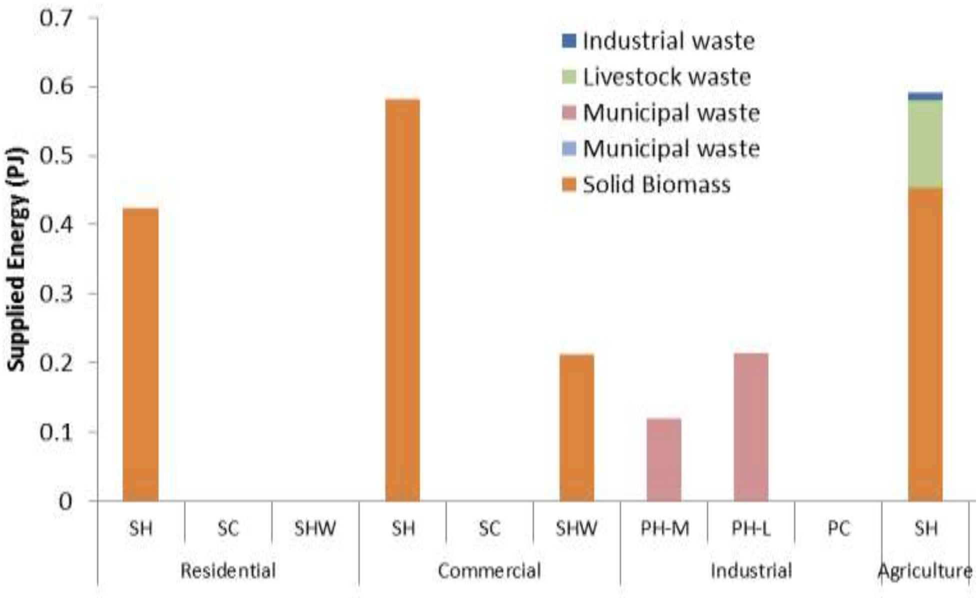

Figure 4.5 Allocation of biomass resources to different segments of demand (PJ)

4.2.2.2 Solar thermal

Solar thermal systems collect the incoming radiation from the sun by heating a fluid in the collector unit. The heated fluid is then used either directly or indirectly with a heat exchanger transferring the heat to its final destination. The amount of heat energy provided per square metre of collector surface area varies with design and location.

Typically, solar thermal systems consist of a solar collector, a heat exchanger, storage, a backup system to meet the balance of demand and a load. The installation of a storage unit allows using the heat on demand rather than at the time of production. A broad variety of non-concentrating[5] solar thermal collectors are available. The two main types are flat-plate, which can be glazed or unglazed, and evacuated tubes. Furthermore, collector efficiency depends on the difference between the collector and the ambient temperature.[6]

This study has assessed the potential of solar thermal technology to provide heat for three different uses: space heating; water heating and cooling, in the following sectors: residential, services and industrial (in particular for processes with a heat temperature

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[5] Concentrating solar collector are used to produce high temperature heat

[6] Unglazed are best for 0°C to 10°C above ambient; evacuated tubes for more than 50°C above ambient and flat-plate for -10°C to 50°C above ambient (IEA 2012)

up to 100 °C)[7]. The global irradiation falling in horizontal surface with average weather condition of Cyprus is 1800 kWh/m^2 per year, based on Joint Research Centre PVGIS database[8].

The deployment of technical potential is mainly limited by roof space availability. The resulting surface of solar collectors for households and service sector has been compared with the urban footprint area by postal code and the corresponding share is far from the 60% of suitable surface for solar collector that is indicated as a technical feasibility barrier by the IEA (2002).

4.2.2.3 Geothermal energy

Analysis performed has identified no extensive geothermal energy resources which could contribute significantly to provision of Cyprus' heating and cooling needs.

4.3 Estimation of the technical potential of efficient heating and cooling solutions

This section provides the technical potential of all technical solutions, including cogeneration as well as other renewable solutions (e.g. solar). The heat equivalent demand was selected for quantifying this potential. This is defined as the heat that is needed to cover heating, hot water and cooling demand produced by heat-driven technologies such as absorption chillers. Table 4.8 shows the demand both in terms of useful energy and heat equivalent for all defined boundaries.

Table 4.8 Heating and cooling demand for high and low energy density areas for the base year (2013)

	Cooling (GWh)	Heating (GWh)	Hot Water (GWh)	Total energy (GWh)	Total heat equivalent (GWh)
Limassol					
Residential	300.0	205.6	82.2	587.9	716.5
Service	220.8	86.2	19.4	326.5	421.1

[7] Solarthermal can cover processes with temperature up to 250 °C. Nevertheless, the data about heat temperature processes in Cyprus distinguish three ranges: low (up to 100 °C); medium, (100-400°C) and high (more than 400 °C). In order to avoid considering processes with temperatures higher than 250 °C, only the range of low temperature has been considered.

[8] The PVGIS provides solar radiation and photovoltaic electricity potential country and regional maps for Europe and is accessible through: http://re.jrc.ec.europa.eu/pvgis/cmaps/eur.htm

Nicosia					
Residential	427.0	313.6	119.1	859.7	1042.7
Service	356.0	160.8	43.5	560.4	713.0
Paphos					
Residential	99.0	71.3	26.5	196.8	239.2
Service	197.5	58.0	28.0	283.5	368.1
Larnaca					
Residential	108.3	73.3	28.8	210.4	256.8
Service	74.9	32.1	13.3	120.2	152.3
Total of high energy density areas				**3145.4**	**3909.7**
Rest of Cyprus (Low energy density areas)					
Industry	27.2	33.4	59.5	120.1	131.7
Residential	747.1	769.4	265.8	1782.4	2102.6
Service	777.5	285.8	97.7	1374.3	1494.2
Agriculture	0	213.3	0.0	213.3	213.3
Total of low energy density areas				**3490.1**	**3941.8**

Figure 4.6 shows the technical potential of the efficient heating and cooling solutions in Cyprus for 2013.

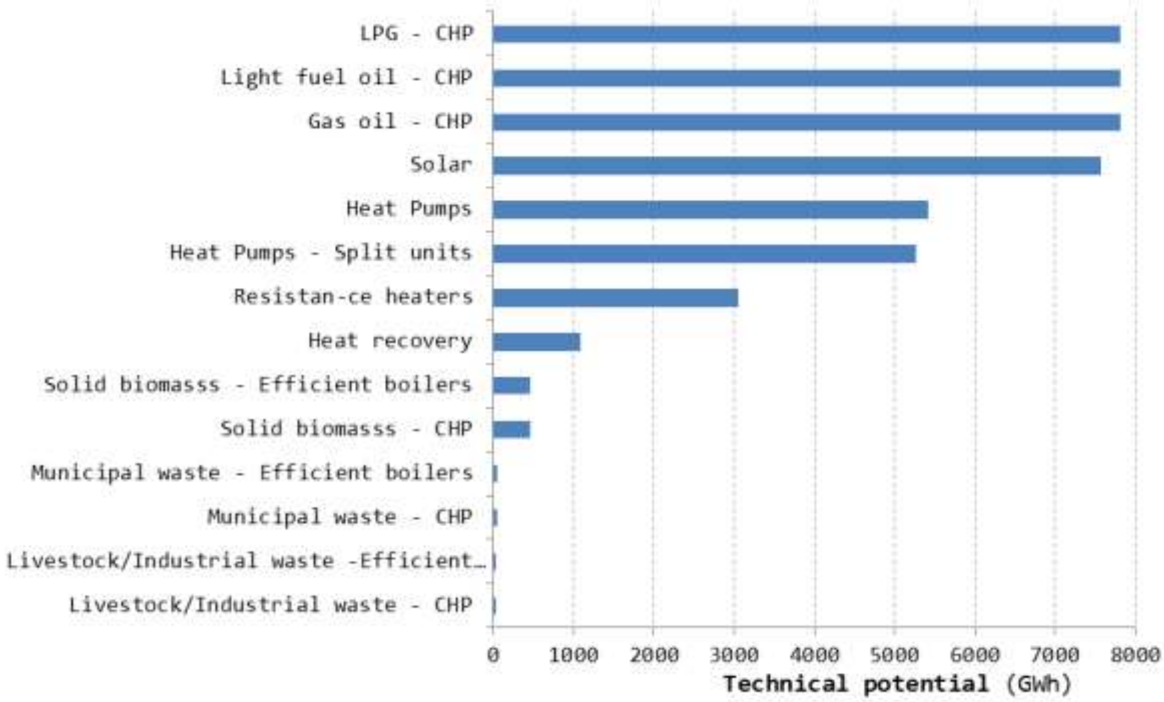

Figure 4.6 Technical potential of efficient heating and cooling solutions in Cyprus, 2013

The evolution of this potential for the period 2013-2050 is presented in Table 4.9. Annex 3 provides detailed results of the technical potential of efficient heating and cooling solutions by system boundary.

Annex VIII of Directive 2012/27/EU requires '*the identification of the heating and cooling demand that could be satisfied by high-efficiency cogeneration, including residential micro-cogeneration, and by district heating and cooling*':

- Heating and cooling demand that could be satisfied by district heating and cooling is the demand of the system boundaries with high demand density as presented in Table 4.8. This potential is 3,909.7 GWh.
- Heating and cooling demand that could be satisfied by high-efficiency cogeneration, including residential micro-cogeneration differs depending on the fuel used. This potential appears in Figure 4.6 and Table 4.9. The highest potential can be achieved by using fossil fuels and the amount in 2013 is 7,811 GWh .

Table 4.9 Technical potential of efficient heating and cooling solutions in Cyprus (GWh)

Year	Heat Pumps	Resistance heaters	Gas oil - CHP	Light fuel oil - CHP	Livestock/ Industrial waste - CHP	Livestock/ Industrial waste - Efficient boilers	Municipal waste - CHP	Municipal waste - Efficient boilers	Solid biomasss - CHP	Solid biomasss - Efficient boilers	Solar	Heat recovery	LPG - CHP	Heat Pumps - Split units
2013	5421	3055	7811	7811	38	38	41	41	456	456	7568	1079	7811	5263
2014	5603	3170	8058	8058	40	40	41	41	454	454	7814	1094	8058	5446
2015	5498	3108	7918	7918	41	41	42	42	452	452	7674	1088	7918	5341
2016	5598	3146	8077	8077	42	42	43	43	451	451	7833	1097	8077	5442
2017	5662	3159	8190	8190	44	44	43	43	450	450	7946	1104	8190	5506
2018	5737	3181	8317	8317	45	45	44	44	448	448	8073	1111	8317	5581
2019	5809	3202	8438	8438	47	47	44	44	447	447	8194	1113	8438	5653
2020	5865	3215	8536	8536	48	48	45	45	446	446	8292	1115	8536	5710
2021	5931	3233	8650	8650	50	50	46	46	444	444	8406	1117	8650	5777
2022	5989	3246	8751	8751	52	52	47	47	443	443	8507	1119	8751	5835
2023	6051	3262	8859	8859	54	54	47	47	442	442	8615	1120	8859	5898
2024	6114	3277	8968	8968	55	55	48	48	440	440	8724	1122	8968	5961
2025	6177	3293	9077	9077	57	57	49	49	439	439	8833	1124	9077	6024
2026	6245	3311	9194	9194	59	59	49	49	438	438	8950	1126	9194	6092
2027	6299	3322	9291	9291	61	61	50	50	436	436	9047	1127	9291	6147
2028	6362	3336	9401	9401	63	63	51	51	435	435	9157	1129	9401	6210
2029	6426	3351	9513	9513	65	65	52	52	434	434	9269	1131	9513	6275
2030	6491	3365	9627	9627	68	68	52	52	432	432	9382	1133	9627	6340
2031	6558	3381	9745	9745	70	70	53	53	431	431	9501	1135	9745	6408
2032	6611	3391	9840	9840	72	72	54	54	430	430	9595	1136	9840	6461
2033	6671	3403	9947	9947	75	75	55	55	429	429	9702	1138	9947	6522
2034	6731	3415	10054	10054	77	77	55	55	427	427	9809	1140	10054	6582
2035	6790	3427	10159	10159	80	80	56	56	426	426	9914	1141	10159	6641
2036	6850	3439	10267	10267	83	83	57	57	425	425	10022	1143	10267	6702
2037	6897	3445	10353	10353	86	86	58	58	423	423	10108	1144	10353	6749
2038	6952	3454	10453	10453	89	89	59	59	422	422	10208	1145	10453	6804
2039	7007	3463	10553	10553	92	92	60	60	421	421	10308	1147	10553	6860
2040	7061	3472	10652	10652	95	95	61	61	420	420	10407	1148	10652	6914
2041	7116	3481	10753	10753	98	98	62	62	418	418	10508	1150	10753	6970
2042	7172	3489	10854	10854	101	101	62	62	417	417	10609	1150	10854	7026
2043	7227	3498	10954	10954	105	105	63	63	416	416	10709	1151	10954	7081
2044	7281	3506	11055	11055	108	108	64	64	414	414	10809	1151	11055	7136
2045	7336	3514	11155	11155	112	112	65	65	413	413	10909	1152	11155	7191
2046	7389	3522	11252	11252	116	116	66	66	412	412	11007	1152	11252	7245
2047	7441	3529	11349	11349	120	120	67	67	411	411	11104	1152	11349	7298
2048	7494	3536	11446	11446	124	124	68	68	409	409	11201	1153	11446	7351
2049	7546	3543	11543	11543	128	128	69	69	408	408	11298	1153	11543	7403
2050	7596	3548	11638	11638	133	133	70	70	407	407	11392	1153	11638	7454

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