AN ENERGY ROADMAP - TOWARDS ACHIEVING DECARBONIZATION FOR THE MALTESE ISLANDS

ANALYSIS FOR A COST-EFFECTIVE AND EFFICIENT HEATING AND COOLING

MINISTRY FOR ENERGY AND HEALTH

Version: Final

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1 Executive Summary

This report (referred to as Assignment 1-Task 5) which forms part of an overarching study intended to develop an " Energy Roadmap: towards achieving decarbonisation for the Maltese Islands", presents the results from a Comprehensive Assessment of the Maltese heating and cooling, demand and supply. The analysis, which was performed based on the guidelines and methodology indicated in the Energy Efficiency Directive 2012/27/EU Annex IX Part 1 and containing information set out in annex VIII, seeks to identify the potential of technically and economically feasible application of high efficiency cogeneration and efficient district heating and cooling.

The report is subdivided into six sequential related sub-tasks as follows:

Sub-task 1- is an evaluation of the heating and cooling demand based on 2013 data for each of the residential, services, industrial and agricultural sectors, starting from real measured and verified consumption information. The exercise also identifies the energy sources and technologies used to satisfy the demand.

Sub-task 2- builds on the results from sub-task 1 and makes projections of the sectorial heating and cooling demand up to 2020 and 2030 taking into consideration the Current Policy Initiatives and measures.

Sub-task 3- Analyses the characteristics of the heating and cooling demand trying to identify those cases where the demand can be satisfied by existing or planned high efficiency cogeneration, or waste-heat sources, possibly integrated within district-heating and cooling networks. Based on the identified heat demand and heat demand forecast in each sector, the task develops the technical potential for the application of efficient heating and cooling systems, in particular those using high-efficiency cogeneration, micro-cogeneration and efficient district-heating and cooling, through adequately sized systems. This means establishing the maximum potential which is technically feasible for local climatic conditions and resources.

Sub-task 4- builds on the conclusions of sub-task 3, identifying those parts of the technical potential whose benefits exceed the costs. The assessment involved running cost-benefit analysis for typical technically suitable systems that may be considered under local climatic and environmental conditions. This included investigation into the application of micro-cogeneration in the residential sector, high-efficiency cogeneration in particular areas of the services sector, collective application of cogeneration in the industrial sector using small district-heating network, and the utilisation of waste heat

Sub-task 5- is a collection of territorial mapping (by local council and sector) of the results obtained in sub-task 1. In particular the maps show (i) Total Heating and Cooling Energy Demand by sector, (ii) Heating and Cooling Demand by sector and utilisation (iii) Energy Sources associated to the various utilisation in each sector.

Sub-task 6- is a series of possible strategies, policies and measures that may be adopted to facilitate the implementation of cost-efficient solutions to satisfy heating and cooling needs using more sustainable methods, and other measures aimed at reducing heating and cooling demand.

The primary objective of this analysis is to investigate the characteristics of the Heating and Cooling demand and how it is expected to develop in the coming years. On the basis of this Malta will be in a better position to make a correct assessment of the most effective technological choices fit for our circumstances, in our endeavour to decarbonise the Heating and Cooling sector.

This analysis is carried out at sectorial level, breaking down the consumption for each sector and trying to formulate its most accurate trajectory, both towards 2020 and 2030. The goal is to assess the potential growth of each sector, the related evolution of the technology and the speed of the technological substitution rate.

The table below gives a summary of the conclusions derived from sub-task 1. It shows that for 2013 the estimated final energy consumption for Heating and Cooling purposes (defined as the energy supplied to the final consumer) was just 685 GWh, of which, water heating purposes consumes (289MWh) followed by summer air conditioning and cooling with (257GWh). Winter spatial heating consumption is relatively lower, showing clearly that the winter climatic conditions are very mild to say the least.

2013		Sectorial Heating & Cooling Demand and Final Energy Consumption			
		Residential	Services	Industrial	Agriculture
Sector Total Final Energy Consumption	GWh	807.60	878.94	544.98	8.58
Heating and Cooling Demand	GWh	494.41	529.93	160.39	5.86
Final energy Consumption for H & C	GWh	358.70	254.01	69.00	3.40
% of H & C to Sector Final Energy Consumption	%	44.41	28.90	12.66	39.62
Final Energy Consumption in Space heating	GWh	87.77	41.82	8.93	0.69
Final Energy Consumption in Space Cooling	GWh	53.93	158.54	44.10	0.43
Final Energy Consumption in Water Heating	GWh	216.97	53.65	15.97	2.28
% Sectorial Final Energy Consumption in Space heating	%	10.87	4.76	1.64	7.56
% Sectorial Final Energy Consumption in Space Cooling	%	6.68	18.04	8.09	5.05
% Sectorial Final Energy Consumption in Water Heating	%	26.87	6.10	2.93	26.73

The forecasts to 2030 sees an increase of final energy consumption for H&C in Malta, in particular in services and industry; the residential sector increase will be limited by energy performance requirements for new and refurbished dwellings (Sub-Task 2). Despite the increase, the final heating demand will remain relatively low compared to what is needed to create favorable conditions for enhancing CHP and district heating; with the expected low thermal demand it is not convenient to install such technologies. This is even more evident for micro-cogeneration that needs stronger demand (Sub-Task 3).

However the sensitivity analysis conducted in respect of changing fuel pricing and the cost of electrical power, possibly supported by Feed-in tariffs, show that in some specific cases, especially with LPG-fuelled plants, e.g. in hospitals, it may become convenient to install CHP plants. In order to reach feasibility the key elements are the maximization of the heating energy use and the value of the power production (Sub – Task 4).

CHP technology seems to have a marginal potential role in Malta, even when taking into account provisions of Directive 2012/27/EU of enhancing this technology and district heating. This is accentuated by the fact that Malta has practically no cheaply available indigenous resources of biomass or biogas, and currently there is no natural gas network to render the fuel supply cheaper than present options. Nevertheless, the economic cost-benefit analysis drawn up in accordance with Directive 2012/27/EU showed some positive results for some scenarios of CHP plants penetration rate especially when considering environmental benefits and health externalities that could receive a better evaluation in the future. However the up-take of CHP technology as small scale stand alone installations is rendered more difficult considering the market competition of equally efficient heating technologies, like heat pumps and condensing boilers.

It is evident from the table above that the local climatic conditions require a much higher summer cooling demand than the wintery heating energetic requirements. This cooling demand is entirely supplied by very efficient heat-pumps which have practically flooded the Maltese residential and economic sectors. Furthermore the recent reduction in electricity tariffs due to higher power generation efficiency, is resulting in a clear shift towards the use of these same heat-pumps for spatial heating purposes, a cheaper more efficient option than the use of LPG gas heaters used in the residential making it even more difficult for the penetration of micro-CHP in the residential sector.

The current local conditions may not be ideal for the implementation of CHP and district heating networks; the report suggests a series of policies and measures that may be adopted to support and promote these technologies for the medium term up to 2020 and further out to 2030 with the introduction of even more ambitious legislation and technological breakthroughs.

2 Acronyms

AC	=	Air Conditioning
ARMS	=	Automated Revenue Management System
BTU	=	British Thermal Unit
CA	=	Comprehensive Assessment
CBA	=	Cost Benefit Analysis
CCGT	=	Combined Cycle Gas Turbine
CHP	=	Combined Heat and Power
COP	=	Coefficient Of Performance
DHC	=	District Heating and Cooling
DHW	=	Domestic Hot Water
DSO	=	Distribution System Operator
EC	=	European Commission
EED	=	Energy Efficiency Directive
EER	=	Energy Efficiency Ratio
EPBD	=	Energy Performance of Buildings Directive
ESCO	=	Energy Service Company
ETS	=	Energy Transfer Stations
EU	=	European Union
FPC	=	Flat Plate Collector
GDP	=	Gross Domestic Product
GIS	=	Geographic Information System
HE	=	High Efficiency
HP	=	Heat Pump
IEA	=	International Energy Agency
JRC	=	Joint Research Centre
KTOE	=	Thousands of Tons of Oil Equivalent
LPG	=	Liquefied Petroleum Gas
MBT	=	Mechanical biological treatment
MEH	=	Malta Ministry of Energy and Health
MEPA	=	Malta Environment and Planning Authority
MRA	=	Malta Resources Authority
MS	=	Member State
NEEAP	=	National Energy Efficiency Action Plan
NPV	=	Net Present Value
NZEB	=	Nearly-Zero Energy Building
NSO	=	National Statistics Office Malta
ORC	=	Organic Rankine Cycle
PV	=	Photovoltaic
SC	=	Solar Cooling
SCOP	=	Seasonal Coefficient of Performance
SEER	=	Seasonal Energy Efficiency Ratio
SHC	=	Solar Heating and Cooling
SME	=	Small and Medium-sized Enterprise
SWH	=	Solar Water Heater
TOE	=	Tons of Oil Equivalent

3 Sub-Task 1 - Heating and cooling demand for Malta

The aim of this Sub-Task is to calculate the heating and cooling demand for Malta starting from real, measured and verified consumption information. The analysis considered the year 2013 as reference year for all the consumption data and the base for all the calculations. In case of need for other auxiliary information (number of equipment, building stock etc.) the analysis took in to account the nearest data to the **year 2013**.

The results presented in the following paragraphs are based on assumptions and methodologies that have been developed specifically for the purposes of this Task. The analysis considers all the most updated data and reference values found within public sources available on the topic. Most of the data have been developed using the methodology described in the following chapters, and may be subjected to changes and revisions when more data and figures will be available.

Main sources of starting information about energy consumption in the Islands were, in order of priority:

a) Real consumption databases provided by:

- Fossil Fuels: MRA[1];
- Electricity:
    - ARMS[2] ltd for the:
        - Monthly electrical consumption;
        - Data sample of the daily average consumption.
    - NSO[3] for consumption by NACE[4].

b) Eurostat data, and in particular the country energy balances[5].

At the end of this first step, the results are provided at national level with the following detail:

1. Sectors:
    - Residential sector;
    - Industrial sector;
    - Services sector.
2. Energy uses:
    - Heating;
    - Cooling;
    - Water Heating.

[1] Malta Resources Authority. For the LPG, elaboration of MEH
[2] Automated Revenue Management System
[3] National Statistics Office Malta
[4] NACE: Nomenclature statistique des activités économiques dans la Communauté européenne
[5] http://ec.europa.eu/eurostat/web/energy/data/energy-balances

3. Energy sources.

Outcomes of this analysis are provided in the both the forms of[6]:

- **Final Energy Consumption**: in analogy with the Eurostat definition, it is the energy supplied to the final consumer's door.
- **Heating and Cooling Energy Demand**: it is the useful energy, available to the consumers after the last conversion made in the consumer conversion equipment, hence final energy consumption minus conversion losses.

Chapter 7, developed for presenting the activities of Sub-Task 5 (Maps of heat loads), provides all the above-mentioned information with a detailed geographical breakdown, based on the councils being part of the Maltese Islands.

The following paragraphs present the methodologies and the obtained results for Sub-Task 1 ordered by sector.

3.1 Energy Consumption data

The Heating and Cooling demand analysis employed real consumption data, referred to the **year 2013** for both fossil fuels and electricity use. The following paragraphs describe the type data that were analyzed and report the adopted methodology.

3.1.1 Fossil Fuels

The fossil fuels consumption data considered in the analysis, apart from the LPG consumption (see paragraph 3.1.1.1), were obtained as an elaboration of the fossil fuels database provided by MRA. Referring to the year 2013 and starting from the MRA database, the following tables summarize the detailed consumption values of the fossil fuels employed for space heating purposes.

Year 2013	**SECTORS**			
Space Heating - toe	**Agricolture**	**Industry**	**Services**	**Residential**
	toe	*toe*	*toe*	*toe*
Petrol	0	0	0	0
Diesel	0	420	1,136	0
Biodiesel	0	0	0	0
Aviation Turbine Fuel	0	0	0	0
Aviation Gasoline Fuel	0	0	0	0
Kerosene	0	2	76	472
Gasoil	0	162	751	0
Fuel oil	0	0	809	0
Propane	4	0	9	219
Coal	0	0	0	0
Light Cycle Oil	0	0	0	0
Total	**4**	**584**	**2,782**	**691**

[6] (Pardo, Vatopoulos, Krook-Riekkola, Moya, & Perez, 2012)

Year 2013 *Space Heating - GWh*	**SECTORS**			
	Agricolture *GWh*	**Industry** *GWh*	**Services** *GWh*	**Residential** *GWh*
Petrol	-	-	-	-
Diesel	-	4.88	13.22	-
Biodiesel	-	-	-	-
Aviation Turbine Fuel	-	-	-	-
Aviation Gasoline Fuel	-	-	-	-
Kerosene	-	0.03	0.88	5.49
Gasoil	-	1.89	8.73	-
Fuel oil	-	-	9.41	-
Propane	0.04	-	0.11	2.55
Coal	-	-	-	-
Light Cycle Oil	-	-	-	-
Total	**0.04**	**6.80**	**32.35**	**8.04**

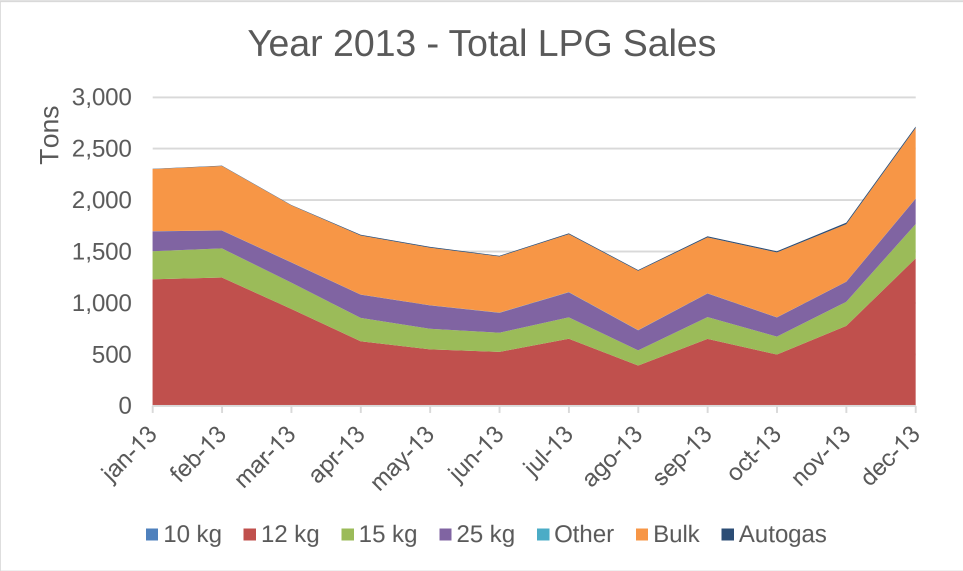
The analysis did not consider the MRA database what concerns the LPG consumption data, for which more accurate and actual values were available (see next paragraph).

3.1.1.1 Liquefied Petroleum Gas

For LPG the consumption data were obtained from the analysis of yearly sales of this fuel. The source data are reported in the following table, containing all the LPG consumed in its various selling forms.

	Total Sales in Cylinders					**Bulk**	**Autogas**
	10 kg	**12 kg**	**15 kg**	**25 kg**	**Other Cylinder sizes**		
	number	*number*	*number*	*number*	*kg*	*kg*	*kg*
jan-13	432	102,136	18,193	7,742	950	604,664	2,736
feb-13	294	103,687	18,886	6,958	1,111	625,944	3,648
mar-13	9	78,462	17,045	7,868	1,272	553,585	3,625
apr-13	97	52,176	15,170	9,046	1,174	573,873	7,467
may-13	3	45,728	13,336	9,103	1,180	559,683	8,094
jun-13	3	43,684	12,427	7,741	1,853	545,722	6,783
jul-13	102	54,233	13,889	9,748	2,248	562,507	8,405
ago-13	2	32,603	9,848	7,805	2,072	576,203	7,524
sep-13	53	54,163	14,142	9,193	1,344	543,889	10,470
oct-13	1	41,514	11,640	7,461	1,092	631,245	11,003
nov-13	78	64,698	15,622	7,799	939	558,865	14,648
dec-13	0	119,452	22,233	9,880	1,234	685,776	14,193

	Total Sales in Cylinders					Bulk	Autogas	Total Sales
	10 kg	12 kg	15 kg	25 kg	Other Cylinder sizes			
	kg	*kg*	*kg*	*kg*	*kg*	*kg*	*kg*	*kg*
jan-13	4,320	1,225,632	272,895	193,550	950	604,664	2,736	**2,304,747**
feb-13	2,940	1,244,246	283,290	173,950	1,111	625,944	3,648	**2,335,129**
mar-13	90	941,544	255,675	196,700	1,272	553,585	3,625	**1,952,491**
apr-13	970	626,112	227,550	226,150	1,174	573,873	7,467	**1,663,296**
may-13	30	548,736	200,040	227,575	1,180	559,683	8,094	**1,545,338**
jun-13	30	524,208	186,405	193,525	1,853	545,722	6,783	**1,458,526**
jul-13	1,020	650,792	208,335	243,700	2,248	562,507	8,405	**1,677,007**
ago-13	20	391,240	147,720	195,125	2,072	576,203	7,524	**1,319,904**
sep-13	530	649,956	212,130	229,825	1,344	543,889	10,470	**1,648,144**
oct-13	10	498,168	174,600	186,525	1,092	631,245	11,003	**1,502,643**
nov-13	780	776,376	234,330	194,975	939	558,865	14,648	**1,780,913**
dec-13	0	1,433,424	333,495	247,000	1,234	685,776	14,193	**2,715,122**
	10,740	**9,510,434**	**2,736,465**	**2,508,600**	**16,469**	**7,021,956**	**98,596**	**21,903,260**



The following tables report the data in a summarized form.

Cylinders sales:	number	tons of LPG
10 kg	1,074	10.74
12 kg	792,536	9,510.43
15 kg	182,431	2,736.47
25 kg	100,344	2,508.60
Other	-	16.47
Total Cylinders sales	-	**14,782.71**

Total Sales	**21,903**	tons
(cylinders, bulk, autogas)	*281*	*GWh*

Total Sales	**21,805**	tons
(cylinders, bulk)	*280*	*GWh*

The tables below report the subdivision of the LPG consumption value into the different sectors. For the **residential sector** only the 10, 12 and 15 kg cylinders were summed, adding a small part of the bulk-LPG sales.

	Total Sales in Cylinders			TOTAL
	10Kg	12Kg	15Kg	
	kg	*kg*	*kg*	*kg*
jan-13	4,320	1,225,632	272,895	**1,502,847**
feb-13	2,940	1,244,246	283,290	**1,530,476**
mar-13	90	941,544	255,675	**1,197,309**
apr-13	970	626,112	227,550	**854,632**
may-13	30	548,736	200,040	**748,806**
jun-13	30	524,208	186,405	**710,643**
jul-13	1,020	650,792	208,335	**860,147**
ago-13	20	391,240	147,720	**538,980**
sep-13	530	649,956	212,130	**862,616**
oct-13	10	498,168	174,600	**672,778**
nov-13	780	776,376	234,330	**1,011,486**
dec-13	0	1,433,424	333,495	**1,766,919**
	10,740	**9,510,434**	**2,736,465**	**12,257,639**

Bulk in the Residential Sector		
Total Storage capacity (170 households)	145,565	liters
Fluid density	0.505	kg/liter
Filling ratio	85%	
Total gas capacity (one filling per year)	62,484	kg

The quantities associated to "Cooking" and "Heating" purposes were calculated starting from an estimation of the yearly value for cooking, calculated as an average of the months April – October (approximately 749,800 kg per month). The monthly value, applied to each month, gave an estimation of the yearly LPG consumption for cooking (73% of the total). The remaining part was then associated to heating purposes, as highlighted below.

Residential sector:		
Total sales - cylinders	12,258	tons
(10,12 and 15kg)	*157.15*	*GWh*
Total sales - bulks	62.48	tons
(estimation)	*0.80*	*GWh*
Residential sector - TOT	**12,320**	**tons**
	157.95	*GWh*

Residential sector - LPG for cooking and heating		
Cooking purposes (73%)	115.35	GWh
Heating purposes (27%)	42.60	GWh

The remaining part of LPG consumption is assumed as used by the economic sectors. The subdivision between "Services" and "Industry" has been done assuming the following shares[7]:

Sector	Share of total consumption	Uses	Share in the sector
Services	70%	Heating	19%
		Other uses	81%
Industry	30%	Heating	0%
		Other uses	100%

[7] Percentages obtained by the MRA database for LPG consumption and applied to actual consumption based on sales data.

Economic sectors:		
Total sales - cylinders	2,525	tons
(25kg and "Other")	*32.37*	*GWh*
Total sales - bulks	6,959.47	tons
	89.22	*GWh*
Economic sectors - TOT	**9,485**	**tons**
	121.60	*GWh*

Services sector - LPG consumption		
Total Consumption	85.12	GWh
Heating purposes	16.17	GWh
Other uses	68.95	GWh

Industry sector - LPG consumption		
Total Consumption	36.48	GWh
Heating purposes	0.00	GWh
Other uses	36.48	GWh

3.1.2 Electricity

As introduced above, electricity consumption data were provided through three different forms:

1. **ARMS ltd** monthly database - Electricity consumption (expressed in kWh or kVAh) with the indications of:

    a. Service City;
    b. Billed period (month of the year);
    c. Rate Category of consumption:

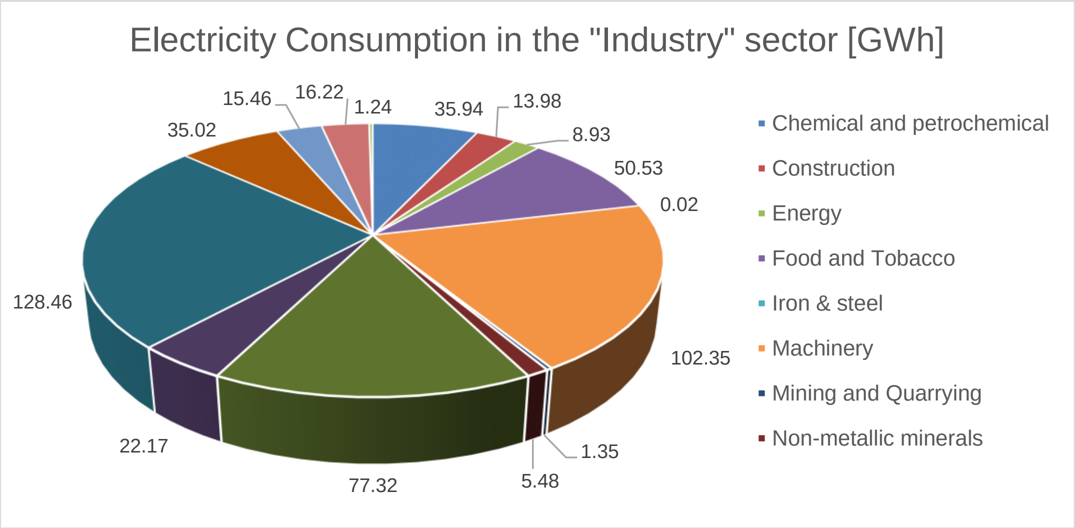
        i. Residential;
        ii. Domestic;
        iii. Non-residential (representing all the sectors apart from the residential).

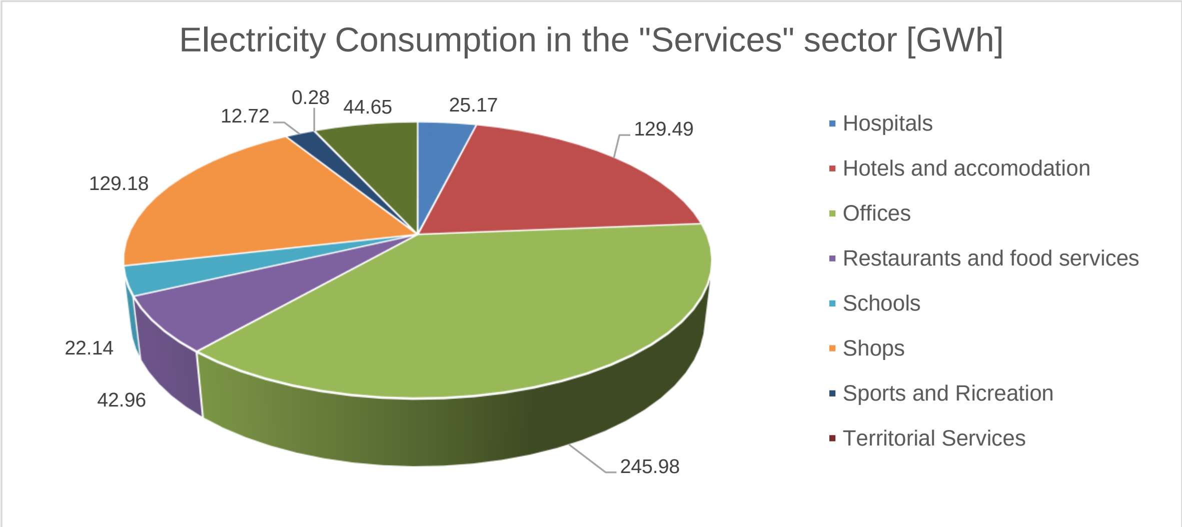
2. **ARMS ltd** daily electricity consumption database - A sample of readings obtained through smart meters for the residential and domestic accounts. The detailed methodology used for analysing these data is reported at paragraph 3.2.1.1.2.

3. **NSO** database - Electricity consumption data for all the economic sectors with the detail of the economic activity based on the NACE classification.

The **NSO** database - **point 3** - allowed obtaining the overall electricity consumption divided in the various economic sectors applying the economic activities classification. The table below reports a summary of the analysis on electricity consumption developed for the year 2013.

NSO Database - year 2013		Final Electricity Consumption			*Share of the Total*
		kWh/y	GWh/y	ktoe/y	
Agricolture/Forestry		**8,541,895**	**8.54**	**0.73**	*0.72%*
Fishing		**909,216**	**0.91**	**0.08**	*0.08%*
Industry					
	Chemical and petrochemical	35,936,205	35.94	3.09	*3.04%*
	Construction	13,975,521	13.98	1.20	*1.18%*
	Energy	8,929,878	8.93	0.77	*0.76%*
	Food and Tobacco	50,534,777	50.53	4.35	*4.28%*
	Iron & steel	17,252	0.02	0.00	*0.00%*
	Machinery	102,349,970	102.35	8.80	*8.66%*
	Mining and Quarrying	1,353,465	1.35	0.12	*0.11%*
	Non-metallic minerals	5,477,702	5.48	0.47	*0.46%*
	Non-specified	77,316,716	77.32	6.65	*6.54%*
	Paper, pulp and print	22,173,657	22.17	1.91	*1.88%*
	Territorial Services	128,461,156	128.46	11.05	*10.87%*
	Textile and Leather	35,021,321	35.02	3.01	*2.96%*
	Transport Equipment	15,458,083	15.46	1.33	*1.31%*
	Warehousing, repairing and maintenance	16,220,497	16.22	1.39	*1.37%*
	Wood and wood products	1,235,006	1.24	0.11	*0.10%*
	Total "Industry"	**514,461,207**	**514.46**	**44.24**	***43.54%***
Services					
	Hospitals	25,171,331	25.17	2.16	*2.13%*
	Hotels and accomodation	129,493,680	129.49	11.13	*10.96%*
	Offices	245,976,642	245.98	21.15	*20.82%*
	Restaurants and food services	42,963,414	42.96	3.69	*3.64%*
	Schools	22,141,477	22.14	1.90	*1.87%*
	Shops	129,177,559	129.18	11.11	*10.93%*
	Sports and Ricreation	12,716,466	12.72	1.09	*1.08%*
	Territorial Services	280,929	0.28	0.02	*0.02%*
	Warehousing, repairing and maintenance	44,652,195	44.65	3.84	*3.78%*
	Total "Services"	**652,573,692**	**652.57**	**56.11**	***55.23%***
Residential		**9,023**	**0.01**	**0.00**	*0.00%*
Transport		**4,980,911**	**4.98**	**0.43**	*0.42%*
TOTAL		**1,181,475,943**	**1,181.48**	**101.59**	***100.00%***





From the analysis of the **ARMS ltd** database at **point 1**, it was possible to identify the electricity consumption for the residential sector for the year 2013, considering both the “Residential” and the “Domestic” rate categories.

From the analysis of the **ARMS ltd** database at **point 2**, it was possible to identify the trend during the year of the electricity consumption for the categories “Residential” and “Domestic”. This result is a key-factor for the report, since it allows to have evidence of the real amounts of electricity used during the year for heating, water heating and cooling purposes in the various sectors.

The same **ARMS ltd** database of **point 1** – provided with the billed period for each consumption record - allowed to point out the trend during the year of the electricity consumption for the Non-residential sectors, including all the economic sectors, and in particular services and industry. Focusing on this last analysis, the list below reports some methodological notes about the use of the ARMS ltd database.

- The monthly consumption data were "normalized" dividing them to the numbers of the days for each month. Hence, the results shown are given in the form of *average daily electricity consumption* differently associated to each month.

- The electricity consumption expressed in "kVAh" were converted into "kWh" using a **power factor** of **0.92**.

- The "Non-residential" consumption data (representing all the sectors apart from the residential) were divided into the different sectors with the support of the NSO database. The NSO database offers the exact subdivision of the electricity consumption in the several economic sectors.

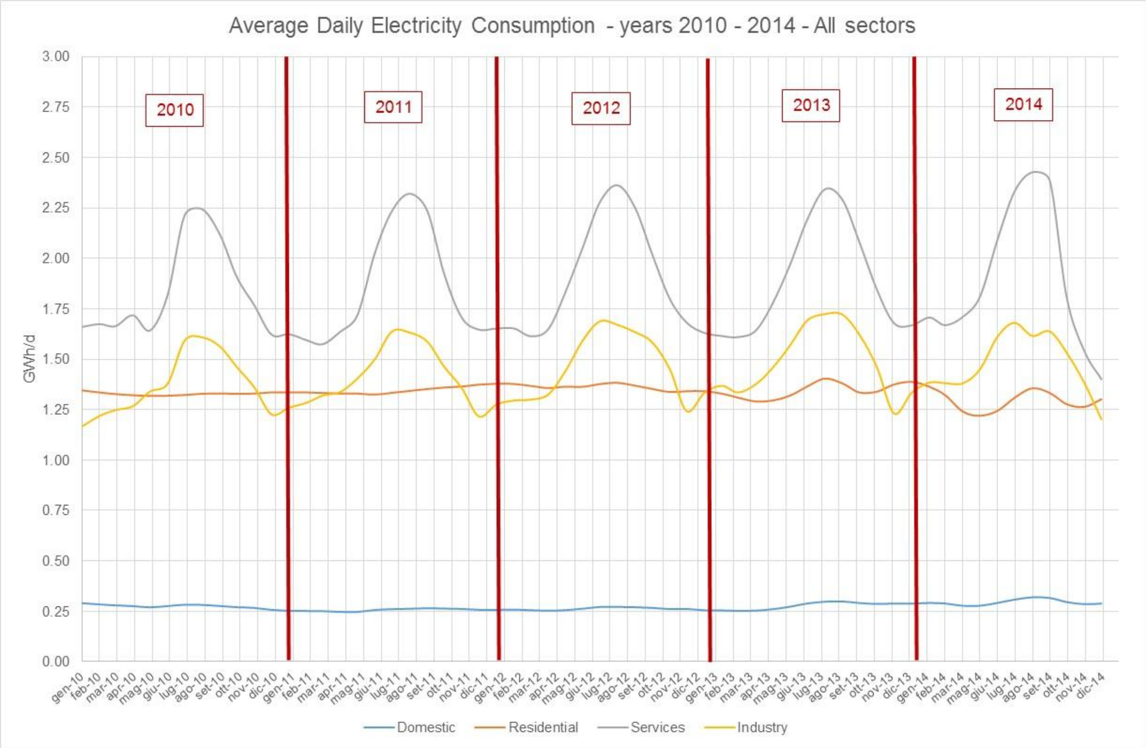
  For each "Service city", it was possible to identify the shares of electricity consumption associated to each sector. These percentages, provided for each Council were thus applied to the "Non-residential" consumption data of the ARMS ltd database.

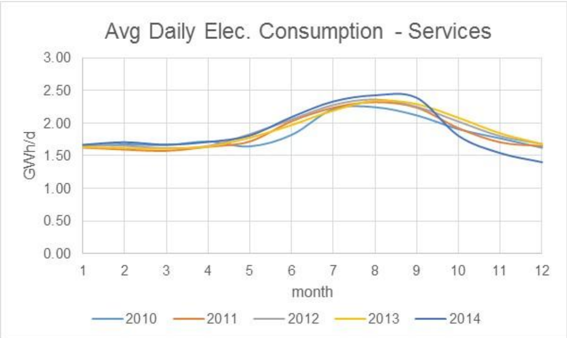
  The final results of this unbundling activity ("Non-residential" electricity consumption divided per sector) were checked against the overall electricity consumption data obtained from the NSO database. Looking to the "Services" and "Industry" sectors, the unbundled data from the ARMS ltd database differs from the corresponding sector data from NSO by a value of approximately 5-6% for both the "Services" and "Industry" sectors.

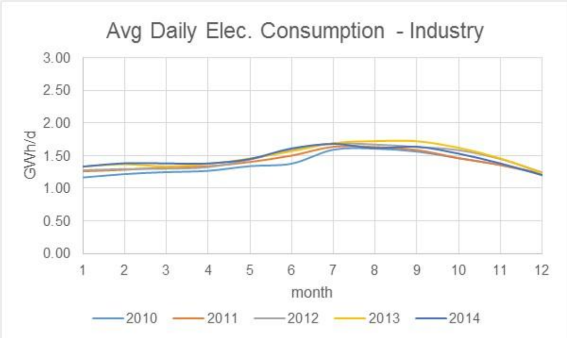
Total Electricity Consumption *(ARMS ltd 2013 unbundled data)*

	Services Sector	Industry Sector
	GWh	GWh
jan-13	50.55	41.34
feb-13	45.22	38.31
mar-13	49.90	41.39
apr-13	49.22	41.24
may-13	55.05	45.15
jun-13	59.10	47.07
jul-13	67.94	52.45
aug-13	72.61	53.42
sep-13	68.71	51.63
oct-13	64.47	50.27
nov-13	55.27	43.74
dec-13	52.03	38.16
TOTAL	**690.06**	**544.18**
NSO 2013 data	**652.57**	**514.46**
Difference	5.74%	5.78%

In order to have a significant feedback about the trend of consumption during the year, this methodology was applied for 2010, 2011, 2012, 2013 (reference year) and 2014. The following chart represents the trend of the average daily electricity consumption during the considered years. In the next charts, the same data are represented distinctly for each sector, overlapping the trend during the different years.







3.1.3 Solar Thermal

The contribution of solar thermal in the **services** and **industry** sectors was calculated considering the statistical data reported in the table below[8] and the estimation of thermal energy from solar water heaters provided by MEH.

Total enterprises reporting Solar water heaters by NACE division

NACE Division	Solar water heater			
	Yes	Per cent	No	Per cent
	Count		Count	
C - Manufacturing	11	1.3	2,265	7.2
D - Electricity, Gas, Steam And Air Conditioning Supply	0	0	2	0
E - Water Supply; Sewerage, Waste Management And Remediation Activities	11	1.3	154	0.5
F - Construction	67	7.9	3,508	11.1
G - Wholesale And Retail Trade; Repair Of Motor Vehicles And Motorcycles	109	12.8	9,070	28.7
H - Transportation And Storage	42	4.9	1,294	4.1
I - Accommodation And Food Service Activities	90	10.6	2,139	6.8
J - Information And Communication	83	9.7	1,092	3.5
K - Financial And Insurance Activities	79	9.3	1,345	4.3
L - Real Estate Activities	60	7.1	1,613	5.1
M - Professional, Scientific And Technical Activities	71	8.3	3,640	11.5
N - Administrative And Support Service Activities	7	0.9	1,617	5.1
P - Education	11	1.3	71	0.2
Q - Human Health And Social Work Activities	62	7.3	826	2.6
R - Arts, Entertainment And Recreation	77	9.1	1,001	3.2
S - Other Service Activities	71	8.3	1,952	6.2
Total	**852**	**100.0**	**31,588**	**100.0**

The following tables report an estimation of the solar thermal contribution for the services and industry sectors.

Number of SWH - Industry	89	*10.49%*
Number of SWH - Services	763	*89.51%*
Number of Solar Water Heaters	**852**	

Non domestic sector		
Thermal Energy from SWH *(Source: MEH)*	3.54	GWh
Total Area - Residential SWH *(Source: MEH)*	5,364	m²
Specific Average SWH production	**660**	**kWh/m²**

Solar Water Heater contribution in the Industry and Services Sector		
Thermal Energy from SWH - Industry	0.37	GWh
Thermal Energy from SWH - Services	3.17	GWh

Considering the overall value provided by Eurostat for the year 2013 - **48.03 GWh**, assumed as referred to all the sectors, the contribution for the **residential** sector was calculated, by difference, considering the results obtained above for the economic sectors.

Parameter	Value	units	Source
Solar Thermal Contribution *(all sectors)*	48.03	GWh/y	*Eurostat*
Solar Thermal Contribution *(economic sectors)*	3.54	GWh/y	*MRA*
Solar Thermal Contribution *(residential sector)*	44.49	GWh/y	

[8] Source: Table 5 of the (NSO-MEH Commercial and Industry Survey, 2014)

3.2 Sectors' analysis

3.2.1 Residential sector

For **heating** purposes, from a qualitative point of view, Maltese households tend mainly to use, during the very short heating periods, portable LPG heaters or reversible heat pumps (in the form of split-unit air conditioner units)[9]. Furthermore, also Kerosene and Propane are used for space heating purposes. Resistance electric-heaters are still used by a small part of the household[10]. As evident from the Final Report of the Census of population and housing 2011[11] smaller portions of the dwellings stock are provided of central heating systems and fireplaces.

For **water heating** purposes, the dominant type of water heating system in Maltese households is the conventional electric water heater. Results of (Grech & Yousif, 2013) show that gas water heaters are uncommon, and only present in 8% of dwellings. In addition, solar water heaters also contribute to satisfy part of the energy demand for water heating.

Therefore, the considered **energy sources** implied in the residential sector for heating and cooling uses are:

- **Heating:**
  - Kerosene;
  - Liquefied Petroleum Gas (LPG);
  - Propane;
  - Solid Biomass;
  - Electric Heating (resistance electric heaters);
  - Electricity (Air Conditioning).

- **Cooling:**
  - Electricity;

- **Water Heating:**
  - Liquefied Petroleum Gas;
  - Solar Thermal;
  - Electricity.

The table contains the sources of consumption data used for the analysis.

Energy Sources	Source of data
Kerosene	MRA
Liquefied Petroleum Gas	MRA
Propane	MRA
Solid Biomass	Eurostat Energy Balances
Electricity	ARMS ltd
Solar Thermal	Eurostat, MRA

9 (Malta's National Energy Efficiency Action Plan, 2014)
10 (Grech & Yousif, 2013)
11 (National Statistics Office, 2014)

3.2.1.1 *Energy Sources*

3.2.1.1.1 Fossil Fuels

The **Fossil Fuels** consumption values for space heating purposes, apart from the LPG, were obtained from the national consumption by economic sector of the fuels used for space heating. The table below highlights the values referred to "Space Heating" used in this paragraph.

Year 2013 *Space Heating - GWh*	**SECTORS** **Agricolture** *GWh*	**Industry** *GWh*	**Services** *GWh*	**Residential** *GWh*
Petrol	-	-	-	-
Diesel	-	4.88	13.22	-
Biodiesel	-	-	-	-
Aviation Turbine Fuel	-	-	-	-
Aviation Gasoline Fuel	-	-	-	-
Kerosene	-	0.03	0.88	5.49
Gasoil	-	1.89	8.73	-
Fuel oil	-	-	9.41	-
Propane	0.04	-	0.11	2.55
Coal	-	-	-	-
Light Cycle Oil	-	-	-	-
Total	**0.04**	**6.80**	**32.35**	**8.04**

For the **LPG** the considered consumption values, already introduced in 3.1.1.1, are the following:

Residential sector - LPG for cooking and heating		
Cooking purposes (73%)	115.35	GWh
Heating purposes (27%)	42.60	GWh

3.2.1.1.2 Electricity

The overall **electricity** consumption value for the residential sector was obtained as an elaboration of the 2013 database provided by ARMS ltd[12]. The following tables reports the results of the elaboration, expressed as monthly consumption in GWh and ktoe.

[12] Considered the rate categories electricity "Residential" and "Domestic.

year 2013	Domestic	Residential
Unit of measure: **GWh**		
gen-13	7.91	41.58
feb-13	7.12	37.22
mar-13	7.81	40.59
apr-13	7.59	38.72
mag-13	8.08	40.15
giu-13	8.19	39.60
lug-13	8.95	42.30
ago-13	9.23	43.52
set-13	8.97	41.40
ott-13	9.03	41.38
nov-13	8.59	40.18
dic-13	8.95	42.62
TOTAL	**100.42**	**489.26**

year 2013	Domestic	Residential
Unit of measure: **ktoe**		
gen-13	0.68	3.58
feb-13	0.61	3.20
mar-13	0.67	3.49
apr-13	0.65	3.33
mag-13	0.69	3.45
giu-13	0.70	3.40
lug-13	0.77	3.64
ago-13	0.79	3.74
set-13	0.77	3.56
ott-13	0.78	3.56
nov-13	0.74	3.46
dic-13	0.77	3.66
TOTAL	**8.63**	**42.07**

Analysis was also carried out on **ARMS ltd** daily electricity consumption database, containing a sample of readings obtained through smart meters for the residential and domestic accounts.

The aim was to identify the trend during the year of the electricity consumption for the categories “Residential” and “Domestic” in order to have evidence of the real amounts of electricity used during the year for heating, water heating and cooling purposes in the various sectors. As a starting point, the database provides the average daily electricity consumption of each “Residential” or “Domestic” account. The methodological approach followed these steps:

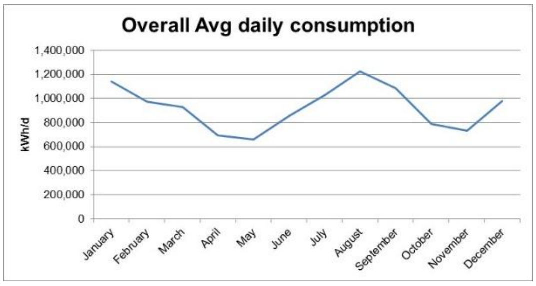
1. Calculation of the **scaled** average daily electricity consumption, to make it consistent with overall electricity consumption value**.**
2. Estimation of daily average electricity consumption for DHW (Domestic Hot Water Production);
3. Deduction of the consumption for DHW from the starting average daily electricity consumption;
4. Calculation of the average net daily consumption of each month (measured in *kWh/d* for *account*);
5. Calculation of the average net consumption for each month (measured in *kWh/d*).

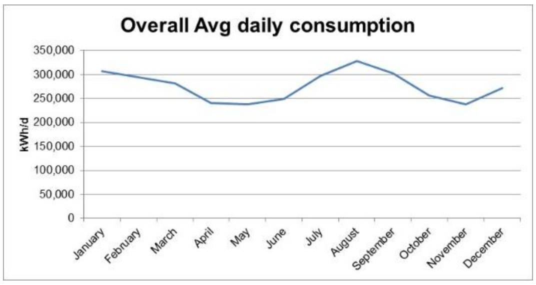
Residential Category

Month	Net Monthly Avg daily Consumption	Days per month	Overall Avg daily Consumption
	*kWh/(d*account)*		*kWh/d*
January	7.65	31	1,142,116
February	6.51	28	972,466
March	6.21	31	927,704
April	4.65	30	695,218
May	4.42	31	660,752
June	5.73	30	856,100
July	6.88	31	1,027,476
August	8.21	31	1,226,532
September	7.27	30	1,086,363
October	5.28	31	788,031
November	4.90	30	731,694
December	6.54	31	977,010

Domestic Category

Month	Net Monthly Avg daily Consumption	Days per month	Overall Avg daily Consumption
	*kWh/(d*account)*		*kWh/d*
January	3.71	31	306,279
February	3.56	28	294,297
March	3.40	31	281,187
April	2.91	30	240,265
May	2.87	31	237,384
June	3.01	30	248,892
July	3.59	31	296,930
August	3.97	31	327,992
September	3.67	30	303,147
October	3.09	31	255,551
November	2.88	30	237,633
December	3.28	31	271,363



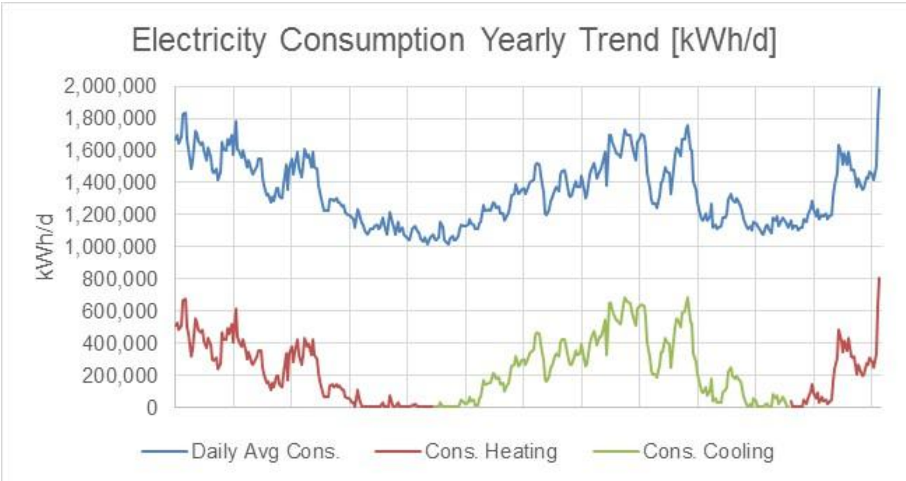


From the charts above it was possible to identify base electricity consumption values that can be assumed permanent during the year. These values are reported in the table.

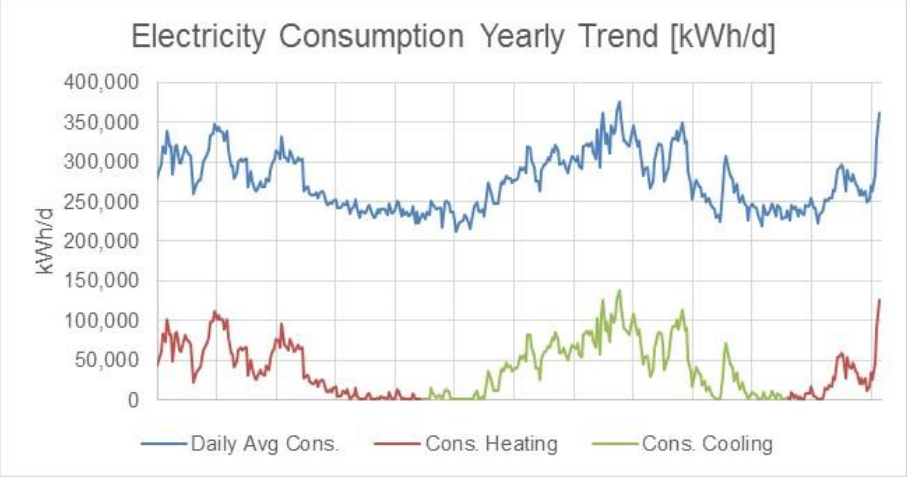
Category	Heating Base	Cooling Base
	kWh/d	*kWh/d*
Residential	700,000	700,000
Domestic	237,000	237,000

The assumption here is that they can represent a base electricity consumption identifying, by **difference**, the electricity associated to space heating and cooling during the winter and the summer period. The following tables and charts report the final results of the analysis.

Residential Category



Domestic Category



TOTAL: Residential and Domestic Category

Category	Electricity Consumption for: Heating *GWh/y*	Cooling *GWh/y*
Residential	38.13	46.08
Domestic	6.43	7.88
TOTAL	**44.56**	**53.96**

The actual consumption values introduced in this paragraph that will appear in the final results as "Final Energy Consumption" were used to validate, adjust and calibrate the heating and cooling model proposed in the following sections.

3.2.1.2 Dwelling stock

The Census of population and housing 2011 highlighted a stock composed by **223,850** dwellings (Table 85), divided into several categories:

1. **152,770** "occupied". Of this amount, a total of **12,450** are considered as "holiday dwellings" (Table 128);
2. **29,848** for "seasonal or secondary use";
3. **41,232** "completely vacant".

Furthermore, the Census provides several significant details, which have been used for calculating the heating and cooling demand in households, namely:

- The number of rooms and members;
- The energy appliances and facilities in the households.

The main reference for the heating modes adopted in the households was the survey (NSO-MEH Households Survey, 2014)[13]. In some cases, general data about the diffusion of appliances (for example water heaters) were converted into a more specific information

[13] Survey on households heating devices

using the results of the survey “Lifestyle trends for heating and cooling in Maltese Households” (Grech & Yousif, 2013). The following specific parameters were thus obtained:

Electric Water Heater share	*92%*
Gas Water Heater share	*8%*

The following table reports a summary of the reference dwelling stock (based on Census data) adopted for calculating the heating and cooling demand of the residential sector:

Heating		
Permanent	Seasonal or secondary use (30%)	**Total**
140,320	8,954	**149,274**

Cooling and Water Heating			
Seasonal or secondary use (30%)	Holidays	Permanents	**Total**
8,954	12,450	140,320	**161,724**

Space heating analysis considered, as base reference:

- The 140,320 “permanent” dwellings (the difference between the “occupied” – 152,770 – and the “holidays” dwellings – 12,450);
- Part of the “seasonal or secondary use” dwellings. This part was estimated as the 30% of the total amount (29,848 dwellings).

In addition to these ones, **space cooling** and **water heating** demand is based also on the 12,450 “holidays” dwellings.

3.2.1.3 Heating and Cooling Consumption

Starting from the overall data introduced in 3.2.1.1, the energy consumption and energy demand associated to heating, cooling and hot water production were calculated following the methodology described in the following paragraphs.

3.2.1.3.1 Heating

As introduced above, the consumption for heating purposes can be referred to the following sources:

- Kerosene;
- Liquefied Petroleum Gas (LPG);
- Propane;
- Solid Biomass;
- Electricity (electric heating and air conditioning in heating mode).

Solid biomass consumptions in the residential sector were entirely associated to space heating needs. For gas and electricity consumptions, a work of analysis and simulation was necessary in order to identify their shares of the overall consumption value associated to space heating. The analysis followed these steps:

Step 1 – Base Reference of the dwelling stock. Since the data in the Census referred to a dwelling stock of 152,770, they were properly scaled for referring to its subset heating base of 140,320. The results of this scaling is reported in table, where the numbers are classified per type of dwelling.

	Terraced house/ Townhouse	Semi detached house	Fully detached house	Maisonette/ Ground floor tenement	Flat/ Apartment/ Penthouse	Semi /Fully detached farmhouse	Other	Total
*ex **Table 88.** Occupied dwellings by type and locality*								
MALTA	**48,239**	**5,338**	**3,107**	**40,547**	**41,258**	**1,200**	**630**	**140,320**
	34.38%	*3.80%*	*2.21%*	*28.90%*	*29.40%*	*0.85%*	*0.45%*	**100.00%**
*ex **Table 109.** Occupied dwellings by type, district and **number of rooms***								
Less than 4 rooms	1,891	52	50	5,515	5,709	237	488	**13,941**
4 rooms	5,110	156	111	7,996	9,629	233	85	**23,319**
5 rooms	9,522	593	335	12,810	14,022	249	47	**37,579**
6 rooms	12,546	1,158	546	8,215	7,723	204	6	**30,397**
7 rooms	8,425	1,150	557	3,511	2,671	117	3	**16,433**
More than 7 rooms	10,746	2,228	1,509	2,500	1,505	160	3	**18,651**
	48,239	**5,338**	**3,107**	**40,547**	**41,258**	**1,200**	**630**	**140,320**
Table 112.** Occupied dwellings by type, district and **number of members								
1 member	*9,036*	*659*	*469*	*9,182*	*11,535*	*428*	*449*	**31,758**
2 members	*13,014*	*1,439*	*929*	*11,172*	*12,189*	*295*	*90*	**39,127**
3 members	*10,237*	*1,183*	*658*	*9,071*	*8,653*	*178*	*52*	**30,032**
4 members	*10,699*	*1,410*	*658*	*8,056*	*6,100*	*151*	*22*	**27,095**
5 members	*3,791*	*479*	*267*	*2,282*	*1,921*	*87*	*7*	**8,834**
More than 5 members	1,462	168	127	784	862	61	9	**3,473**
	48,239	**5,338**	**3,107**	**40,547**	**41,258**	**1,200**	**630**	**140,320**
*ex **Table 122a.** Occupied dwellings by availability of household appliances/facilities, district and type of dwelling*								
Air conditioning	24,704	3,843	2,279	20,188	21,674	365	83	**73,135**
	51.21%	*71.99%*	*73.34%*	*49.79%*	*52.53%*	*30.40%*	*13.12%*	**52.12%**
Central heating	529	209	241	371	802	0	0	**2,151**
	1.10%	*3.91%*	*7.74%*	*0.92%*	*1.94%*	*0.00%*	*0.00%*	**1.53%**
Fireplace	6,461	1,613	1,209	4,544	3,265	141	4	**17,236**
	13.39%	*30.21%*	*38.90%*	*11.21%*	*7.91%*	*11.72%*	*0.58%*	**12.28%**
Heater	29,997	3,754	2,135	23,009	23,024	553	156	**82,628**
	62.18%	*70.32%*	*68.70%*	*56.75%*	*55.80%*	*46.09%*	*24.78%*	**58.89%**

In parallel, the same work has been developed for "seasonal and secondary use" dwellings, considered in the base reference for space heating calculation.

Step 2 – Identification of heating equipment. The main reference for the heating modes adopted in the households was the survey (NSO-MEH Households Survey, 2014).

Step 3 – Heating habits. In Malta, the coldest months are generally, December, January, and February (Grech & Yousif, 2013). The survey and the linked report *"Lifestyle trends for heating and cooling in Maltese Households"* indicates that most of dwellings are heated for not more than 2 to 3 months. Ten percent of those interviewed indicated that they do not heat their house during winter. For considering that not all the households are heated for the same number of hours in the year, the following heating habits distribution presented in (Grech & Yousif, 2013) was applied to the base reference building stock.

Heating habits	
No heating	*10%*
Heating for 1 month	*23%*
Heating for 2 months	*38%*
Heating for 3 months or more	*29%*

The same report (Grech & Yousif, 2013) highlights that during the heating season most heaters are turned on for 1 to 5 hours daily, depending on individual needs and size of residence.

Step 4 – Number of rooms. The energy spent for heating is also related to the household space that needs to be heated. For this reason, the calculation considered also the number of rooms in the household provided by the Census 2011.

ex ***Table 109.*** *Occupied dwellings by type, district and* ***number of rooms***

Less than 4 rooms	1,891	52	50	5,515	5,709	237	488	**13,941**
4 rooms	5,110	156	111	7,996	9,629	233	85	**23,319**
5 rooms	9,522	593	335	12,810	14,022	249	47	**37,579**
6 rooms	12,546	1,158	546	8,215	7,723	204	6	**30,397**
7 rooms	8,425	1,150	557	3,511	2,671	117	3	**16,433**
More than 7 rooms	10,746	2,228	1,509	2,500	1,505	160	3	**18,651**
	48,239	**5,338**	**3,107**	**40,547**	**41,258**	**1,200**	**630**	**140,320**

The number of rooms was related to the necessary heat power by:

- Applying an average power for electric and gas fuelled heating equipment;
- Introducing a reference correspondence between the number of rooms and the average number of heating devices installed in the dwelling.

Step 5 – Heating Energy Consumption. By associating all the data introduced with the previous steps, it was possible to estimate the overall final energy consumption for space heating and due to the following facilities:

- Gas Heaters;
- Electric Heaters;
- Electricity for air-conditioners in heating mode.

The final electricity consumption obtained from the table is divided with the model proposed above into:

- Electric Heating (resistance electric heaters);
- Electricity (Air Conditioning).

Step 6 – Conversion Efficiency. The conversion efficiency was used for converting the final energy consumption (supplied to the final consumer's door) to the useful energy (heating demand), available to the consumers after the last conversion made in the conversion equipment. The table summarizes the efficiency parameters used for the heating demand analysis.

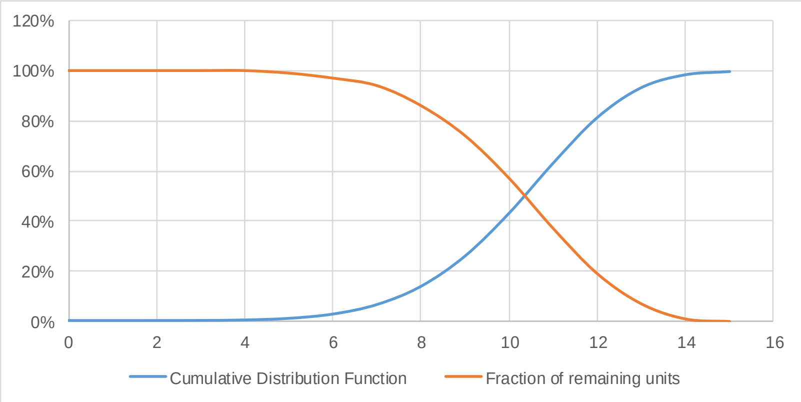
Gas heater efficiency	90%
Electric heater efficiency	95%
Diesel/Gasoil heating efficiency	85%
Fireplace heating efficiency	35%
Average SCOP	2.96

The overall average SCOP[14] at national level for residential air conditioners was determined through a statistical methodology applying a Weibull distribution to fit the curve of AC unit's mortality. The probability density function used was:

Probability Density Function (PDF) = $(k/\lambda)(x/\lambda)^{k-1}e^{-(x/\lambda)^k}$
Cumulative Distribution Function (CDF) = $1 - e^{-(x/\lambda)^k}$
Fraction of Units Remaining = 1 - CDF
Mean Lifetime (μ) = $\lambda\Gamma(1 + 1/k)$; k = shape factor, λ = scale factor

[14] SCOP = Seasonal Coefficient of Performance

with scale factor λ equal to 11, and shape factor k equal to 6[15]. The consequent "Cumulative Distribution Function" and" Fraction of remaining units" are represented in the following charts.



The average heating performance parameter SCOP of the AC units installed in the Maltese Islands - with focus to the year 2013 - was calculated considering:

- The "Fraction of remaining units", as introduced above, sold in the years before 2013;
- The total number and the age of the installed AC units[16];
- The shares of AC units sales within the several energy class labels in the years before 2013;

The shares of AC units performances associated to the different energy class labels.

SPLIT E MULTISPLIT RAFFEDDATI AD ARIA		
Raffrescamento	Classe	Riscaldamento
3.20<EER	A	3.60<COP
3.20≥EER>3.00	B	3.60≥COP>3.40
3.00≥EER>2.80	C	3.40≥COP>3.20
2.80≥EER>2.60	D	3.20≥COP>2.80
2.60≥EER>2.40	E	2.80≥COP>2.60
2.40≥EER>2.20	F	2.60≥COP>2.40
2.20≥EER	G	2.40≥COP

3.2.1.3.2 Cooling

For determining the electricity consumption due to space cooling, the following steps have been followed.

Step 1 – Base Reference of the dwelling stock. As introduced in 3.2.1.2, space cooling has been simulated as applied to the:

- 152,770 "occupied" dwellings (formed by 140,320 "permanent" and the 12,450 "holidays" dwellings);
- Part of the 29,848 "seasonal or secondary use" dwellings.

Step 2 – Cooling habits. In analogy with what presented for heating, the calculation of electricity consumption for cooling in the residential sector considered the habits presented in (Grech & Yousif, 2013).

[15] Source: MEH
[16] (NSO-MEH Households Survey, 2014), Table 2 - Total number of air conditioning systems in private dwellings by number of years installed.

Cooling habits	
No cooling	*2%*
Cooling for 1 month	*8%*
Cooling for 2 months	*25%*
Cooling for 3 months or more	*65%*

Statistical distribution of space cooling habits [nr of households]

No cooling	*1,050*	*116*	*68*	*883*	*898*	*26*	*14*	**15,277**
1 month	*4,202*	*465*	*271*	*3,532*	*3,594*	*104*	*55*	**35,137**
2 months	*13,130*	*1,453*	*846*	*11,036*	*11,230*	*327*	*172*	**58,053**
3 months or more	*34,137*	*3,778*	*2,199*	*28,694*	*29,197*	*849*	*446*	**44,303**
	52,519	***5,812***	***3,383***	***44,145***	***44,919***	***1,306***	***686***	152,770

Step 3 – Number of rooms. The energy spent for cooling is also related to the household space that needs to be cooled. For this reason, the calculation considered also the number of rooms in the household provided by the Census 2011.

The number of rooms was related to the necessary heat power by:

Table 109. *Occupied dwellings by type, district and* ***number of rooms***

Less than 4 rooms	2,059	57	54	6,004	6,215	258	531	**15,178**
4 rooms	5,563	170	121	8,705	10,483	254	92	**25,388**
5 rooms	10,367	646	365	13,947	15,266	271	51	**40,913**
6 rooms	13,659	1,261	594	8,944	8,408	222	6	**33,094**
7 rooms	9,172	1,252	606	3,823	2,908	127	3	**17,891**
More than 7 rooms	11,699	2,426	1,643	2,722	1,639	174	3	**20,306**
	52,519	**5,812**	**3,383**	**44,145**	**44,919**	**1,306**	**686**	**152,770**

- Applying an average cooling power for air conditioners;
- Introducing a reference correspondence between the number of rooms and the average number of air conditioning units installed in the dwelling, considering – as reference - the overall number of installed AC units (164,654)[17].

Step 4 – Cooling Energy Consumption. By associating all the data introduced with the previous steps, it was possible to estimate the overall final energy consumption of electricity for space cooling.

Actual electricity consumption values (paragraph 3.2.1.1.2) allowed validating, adjusting and calibrating all the proposed calculation for space heating consumption.

Step 5 – Conversion Efficiency. The average cooling performance parameter SEER[18] of the AC units installed in the Maltese Islands - with focus to the year 2013 - was calculated considering the same methodology reported in 3.2.1.3.1.

Average SEER	2.72

3.2.1.3.3 Water Heating

As introduced above, the consumption for heating purposes can be referred to the following sources:

- Liquefied Petroleum Gas;
- Solar Thermal;
- Electricity.

Energy from solar thermal installation (paragraph 0) was entirely associated to water heating needs. For gas and electricity consumptions, similarly to what presented for space heating, a

[17] (NSO-MEH Households Survey, 2014)
[18] SEER = Seasonal Energy Efficiency Ratio

work of analysis and simulation was necessary in order to identify the shares associated to water heating. The analysis followed these steps:

Step 1 – Base Reference of the dwelling stock. As introduced in 3.2.1.1, water heating has been simulated as applied to the:

- 152,770 "occupied" dwellings (formed by 140,320 "permanent" and the 12,450 "holidays" dwellings);
- Part of the 29,848 "seasonal or secondary use" dwellings.

Step 2 – Number of members. Key parameter for calculating the consumption for hot water production was the number of members occupying the households being part of the dwelling stock. These data were obtained from the Census 2011.

Step 3 – Thermal Energy for Water Heating. The total thermal energy requested for the hot water needs of households was determined as based on:

1. The yearly thermal energy requested per person (expressed in yearly kWh/person);

Water density	1,000	kg/m³	
Water specific heat	1.17E-03	kWh/(kg*K)	
Daily DHW volume per person	40	l/d	*Source: MEH*
	0.04	m³/d	
Water outlet temperature	55	°C	
Water inlet temperature	19	°C	
Thermal gradient	36	°C	
Requested thermal energy per day	1.68	kWh/(d*person)	

2. The number of members occupying the households.

Step 4 – Identification of water heating equipment. Following what already introduced in 3.2.1.1, it was possible to identify the shares of each water heating equipment in the dwelling stock.

Water Heater	43,400	4,412	2,533	37,267	38,786	909	431	**127,739**
	89.97%	*82.66%*	*81.53%*	*91.91%*	*94.01%*	*75.80%*	*68.37%*	***91.03%***
Electric Water Heater	*39,907*	*4,057*	*2,329*	*34,267*	*35,663*	*836*	*396*	**117,456**
Gas Water Heater	*3,494*	*355*	*204*	*3,000*	*3,122*	*73*	*35*	**10,283**
Solar Water Heater	6,814	1,571	1,060	3,481	2,768	137	2	**15,832**
	14.13%	*29.42%*	*34.11%*	*8.58%*	*6.71%*	*11.39%*	*0.31%*	***11.28%***

Step 5 - Energy for Water Heating production. The thermal energy for water heating was then converted into electricity or gas consumption based on the efficiency of typical market water heaters. Nevertheless, solar water heaters cover part of the thermal needs for hot water of the households, with a contribution that depends on solar radiation and average solar heaters size..

Step 6 – Conversion Efficiency. The conversion efficiency was used for converting the final energy consumption (supplied to the final consumer's door) to the useful energy (water heating demand), available to the consumers after the last conversion made in the conversion equipment. The table summarizes the efficiency parameters used for the water heating demand analysis.

Gas Water heater efficiency	90%
Electricity Water heater efficiency	97%

3.2.1.4 Final Results

The following table contains the main results of the unbundling activity reported above and referred in particular to gas and electricity consumption.

The second one reports the **final energy consumption** and the **heating and cooling energy demand** as defined at the beginning of the chapter and calculated in the previous paragraphs divided per energy sources. The energy demand considers the efficiency of the last conversion made in the consumer conversion equipment.

The third one represents the same information ordered per energy uses and then per energy sources.

Finally, the last tables show the shares of the total energy consumption in the sector[19] (for fossil fuels involved in space heating and electricity) associated to space heating and cooling.

Energy Uses/Sources	**Seasonal** Nr: 8,954	**Holidays** Nr: 12,450	**Permanent** Nr: 140,320	**TOTAL Nr: 161,724**
	GWh/y	GWh/y	GWh/y	**GWh/y**
Heating				
Kerosene	0.32	-	5.17	**5.49**
Liquefied Petroleum Gas	1.63	-	26.10	**27.72**
Propane	0.15	-	2.40	**2.55**
Electricity	2.47	-	42.09	**44.56**
Cooling				
Electricity	2.74	4.17	47.04	**53.96**
Cooking				
Liquefied Petroleum Gas	6.73	3.09	105.54	**115.35**
Electricity	2.42	1.12	16.43	**19.97**
Water Heating				
Solar Thermal	1.36	1.50	41.63	**44.49**
Liquefied Petroleum Gas	0.95	0.33	13.59	**14.87**
Electricity	10.03	3.52	144.06	**157.61**

[19] The total values do not consider the consumption for transport purposes.

Energy Sources & Uses	Final Energy Consumption			Heating and Cooling Energy Demand		
	ktoe/y	GWh/y	%	ktoe/y	GWh/y	%
Kerosene						
Heating	0.47	5.49	1.53%	0.42	4.94	1.00%
Liquefied Petroleum Gas						
Heating	2.38	27.72	7.73%	2.15	24.95	5.05%
Water Heating	1.28	14.87	4.15%	1.15	13.38	2.71%
	3.66	**42.60**	**11.88%**	**3.30**	**38.34**	**7.75%**
Propane						
Heating	0.22	2.55	0.71%	0.20	2.29	0.46%
Solar Thermal						
Water Heating	3.83	44.49	12.40%	3.83	44.49	9.00%
Solid Biomass						
Heating	0.64	7.44	2.08%	0.22	2.61	0.53%
Electricity						
Electric Heating	1.27	14.75	4.11%	1.21	14.01	2.83%
Heating (Air Conditioning)	2.56	29.81	8.31%	7.59	88.29	17.86%
Cooling	4.64	53.96	15.04%	12.60	146.56	29.64%
Water Heating	13.55	157.61	43.94%	13.15	152.88	30.92%
	22.02	**256.13**	**71.40%**	**34.54**	**401.75**	**81.26%**
TOTAL	**30.84**	**358.70**	**100.00%**	**42.51**	**494.41**	**100.00%**

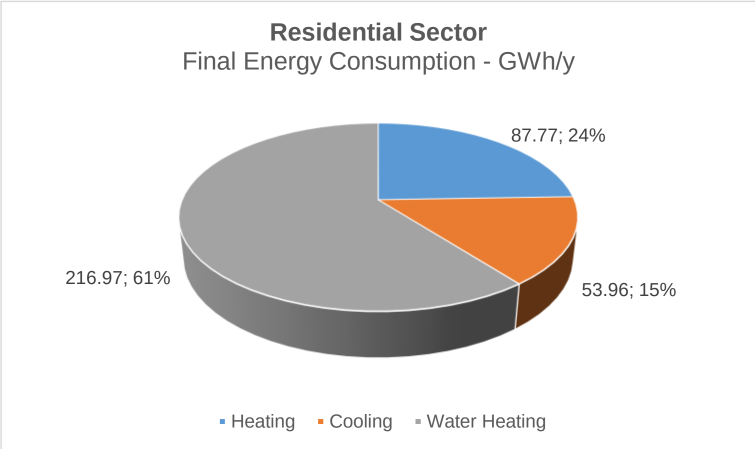
Energy Uses & Sources	Final Energy Consumption			Heating and Cooling Energy Demand		
	ktoe/y	GWh/y	% of the total	ktoe/y	GWh/y	% of the total
Heating						
Kerosene	0.47	5.49	1.53%	0.42	4.94	1.00%
Liquefied Petroleum Gas	2.38	27.72	7.73%	2.15	24.95	5.05%
Propane	0.22	2.55	0.71%	0.20	2.29	0.46%
Solid Biomass	0.64	7.44	2.08%	0.22	2.61	0.53%
Electric Heating	1.27	14.75	4.11%	1.21	14.01	2.83%
Heating (Air Conditioning)	2.56	29.81	8.31%	7.59	88.29	17.86%
	7.55	**87.77**	**24.47%**	**11.79**	**137.10**	**27.73%**
Cooling						
Electricity	4.64	53.96	15.04%	12.60	146.56	29.64%
Water Heating						
Liquefied Petroleum Gas	1.28	14.87	4.15%	1.15	13.38	2.71%
Solar Thermal	3.83	44.49	12.40%	3.83	44.49	9.00%
Electricity	13.55	157.61	43.94%	13.15	152.88	30.92%
	18.66	**216.97**	**60.49%**	**18.12**	**210.76**	**42.63%**
TOTAL	**30.84**	**358.70**	**100.00%**	**42.51**	**494.41**	**100.00%**

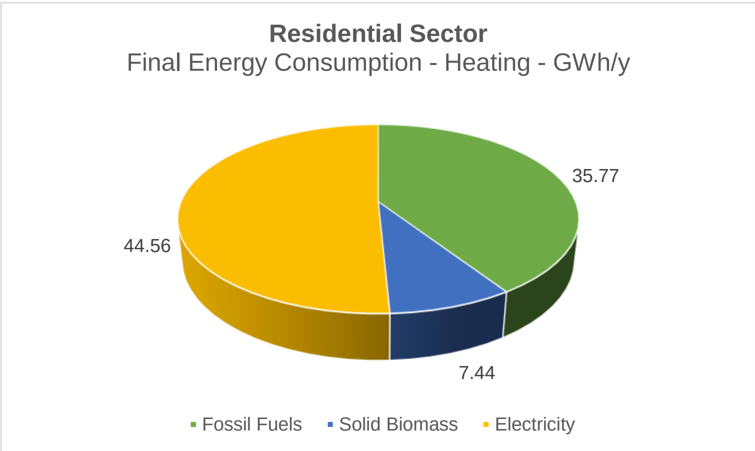
Energy Sources	Total Sector Consumption	Consumptions for Heating and Cooling purposes			
		Space Heating	Space Cooling	Water Heating	**Total Heating & Cooling**
	GWh/y	GWh/y	GWh/y	GWh/y	**GWh/y**
Kerosene	**5.49**	5.49	-	-	**5.49**
Liquefied Petroleum Gas	**157.95**	27.72	-	14.87	**42.60**
Propane	**2.55**	2.55	-	-	**2.55**
Solar Thermal	**44.49**	-	-	44.49	**44.49**
Solid Biomass	**7.44**	7.44	-	-	**7.44**
Electricity	**589.68**	44.56	53.96	157.61	**256.13**
TOTAL	**807.60**	**87.77**	**53.96**	**216.97**	**358.70**

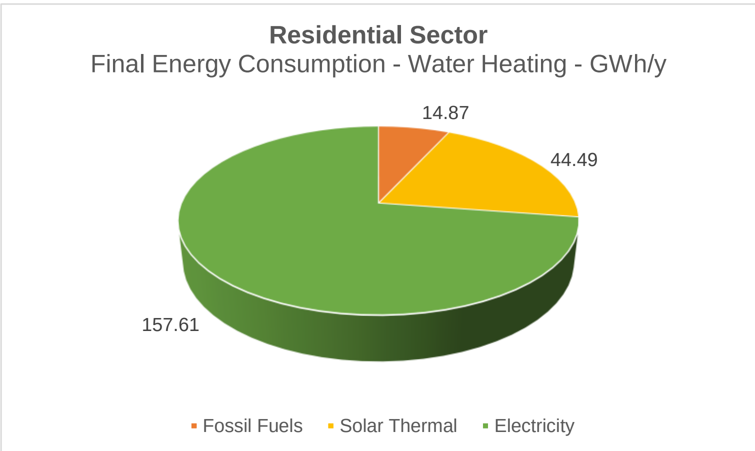
Energy Sources	Consumptions for Heating and Cooling purposes			
	Space Heating	Space Cooling	Water Heating	**Total Heating & Cooling**
	%	%	%	**%**
Kerosene	100.00%	-	-	**100.00%**
Liquefied Petroleum Gas	17.55%	-	9.42%	**26.97%**
Propane	100.00%	-	-	**100.00%**
Solar Thermal	-	-	100.00%	**100.00%**
Solid Biomass	100.00%	-	-	**100.00%**
Electricity	7.56%	9.15%	26.73%	**43.43%**
H&C / Total	**10.87%**	**6.68%**	**26.87%**	**44.41%**

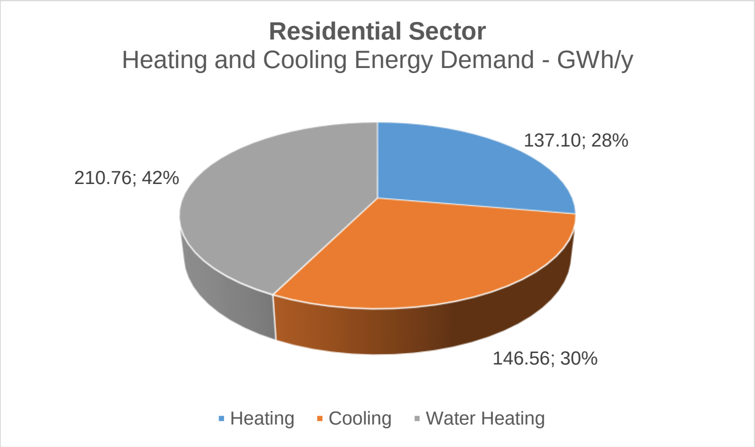
Energy Sources	Total Sector Consumption	Consumptions for Heating and Cooling purposes			
		Space Heating	Space Cooling	Water Heating	**Total Heating & Cooling**
	GWh/y	GWh/y	GWh/y	GWh/y	**GWh/y**
Fossil Fuels	**165.99**	35.77	-	14.87	**50.64**
Solar Thermal	**44.49**	-	-	44.49	**44.49**
Solid Biomass	**7.44**	7.44	-	-	**7.44**
Electricity	**589.68**	44.56	53.96	157.61	**256.13**
TOTAL	**807.60**	**87.77**	**53.96**	**216.97**	**358.70**

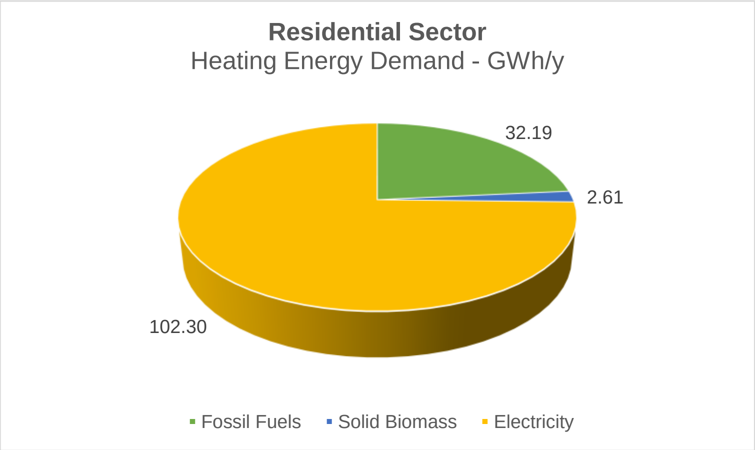
Energy Sources	Consumptions for Heating and Cooling purposes			
	Space Heating	Space Cooling	Water Heating	**Total Heating & Cooling**
	%	%	%	**%**
Fossil Fuels	21.55%	-	8.96%	**30.51%**
Solar Thermal	-	-	100.00%	**100.00%**
Solid Biomass	100.00%	-	-	**100.00%**
Electricity	7.56%	9.15%	26.73%	**43.43%**
H&C / Total	**10.87%**	**6.68%**	**26.87%**	**44.41%**

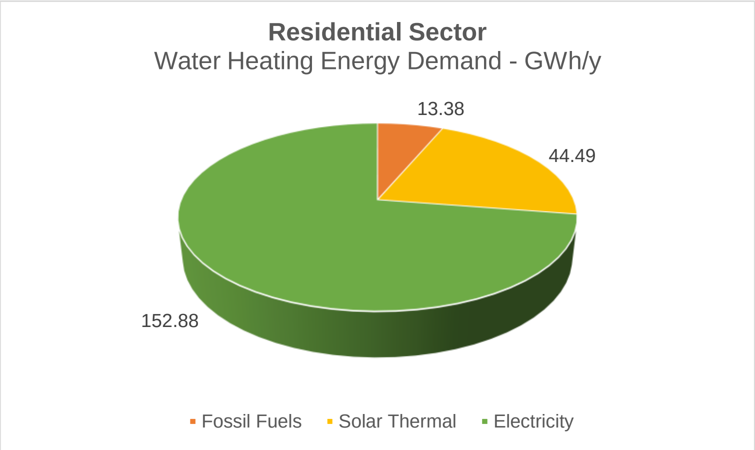

Residential Sector
Final Energy Consumption - GWh/y
87.77; 24%
53.96; 15%
216.97; 61%
Heating
Cooling
Water Heating


Residential Sector
Final Energy Consumption - Heating - GWh/y
35.77
44.56
7.44
Fossil Fuels
Solid Biomass
Electricity


Residential Sector
Final Energy Consumption - Water Heating - GWh/y
14.87
44.49
157.61
Fossil Fuels
Solar Thermal
Electricity


Residential Sector
Heating and Cooling Energy Demand - GWh/y
137.10; 28%
210.76; 42%
146.56; 30%
Heating
Cooling
Water Heating


Residential Sector
Heating Energy Demand - GWh/y
32.19
2.61
102.30
Fossil Fuels
Solid Biomass
Electricity


Residential Sector
Water Heating Energy Demand - GWh/y
13.38
44.49
152.88
Fossil Fuels
Solar Thermal
Electricity

3.2.2 Services sector

In the services sector, the main energy sources used for space heating, space cooling and water heating are:

- **Heating:**
  - Diesel;
  - Fuel oil;
  - Liquefied Petroleum Gas;
  - Electricity.

- **Cooling:**
  - Electricity;

- **Water Heating:**
  - Diesel;
  - Kerosene;
  - Gasoil;
  - Fuel oil;
  - Liquefied Petroleum Gas;
  - Propane;
  - Solar Thermal;
  - Electricity.

The table contains the sources of consumption data used for the analysis.

Energy Sources	Source of data
Diesel	MRA
Kerosene	MRA
Gasoil	MRA
Fuel Oil	MRA
Liquefied Petroleum Gas	MRA
Propane	MRA
Solar Thermal	Eurostat, MRA
Electricity	NSO and ARMS ltd

3.2.2.1 Energy Sources

3.2.2.1.1 Fossil Fuels

The **Fossil Fuels** consumption values for space heating purposes, apart from the LPG, were obtained from an elaboration of the fossil fuels database provided by MRA containing the national consumption by economic sector of the fuels used for space heating. The table below highlights the values referred to “Space Heating” used in this paragraph.

Year 2013	SECTORS			
Space Heating - GWh	**Agricolture**	**Industry**	**Services**	**Residential**
	GWh	*GWh*	*GWh*	*GWh*
Petrol	-	-	-	-
Diesel	-	4.88	13.22	-
Biodiesel	-	-	-	-
Aviation Turbine Fuel	-	-	-	-
Aviation Gasoline Fuel	-	-	-	-
Kerosene	-	0.03	0.88	5.49
Gasoil	-	1.89	8.73	-
Fuel oil	-	-	9.41	-
Propane	0.04	-	0.11	2.55
Coal	-	-	-	-
Light Cycle Oil	-	-	-	-
Total	**0.04**	**6.80**	**32.35**	**8.04**

The details of each fossil fuel value is reported in the following tables[20].

DIESEL

year 2013	Fuel Consumption Space Heating GWh/y	Fuel Consumption Space Heating ktoe/y	*Share of the Total (Services)*
Services			
Hospitals	0.36	0.031	*2.73%*
Hotels and accomodation*	4.41	0.379	*33.34%*
Offices	-	-	-
Restaurants and food services*	1.46	0.126	*11.06%*
Schools	-	-	-
Shops	0.03	0.002	*0.20%*
Sports and Ricreation	6.96	0.598	*52.67%*
Territorial Services	-	-	-
Warehousing, repairing and maintenance	-	-	-
Total "Services"	**13.22**	**1.136**	*100.00%*

KEROSENE

year 2013	Fuel Consumption Space Heating GWh/y	Fuel Consumption Space Heating ktoe/y	*Share of the Total (Services)*
Services			
Hospitals	0.76	0.065	*85.41%*
Hotels and accomodation*	-	-	-
Offices	0.13	0.011	*14.59%*
Restaurants and food services*	-	-	-
Schools	-	-	-
Shops	-	-	-
Sports and Ricreation	-	-	-
Territorial Services	-	-	-
Warehousing, repairing and maintenance	-	-	-
Total "Services"	**0.88**	**0.076**	*100.00%*

GASOIL

year 2013	Fuel Consumption Space Heating GWh/y	Fuel Consumption Space Heating ktoe/y	*Share of the Total (Services)*
Services			
Hospitals	1.81	0.155	*20.70%*
Hotels and accomodation*	5.20	0.447	*59.54%*
Offices	-	-	-
Restaurants and food services*	1.73	0.148	*19.76%*
Schools	-	-	-
Shops	-	-	-
Sports and Ricreation	-	-	-
Territorial Services	-	-	-
Warehousing, repairing and maintenance	-	-	-
Total "Services"	**8.73**	**0.751**	*100.00%*

FUEL OIL

year 2013	Fuel Consumption Space Heating GWh/y	Fuel Consumption Space Heating ktoe/y	*Share of the Total (Services)*
Services			
Hospitals	4.07	0.350	*43.23%*
Hotels and accomodation*	4.01	0.345	*42.63%*
Offices	-	-	-
Restaurants and food services*	1.33	0.114	*14.14%*
Schools	-	-	-
Shops	-	-	-
Sports and Ricreation	-	-	-
Territorial Services	-	-	-
Warehousing, repairing and maintenance	-	-	-
Total "Services"	**9.41**	**0.809**	*100.00%*

[20] The (*) in the table indicates that these data were presented together in the yearly consumption; here they are here divided proportionally to the electricity consumption for maintaining the same classification.

PROPANE

year 2013	Fuel Consumption Space Heating		*Share of the Total (Services)*
	GWh/y	ktoe/y	
Services			
Hospitals	0.11	0.009	*100.00%*
Hotels and accomodation*	-	-	-
Offices	-	-	-
Restaurants and food services*	-	-	-
Schools	-	-	-
Shops	-	-	-
Sports and Ricreation	-	-	-
Territorial Services	-	-	-
Warehousing, repairing and maintenance	-	-	-
Total "Services"	**0.11**	**0.009**	*100.00%*

For the **LPG** the considered consumption values, already introduced in 3.1.1.1, are the following:

Services sector - LPG consumption		
Total Consumption	85.12	GWh
Heating purposes	16.17	GWh
Other uses	68.95	GWh

3.2.2.1.2 Electricity

The overall **electricity** consumption value for the services sector was obtained as an elaboration of the 2013 database provided by NSO. The database contains the electricity consumption data for the economic sectors, divided between the several categories using the economic activities classification.

The following table reports the results of the elaboration for the services sector, expressed as yearly consumption in GWh and ktoe and classified per type of service activity.

year 2013	**Final Electricity Consumption**			*Share of the Total (Services)*
	kWh/y	GWh/y	ktoe/y	
Services				
Hospitals	25,171,331	25.17	2.16	*3.86%*
Hotels and accomodation	129,493,680	129.49	11.13	*19.84%*
Offices	245,976,642	245.98	21.15	*37.69%*
Restaurants and food services	42,963,414	42.96	3.69	*6.58%*
Schools	22,141,477	22.14	1.90	*3.39%*
Shops	129,177,559	129.18	11.11	*19.80%*
Sports and Ricreation	12,716,466	12.72	1.09	*1.95%*
Territorial Services	280,929	0.28	0.02	*0.04%*
Warehousing, repairing and maintenance	44,652,195	44.65	3.84	*6.84%*
Total "Services"	**652,573,692**	**652.57**	**56.11**	*100.00%*

In absence of actual and specific data of electricity consumption for space heating and cooling, this value was estimated starting from the yearly electricity consumption given with monthly detail within the ARMS ltd database.

In particular, the **ARMS ltd** database– provided with the billed period for each consumption record - allowed to point out the trend during the year of the electricity consumption for the Non-residential sectors, including all the economic sectors, and in particular **Services** and Industry. It was then possible to identify the amount of electricity associated to space heating and cooling following these steps:

1. Identification of the daily minimum values of electricity consumption (assumed constant throughout the year and representing a base electricity consumption). The assumption here is that they can represent a base electricity consumption identifying, by difference, the electricity associated to space heating and cooling.

2. Calculation of the difference of each daily consumption – referred to all the months – in respect to the minimum values.

3. Application of this delta to all the days of each months.

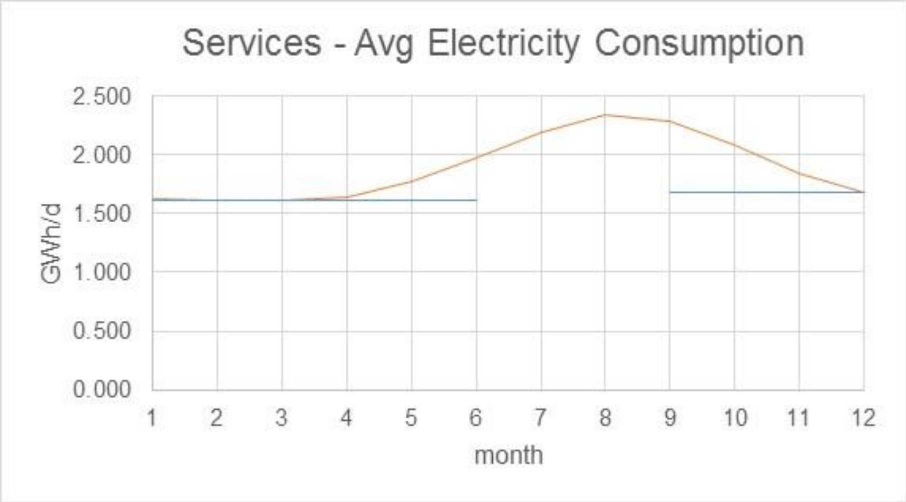
In particular, the following table and chart report the daily average electricity consumption for each month. The minimum values of the year are highlighted in bold.

Total Electricity Consumption *(ARMS ltd 2013 data)*

	Services Sector
	GWh
jan-13	50.55
feb-13	45.22
mar-13	49.90
apr-13	49.22
may-13	55.05
jun-13	59.10
jul-13	67.94
aug-13	72.61
sep-13	68.71
oct-13	64.47
nov-13	55.27
dec-13	52.03
TOTAL	**690.06**

		Days per month	Avg Daily Electricity Consumption
		dd/m	GWh/d
1	jan-13	*31*	1.631
2	feb-13	*28*	1.615
3	mar-13	*31*	**1.610**
4	apr-13	*30*	1.641
5	may-13	*31*	1.776
6	jun-13	*30*	1.970
7	jul-13	*31*	2.192
8	aug-13	*31*	2.342
9	sep-13	*30*	2.290
10	oct-13	*31*	2.080
11	nov-13	*30*	1.842
12	dec-13	*31*	**1.678**

Average daily electricity consumption in the Services sector



The tables below report the above-described calculation, that leads to the identification of the electricity consumed for **space heating** and **cooling** in the sector. The base electricity consumption (assumed constant throughout the year) considered in the calculation were reduced of **15%** in order to considering the needs for heating also in a middle month in the year like March, that otherwise would have a zero consumption for space heating.

SERVICES SECTOR - SPACE HEATING

	Days per month	Avg electricity consumption	Base electricity consumption	Base electricity consumption **Reduced**	**Electricity Consumption for Space Heating**	Yearly %
	dd/m	GWh/d	GWh/d	GWh/d	**GWh**	%
jan-13	*31*	1.631	1.610	1.368	**8.14**	*27%*
feb-13	*28*	1.615	1.610	1.368	**6.91**	*23%*
mar-13	*31*	**1.610**	1.610	1.368	**7.48**	*25%*
apr-13	*30*	1.641				
may-13	*31*	1.776				
jun-13	*30*	1.970				
jul-13	*31*	2.192				
aug-13	*31*	2.342				
sep-13	*30*	2.290				
oct-13	*31*	2.080				
nov-13	*30*	1.842				
dec-13	*31*	**1.678**	1.678	1.427	**7.80**	*26%*
TOTAL					**30.33**	*100%*

SERVICES SECTOR - SPACE COOLING

	Days per month	Avg electricity consumption	Base electricity consumption	Base electricity consumption **Reduced**	**Electricity Consumption for Space Cooling**	Yearly %
	dd/m	GWh/d	GWh/d	GWh/d	**GWh**	%
jan-13	*31*	1.631				
feb-13	*28*	1.615				
mar-13	*31*	1.610				
apr-13	*30*	1.641	1.610	1.368	**8.18**	*5%*
may-13	*31*	1.776	1.610	1.368	**12.63**	*8%*
jun-13	*30*	1.970	1.610	1.368	**18.06**	*11%*
jul-13	*31*	2.192	1.610	1.368	**25.52**	*16%*
aug-13	*31*	2.342	1.610	1.368	**30.20**	*19%*
sep-13	*30*	2.290	1.610	1.368	**27.66**	*17%*
oct-13	*31*	2.080	1.610	1.368	**22.06**	*14%*
nov-13	*30*	1.842	1.610	1.368	**14.23**	*9%*
dec-13	*31*	1.678				
TOTAL					**158.54**	*100%*

The consumption values introduced in this paragraph, that will appear in the final results as "Final Energy Consumption" were used to validate, adjust and calibrate the heating and cooling model proposed in the following sections.

3.2.2.2 Heating and Cooling Consumption

Starting from the overall data introduced in 3.2.2.1, the energy consumption and energy demand associated to heating, cooling and hot water production were calculated following the methodology described below.

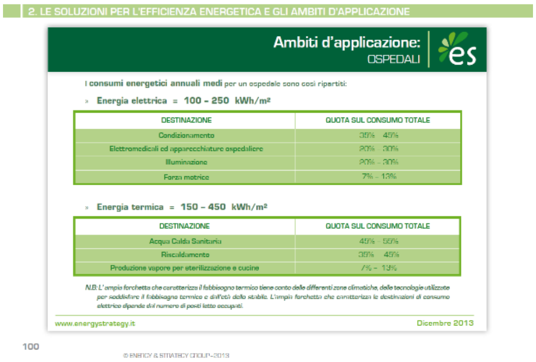
Fossil fuels consumption in the services sector was entirely associated to water heating needs, except for the hospitality sector, where the survey (GENESIS - Green Engineering, 2015) reveals the use of fossil fuels[21] also for space heating purposes.

Solar thermal contribution was entirely associated to water heating needs.

The overall **electricity** consumptions for space heating and cooling were determined with the approach proposed in the previous paragraph. For giving a preliminary estimation of how this overall sectorial consumption is divided into the different services-sector related activities, literature values were applied. Literature values[22] are in form of benchmarks of consumption (expressed in kWh/m²) associated to heating, cooling and water heating for most of the buildings operating in the "services" sector. Each activity was associated, when available, to the most similar category proposed by (Politecnico di Milano - Italy, 2013).

[21] In particular Diesel, Fuel oil and LPG.
[22] (Politecnico di Milano - Italy, 2013)

Hospitals


2. LE SOLUZIONI PER L'EFFICIENZA ENERGETICA E GLI AMBITI D'APPLICAZIONE

Ambiti d'applicazione: OSPEDALI

I consumi energetici annuali medi per un ospedale sono così ripartiti:

» **Energia elettrica = 100 – 250 kWh/m²**

DESTINAZIONE	QUOTA SUL CONSUMO TOTALE
Condizionamento	35% – 45%
Elettromedicali ed apparecchiature ospedaliere	20% – 30%
Illuminazione	20% – 30%
Forza motrice	7% – 13%

» **Energia termica = 150 – 450 kWh/m²**

DESTINAZIONE	QUOTA SUL CONSUMO TOTALE
Acqua Calda Sanitaria	45% – 55%
Riscaldamento	35% – 45%
Produzione vapore per sterilizzazione e cucine	7% – 13%

N.B: L' ampia forchetta che caratterizza il fabbisogno termico tiene conto delle differenti zone climatiche, delle tecnologie utilizzate per soddisfare il fabbisogno termico e dall'età dello stabile. L'ampia forchetta che caratterizza le destinazioni di consumo elettrico dipende dal numero di posti letto occupati.

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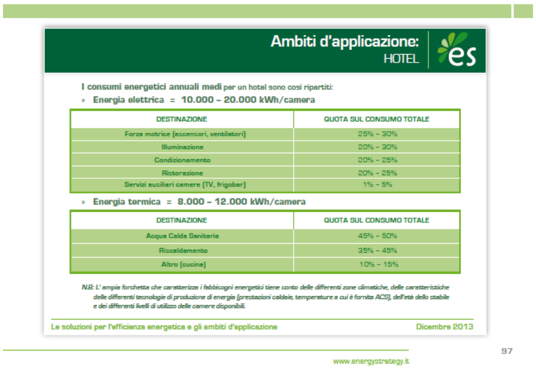
Hotels


Ambiti d'applicazione: HOTEL

I consumi energetici annuali medi per un hotel sono così ripartiti:

» **Energia elettrica = 10.000 – 20.000 kWh/camera**

DESTINAZIONE	QUOTA SUL CONSUMO TOTALE
Forza motrice (ascensori, ventilatori)	25% – 30%
Illuminazione	20% – 30%
Condizionamento	20% – 25%
Ristorazione	20% – 25%
Servizi ausiliari camere (TV, frigobar)	1% – 5%

» **Energia termica = 8.000 – 12.000 kWh/camera**

DESTINAZIONE	QUOTA SUL CONSUMO TOTALE
Acqua Calda Sanitaria	45% – 50%
Riscaldamento	35% – 45%
Altro (cucina)	10% – 15%

N.B: L' ampia forchetta che caratterizza i fabbisogni energetici tiene conto delle differenti zone climatiche, delle caratteristiche delle differenti tecnologie di produzione di energia (prestazioni caldaie, temperature a cui è fornita ACS), dell'età dello stabile e dei differenti livelli di utilizzo delle camere disponibili.

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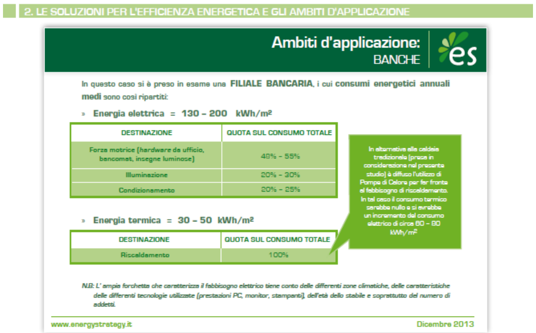
Offices


2. LE SOLUZIONI PER L'EFFICIENZA ENERGETICA E GLI AMBITI D'APPLICAZIONE

Ambiti d'applicazione: BANCHE

In questo caso si è preso in esame una **FILIALE BANCARIA**, i cui **consumi energetici annuali medi** sono così ripartiti:

» **Energia elettrica = 130 – 200 kWh/m²**

DESTINAZIONE	QUOTA SUL CONSUMO TOTALE
Forza motrice (*hardware* da ufficio, bancomat, insegne luminose)	48% – 55%
Illuminazione	20% – 30%
Condizionamento	20% – 25%

» **Energia termica = 30 – 50 kWh/m²**

DESTINAZIONE	QUOTA SUL CONSUMO TOTALE
Riscaldamento	100%

In alternativa alle caldaie tradizionale (presa in considerazione nel presente studio) è diffuso l'utilizzo di Pompe di Calore per far fronte al fabbisogno di riscaldamento. In tal caso il consumo termico sarebbe nullo e si avrebbe un incremento del consumo elettrico di circa 80 – 90 kWh/m²

N.B: L' ampia forchetta che caratterizza il fabbisogno elettrico tiene conto delle differenti zone climatiche, delle caratteristiche delle differenti tecnologie utilizzate (prestazioni PC, monitor, stampanti), dell'età dello stabile e soprattutto del numero di addetti.

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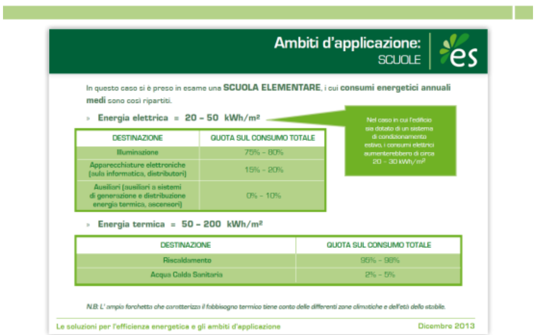
Schools


Ambiti d'applicazione: SCUOLE

In questo caso si è preso in esame una **SCUOLA ELEMENTARE**, i cui **consumi energetici annuali medi** sono così ripartiti.

» **Energia elettrica = 20 – 50 kWh/m²**

DESTINAZIONE	QUOTA SUL CONSUMO TOTALE
Illuminazione	75% – 80%
Apparecchiature elettroniche (aula informatica, distributori)	15% – 20%
Ausiliari (ausiliari a sistemi di generazione e distribuzione energia termica, ascensori)	0% – 10%

Nel caso in cui l'edificio sia dotato di un sistema di condizionamento estivo, i consumi elettrici aumenterebbero di circa 20 – 30 kWh/m²

» **Energia termica = 50 – 200 kWh/m²**

DESTINAZIONE	QUOTA SUL CONSUMO TOTALE
Riscaldamento	95% – 98%
Acqua Calda Sanitaria	2% – 5%

N.B: L' ampia forchetta che caratterizza il fabbisogno termico tiene conto delle differenti zone climatiche e dell'età dello stabile.

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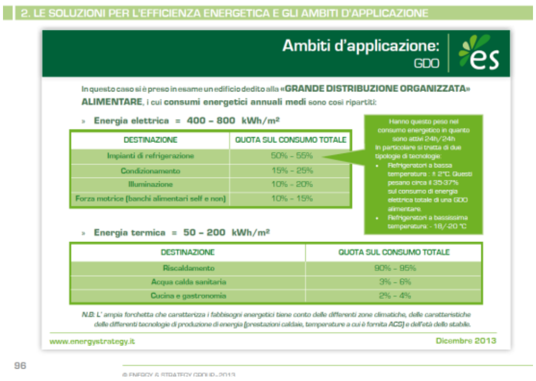
Shops


2. LE SOLUZIONI PER L'EFFICIENZA ENERGETICA E GLI AMBITI D'APPLICAZIONE

Ambiti d'applicazione: GDO

In questo caso si è preso in esame un edificio dedito alla **«GRANDE DISTRIBUZIONE ORGANIZZATA» ALIMENTARE**, i cui **consumi energetici annuali medi** sono così ripartiti:

» **Energia elettrica = 400 – 800 kWh/m²**

DESTINAZIONE	QUOTA SUL CONSUMO TOTALE
Impianti di refrigerazione	50% – 55%
Condizionamento	15% – 25%
Illuminazione	10% – 20%
Forza motrice (banchi alimentari self e non)	10% – 15%

Hanno questo peso nel consumo energetico in quanto sono attivi 24h/24h
In particolare si tratta di due tipologie di tecnologie:
- Refrigeratori a bassa temperatura : ± 2°C. Questi pesano circa il 35-37% sul consumo di energia elettrica totale di una GDO alimentare
- Refrigeratori a bassissima temperatura: - 18/-20 °C

» **Energia termica = 50 – 200 kWh/m²**

DESTINAZIONE	QUOTA SUL CONSUMO TOTALE
Riscaldamento	90% – 95%
Acqua calda sanitaria	3% – 6%
Cucina e gastronomia	2% – 4%

N.B: L' ampia forchetta che caratterizza i fabbisogni energetici tiene conto delle differenti zone climatiche, delle caratteristiche delle differenti tecnologie di produzione di energia (prestazioni caldaie, temperature a cui è fornita ACS) e dell'età dello stabile.

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Starting from the overall electricity consumption, these values allowed to estimate, at national level, the electrical energy, for each services-related activity, spent for heating and cooling needs.

year 2013	Final Electricity Consumption	% Shares: Heating	Cooling	DHW	Other
	GWh/y	%	%	%	%
Services					
* Hospitals	25.17	8%	31%	8%	54%
* Hotels and accomodation	129.49	4%	24%	4%	68%
* Offices	245.98	4%	23%	1%	71%
Restaurants and food services	42.96	4%	24%	4%	68%
* Schools	22.14	23%	21%	5%	51%
* Shops	129.18	3%	26%	1%	71%
Sports and Ricreation	12.72	4%	24%	4%	68%
Territorial Services	0.28	4%	23%	1%	71%
Warehousing, repairing and maintenance	44.65	3%	26%	1%	71%
Total "Services"	**652.57**				

The following table shows the final results for each services-sector related activity. In particular, it highlights the shares of electricity consumption associated to space heating, cooling and water heating.

year 2013	Final Electricity Consumption	% Shares: Heating	Cooling	DHW	Other	% > Consumpt: Heating	Cooling	DHW	Other	Rip. H,C,DHW: Heating	Cooling	DHW	**Total**
	GWh/y	%	%	%	%	GWh/y	GWh/y	GWh/y	GWh/y	%	%	%	**%**
Services													
* Hospitals	25.17	8%	31%	8%	54%	1.95	7.70	1.89	13.63	17%	67%	16%	**100%**
* Hotels and accomodation	129.49	4%	24%	4%	68%	5.36	30.74	5.18	88.22	13%	74%	13%	**100%**
* Offices	245.98	4%	23%	1%	71%	10.90	57.40	2.16	175.51	15%	81%	3%	**100%**
Restaurants and food services	42.96	4%	24%	4%	68%	1.78	10.20	1.72	29.27	13%	74%	13%	**100%**
* Schools	22.14	23%	21%	5%	51%	5.18	4.71	1.03	11.23	47%	43%	9%	**100%**
* Shops	129.18	3%	26%	1%	71%	3.44	33.23	0.72	91.79	9%	89%	2%	**100%**
Sports and Ricreation	12.72	4%	24%	4%	68%	0.53	3.02	0.51	8.66	13%	74%	13%	**100%**
Territorial Services	0.28	4%	23%	1%	71%	0.01	0.07	0.00	0.20	15%	81%	3%	**100%**
Warehousing, repairing and maintenance	44.65	3%	26%	1%	71%	1.19	11.49	0.25	31.73	9%	89%	2%	**100%**
						30.33	**158.54**	**13.45**	**450.26**	**15%**	**78%**	**7%**	**100%**
Total "Services"	**652.57**					*4.65%*	*24.29%*	*2.06%*	*69.00%*				

Efficiency parameters allowed to convert the final energy consumption (supplied to the final consumer’s door) to the useful energy (heating demand), available to the consumers after the last conversion made in the conversion equipment. The table summarizes the efficiency parameters used for the heating demand analysis.

Fossil Fuels - Conversion efficiency	85%
Average SCOP	2.95
Average SEER	2.70
Electrical Water heating efficiency	90%

Calculation of average SCOP and SEER. The parameters were calculated with the same methodology adopted for the residential sector, based on the Weibull distribution, the total number and the age of the installed AC units.

Total number of split units by number of years installed and NACE division[23]

[23] (NSO-MEH Commercial and Industry Survey, 2014), Table 2

NACE Division	Less than 7 years	Per cent	Greater than 7 years	Per cent
C - Manufacturing	1,786	6.4	1,101	5.6
D - Electricity, Gas, Steam And Air Conditioning Supply	0	0	0	0
E - Water Supply; Sewerage, Waste Management […]	54	0.2	37	0.2
F - Construction	1,722	6.1	761	3.9
G - Wholesale And Retail Trade; Repair Of Motor Vehicles And Motorcycles	4,268	15.2	3,662	18.7
H - Transportation And Storage	924	3.3	474	2.4
I - Accommodation And Food Service Activities	1,922	6.8	2,371	12.1
J - Information And Communication	1,154	4.1	507	2.6
K - Financial And Insurance Activities	895	3.2	431	2.2
L - Real Estate Activities	3,203	11.4	1,612	8.2
M - Professional, Scientific And Technical Activities	5,304	18.9	2,485	12.7
N - Administrative And Support Service Activities	3,593	12.8	3,733	19
P - Education	319	1.1	287	1.5
Q - Human Health And Social Work Activities	1,211	4.3	1,120	5.7
R - Arts, Entertainment And Recreation	805	2.9	189	1
S - Other Service Activities	963	3.4	839	4.3
Total	**28,121**	**100.0**	**19,609**	**100.0**

Sector	Less than 7 years	Greater than 7 years
Services	24,560	17,710
Industry	3,562	1,899

3.2.2.3 Final Results

The first table contains the main results of the unbundling activity reported above and referred in particular to electricity consumption. The second one reports the **final energy consumption** and the **heating and cooling energy demand** as defined at the beginning of the chapter and calculated in the previous paragraphs divided per energy sources. The energy demand considers the efficiency of the last conversion made in the consumer conversion equipment. The third one represents the same information ordered per energy uses and then per energy sources. Finally, the last tables show the shares of the total consumption in the sector[24] (for fossil fuels involved in space heating and electricity) associated to space heating and cooling.

Final Energy Consumption

Energy Uses/Sources	Hospitals	Hotels and accomodation	Offices	Restaurants and food services	Schools	Shops	Sports and Ricreation	Territorial Services	Warehousing, repairing and maintenance	**TOTAL**
	GWh/y	GWh/y	GWh/y	GWh/y	GWh/y	GWh/y	GWh/y	GWh/y	GWh/y	**GWh/y**
Heating										
Diesel		2.20								**2.20**
Fuel oil		1.20								**1.20**
Liquefied Petroleum Gas		8.09								**8.09**
Electricity	1.95	5.36	10.90	1.78	5.18	3.44	0.53	0.01	1.19	**30.33**
	1.95	**16.85**	**10.90**	**1.78**	**5.18**	**3.44**	**0.53**	**0.01**	**1.19**	**41.82**
Cooling										
Electricity	7.70	30.74	57.40	10.20	4.71	33.23	3.02	0.07	11.49	**158.54**
	7.70	**30.74**	**57.40**	**10.20**	**4.71**	**33.23**	**3.02**	**0.07**	**11.49**	**158.54**
Water Heating										
Electricity	1.89	5.18	2.16	1.72	1.03	0.72	0.51	0.00	0.25	**13.45**
Solar Thermal	0.32	1.90			0.32		0.63			**3.17**
Diesel	0.36	2.20		1.46		0.03	6.96			**11.01**
Kerosene	0.76		0.13							**0.88**
Gasoil	1.81	5.20		1.73						**8.73**
Fuel oil	4.07	2.81		1.33						**8.21**
Liquefied Petroleum Gas		8.09								**8.09**
Propane	0.11									**0.11**
	9.31	**25.38**	**2.29**	**6.24**	**1.34**	**0.74**	**8.10**	**0.00**	**0.25**	**53.65**
TOTAL	**18.96**	**72.97**	**70.59**	**18.21**	**11.23**	**37.41**	**11.65**	**0.08**	**12.92**	**254.01**

[24] The total values do not consider the consumption for transport purposes.

Energy Sources & Uses	Final Energy Consumption			Heating and Cooling Energy Demand		
	ktoe/y	GWh/y	%	ktoe/y	GWh/y	%
Diesel						
Heating	0.19	2.20	0.87%	0.16	1.87	0.32%
Water Heating	0.95	11.01	4.34%	0.85	9.91	1.72%
	1.14	**13.22**	**5.20%**	**1.01**	**11.78**	**2.05%**
Kerosene						
Water Heating	0.08	0.88	0.35%	0.07	0.80	0.14%
	0.08	**0.88**	**0.35%**	**0.07**	**0.80**	**0.14%**
Gasoil						
Water Heating	0.75	8.73	3.44%	0.68	7.86	1.36%
	0.75	**8.73**	**3.44%**	**0.68**	**7.86**	**1.36%**
Fuel oil						
Heating	0.10	1.20	0.47%	0.09	1.02	0.18%
Water Heating	0.71	8.21	3.23%	0.64	7.39	1.28%
	0.81	**9.41**	**3.71%**	**0.72**	**8.41**	**1.46%**
Liquefied Petroleum Gas						
Heating	0.70	8.09	3.18%	0.59	6.87	1.19%
Water Heating	0.70	8.09	3.18%	0.63	7.28	1.26%
	1.39	**16.17**	**6.37%**	**1.22**	**14.15**	**2.46%**
Propane						
Water Heating	0.01	0.11	0.04%	0.01	0.10	0.02%
	0.01	**0.11**	**0.04%**	**0.01**	**0.10**	**0.02%**
Solar Thermal						
Water Heating	0.27	3.17	1.25%	0.27	3.17	0.55%
	0.27	**3.17**	**1.25%**	**0.27**	**3.17**	**0.55%**
Electricity						
Heating	2.61	30.33	11.94%	7.68	89.36	15.51%
Cooling	13.63	158.54	62.41%	36.84	428.47	74.36%
Water Heating	1.16	13.45	5.29%	1.04	12.10	2.10%
	17.40	**202.32**	**79.65%**	**45.57**	**529.93**	**91.97%**
TOTAL	**21.84**	**254.01**	**100.00%**	**49.54**	**576.20**	**100.00%**

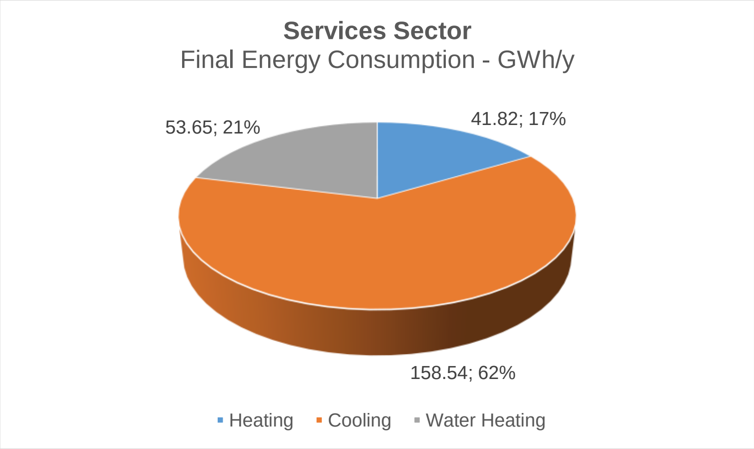
Energy Uses & Sources	Final Energy Consumption			Heating and Cooling Energy Demand		
	ktoe/y	GWh/y	% of the total	ktoe/y	GWh/y	% of the total
Heating						
Diesel	0.19	2.20	0.87%	0.16	1.87	0.32%
Fuel oil	0.10	1.20	0.47%	0.09	1.02	0.18%
Liquefied Petroleum Gas	0.70	8.09	3.18%	0.59	6.87	1.19%
Electricity	2.61	30.33	11.94%	7.68	89.36	15.51%
	3.60	**41.82**	**16.47%**	**8.52**	**99.13**	**17.20%**
Cooling						
Electricity	13.63	158.54	62.41%	36.84	428.47	74.36%
	13.63	**158.54**	**62.41%**	**36.84**	**428.47**	**74.36%**
Water Heating						
Diesel	0.95	11.01	4.34%	0.85	9.91	1.72%
Kerosene	0.08	0.88	0.35%	0.07	0.80	0.14%
Gasoil	0.75	8.73	3.44%	0.68	7.86	1.36%
Fuel oil	0.71	8.21	3.23%	0.64	7.39	1.28%
Liquefied Petroleum Gas	0.70	8.09	3.18%	0.63	7.28	1.26%
Propane	0.01	0.11	0.04%	0.01	0.10	0.02%
Solar Thermal	0.27	3.17	1.25%	0.27	3.17	0.55%
Electricity	1.16	13.45	5.29%	1.04	12.10	2.10%
	4.61	**53.65**	**21.12%**	**4.18**	**48.60**	**8.43%**
TOTAL	**21.84**	**254.01**	**100.00%**	**49.54**	**576.20**	**100.00%**

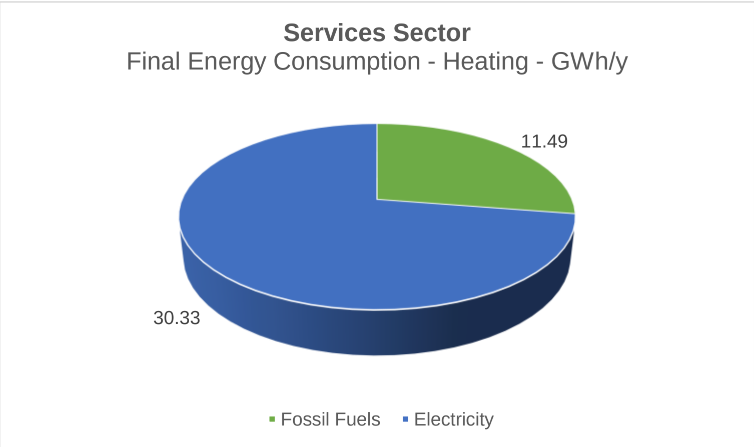
Energy Sources	Total Sector Consumption	Consumptions for Heating and Cooling purposes			
		Space Heating	Space Cooling	Water Heating	**Total Heating & Cooling**
	GWh/y	GWh/y	GWh/y	GWh/y	**GWh/y**
Diesel	**33.20**	2.20	-	11.01	**13.22**
Kerosene	**0.88**	-	-	0.88	**0.88**
Gasoil	**24.62**	-	-	8.73	**8.73**
Fuel oil	**79.25**	1.20	-	8.21	**9.41**
Liquefied Petroleum Gas	**85.12**	8.09	-	8.09	**16.17**
Propane	**0.12**	-	-	0.11	**0.11**
Solar Thermal	**3.17**	-	-	3.17	**3.17**
Electricity	**652.57**	30.33	158.54	13.45	**202.32**
TOTAL	**878.94**	**41.82**	**158.54**	**53.65**	**254.01**

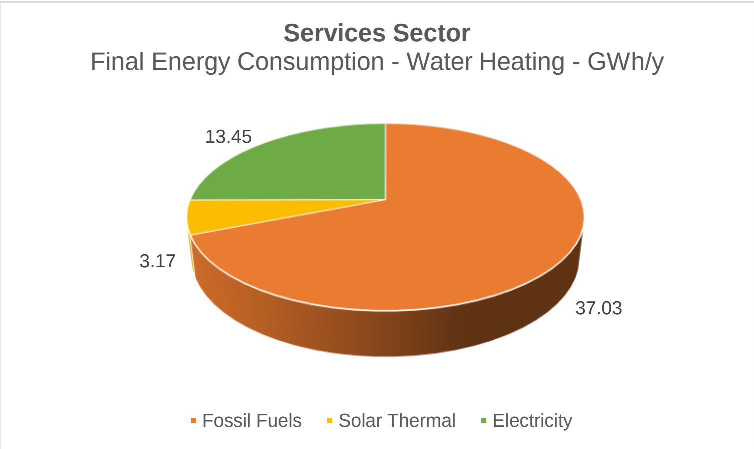
Energy Sources	Consumptions for Heating and Cooling purposes			
	Space Heating	Space Cooling	Water Heating	**Total Heating & Cooling**
	%	%	%	**%**
Diesel	6.63%	-	33.17%	**39.80%**
Kerosene	-	-	100.00%	**100.00%**
Gasoil	-	-	35.48%	**35.48%**
Fuel oil	1.52%	-	10.36%	**11.88%**
Liquefied Petroleum Gas	9.50%	-	9.50%	**19.00%**
Propane	-	-	85.94%	**85.94%**
Solar Thermal	-	-	100.00%	**100.00%**
Electricity	4.65%	24.29%	2.06%	**31.00%**
H&C / Total	**4.76%**	**18.04%**	**6.10%**	**28.90%**

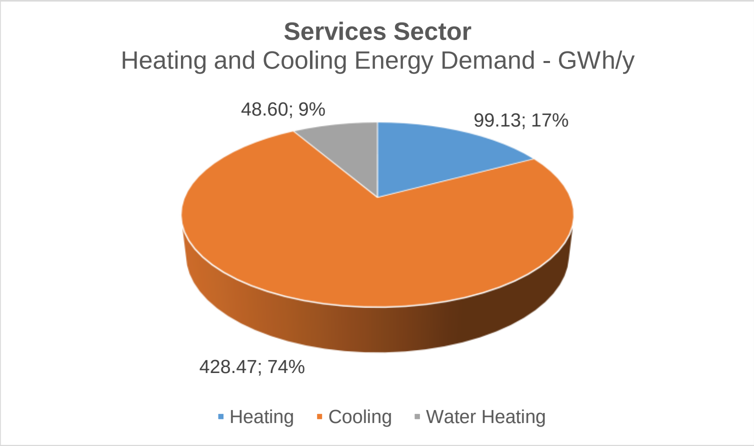
Energy Sources	Total Sector Consumption	Consumptions for Heating and Cooling purposes			
		Space Heating	Space Cooling	Water Heating	**Total Heating & Cooling**
	GWh/y	GWh/y	GWh/y	GWh/y	**GWh/y**
Fossil Fuels	**223.19**	**11.49**	**-**	**37.03**	**48.53**
Solar Thermal	**3.17**	**-**	**-**	**3.17**	**3.17**
Electricity	**652.57**	30.33	158.54	13.45	**202.32**
TOTAL	**878.94**	**41.82**	**158.54**	**53.65**	**254.01**

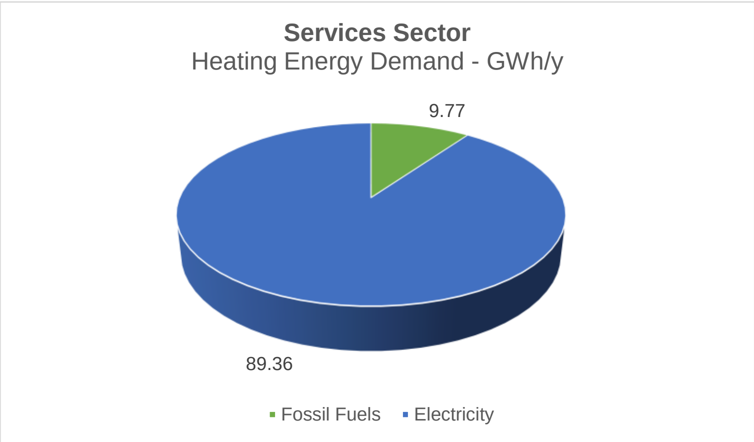
Energy Sources	Consumptions for Heating and Cooling purposes			
	Space Heating	Space Cooling	Water Heating	**Total Heating & Cooling**
	%	%	%	**%**
Fossil Fuels	5.15%	-	16.59%	**21.74%**
Solar Thermal	-	-	100.00%	**100.00%**
Electricity	4.65%	24.29%	2.06%	**31.00%**
H&C / Total	**4.76%**	**18.04%**	**6.10%**	**28.90%**

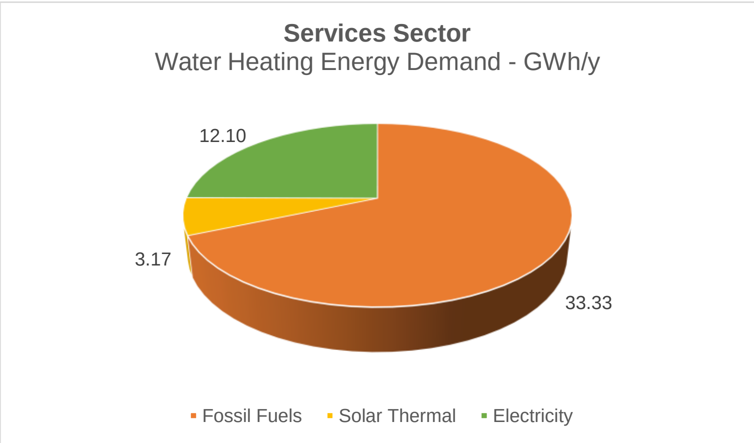

Services Sector
Final Energy Consumption - GWh/y
53.65; 21%
41.82; 17%
158.54; 62%
Heating
Cooling
Water Heating


Services Sector
Final Energy Consumption - Heating - GWh/y
11.49
30.33
Fossil Fuels
Electricity


Services Sector
Final Energy Consumption - Water Heating - GWh/y
13.45
3.17
37.03
Fossil Fuels
Solar Thermal
Electricity


Services Sector
Heating and Cooling Energy Demand - GWh/y
48.60; 9%
99.13; 17%
428.47; 74%
Heating
Cooling
Water Heating


Services Sector
Heating Energy Demand - GWh/y
9.77
89.36
Fossil Fuels
Electricity


Services Sector
Water Heating Energy Demand - GWh/y
12.10
3.17
33.33
Fossil Fuels
Solar Thermal
Electricity

3.2.3 Industry sector

In the industry sector, the main energy sources used for space heating, space cooling and water heating are:

- **Heating:**
  - Electricity;

- **Cooling:**
  - Electricity;

- **Water Heating:**
  - Diesel;
  - Kerosene;
  - Gasoil;
  - Liquefied Petroleum Gas;
  - Solar Thermal;
  - Electricity.

The table contains the sources of consumption data used for the analysis.

Energy Sources	Source of data
Diesel	MRA
Kerosene	MRA
Gasoil	MRA
Liquefied Petroleum Gas	MRA
Solar Thermal	Eurostat, MRA
Electricity	NSO and ARMS ltd

3.2.3.1 Energy Sources

3.2.3.1.1 Fossil Fuels

The **Fossil Fuels** consumption values for space heating purposes, apart from the LPG, were obtained from an elaboration of the fossil fuels database provided by MRA containing the national consumption by economic sector of the fuels used for space heating. The table below highlights the values referred to “Space Heating” used in this paragraph.

Year 2013	**SECTORS**			
Space Heating - GWh	**Agricolture** *GWh*	**Industry** *GWh*	**Services** *GWh*	**Residential** *GWh*
Petrol	-	-	-	-
Diesel	-	4.88	13.22	-
Biodiesel	-	-	-	-
Aviation Turbine Fuel	-	-	-	-
Aviation Gasoline Fuel	-	-	-	-
Kerosene	-	0.03	0.88	5.49
Gasoil	-	1.89	8.73	-
Fuel oil	-	-	9.41	-
Propane	0.04	-	0.11	2.55
Coal	-	-	-	-
Light Cycle Oil	-	-	-	-
Total	**0.04**	**6.80**	**32.35**	**8.04**

The details of each fossil fuel value is reported in the following tables.

DIESEL

year 2013	Fuel Consumption *Space Heating*		*Share of the Total (Industry)*
	GWh/y	ktoe/y	
Industry			
Manufacturing	4.88	0.420	*100.00%*
Total "Industry"	**4.88**	**0.420**	*100.00%*

KEROSENE

year 2013	Fuel Consumption *Space Heating*		*Share of the Total (Industry)*
	GWh/y	ktoe/y	
Industry			
Manufacturing	0.03	0.002	*100.00%*
Total "Industry"	**0.03**	**0.002**	*100.00%*

GASOIL

year 2013	Fuel Consumption *Space Heating*		*Share of the Total (Industry)*
	GWh/y	ktoe/y	
Industry			
Manufacturing	1.89	0.162	*100.00%*
Total "Industry"	**1.89**	**0.162**	*100.00%*

For the **LPG** the considered consumption values, already introduced in 3.1.1.1, are the following:

Industry sector - LPG consumption		
Total Consumption	36.48	GWh
Heating purposes	0.00	GWh
Other uses	36.48	GWh

3.2.3.1.2 Electricity

The overall **electricity** consumption value for the industry sector was obtained as an elaboration of the 2013 database provided by NSO. The database contains the electricity consumption data for both the Industry and Services sectors, divided between the two categories using the economic activities classification. The following table reports the results of the elaboration for the industry sector, expressed as yearly consumption in GWh and ktoe and classified per type of industrial activity.

year 2013	Electricity Consumption			*Share of the Total*
	kWh/y	GWh/y	ktoe/y	*(Industry)*
Industry				
Chemical and petrochemical	35,936,205	35.94	3.09	*6.99%*
Construction	13,975,521	13.98	1.20	*2.72%*
Energy	8,929,878	8.93	0.77	*1.74%*
Food and Tobacco	50,534,777	50.53	4.35	*9.82%*
Iron & steel	17,252	0.02	0.00	*0.00%*
Machinery	102,349,970	102.35	8.80	*19.89%*
Mining and Quarrying	1,353,465	1.35	0.12	*0.26%*
Non-metallic minerals	5,477,702	5.48	0.47	*1.06%*
Non-specified	77,316,716	77.32	6.65	*15.03%*
Paper, pulp and print	22,173,657	22.17	1.91	*4.31%*
Territorial Services	128,461,156	128.46	11.05	*24.97%*
Textile and Leather	35,021,321	35.02	3.01	*6.81%*
Transport Equipment	15,458,083	15.46	1.33	*3.00%*
Warehousing, repairing and maintenance	16,220,497	16.22	1.39	*3.15%*
Wood and wood products	1,235,006	1.24	0.11	*0.24%*
Total "Industry"	**514,461,207**	**514.46**	**44.24**	*100.00%*

In absence of actual and specific data of electricity consumption for space heating and cooling, this value was estimated starting from the yearly electricity consumption given with monthly detail within the ARMS ltd database.

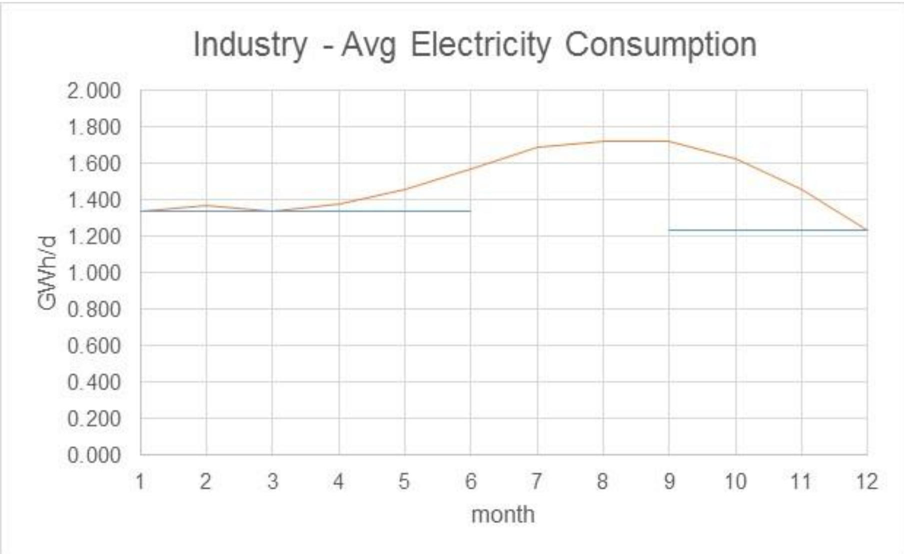
In particular, the **ARMS ltd** database – provided with the billed period for each consumption record - allowed to point out the trend during the year of the electricity consumption for the Non-residential sectors, including all the economic sectors, and in particular Services and **Industry**. It was then possible to identify the amount of electricity associated to space heating and cooling following the same methodology proposed for the “Services” sector.

In particular, the following table and chart report the daily average electricity consumption for each month. The minimum values of the year are highlighted in bold.

Total Electricity Consumption *(ARMS ltd 2013 data)*	Industry Sector
	GWh
jan-13	41.34
feb-13	38.31
mar-13	41.39
apr-13	41.24
may-13	45.15
jun-13	47.07
jul-13	52.45
aug-13	53.42
sep-13	51.63
oct-13	50.27
nov-13	43.74
dec-13	38.16
TOTAL	**544.18**

		Days per month	Avg Daily Electricity Consumption
		dd/m	GWh/d
1	jan-13	*31*	**1.333**
2	feb-13	*28*	1.368
3	mar-13	*31*	1.335
4	apr-13	*30*	1.375
5	may-13	*31*	1.457
6	jun-13	*30*	1.569
7	jul-13	*31*	1.692
8	aug-13	*31*	1.723
9	sep-13	*30*	1.721
10	oct-13	*31*	1.622
11	nov-13	*30*	1.458
12	dec-13	*31*	**1.231**

Average daily electricity consumption in the industry sector



The tables below report the above-described calculation, that leads to the identification of the electricity consumed for **space heating** and **cooling** in the sector. The base electricity consumption (assumed constant throughout the year) considered in the calculation were adjusted:

- With an assumed base reduction of **5%** for the space heating, in order to considering the needs for heating also in a middle month in the year like March, that otherwise would have a nearly zero consumption for space heating.
- With an assumed base increase of **5%** during the summer period, for considering that not all the increase of electricity consumption is associated to space cooling.

INDUSTRY SECTOR - SPACE HEATING

	Days per month	Avg electricity consumption	Base electricity consumption	Base electricity consumption **Reduced**	**Electricity Consumption for Space Heating**	Yearly %
	dd/m	GWh/d	GWh/d	GWh/d	**GWh**	%
jan-13	*31*	**1.333**	1.333	1.267	**2.07**	*23%*
feb-13	*28*	1.368	1.333	1.267	**2.83**	*32%*
mar-13	*31*	1.335	1.333	1.267	**2.12**	*24%*
apr-13	*30*	1.375				
may-13	*31*	1.457				
jun-13	*30*	1.569				
jul-13	*31*	1.692				
aug-13	*31*	1.723				
sep-13	*30*	1.721				
oct-13	*31*	1.622				
nov-13	*30*	1.458				
dec-13	*31*	**1.231**	1.231	1.169	**1.91**	*21%*
TOTAL					**8.93**	*100%*

INDUSTRY SECTOR - SPACE COOLING

	Days per month	Avg electricity consumption	Base electricity consumption	Base electricity consumption **Reduced**	**Electricity Consumption for Space Cooling**	Yearly %
	dd/m	GWh/d	GWh/d	GWh/d	**GWh**	%
jan-13	*31*	1.333				
feb-13	*28*	1.368				
mar-13	*31*	1.335				
apr-13	*30*	1.375	1.333	1.400	**0.00**	*0%*
may-13	*31*	1.457	1.333	1.400	**1.75**	*4%*
jun-13	*30*	1.569	1.333	1.400	**5.06**	*11%*
jul-13	*31*	1.692	1.333	1.400	**9.04**	*21%*
aug-13	*31*	1.723	1.333	1.400	**10.02**	*23%*
sep-13	*30*	1.721	1.333	1.400	**9.62**	*22%*
oct-13	*31*	1.622	1.333	1.400	**6.87**	*16%*
nov-13	*30*	1.458	1.333	1.400	**1.73**	*4%*
dec-13	*31*	1.231				
TOTAL					**44.10**	*100%*

The consumption values introduced in this paragraph, that will appear in the final results as "Final Energy Consumption" were used to validate, adjust and calibrate the heating and cooling model proposed in the following sections.

3.2.3.2 Heating and Cooling Consumption

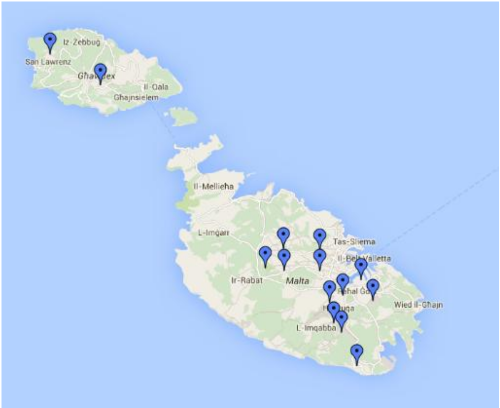
Starting from the overall data introduced in 3.2.3.1, the energy consumption and energy demand associated to heating, cooling and hot water production were calculated following the methodology described below.

Fossil fuels consumption and the **solar thermal** contribution in the industry sector – introduced in the previous paragraph - was entirely associated to water heating needs.

The **electricity** consumptions for space heating and cooling were determined with the approach proposed in the previous paragraph. In order to verify the reliability of these results, the following methodology was also applied.

Step 1 – Identification of Industrial areas. A total of **15** main industrial areas were identified in the Maltese Islands[25]. The table below reports the areas' size estimations obtained from the website http://www.maltaenterprise.com or from direct measurements obtained from Google Earth and AutoCAD.

[25] http://www.maltaenterprise.com/en/business/industrial-zones



INDUSTRIAL ZONES	Industrial units	Total site area
		m²
Attard Industrial Estate	21	48,404
Bulebel Industrial Estate	108	591,381
Hal Far Industrial Estate	73	1,182,566
Kirkop Industrial Estate	n.a.	69,338
Kordin Industrial Estate	101	259,903
Luqa Industrial Estate	148	90,832
Marsa Industrial Estate	113	487,597
Mosta Technopark	27	60,300
MrieHel Industrial Estate	30	99,409
Safi Aviation Park	n.a.	233,376
San Gwann Industrial Estate	81	271,207
Ta' Qali Crafts Village	40	105,000
Ta' Dbiegi Crafts Village	28	7,000
Xewkija Industrial Estate	58	129,022
TOTAL	**828**	**3,635,335**

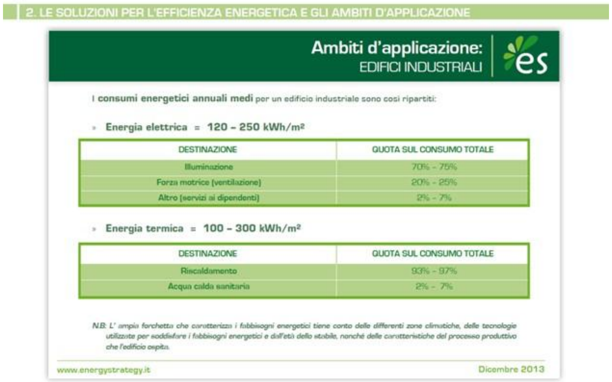
Step 2 – Determination of heating and cooling areas. The activity of Solar Cooling assessment developed in the framework of Task 2, Sub-Task 4 provided a coefficient for estimating the rooftops area. Within this step, the coefficient was used for calculating the total floor area. The heating area and the cooling area were obtained as a portion of the total floor area with the use of two different coefficients.

% Floor Area *(Floor Area/Total Area)*	43.6%
% Heating area *(Heating area/Floor Area)*	15%
% Cooling area *(Cooling area/Floor Area)*	60%

INDUSTRIAL ZONES	Industrial units	Total site area	Total floor area	Total Heating Area	Total Cooling Area
		m²	m²	m²	m²
Attard Industrial Estate	21	48,404	21,104	3,166	12,662
Bulebel Industrial Estate	108	591,381	257,842	38,676	154,705
Hal Far Industrial Estate	73	1,182,566	515,599	77,340	309,359
Kirkop Industrial Estate	n.a.	69,338	30,231	4,535	18,139
Kordin Industrial Estate	101	259,903	113,318	16,998	67,991
Luqa Industrial Estate	148	90,832	39,603	5,940	23,762
Marsa Industrial Estate	113	487,597	212,592	31,889	127,555
Mosta Technopark	27	60,300	26,291	3,944	15,774
MrieHel Industrial Estate	30	99,409	43,342	6,501	26,005
Safi Aviation Park	n.a.	233,376	101,752	15,263	61,051
San Gwann Industrial Estate	81	271,207	118,246	17,737	70,948
Ta' Qali Crafts Village	40	105,000	45,780	6,867	27,468
Ta' Dbiegi Crafts Village	28	7,000	3,052	458	1,831
Xewkija Industrial Estate	58	129,022	56,254	8,438	33,752
TOTAL	**828**	**3,635,335**	**1,585,006**	**237,751**	**951,004**

Step 3 – Yearly specific energy demand. Specific energy demand parameters were calculated starting from the values proposed by (Politecnico di Milano - Italy, 2013).

Industrial Buildings



2. LE SOLUZIONI PER L'EFFICIENZA ENERGETICA E GLI AMBITI D'APPLICAZIONE

Ambiti d'applicazione:
EDIFICI INDUSTRIALI

I consumi energetici annuali medi per un edificio industriale sono così ripartiti:

- **Energia elettrica = 120 – 250 kWh/m²**

DESTINAZIONE	QUOTA SUL CONSUMO TOTALE
Illuminazione	70% - 75%
Forza motrice (ventilazione)	20% - 25%
Altro (servizi ai dipendenti)	2% - 7%

- **Energia termica = 100 – 300 kWh/m²**

DESTINAZIONE	QUOTA SUL CONSUMO TOTALE
Riscaldamento	93% - 97%
Acqua calda sanitaria	2% - 7%

N.B: L' ampia forchetta che caratterizza i fabbisogni energetici tiene conto delle differenti zone climatiche, delle tecnologie utilizzate per soddisfare i fabbisogni energetici e dall'età dello stabile, nonché delle caratteristiche del processo produttivo che l'edificio ospita.

www.energystrategy.it Dicembre 2013

Benchmark value	kWh/m²
Specific Heating Demand	111.05
Specific Cooling Demand	125.74
Specific Water Heating Demand	5.00

Step 4 – Heating and Cooling Energy Demand. Multiplying the specific energy demand by the heating and cooling areas it was possible to identify the Heating and Cooling Energy Demand (referred to the 15 industrial areas introduced at Step 1).

Heating and Cooling Energy Demand		
Water Heating	**Heating**	**Cooling**
kWh/y	kWh/y	kWh/y
105,521	351,528	1,592,134
1,289,211	4,294,837	19,452,070
2,577,994	8,588,250	38,897,693
151,157	503,559	2,280,708
566,589	1,887,516	8,548,890
198,014	659,657	2,987,702
1,062,961	3,541,117	16,038,342
131,454	437,922	1,983,425
216,712	721,946	3,269,822
508,760	1,694,866	7,676,348
591,231	1,969,610	8,920,709
228,900	762,550	3,453,725
15,260	50,837	230,248
281,268	937,007	4,243,871
7,925,030	**26,401,203**	**119,575,689**

Step 5 – Conversion Efficiency. The conversion efficiency was used for converting the heating and cooling energy demand, available to the consumers after the last conversion made in the conversion equipment to the final energy consumption (supplied to the final consumer's door). The table summarizes the efficiency parameters used for the water heating demand analysis.

Fossil Fuel - Conversion efficiency	85%
Average SCOP	2.96
Average SEER	2.71
Water heaters efficiency	90%

The parameters SCOP and SEER were calculated with the same methodology adopted for the residential sector, based on the Weibull distribution, the total number and the age of the installed AC units.

Total number of split units by number of years installed and NACE division[26]

NACE Division	Less than 7 years	Per cent	Greater than 7 years	Per cent
C - Manufacturing	1,786	6.4	1,101	5.6
D - Electricity, Gas, Steam And Air Conditioning Supply	0	0	0	0
E - Water Supply; Sewerage, Waste Management [...]	54	0.2	37	0.2
F - Construction	1,722	6.1	761	3.9
G - Wholesale And Retail Trade; Repair Of Motor Vehicles And Motorcycles	4,268	15.2	3,662	18.7
H - Transportation And Storage	924	3.3	474	2.4
I - Accommodation And Food Service Activities	1,922	6.8	2,371	12.1
J - Information And Communication	1,154	4.1	507	2.6
K - Financial And Insurance Activities	895	3.2	431	2.2
L - Real Estate Activities	3,203	11.4	1,612	8.2
M - Professional, Scientific And Technical Activities	5,304	18.9	2,485	12.7
N - Administrative And Support Service Activities	3,593	12.8	3,733	19
P - Education	319	1.1	287	1.5
Q - Human Health And Social Work Activities	1,211	4.3	1,120	5.7
R - Arts, Entertainment And Recreation	805	2.9	189	1
S - Other Service Activities	963	3.4	839	4.3
Total	**28,121**	**100.0**	**19,609**	**100.0**

Sector	Less than 7 years	Greater than 7 years
Services	24,560	17,710
Industry	3,562	1,899

[26] (NSO-MEH Commercial and Industry Survey, 2014), Table 2

Final Electricity Consumption		
Water Heating	Heating	Cooling
kWh/y	kWh/y	kWh/y
117,245	118,902	587,186
1,432,456	1,452,695	7,174,002
2,864,438	2,904,908	14,345,627
167,952	170,325	841,135
629,543	638,437	3,152,865
220,015	223,124	1,101,877
1,181,068	1,197,755	5,915,006
146,060	148,124	731,495
240,791	244,193	1,205,924
565,289	573,275	2,831,068
656,924	666,205	3,289,994
254,333	257,927	1,273,748
16,956	17,195	84,917
312,520	316,935	1,565,157
8,805,589	**8,930,000**	**44,100,000**

3.2.3.3 Final Results

The following table reports the **final energy consumption** and the **heating and cooling energy demand** as defined at the beginning of the chapter and calculated in the previous paragraphs divided per energy sources. The energy demand considers the efficiency of the last conversion made in the consumer conversion equipment.

The second one represents the same information ordered per energy uses and then per energy sources.

Finally, the last tables show the shares of the total consumption in the sector[27] (for fossil fuels involved in space heating and electricity) associated to space heating and cooling.

[27] The total values do not consider the consumption for transport purposes.

Energy Sources & Uses	Final Energy Consumption			Heating and Cooling Energy Demand		
	ktoe/y	GWh/y	%	ktoe/y	GWh/y	%
Diesel						
Water Heating	0.42	4.88	7.07%	0.38	4.39	2.74%
	0.42	**4.88**	**7.07%**	**0.38**	**4.39**	**2.74%**
Kerosene						
Water Heating	0.002	0.03	0.04%	0.00	0.03	0.02%
	0.002	**0.03**	**0.04%**	**0.002**	**0.03**	**0.02%**
Gasoil						
Water Heating	0.16	1.89	2.74%	0.15	1.70	1.06%
	0.16	**1.89**	**2.74%**	**0.15**	**1.70**	**1.06%**
Solar Thermal						
Water Heating	0.03	0.37	0.54%	0.03	0.37	0.23%
	0.03	**0.37**	**0.54%**	**0.032**	**0.37**	**0.23%**
Electricity						
Heating	0.77	8.93	12.94%	2.27	26.40	16.46%
Cooling	3.79	44.10	63.91%	10.28	119.58	74.55%
Water Heating	0.76	8.81	12.76%	0.68	7.93	4.94%
	5.32	**61.84**	**89.61%**	**13.23**	**153.90**	**95.95%**
TOTAL	**5.93**	**69.00**	**100.00%**	**13.79**	**160.39**	**100.00%**

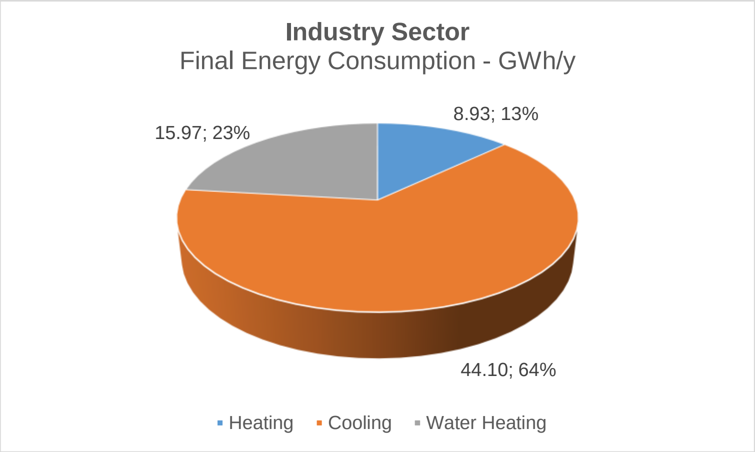
Energy Uses & Sources	Final Energy Consumption			Heating and Cooling Energy Demand		
	ktoe/y	GWh/y	% of the total	ktoe/y	GWh/y	% of the total
Heating						
Electricity	0.77	8.93	12.94%	2.27	26.40	16.46%
	0.77	**8.93**	**12.94%**	**2.27**	**26.40**	**16.46%**
Cooling						
Electricity	3.79	44.10	63.91%	10.28	119.58	74.55%
	3.79	**44.10**	**63.91%**	**10.28**	**119.58**	**74.55%**
Water Heating						
Diesel	0.42	4.88	7.07%	0.38	4.39	2.74%
Kerosene	0.002	0.03	0.04%	0.002	0.03	0.02%
Gasoil	0.16	1.89	2.74%	0.15	1.70	1.06%
Solar Thermal	0.03	0.37	0.54%	0.03	0.37	0.23%
Electricity	0.76	8.81	12.76%	0.68	7.93	4.94%
	1.37	**15.97**	**23.15%**	**1.24**	**14.41**	**8.99%**
TOTAL	**5.93**	**69.00**	**100.00%**	**13.79**	**160.39**	**100.00%**

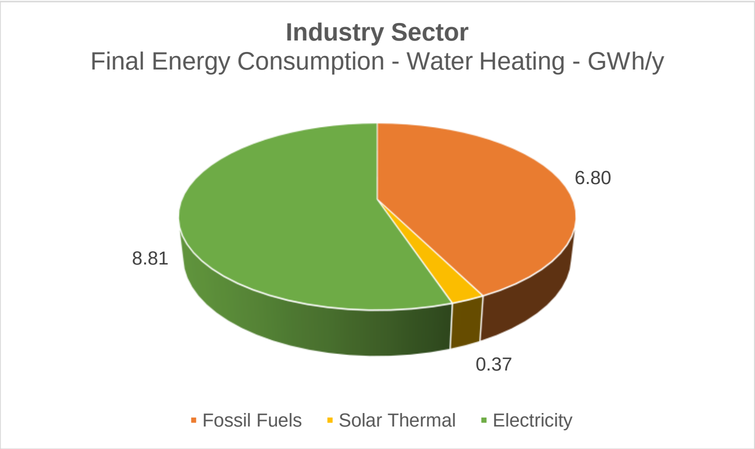
Energy Sources	Total Sector Consumption	Consumptions for Heating and Cooling purposes			
		Space Heating	Space Cooling	Water Heating	Total Heating & Cooling
	GWh/y	GWh/y	GWh/y	GWh/y	**GWh/y**
Diesel	**17.23**	-	-	4.88	**4.88**
Kerosene	**0.46**	-	-	0.03	**0.03**
Gasoil	**12.47**	-	-	1.89	**1.89**
Solar Thermal	**0.37**	-	-	0.37	**0.37**
Electricity	**514.46**	8.93	44.10	8.81	**61.84**
TOTAL	**544.98**	**8.93**	**44.10**	**15.97**	**69.00**

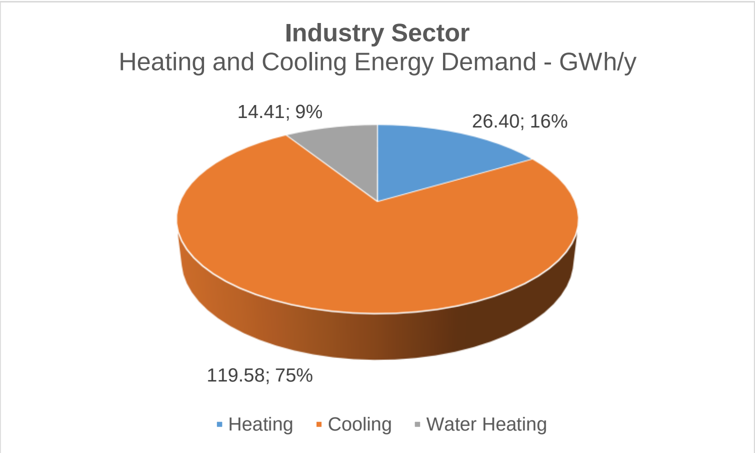
Energy Sources	Consumptions for Heating and Cooling purposes			
	Space Heating	Space Cooling	Water Heating	Total Heating & Cooling
	%	%	%	**%**
Diesel	-	-	28.33%	**28.33%**
Kerosene	-	-	6.11%	**6.11%**
Gasoil	-	-	15.15%	**15.15%**
Solar Thermal	-	-	100.00%	**100.00%**
Electricity	1.74%	8.57%	1.71%	**12.02%**
H&C / Total	**1.64%**	**8.09%**	**2.93%**	**12.66%**

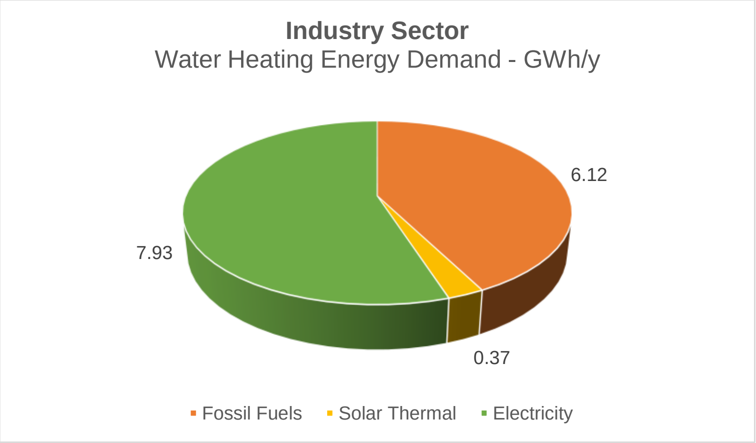
Energy Sources	Total Sector Consumption	Consumptions for Heating and Cooling purposes			
		Space Heating	Space Cooling	Water Heating	Total Heating & Cooling
	GWh/y	GWh/y	GWh/y	GWh/y	**GWh/y**
Fossil Fuels	**30.15**	**-**	**-**	6.80	**6.80**
Solar Thermal	**0.37**	**-**	**-**	0.37	**0.37**
Electricity	**514.46**	8.93	44.10	8.81	**61.84**
TOTAL		**8.93**	**44.10**	**15.97**	**69.00**

Energy Sources	Consumptions for Heating and Cooling purposes			
	Space Heating	Space Cooling	Water Heating	Total Heating & Cooling
	%	%	%	**%**
Fossil Fuels	-	-	22.54%	**22.54%**
Solar Thermal	-	-	100.00%	**100.00%**
Electricity	1.74%	8.57%	1.71%	**12.02%**
H&C / Total	**1.64%**	**8.09%**	**2.93%**	**12.66%**


Industry Sector
Final Energy Consumption - GWh/y
8.93; 13%
15.97; 23%
44.10; 64%
Heating
Cooling
Water Heating


Industry Sector
Final Energy Consumption - Water Heating - GWh/y
6.80
8.81
0.37
Fossil Fuels
Solar Thermal
Electricity


Industry Sector
Heating and Cooling Energy Demand - GWh/y
14.41; 9%
26.40; 16%
119.58; 75%
Heating
Cooling
Water Heating


Industry Sector
Water Heating Energy Demand - GWh/y
6.12
7.93
0.37
Fossil Fuels
Solar Thermal
Electricity

3.2.4 Agriculture sector

In the services sector, the main energy sources used for space heating, space cooling and water heating are:

- **Heating:**
  - Propane;
  - Electricity.

- **Cooling:**
  - Electricity;

- **Water Heating:**
  - Electricity.

The table contains the sources of consumption data used for the analysis.

Energy Sources	Source of data
Propane	MRA
Electricity	NSO

3.2.4.1 Consumption data

The **Fossil Fuels** consumption values for space heating purposes were obtained from an elaboration of the fossil fuels database provided by MRA containing the national consumption by economic sector of the fuels used for space heating. The table below highlights the values used in this paragraph.

Year 2013	SECTORS			
Space Heating - GWh	Agricolture *GWh*	Industry *GWh*	Services *GWh*	Residential *GWh*
Petrol	-	-	-	-
Diesel	-	4.88	13.22	-
Biodiesel	-	-	-	-
Aviation Turbine Fuel	-	-	-	-
Aviation Gasoline Fuel	-	-	-	-
Kerosene	-	0.03	0.88	5.49
Gasoil	-	1.89	8.73	-
Fuel oil	-	-	9.41	-
Propane	0.04	-	0.11	2.55
Coal	-	-	-	-
Light Cycle Oil	-	-	-	-
Total	**0.04**	**6.80**	**32.35**	**8.04**

The overall **Electricity** consumption value for the agriculture sector was obtained as an elaboration of the 2013 database provided by NSO. The database contains the electricity consumption data divided between the several economic sectors using economic activities classification.

The following table reports the results of the elaboration for the agriculture sector, expressed as yearly consumption in GWh and ktoe.

year 2013	Final Electricity Consumption		
	kWh/y	GWh/y	ktoe/y
Agricolture/Forestry	8,541,895.13	8.54	0.73

3.2.4.2 Heating and Cooling Consumption

Fossil fuels consumption in the services sector was entirely associated to heating needs.

For **electricity** consumptions, starting from the overall data introduced in 3.2.4.1, the energy consumption and energy demand associated to heating, cooling and hot water production was calculated using the shares of total electricity consumption associated to the various energy uses obtained from the residential sector.

Heating	8%
Cooling	9%
Water Heating	27%

In analogy with the residential sector, the table summarizes the efficiency parameters used for the heating demand analysis.

Gas heater efficiency	90%
Electric heater efficiency	100%
Average SCOP	2.96
Electricity Water heater efficiency	97%
Average SEER	2.72

3.2.4.3 Final Results

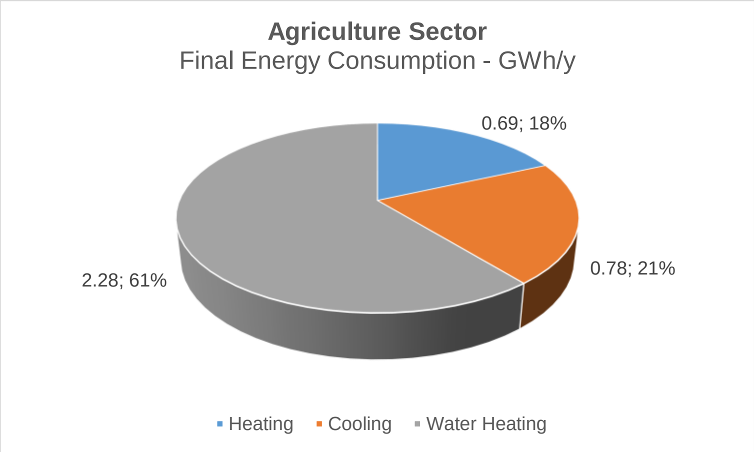
The following table reports the **final energy consumption** and the **heating and cooling energy demand** as defined at the beginning of the chapter and calculated in the previous paragraphs divided per energy sources. The energy demand considers the efficiency of the last conversion made in the consumer conversion equipment.

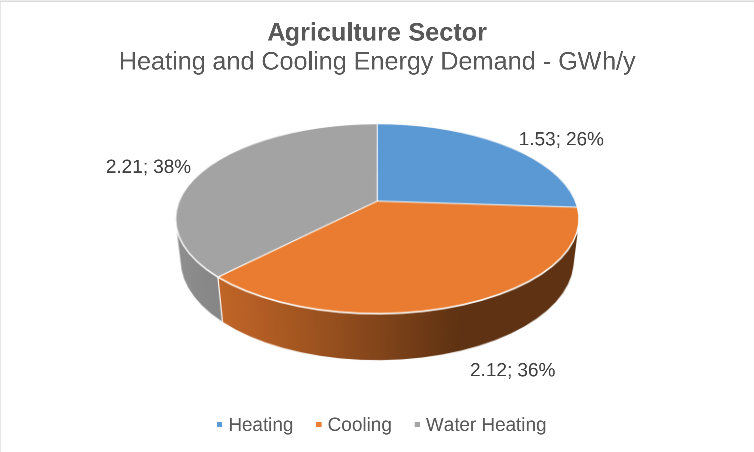
The last two tables show the shares of the total consumption in the sector (for fossil fuels involved in space heating and electricity) associated to space heating and cooling.

Energy Uses & Sources	Final Energy Consumption			Heating and Cooling Energy Demand		
	ktoe/y	GWh/y	% of the total	ktoe/y	GWh/y	% of the total
Heating						
Propane	0.003	0.04	1.07%	0.003	0.04	0.61%
Electric Heater	0.018	0.21	5.70%	0.018	0.21	3.64%
Electricity (Air Conditioning)	0.037	0.43	11.51%	0.11	1.28	21.80%
	0.06	**0.69**	**18.28%**	**0.13**	**1.53**	**26.06%**
Cooling						
Electricity	0.07	0.78	20.84%	0.18	2.12	36.19%
	0.07	**0.78**	**20.84%**	**0.18**	**2.12**	**36.19%**
Water Heating						
Electricity	0.196	2.28	60.88%	0.19	2.21	37.75%
	0.20	**2.28**	**60.88%**	**0.19**	**2.21**	**37.75%**
TOTAL	**0.32**	**3.75**	**100.00%**	**0.50**	**5.86**	**100.00%**

Energy Sources	Total Sector Consumption	Consumptions for Heating and Cooling purposes			
		Space Heating	Space Cooling	Water Heating	Total Heating & Cooling
	GWh/y	GWh/y	GWh/y	GWh/y	**GWh/y**
Propane	**0.04**	0.04	-	-	**0.04**
Electricity	**8.54**	0.65	0.43	2.28	**3.36**
TOTAL	**8.58**	**0.69**	**0.43**	**2.28**	**3.40**

Energy Sources	Consumptions for Heating and Cooling purposes			
	Space Heating	Space Cooling	Water Heating	Total Heating & Cooling
	%	%	%	**%**
Propane	100.00%	-	-	**100.00%**
Electricity	7.56%	5.05%	26.73%	**39.34%**
H&C / Total	**7.99%**	**5.03%**	**26.60%**	**39.62%**



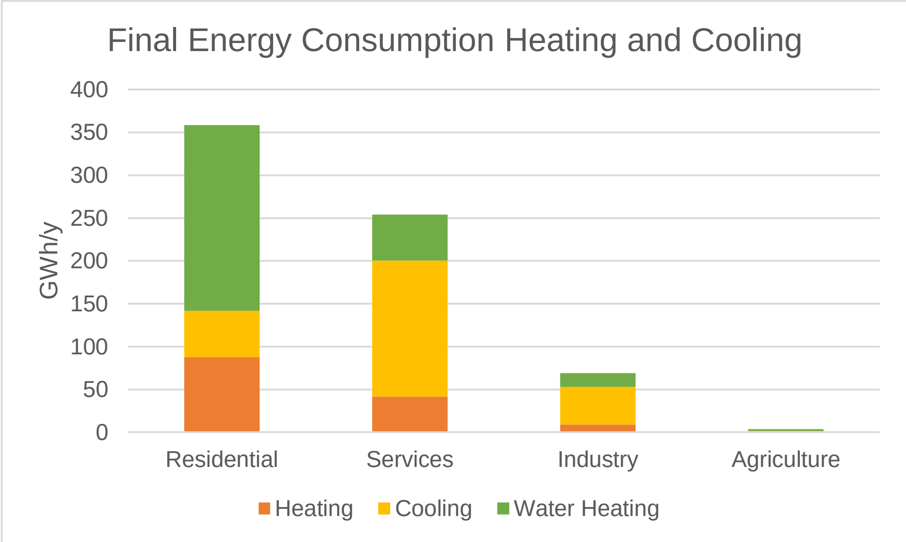


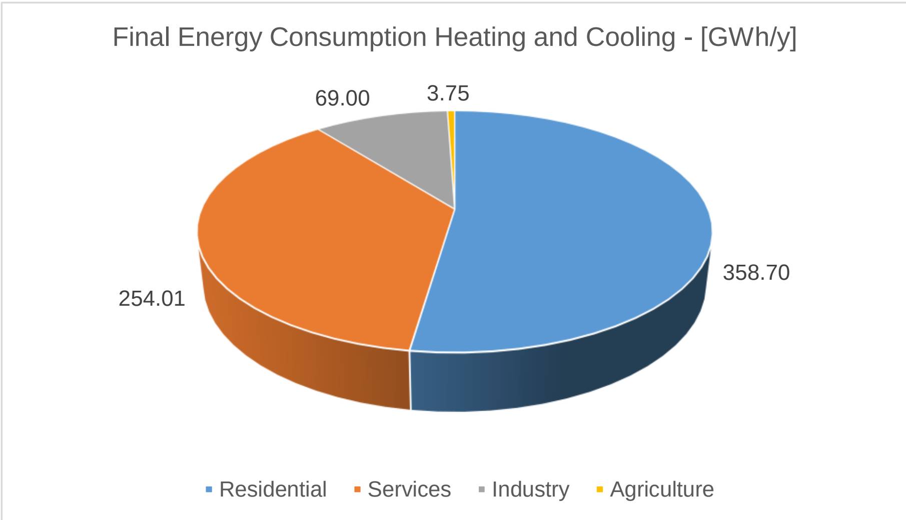
3.3 Total Results

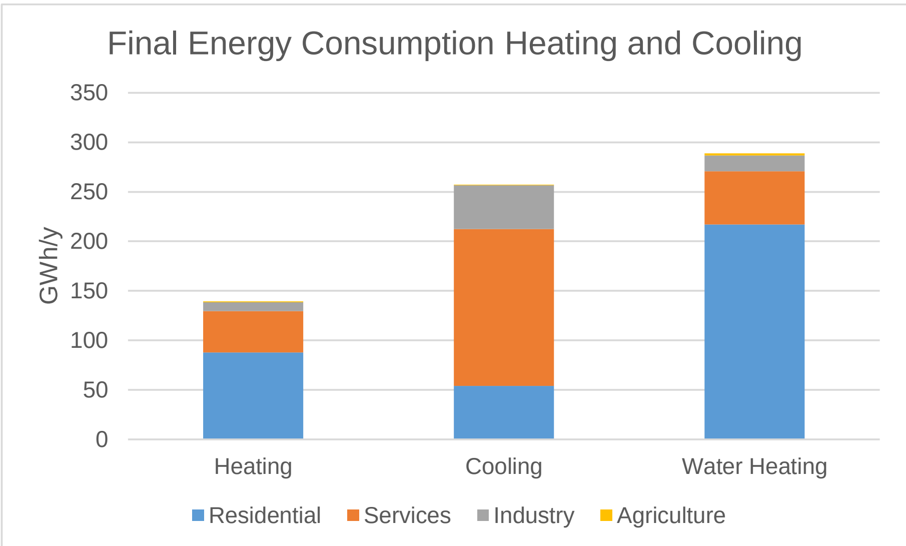
The following two paragraphs summarize and represent the results obtained within the several sectors about the Final Energy Consumption and the Heating and Cooling Energy Demand.

3.3.1 Final Energy Consumption

Sector	Heating	Cooling	Water Heating	TOTAL
	GWh/y	GWh/y	GWh/y	GWh/y
Residential	87.77	53.96	216.97	**358.70**
Services	41.82	158.54	53.65	**254.01**
Industry	8.93	44.10	15.97	**69.00**
Agriculture	0.69	0.78	2.28	**3.75**
	139.21	**257.38**	**288.88**	**685.46**

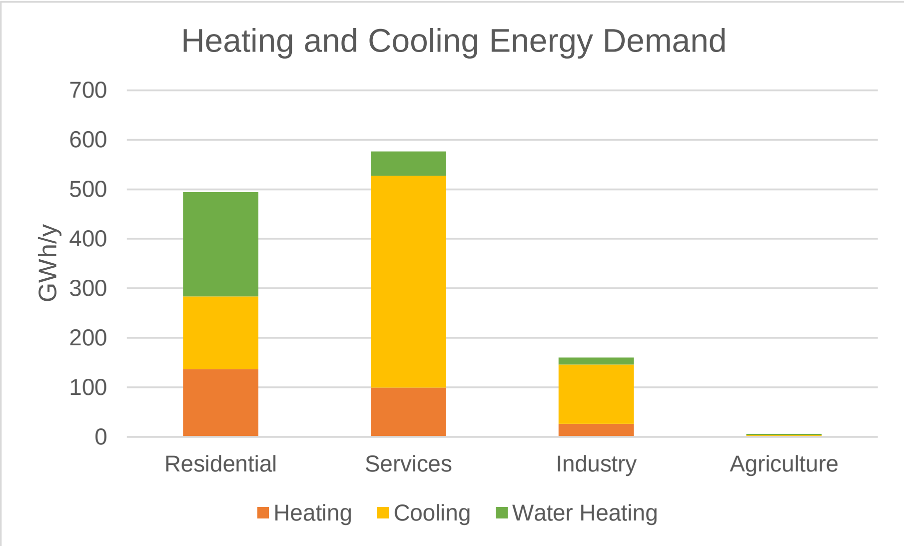

Final Energy Consumption Heating and Cooling
GWh/y
400
350
300
250
200
150
100
50
0
Residential
Services
Industry
Agriculture
Heating
Cooling
Water Heating

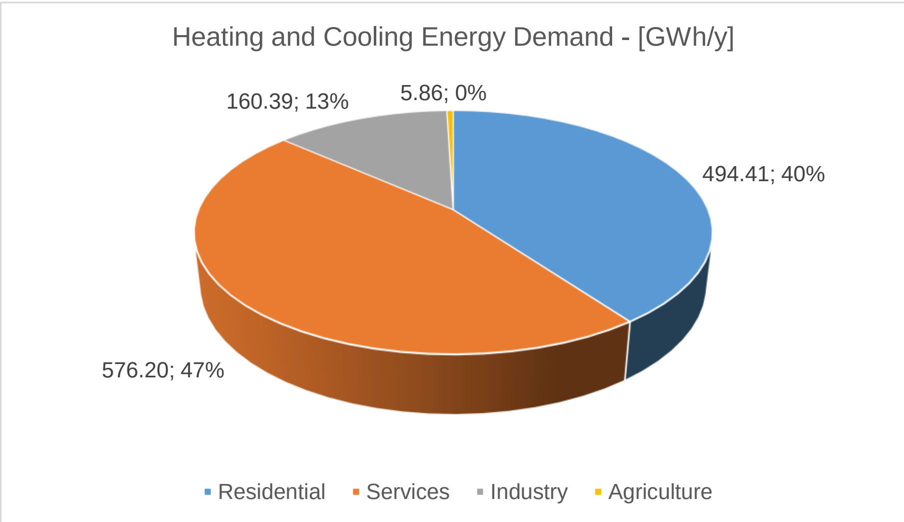

Final Energy Consumption Heating and Cooling - [GWh/y]
69.00
3.75
358.70
254.01
Residential
Services
Industry
Agriculture

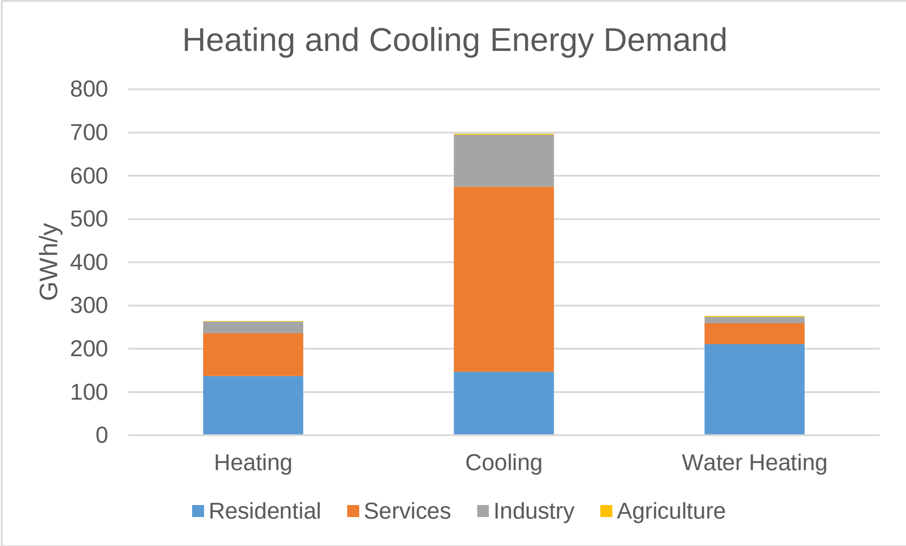

Final Energy Consumption Heating and Cooling
GWh/y
350
300
250
200
150
100
50
0
Heating
Cooling
Water Heating
Residential
Services
Industry
Agriculture

3.3.2 Heating and Cooling Energy Demand

Sector	Heating	Cooling	Water Heating	TOTAL
	GWh/y	GWh/y	GWh/y	GWh/y
Residential	137.10	146.56	210.76	**494.41**
Services	99.13	428.47	48.60	**576.20**
Industry	26.40	119.58	14.41	**160.39**
Agriculture	1.53	2.12	2.21	**5.86**
	264.15	**696.73**	**275.98**	**1,236.87**

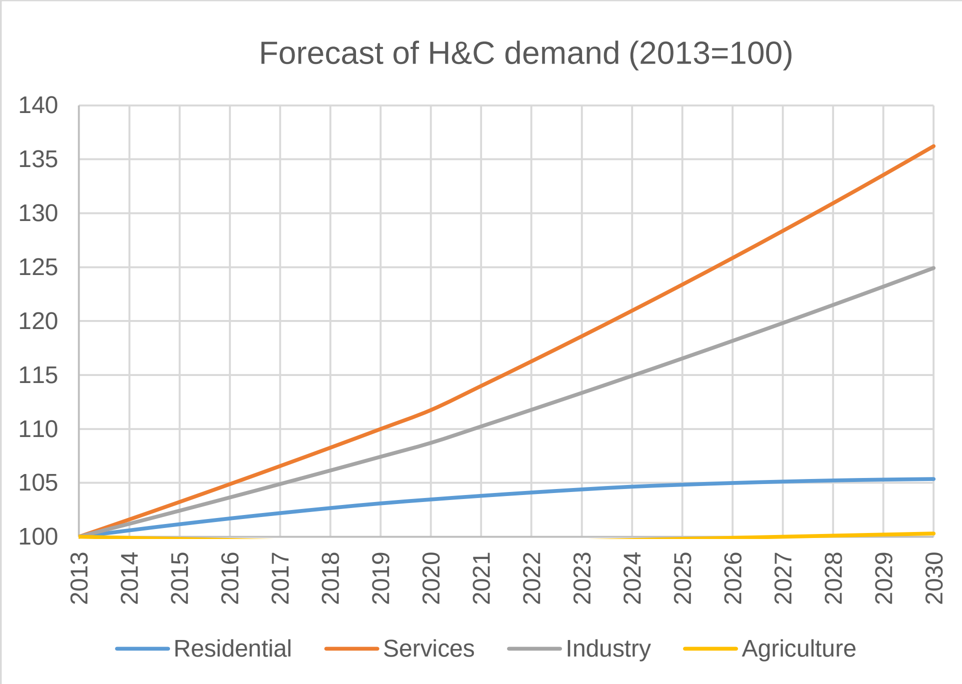





Heating and Cooling Energy Demand
GWh/y
800
700
600
500
400
300
200
100
0
Heating
Cooling
Water Heating
Residential
Services
Industry
Agriculture

4 Sub-Task 2 – Forecast of heating and cooling demand

Aim of this chapter is to present a possible forecast of how the heating and cooling demand obtained within Chapter 3 will change in the next years. The scenarios reported below for the residential, industry, services and agriculture sectors, outline possible scenarios projected up to the year 2030.



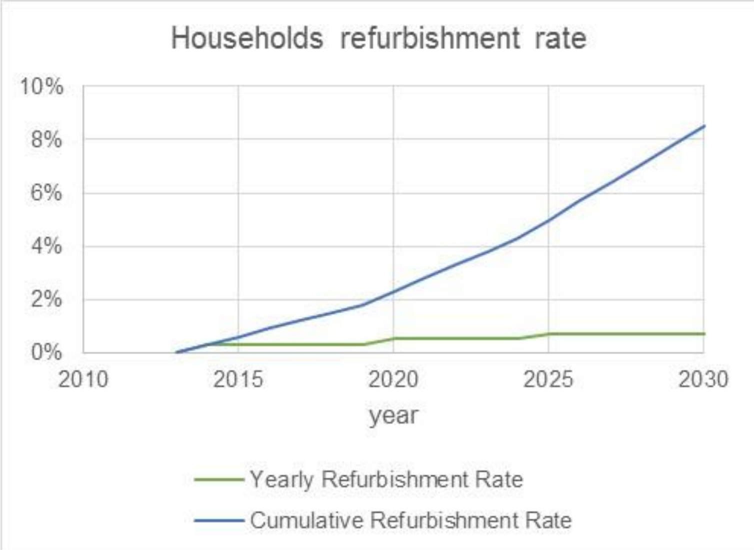
4.1 Residential sector

This paragraph explains the methodology adopted for the projections for the residential sector. As a starting point, the following table summarizes the main results expressed in terms of heating and cooling energy demand (ktoe) achieved within Sub-Task 1.

Sub-Task 1 Results [ktoe]	
Residential sector	**2013**
Heating demand	**11.79**
Cooling demand	**12.60**
Water Heating demand	**18.12**
Total	**42.51**

Starting from the reference number of buildings introduced in 3.2.1.3, characterized by the demand reported in table above, the evolution scenario up to 2030 was determined considering the following factors and hypothesis:

- **Refurbishment rate.** A yearly rate, expressed in terms of percentage of the dwelling stock, was introduced for estimating the portion of households that will be refurbished up to 2030. The introduced yearly rate implies a final portion of refurbished households at the year 2030 of 8.5%, as visible in the chart below.



Refurbished households, thanks to potential investments improving the buildings' performance (insulation, glazing replacement, shadings etc.)[28], are estimated to reduce their energy heating and cooling demand and to save 40% in respect of the not-refurbished ones.

This percentage was estimated as an extrapolation of reported in the publication "*Nearly-zero Energy buildings Plan for Malta"* (Ministry for Transport and Infrastructure, Malta, 2015), that reports:

"[…] existing building stock built prior to the introduction of the first minimum energy requirements in 2007 has an average primary energy demand of 199 kWh/m²yr. If renovated according to the current minimum requirements this demand will go down to 110 kWh/m²yr".

- **New buildings.** The growth of the dwelling stock was estimated considering the indication of the NEEAP[29] (4,444 new residential dwellings approved by MEPA[30] in the year 2010) and the variation rate of building permits given extrapolated by Eurostat data[31]. New buildings are expected to have a lower energy demand in respect of current buildings, of approximately 50%.

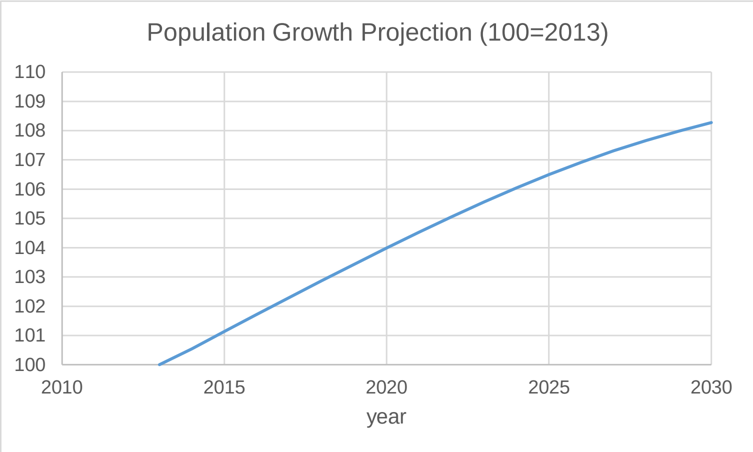
  This percentage was estimated as an extrapolation of reported in the publication "*Nearly-zero Energy buildings Plan for Malta"* (Ministry for Transport and Infrastructure, Malta, 2015), that reports:

  "[…] Samples studies (BRO, dwellings, 2013) have shown that the average delivered energy demand for Space conditioning, hot water, lighting and ventilation

[28] (EU Concerted Action; Maltese Ministry for Resources and Rural Affair, 2012)
[29] (Malta's National Energy Efficiency Action Plan, 2014)
[30] Malta Environment and Planning Authority
[31] Eurostat, [sts_cobp_a]: Building permits - number of dwellings - Residential buildings, except residences for communities

in a typical existing buildings is 59 kWh/m²yr. The respective value for the delivered energy demand in typical new dwellings is 28kWh/m²yr".

- **Water Heater demand.** The growth of water heating demand in the residential sector was linked to the growth of the population rather than the growth of the dwelling stock. For this purpose, the Eurostat projections[32] of the population were used.



The following table summarizes the main parameters used in the simulation.

Parameters	**value**	**units**
Reference number of buildings	161,724	-
Existing building: average H&C demand	0.26	toe/dw
Share of Heating demand	28%	-
Share of Cooling demand	30%	-
Share of Water Heating demand	43%	-
Refurbished building		
Refurbished building: average savings	40%	
Post intervention: average H&C demand	0.16	toe/dw
New buildings		
New residential dwellings 2014	2,400	-
Yearly buildings permits decrease	9%	

The complete forecast trend estimation up to 2030 is reported here below.

[32] Eurostat, [proj_13npms]

Residential sector

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Households Refurbishment																		
Refurbishment Rate	***0.00%***	*0.30%*	*0.30%*	*0.30%*	*0.30%*	*0.30%*	*0.30%*	***0.50%***	*0.50%*	*0.50%*	*0.50%*	*0.50%*	*0.70%*	*0.70%*	*0.70%*	*0.70%*	*0.70%*	***0.70%***
Yearly refurbished household	**0**	485	485	485	485	485	485	**809**	809	809	809	809	1,132	1,132	1,132	1,132	1,132	**1,132**
Total Refurbished	**0**	485	970	1,456	1,941	2,426	2,911	**3,720**	4,528	5,337	6,146	6,954	8,086	9,218	10,350	11,482	12,615	**13,747**
Heating demand	**0.00**	0.02	0.04	0.06	0.08	0.11	0.13	**0.16**	0.20	0.23	0.27	0.30	0.35	0.40	0.45	0.50	0.55	**0.60**
Cooling demand	**0.00**	0.02	0.05	0.07	0.09	0.11	0.14	**0.17**	0.21	0.25	0.29	0.33	0.38	0.43	0.48	0.54	0.59	**0.64**
Not-refurbished households																		
Still not refurbished household	**161,724**	161,239	160,754	160,269	159,784	159,299	158,813	**158,005**	157,196	156,387	155,579	154,770	153,638	152,506	151,374	150,242	149,110	**147,978**
Heating demand	**11.79**	11.75	11.72	11.68	11.65	11.61	11.58	**11.52**	11.46	11.40	11.34	11.28	11.20	11.12	11.03	10.95	10.87	**10.79**
Cooling demand	**12.60**	12.56	12.53	12.49	12.45	12.41	12.38	**12.31**	12.25	12.19	12.12	12.06	11.97	11.88	11.80	11.71	11.62	**11.53**
Water Heating	**18.12**	18.22	18.33	18.43	18.54	18.64	18.74	**18.84**	18.94	19.04	19.13	19.22	19.30	19.38	19.45	19.51	19.57	**19.62**
New households																		
New buildings	**0**	2,400	2,184	1,987	1,809	1,646	1,498	**1,363**	1,240	1,129	1,027	935	850	774	704	641	583	**531**
New building efficiency improvement	***50.00%***	*50.00%*	*50.00%*	*50.00%*	*50.00%*	*50.00%*	*50.00%*	***50.00%***	*50.00%*	*50.00%*	*50.00%*	*50.00%*	*50.00%*	*50.00%*	*50.00%*	*50.00%*	*50.00%*	***50.00%***
Additional Yearly Heating demand	**0.00**	0.09	0.08	0.07	0.07	0.06	0.05	**0.05**	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	**0.02**
Additional Yearly Cooling demand	**0.00**	0.09	0.09	0.08	0.07	0.06	0.06	**0.05**	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.02	0.02	**0.02**
Heating demand	**0.00**	0.09	0.17	0.24	0.31	0.37	0.42	**0.47**	0.51	0.56	0.59	0.63	0.66	0.69	0.71	0.74	0.76	**0.78**
Cooling demand	**0.00**	0.09	0.18	0.26	0.33	0.39	0.45	**0.50**	0.55	0.59	0.63	0.67	0.70	0.73	0.76	0.79	0.81	**0.83**

H&C Energy Demand (ktoe)	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Heating	**11.79**	11.86	11.93	11.99	12.04	12.08	12.12	**12.15**	12.17	12.19	12.20	12.21	12.21	12.21	12.20	12.19	12.18	**12.16**
Cooling	**12.60**	12.68	12.75	12.81	12.87	12.92	12.96	**12.99**	13.01	13.03	13.04	13.06	13.05	13.05	13.04	13.03	13.02	**13.00**
Water Heating	**18.12**	18.22	18.33	18.43	18.54	18.64	18.74	**18.84**	18.94	19.04	19.13	19.22	19.30	19.38	19.45	19.51	19.57	**19.62**
Total	**42.51**	**42.76**	**43.00**	**43.23**	**43.44**	**43.64**	**43.83**	**43.98**	**44.12**	**44.26**	**44.38**	**44.49**	**44.56**	**44.63**	**44.69**	**44.73**	**44.76**	**44.79**

4.2 Industry and Services sector

As a starting point, the following table summarizes the main results expressed in terms of heating and cooling energy demand (ktoe) achieved within Sub-Task 1.

Sub-Task 1 Results [ktoe]	
Industry sector	**2013**
Heating demand	**2.27**
Cooling demand	**10.28**
Water Heating demand	**1.24**
Total	**13.79**

Sub-Task 1 Results [ktoe]	
Services sector	**2013**
Heating demand	**8.52**
Cooling demand	**36.84**
Water Heating demand	**4.18**
Total	**49.54**

Differently from the residential sector, the forecast estimation about heating and cooling demand was carried out with reference to the assumptions adopted in the EU's Energy Trends publications[33]. The EU's Energy Trends publications present energy market scenarios for 2030 and 2050 based on current trends and policies. They highlight possible energy demand, energy prices, greenhouse gas emissions, and other potential developments[34].

In the report *EU Energy Transport and GHG Emissions trends to 2050,* the reference 2013 scenario builds on macroeconomic projections of GDP. The GDP projection assumes a recovery from the current economic crisis, followed by steady GDP growth rates in the medium term assumed 1.6% pa over the period 2015-2030.

In particular, the key economic assumptions for Malta (Appendix 1, page 80) assumes, for the **industry sector** an overall growth rate of the sectorial value added of **1.2%** for the

[33] EU Energy Transport and GHG Emissions trends to 2050 (European Commission, 2014)
[34] http://ec.europa.eu/energy/en/statistics/energy-trends-2050

decade 2010-2020 and **1.4%** for the period 2020-2030. For the **services** (tertiary) sector the same values are estimated respectively **1.6%** and **2.0%**.

REFERENCE 2013

Malta: Key Demographic and Economic Assumptions

	2000	2010	2020	2030	2040	2050	'00-'10	'10-'20	'20-'30	'30-'40	'40-'50
Main Demographic Assumptions											
Population (Million)	0.4	0.4	0.4	0.4	0.4	0.4	0.9	0.0	0.0	-0.2	-0.3
Average household size (persons)	2.9	2.6	2.5	2.5	2.5	2.4	-1.0	-0.3	-0.2	-0.2	-0.1
Gross Domestic Product (in 000 MEuro'10)	**5.3**	**6.1**	**7.1**	**8.6**	**10.2**	**11.3**	**1.5**	**1.5**	**1.9**	**1.7**	**1.1**
Household Expenditure (in Euro'10/capita)	**8524.9**	**9099.6**	**10886.3**	**13449.1**	**16431.3**	**18794.7**	**0.7**	**1.8**	**2.1**	**2.0**	**1.4**
SECTORAL VALUE ADDED (in 000 MEuro'10)		**5.3**	**6.2**	**7.5**	**8.8**	**9.8**		**1.5**	**1.9**	**1.6**	**1.0**
Industry		0.7	0.8	0.9	1.0	1.1		1.2	1.4	1.2	0.5
iron and steel		0.0	0.0	0.0	0.0	0.0		-0.5	1.0	0.5	-0.4
non ferrous metals		0.0	0.0	0.0	0.0	0.0		-0.5	1.0	0.5	-0.4
chemicals		0.1	0.1	0.1	0.2	0.2		2.3	0.7	0.7	0.0
non metallic minerals		0.0	0.0	0.0	0.0	0.0		1.6	1.2	0.7	0.2
paper pulp		0.1	0.1	0.1	0.1	0.1		0.8	1.7	1.4	1.0
food, drink and tobacco		0.1	0.1	0.1	0.1	0.1		1.6	1.8	1.3	0.6
engineering		0.2	0.3	0.3	0.4	0.4		1.2	1.9	1.7	0.7
textiles		0.0	0.0	0.0	0.0	0.0		-0.3	-0.5	-0.6	-0.9
other industries (incl. printing)		0.2	0.2	0.2	0.2	0.2		0.6	1.0	0.9	0.1
Construction		0.2	0.2	0.3	0.3	0.3		1.1	1.2	1.1	0.3
Tertiary		4.3	5.1	6.2	7.4	8.3		1.6	2.0	1.8	1.2
market services		2.7	3.3	4.1	5.0	5.8		2.0	2.3	2.0	1.5
non market services		1.1	1.1	1.3	1.4	1.4		0.6	1.4	1.0	0.1
trade		0.5	0.6	0.7	0.9	1.0		1.8	1.9	1.7	1.2
agriculture		0.1	0.1	0.1	0.1	0.1		-0.1	0.1	0.0	0.0
Energy sector and others		0.1	0.1	0.1	0.1	0.1		-0.5	1.0	0.5	-0.4

These growth rates were applied to the heating and cooling energy demands of the industry and services sectors reported in the tables.

4.3 Agriculture sector

As a starting point, the following table summarizes the main results expressed in terms of heating and cooling energy demand (ktoe) achieved within Sub-Task 1.

Sub-Task 1 Results [ktoe]	
Agricolture sector	**2013**
Heating demand	**0.13**
Cooling demand	**0.18**
Water Heating demand	**0.19**
Total	**0.50**

The forecast estimation about heating and cooling demand was estimated with reference to the assumptions adopted in the EU's Energy Trends publications. In particular, the key economic assumptions for Malta (Appendix 1, page 80) assumes for the agriculture sector an overall growth rate of -0.1% for the decade 2010-2020 and +0.1% for the period 2020-2030.

These growth rates were directly applied to the energy demand in a unique scenario.

The complete forecast trend estimation for the Industry and Services Sector and the Agriculture Sector up to 2030 is reported here below.

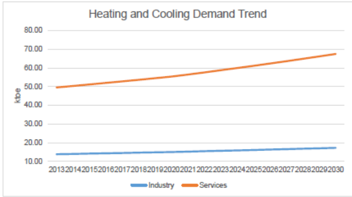
Industry, Services and Agricolture Sectors

Industry		
Value Added yearly growth rate	1.2%	up to 2020 *
	1.4%	up to 2030 *

Services		
Value Added yearly growth rate	1.6%	up to 2020 *
	2.0%	up to 2030 *

Agricolture		
Value Added yearly growth rate	-0.1%	up to 2020 *
	0.1%	up to 2030 *

** European Commission - EU Energy, Transport and GHG emissions trends to 2050*



INDUSTRY

H&C Energy Demand (ktoe)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Heating	2.27	2.30	2.32	2.35	2.38	2.41	2.44	2.47	2.50	2.54	2.57	2.61	2.65	2.68	2.72	2.76	2.80	2.84
Cooling	10.28	10.41	10.53	10.66	10.78	10.91	11.04	11.18	11.33	11.49	11.65	11.82	11.98	12.15	12.32	12.49	12.67	12.84
Water Heating	1.24	1.25	1.27	1.28	1.30	1.32	1.33	1.35	1.37	1.39	1.40	1.42	1.44	1.46	1.48	1.51	1.53	1.55
Total	**13.79**	**13.96**	**14.12**	**14.29**	**14.47**	**14.64**	**14.81**	**14.99**	**15.20**	**15.41**	**15.63**	**15.85**	**16.07**	**16.30**	**16.52**	**16.76**	**16.99**	**17.23**

SERVICES

H&C Energy Demand (ktoe)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Heating	8.52	8.66	8.80	8.94	9.08	9.23	9.38	9.53	9.72	9.91	10.11	10.31	10.52	10.73	10.94	11.16	11.38	11.61
Cooling	36.84	37.43	38.03	38.64	39.26	39.89	40.52	41.17	42.00	42.84	43.69	44.57	45.46	46.37	47.29	48.24	49.20	50.19
Water Heating	4.18	4.25	4.31	4.38	4.45	4.52	4.60	4.67	4.76	4.86	4.96	5.05	5.16	5.26	5.36	5.47	5.58	5.69
Total	**49.54**	**50.34**	**51.14**	**51.96**	**52.79**	**53.64**	**54.49**	**55.37**	**56.47**	**57.60**	**58.76**	**59.93**	**61.13**	**62.35**	**63.60**	**64.87**	**66.17**	**67.49**

AGRICOLTURE

H&C Energy Demand (ktoe)	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Heating	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Cooling	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18	0.18
Water Heating	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Total	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.50**	**0.51**	**0.51**

5 Sub-Task 3 – Technical Potential

The aim of Sub-Task 3 is to analyze the characteristics of the heating and cooling demand and trying to identify the demand that could be satisfied by existing or planned high efficiency cogeneration, district heating or waste heat sources.

Sub-Task 3 builds on the analysis of Sub-Task 1 and 2:

- **Sub-Task 1** established a detailed description of the heating and cooling demand, with sector and geographic breakdown;
- **Sub-Task 2** developed a forecast of how the demand will evolve up to 2020 and 2030, taking into consideration the trends in all major sectors of the economy.

Based on the identified heat demand and heat demand forecast, **Sub-Task 3**[35] identifies those elements of the heat demand that technically could be satisfied by high-efficiency cogeneration, micro-cogeneration and efficient district-heating and cooling. This means establishing the maximum or **technical potential**.

On the other hand, **Sub-Task 4** identifies those parts of the technical potential that can economically be met by high-efficiency cogeneration, including residential micro cogeneration, by the refurbishment of existing and the construction of new generation and industrial installations, by utilizing waste heat, and by refurbishing and building district heating and cooling infrastructures. This is the potential whose benefits exceed the costs. It is the only potential that needs to be achieved. This potential can be called the **economic potential**.

The analysis considered the year 2013 as reference year for all the consumption data, and it started from the outcomes of Sub-Task 1 and Sub-Task 2 as base for all the calculations and simulations. The following paragraphs explore the possibilities of efficient heating and cooling differentiating:

- High-efficiency Cogeneration and district Heating and Cooling;
- Heat recovery.

[35] (Commission Staff Working Document, 2013)

5.1 High-efficiency Cogeneration and district heating and cooling

Co-generation or Combined Heat and Power (CHP)[36] is the simultaneous generation of thermal energy and electricity or mechanical energy by using fossil or renewable fuels, most often natural gas, coal or wood biomass and biogas. CHP saves energy due to the simultaneous production of electricity and heat on-site and thereby preventing major losses that occur at most central electricity production facilities nowadays.

In this introductory paragraph, it is useful to quote the "Checklist for considering CHP" contained in the report (Cogeneration Observatory and Dissemination Europe, 2014)[37]:

- Stable and predictable heat or/and cooling demand for heating or process use on site of at least 4,000 hours per year.
- Appropriate energy market conditions – higher electricity price compared to the fuel price (ratio of at least 2:1).
- Support mechanisms in place, if energy market conditions request additional support: feed-in, certificates, tax relief, subsidies etc.
- Availability of fuel on the location: natural gas, wood biomass, biogas, LPG etc.
- Proper place for installation of CHP unit: room, connections, chimney etc.
- Financial resources: own, loans, energy-contracting, subsidies etc.

The following paragraphs explore the possibilities of High-efficiency Cogeneration in the residential, services and industry sectors. District Heating Networks were applied to one sample industrial area, as reported in 5.1.3.3.2.

5.1.1 Residential sector

The following paragraph reports an estimation of the technical potential of CHP applied to the residential sector. Currently Malta does not have a network of natural gas distribution (a feasibility study considering a number of distribution hubs is still underway), so the analysis considered the installation of **LPG**-fueled units.

The choice of this fuel presupposes a detailed evaluation, which must be carried out case by case, with the aim to evaluate the adequacy and suitability of the location, the sizing of the storage, and the real feasibility of the installation according to the technical and safety regulation constraints.

Fast recent development of micro CHP technologies like gas and Stirling engines, as well as fuel cells, enables the use of cogeneration for efficient heating and electricity supply of single and multifamily buildings in accordance with the close to zero energy building concept (active building). The potential application of micro-CHP Plants in the residential sector followed the following steps:

Step 1 – Identification of a reference micro-CHP unit. The table reports the thermal and electrical capacity of the adopted reference micro-CHP unit.

µCHP reference unit		
Electrical capacity	5.50	kWe
Thermal capacity	12.50	kWt

[36] (Cogeneration Observatory and Dissemination Europe, 2014)
[37] www.code2-project.eu

Step 2 – Identification of the average household size. With the support of the data provided within the Census 2011 and introducing, as parameter, an average room size, it was possible to define a value of average household size.

	Terraced house/ Townhouse	Semi detached house	Fully detached house	Maisonette/ Ground floor tenement	Flat/ Apartment/ Penthouse	Semi /Fully detached farmhouse	Other	Total
***Table 88.** Occupied dwellings by type and locality*								
MALTA	**48,239**	**5,338**	**3,107**	**40,547**	**41,258**	**1,200**	**630**	**140,320**
	34.38%	*3.80%*	*2.21%*	*28.90%*	*29.40%*	*0.85%*	*0.45%*	**100.00%**
Table 109.** Occupied dwellings by type, district and **number of rooms								
Less than 4 rooms	1,891	52	50	5,515	5,709	237	488	**13,941**
4 rooms	5,110	156	111	7,996	9,629	233	85	**23,319**
5 rooms	9,522	593	335	12,810	14,022	249	47	**37,579**
6 rooms	12,546	1,158	546	8,215	7,723	204	6	**30,397**
7 rooms	8,425	1,150	557	3,511	2,671	117	3	**16,433**
More than 7 rooms	10,746	2,228	1,509	2,500	1,505	160	3	**18,651**
	48,239	**5,338**	**3,107**	**40,547**	**41,258**	**1,200**	**630**	**140,320**
Surfaces. m²								
3	56,736	1,571	1,488	165,441	171,255	7,109	14,632	**418,232**
4	204,386	6,246	4,446	319,823	385,147	9,332	3,380	**932,760**
5	476,107	29,668	16,763	640,519	701,095	12,446	2,342	**1,878,940**
6	752,752	69,494	32,736	492,906	463,367	12,234	331	**1,823,820**
7	589,717	80,498	38,963	245,801	186,971	8,166	193	**1,150,308**
8	859,647	178,263	120,728	200,014	120,434	12,786	220	**1,492,093**
	2,939,344	**365,739**	**215,123**	**2,064,505**	**2,028,270**	**62,073**	**21,098**	**7,696,153**

Step 3 – Identification of benchmark consumption value. Starting from the heating and cooling demand calculated within Sub-Task 1, benchmark consumption values were identified.

Total household Heating demand	137.10	GWh/y	*Source: Sub-Task 1*
Total household Water Heating demand	210.76	GWh/y	*Source: Sub-Task 1*
Total household Heating demand	**347.85**	**GWh/y**	
Average specific Heating demand	918	kWh/(dw*y)	
	16.75	kWh/(m²*y)	
Average specific Water Heating demand	1,303	kWh/(dw*y)	
	23.76	kWh/(m²*y)	

Step 4 – Minimum household size. Using the average household size and the benchmark consumption value it was possible to identify the minimum household size necessary for hosting the reference micro-CHP unit introduced above.

Only heating mode		
Months per year	3	mm/y
Hours per day	6	hh/day
Hours per year	**540**	**hh/y**
Electrical Production	**2,970**	**kWh/y**
Thermal Production	6,750	kWh/y
Useful thermal energy	95%	
Thermal Production	**6,413**	**kWh/y**
Sizing based on the heating demand	50%	
Minimum household size	*766*	*m²*
Number of average households	***14***	***-***

Step 5 - Reference micro-CHP unit for Water Heating. The following table reports the additional operating hours that can be considered in case of use of the CHP-unit for water heating production.

Water heating mode		
Number of average households	14	
Daily water heating energy demand	3.57	kWh/(dw*d)
Operating hours per day	4.44	hh/d
Hours per year	**1,622**	**hh/y**

Step 6 – Total Potential. The previous step gave the number of average households that must be considered together for hosting one **r**eference micro-CHP unit.

The final technical potential was calculated replicating the reference unit only in the multi-family buildings obtained from the Census 2011 and in particular for flat/apartment/penthouse. A coefficient for considering the feasibility of the installation was applied considering that the typical multi-dwelling buildings are very rarely composed of 14 units.

Flat/ Apartment/ Penthouse	41,258	
Rate of feasibility	10%	
Number of applicable cases	4,126	
Number of plants	200	
Total installed thermal power	2.50	MWt
Total installed electrical power	1.10	MWe
Thermal energy - Heating	**1.35**	**GWh/y**
Thermal energy - Water Heating	**4.05**	**GWh/y**

5.1.2 Services

This paragraph analyses the technical potential of high-efficiency cogeneration applied to the services sector, and in particular for **hotels** and **hospitals**. Gas turbines and engines (small and micro)[38] are key CHP technologies for sustainable supply of electricity, heat and optional cooling (tri-generation or CCHP) in buildings and other process use in services, especially in health, tourism, etc. Currently Malta does not have a network of natural gas distribution (a feasibility study considering a number of distribution hubs is still underway), so the analysis considered the installation of **LPG** and **gasoil** fueled units.

The choice of this fuel presupposes a detailed evaluation, which must be carried out case by case, with the aim to evaluate the adequacy and suitability of the location, the sizing of the storage, and the real feasibility of the installation according to the technical and safety regulation constraints.

Without actual consumption data about hotels or hospitals, the sizing of the units started from the results of Sub-Task 1, summarized in the tables below, and it was developed through theoretical "Plant Types" associated to typical buildings.

[38] (Cogeneration Observatory and Dissemination Europe, 2014)

Sub-Task 1 Results		
Hotels		
Heating demand	25.55	GWh/y
Cooling demand	83.07	GWh/y
Water heating	23.03	GWh/y
Hospitals		
Heating demand	5.75	GWh/y
Cooling demand	20.81	GWh/y
Water heating	3.36	GWh/y

In particular, for studying the application of CHP through "Plant types", this energy demand was distributed considering the total number of hotels and hospitals in Malta, thus obtaining the demand referred to some typical buildings. The choice of the CHP units considered the sizes and the technical features reported in the following table.

Thermal Power	Electrical Power	Cooling Power	Cost	Efficiencies		Consumption	
						Gasoil	LPG
kWt	*kWe*	*kWc*	*€/kWe*	*η el*	η tot	l/h	
45	35	32	€ 2,600	39%	88%	8.92	14.41
55	49	39	€ 2,500	40%	85%	12.08	19.52
120	110	84	€ 2,100	40%	83%	27.11	43.81
180	170	126	€ 2,000	42%	87%	39.68	64.13
220	210	154	€ 1,900	43%	87%	48.52	78.42
280	270	196	€ 1,800	40%	81%	66.87	108.06
320	300	224	€ 1,800	40%	82%	74.30	120.07
400	380	280	€ 1,700	40%	83%	92.31	149.18
530	500	371	€ 1,600	41%	85%	119.68	193.41

5.1.2.1 Hospitals

The paragraph analyses the technical potential achievable with CHP Plants installed in the hospitals sector. In particular, the configuration refers to co or tri-generation plants (CHP combined heat and power or CCHP - combined cooling, heat and power).

The analysis started from the number of hospitals[39] assuming a number of bed places for each hospital in the Islands. The energy demand obtained within Sub-Task 1 was then distributed into the several building types proportionally with the number of bed places for each type.

Type	Number of establishments	Bedplaces	Share	Heating Demand		Cooling Demand		Water Heating Demand	
				Total	Avg	Total	Avg	Total	Avg
				GWh/y	MWh/(y*est)	GWh/y	MWh/(y*est)	GWh/y	MWh/(y*est)
Hospital ≈ 50 beds	3	150	8.22%	0.47	158	1.71	570	0.28	92
Hospital ≈ 150 beds	2	320	17.53%	1.01	504	3.65	1,824	0.59	295
Hospital ≈ 500 beds	1	530	29.04%	1.67	1,671	6.04	6,042	0.98	977
Hospital ≈ 800 beds	1	825	45.21%	2.60	2,600	9.41	9,405	1.52	1,520
Total	**7**	**1,825**	**100%**	**5.75**		**20.81**		**3.36**	

Three different hypothesis **reference CHP Plants** were then sized, through the thermal load profiles, for three different types of hospital building:

- **Type 1:** Hospital with about nr.150 beds;

39 (Ministry for Transport and Infrastructure, Malta, 2015), page 15, reports seven hospitals in 2013.

- **Type 2:** Hospitals with about nr.500 beds;
- **Type 3:** Hospitals with about nr.800 beds.

The thermal load profiles were extrapolated starting from the energy demand of each building type (Sub-Task 1) and the distribution during the year of the Heating Degree Days[40] and the Cooling Degree Days[41] for Malta.

Type 1

		Heating				Cooling					Water Heating		
		HDD	MWh	Avg kWt	hh/m	CDD	MWh	Avg kWc	Avg kWt	hh/m	MWh	Avg kWt	hh/m
Jan	31	131	155	502	310						25	162	155
Feb	28	147	175	626	280						23	162	140
Mar	31	59	70	226	310						25	162	155
Apr	30					0	0	0	0	0	24	162	150
May	31					0	0	0	0	0	25	162	155
June	30					0	0	0	0	0	24	162	150
July	31					0	0	0	0	0	25	162	155
Aug	31					0	0	0	0	0	25	162	155
Sept	30					0	0	0	0	0	24	162	150
Oct	31					0	0	0	0	0	25	162	155
Nov	30					0	0	0	0	0	24	162	150
Dec	31	87	104	334	310						25	162	155
	365	**425**	**504**	**-**	**1,210**	**0**	**0**	**-**	**-**	**0**	**295**		**1,825**

Type 2

		Heating				Cooling					Water Heating		
		HDD	MWh	Avg kWt	hh/m	CDD	MWh	Avg kWc	Avg kWt	hh/m	MWh	Avg kWt	hh/m
Jan	31	131	515	1,661	310						83	535	155
Feb	28	147	580	2,072	280						75	535	140
Mar	31	59	232	749	310						83	535	155
Apr	30					0	0	0	0	0	80	535	150
May	31					0	0	0	0	0	83	535	155
June	30					0	0	0	0	0	80	535	150
July	31					0	0	0	0	0	83	535	155
Aug	31					0	0	0	0	0	83	535	155
Sept	30					0	0	0	0	0	80	535	150
Oct	31					0	0	0	0	0	83	535	155
Nov	30					0	0	0	0	0	80	535	150
Dec	31	87	343	1,107	310						83	535	155
	365	**425**	**1,671**	**-**	**1,210**	**0**	**0**	**-**	**-**	**0**	**977**		**1,825**

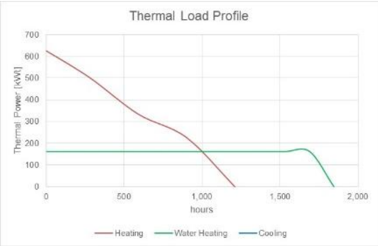
Type 3

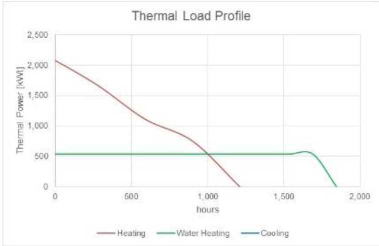
		Heating				Cooling					Water Heating		
		HDD	MWh	Avg kWt	hh/m	CDD	MWh	Avg kWc	Avg kWt	hh/m	MWh	Avg kWt	hh/m
Jan	31	131	802	2,586	310						129	833	155
Feb	28	147	903	3,225	280						117	833	140
Mar	31	59	362	1,166	310						129	833	155
Apr	30					9	94	312	446	300	125	833	150
May	31					35	365	1,176	1,680	310	129	833	155
June	30					103	1,073	3,576	5,109	300	125	833	150
July	31					195	2,031	6,552	9,359	310	129	833	155
Aug	31					220	2,291	7,392	10,559	310	129	833	155
Sept	30					142	1,479	4,930	7,043	300	125	833	150
Oct	31					99	1,031	3,326	4,752	310	129	833	155
Nov	30					100	1,042	3,472	4,960	300	125	833	150
Dec	31	87	534	1,723	310						129	833	155
	365	**425**	**2,600**	**-**	**1,210**	**903**	**9,405**	**-**	**-**	**2,440**	**1,520**		**1,825**

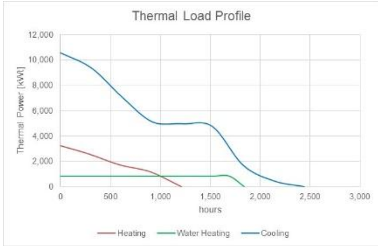
Thermal Load Profiles

Type 1 **Type 2** **Type 3**

[40] Source: Eurostat, http://ec.europa.eu/eurostat/web/energy/data
[41] www.degreedays.net (using temperature data from www.wunderground.com)







The sizing of the CHP units was made assuming these thermal load profiles and trying to maximize, in choice of the units' thermal capacity, the number of yearly operating hours. For this reason, the chosen thermal capacity of the units will not be maximum thermal load of the building, but a lower value that can guarantee the highest operating hours during the year.

Matching the number of hospitals and the thermal capacity parameters, it is possible to evaluate the overall technical potential of installation in the hospitals sector.

Type	PLANT TYPE				Technical Potential				
	System	Elec. Power	Thermal Power	Cooling Power	Technical Feasibility Coefficient	Nr of plants	Elec. Power	Thermal Power	Cooling Power
		kWe	kWt	kWc			MWe	MWt	MWc
Hospital ≈ 50 beds	-	-	-	-	-	-	-	-	-
Hospital ≈ 150 beds	CHP	35	45	0	50%	1	0.04	0.05	0.00
Hospital ≈ 500 beds	CHP	210	220	0	100%	1	0.21	0.22	0.00
Hospital ≈ 800 beds	CCHP	380	400	280	100%	1	0.38	0.40	0.28
							0.63	**0.67**	**0.28**

Type	Energy Production			% of the total demand	
	Electricity	Th. Energy Heating	Cooling Energy	Th. Energy Heating	Cooling Energy
	MWhe	MWht	MWhc	%	%
Hospital ≈ 50 beds	-	-	-	-	-
Hospital ≈ 150 beds	106	137	0	8.5%	0.0%
Hospital ≈ 500 beds	637	668	0	25.2%	0.0%
Hospital ≈ 800 beds	2,081	1,214	683	29.5%	7.3%
	2,824	**2,018**	**683**	**22.1%**	**3.3%**

5.1.2.2 Hotels

The paragraph analyses the technical potential achievable with gasoil-fueled CHP Plants installed in the hotels sector. In particular, the configuration refers to co or tri-generation plants (CHP combined heat and power or CCHP - combined cooling, heat and power).

The hotels sector, the analysis started from the overall number of establishments[42] and the number of rooms in the Islands. The applied methodology is the same used for the "Hospitals" buildings.

[42] Source: Eurostat [tour_cap_nats]

Type	Number of establishments *(Eurostat)*	Share	Bedplaces	Heating Demand Total	Heating Demand Avg	Cooling Demand Total	Cooling Demand Avg	Water Heating Demand Total	Water Heating Demand Avg
				GWh/y	MWh/(y*est)	GWh/y	MWh/(y*est)	GWh/y	MWh/(y*est)
Less than 25 rooms	27	17.65%	839	0.52	19.07	1.67	62.01	0.46	17.19
25-99 rooms	62	40.52%	7,771	4.77	76.94	15.51	250.12	4.30	69.35
100-249 rooms	42	27.45%	14,630	8.98	213.82	29.19	695.11	8.09	192.74
250 or more	22	14.38%	18,386	11.29	513.00	36.69	1,667.72	10.17	462.42
Total	**153**	**100.00%**	**41,626**	**25.55**		**83.07**		**23.03**	

Three different **reference CHP Plants** were then sized, starting from the thermal load profiles, for three different types of hotel:

- **Type 1:** 25-99 rooms;
- **Type 2:** 100-249 rooms;
- **Type 3:** 250 or more.

Type 1

		Heating				Cooling					Water Heating		
		HDD	MWh	Avg kWt	hh/m	CDD	MWh	Avg kWc	Avg kWt	hh/m	MWh	Avg kWt	hh/m
Jan	31	131	23.72	153	155						4	41	93
Feb	28	147	26.72	191	140						5	54	84
Mar	31	59	10.70	69	155						5	52	93
Apr	30					0	0.00	0	0	0	6	65	90
May	31					0	0.00	0	0	0	6	69	93
June	30					0	0.00	0	0	0	7	76	90
July	31					0	0.00	0	0	0	7	77	93
Aug	31					0	0.00	0	0	0	7	79	93
Sept	30					0	0.00	0	0	0	7	80	90
Oct	31					0	0.00	0	0	0	7	71	93
Nov	30					0	0.00	0	0	0	5	56	90
Dec	31	87	15.80	102	155						4	40	93
	365	**425**	**76.94**	**-**	**605**	**0**	**0.00**	**-**	**-**	**0**	**69.35**		**1,095**

Type 2

		Heating				Cooling					Water Heating		
		HDD	MWh	Avg kWt	hh/m	CDD	MWh	Avg kWc	Avg kWt	hh/m	MWh	Avg kWt	hh/m
Jan	31	131	65.92	425	155						11	113	93
Feb	28	147	74.26	530	140						13	150	84
Mar	31	59	29.73	192	155						14	146	93
Apr	30					0	0.00	0	0	0	16	181	90
May	31					0	0.00	0	0	0	18	191	93
June	30					0	0.00	0	0	0	19	212	90
July	31					0	0.00	0	0	0	20	214	93
Aug	31					0	0.00	0	0	0	20	220	93
Sept	30					0	0.00	0	0	0	20	221	90
Oct	31					0	0.00	0	0	0	18	197	93
Nov	30					0	0.00	0	0	0	14	157	90
Dec	31	87	43.92	283	155						10	112	93
	365	**425**	**213.82**	**-**	**605**	**0**	**0.00**	**-**	**-**	**0**	**192.74**		**1,095**

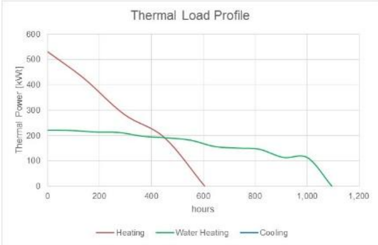
Type 3

		Heating				Cooling					Water Heating		
		HDD	MWh	Avg kWt	hh/m	CDD	MWh	Avg kWc	Avg kWt	hh/m	MWh	Avg kWt	hh/m
Jan	31	131	158.15	1,020	155						25	271	93
Feb	28	147	178.16	1,273	140						30	360	84
Mar	31	59	71.32	460	155						32	349	93
Apr	30					9	16.62	69	99	240	39	435	90
May	31					35	64.64	261	372	248	43	457	93
June	30					103	190.23	793	1,132	240	46	508	90
July	31					195	360.14	1,452	2,075	248	48	512	93
Aug	31					220	406.31	1,638	2,340	248	49	527	93
Sept	30					142	262.25	1,093	1,561	240	48	530	90
Oct	31					99	182.84	737	1,053	248	44	472	93
Nov	30					100	184.69	770	1,099	240	34	376	90
Dec	31	87	105.37	680	155						25	269	93
	365	**425**	**513.00**	**-**	**605**	**903**	**1,667.72**	**-**	**-**	**1,952**	**462.42**		**1,095**

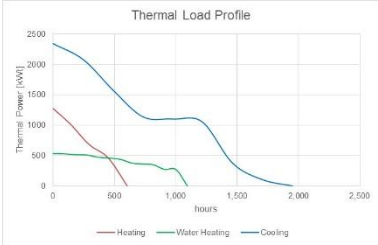
Thermal Load Profiles

Type 1

Type 2



Type 3



Matching the number of hotels and the thermal capacity parameters, it is possible to evaluate the overall technical potential of installation in the hotels sector.

Type	PLANT TYPE				Technical Potential				
	System	Elec. Power	Thermal Power	Cooling Power	Technical Feasibility Coefficient	Nr of plants	Elec. Power	Thermal Power	Cooling Power
		kWe	kWt	kWc			MWe	MWt	MWc
Less than 25 rooms	-	-	-	-	-	-	-	-	-
25-99 rooms	CHP	35	45	0	20%	12	0.43	0.56	0.00
100-249 rooms	CHP	110	120	0	40%	17	1.85	2.02	0.00
250 or more	CCHP	300	320	224	50%	11	3.30	3.52	2.46
Total						**40**	**5.58**	**6.09**	**2.46**

Type	Energy Production			% of the total demand	
	Electricity	Th. Energy Heating	Cooling Energy	Th. Energy Heating	Cooling Energy
	MWhe	MWht	MWhc	%	%
Less than 25 rooms	-	-	-	-	-
25-99 rooms	738	949	0	10.5%	0.0%
100-249 rooms	3,142	3,427	0	20.1%	0.0%
250 or more	12,052	5,984	4,810	27.9%	13.1%
Total	**15,931**	**10,360**	**4,810**	**21.3%**	**5.8%**

5.1.3 Industry

This paragraph analyses the technical potential of high-efficiency cogeneration (combined with district Heating and Cooling) applied to the industry sector. CHP units[43] can provide a significant share of steam, hot water and hot air in process industry for process use, heating and cooling and a large share of electricity demand by use of gas and steam turbines, internal combustion engines, ORC etc. Biomass and biogas CHP applications using renewable industrial waste products offer optimal resource efficiency and economic benefits for the company.

In particular, the following paragraphs explore the possibilities of efficient heating and cooling that could be implemented in the industry sector considering:

- **Existing Biogas Facilities**: infrastructures using bio-waste already installed and operating in the islands;

- **New potential biogas facilities**: projects making use of biogas from waste management, which potentially may be implemented. It is important to highlight that the realization of such kind of facilities strictly depends on:

[43] (Cogeneration Observatory and Dissemination Europe, 2014)

- The waste strategy that is still being developed;
- The studies and evaluations undertaken by the national agricultural department.

- **CHP Plants** fueled with LPG.

5.1.3.1 Existing Biogas Facilities

As highlighted by (CODE2 Cogeneration Observatory and Dissemination Europe, July 2014) and according to the report "Malta Indicative National Energy Efficiency Target for 2020 in accordance with Article 3 of Directive 2012/27/EU", *"one of the potential sectors for the development of CHP is the waste sector".*

The table[44] below reports the facilities, already existing on the Maltese Islands, which produces energy from bio-waste treatment.

Location	Facility	Date Commissioned	Annual capacity	Installed capacity	Thermal energy production	Electricity production
				MWe	GWht	GWhe
Sant'Antnin, Marsascala	MBT	2010	35,000 tons	1.8	2.2	2.5
Ta' Barkat	MBT	2013	n.a.	0.991	5.14	4.3
Ghallis, Maghtab	Malta North MBT	2015	41,000 tons	*calculated*	*calculated*	*calculated*
Ghallis, Maghtab	Landfill	2006	280,000 m³	0.2	1.9	1.3
			Total →	**2.9**	**9.2**	**8.1**

The analysis of the facilities and of the available data – reported in the following paragraphs - showed that currently the thermal energy produced by these plants is mostly used for the systems' internal processes.

Without this internal use, the heat required for the processes should be produced with traditional technologies (i.e.: efficient boilers fuelled by fossil fuels) with a cost of the thermal energy estimated as follows[45].

Liquefied Petroleum Gas

LPG		
Net calorific value	46.15	GJ/ton
	0.046	TJ/ton
	0.013	GWh/ton
	12.82	kWh/kg
Fuel density	0.5222	kg/l
Fuel Price	**€ 0.96**	**/kg**
	€ 0.50	**/liter**
Calorific Value	**6.69**	**kWh/l**
Conversion Efficiency	95%	
Heating Energy Price	**€ 0.079**	**/kWh**

Gasoil

Gasoil		
Net calorific value	43.38	GJ/ton
	0.043	TJ/ton
	0.012	GWh/ton
	12.05	kWh/kg
Fuel density	0.8439	kg/l
Fuel Price	**€ 1.05**	**/liter**
Calorific Value	**10.17**	**kWh/l**
Conversion Efficiency	95%	
Heating Energy Price	**€ 0.109**	**/kWh**

Furthermore, the very limited amount of thermal energy available for a possible export does not seem sufficient to justify the realization of infrastructures, such as district heating networks, for exporting the produced thermal energy.

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[44] Source: MEH
[45] Price of LPG: elaboration of MEH, August 2015
Price of Gasoil: http://www.enemalta.com.mt/index.aspx?cat=2&art=7&art1=230, August 2015

5.1.3.1.1 Sant'Antnin, Marsascala

The system is located at Sant'Antnin Waste Treatment Plant (1.7 MW), the main waste treatment plant in Malta. The Sant'Antnin Waste Treatment Plant includes a biological treatment plant for the production of biogas through the anaerobic digestion of biodegradable municipal solid waste.

The biogas produced is used by a combustion engine; the excess of power is fed to the grid while the heat is currently used in part for internal process and in part delivered to a nearby swimming pool. This CHP plants, licensed on October 2011, consists of two engines: one capable of generating 1 MW_e, and a second capable of generating 0.7 MW_e.

5.1.3.1.2 Ta' Barkat

The following table reports the results of the analysis carried out on the Ta' Barkat facilities, consisting of three reciprocating engines fuelled by biogas. The figures shows that the thermal energy is almost all used in the internal phases of the process, and so that there is not a significant potential use of the heat produced.

Description	units	Generator A	Generator B	Generator C	TOTAL
Type of engine	-	Reciprocating	Reciprocating	Reciprocating	-
Biogas Net Calorific Value	*MJ/m³*	23	23	23	-
	kWh/m³	6.39	6.39	6.39	-
Operating hours 2013	*hh/y*	4,734	4,611	3,770	-
Electricity Production 2013	*GWh/y*	1.56	1.52	1.25	**4.33**
Electrical Power	***kWe***	**330**	**330**	**332**	**991**
Electric Efficiency	*%*	37.10%	37.10%	37.10%	-
Consumption 2013	*GWh/y*	4.20	4.10	3.37	**11.67**
	m³/y	658,098	641,224	527,322	**1,826,644**
Ratio Thermal power/Electrical power	-	1.19	1.19	1.19	-
Thermal Power	*kWt*	391	391	393	1,175
Thermal Energy Production 2013	***GWh/y***	**1.85**	**1.80**	**1.48**	**5.14**
Overall plant efficiency	*%*	81.10%	81.10%	81.10%	-
Output of USED Thermal Energy	***GWh/y***	**1.85**	**1.80**	**1.48**	**5.14**
Available Thermal Energy	***GWh/y***	**0**	**0**	**0**	**0.00**

5.1.3.1.3 Ghallis-Maghtab

The available information revealed how the heat produced by the facility is mostly used to dry-up the compost from which the biogas is generated.

A new potential CHP plant powered by the biogas obtained by the Malta North MBT Mechanical Biological Treatment may be realized. Based on the above-introduced annual capacity of 41,000 tons, the potential capacity is estimated in approximately **0.720 kW_e** and **0.708 kW_t**.

However, the use of the thermal energy produced by this new potential facility in Ghallis-Maghtab is strictly subjected to the identification of a possible area that can use the energy produced for heating purposes.

The nearest area (highlighted in the map) is mostly formed by warehouses and garages and so it is not and ideal candidate for the use of thermal energy.

5.1.3.2 New potential Biogas facilities

The potential amount of biogas from waste currently producible on the island have been obtained from the Report "Analysis of the potential of small scale energy emanating from waste" developed under Assignment I – Task 2 – Sub-Task 6. The quantities involved are listed below.

MASS BALANCE OF THE ANAEROBIC DIGESTION PLANT

FLUX TYPOLOGY	MATERIALS		QUANTITIES	
			ton/dwork	t/y
INPUT MATERIALS	BIOWASTE		12.86	3,986.07
	WATER		5.14	1,594.43
	TOTAL		18.00	5,580.50
OUTPUT MATERIALS	PRODUCTS	BIOGAS	1.44	474.34
		DIGESTATE	7.14	2,212.27
	WASTE	WATER	7.92	2,455.42
		SCREENINGS AND SAND	1.41	438.47
	TOTAL		17.91	5,580.50

For a detailed description of the process, please refer to the related Report. Based on the above values, the study identified the possibility for the creation of three new **Mechanical Biological Treatment** plants (MBTs) of equal size, without associating a specific location.

*In order to use all the available biogas in the operational mode of high-efficiency cogeneration, the assumption here is to deploy the MBT to service – with district heating network - of **industrial areas** needing thermal energy for winter heating and for industrial processes demand.*

*As introduced above, it is important to highlight that the realization of such kind of facilities strictly depends on the **waste strategy** that is still being developed and the evaluations undertaken by the national **agricultural department**.*

The placing of the MBTs around the industrial zones causes fewer problems in terms of noise and odour emissions. Hence, in this case the MBTs can be placed immediately next to the CHP system avoiding the necessity to realize a biogas pipeline connecting the MBT to the point where the biogas is used for heating production purposes.

The quoted document presents a case study of a CHP system with technical features and economic analysis. This case study takes the following assumptions:

- Energy production of the system guaranteed by a biogas fueled co-generator with electrical power of **250 kW** and thermal power of **290 kW**;
- Operation of about 3,960 hours/year;
- Average electrical efficiency of 39%.

5.1.3.3 LPG-fueled CHP Plants

The technical potential of CHP in the industry sector was evaluated considering the hypothesis and assumptions introduced for the other sectors. The analysis considered two different cases:

1. The installation of a CHP unit for serving a single industry;
2. A district heating network – in combination with a CHP Plant – placed in an existing industrial area.

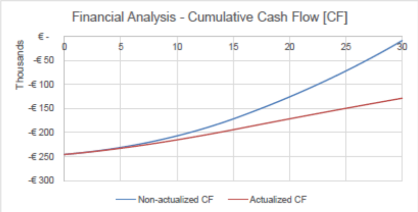
The use of LPG presupposes a detailed evaluation, which must be carried out case by case, with the aim to evaluate the adequacy and suitability of the location, the sizing of the storage, and the real feasibility of the installation according to the technical and safety regulation constraints.

5.1.3.3.1 Single industry CHP unit

In absence of actual consumption data about a specific industry activity, the analysis aimed to give a general evaluation in order to highlight cases and possibilities in the industry sector that can make the CHP installations viable in a cost-effective way. As an assumption, the calculation and the financial analysis presented below started from a CHP unit characterized by an electrical power of **110 kWe** and **120 kWt**.

Plant type

Year	Revenues [Electricity]	Savings [H&C]	Fuel cost	O&M cost	Investment	Financial costs	Cash Flow [CF]	Cumulative Non-actualized CF	Actualized CF	Net Present Value
0	€ -	€ -	€ -	€ -	-€ 245,800	€ -	-€ 245,800	-€ 245,800	-€ 245,800	-€ 245,800
1	€ 23,064	€ 29,583	-€ 45,370	-€ 2,090	€ -	-€ 2,950	€ 2,238	-€ 243,562	€ 2,152	-€ 243,648
2	€ 23,621	€ 30,207	-€ 46,327	-€ 2,132	€ -	-€ 2,802	€ 2,567	-€ 240,995	€ 2,374	-€ 241,274
3	€ 24,191	€ 30,844	-€ 47,304	-€ 2,174	€ -	-€ 2,649	€ 2,908	-€ 238,087	€ 2,585	-€ 238,689
4	€ 24,775	€ 31,495	-€ 48,302	-€ 2,218	€ -	-€ 2,490	€ 3,260	-€ 234,826	€ 2,787	-€ 235,902
5	€ 25,373	€ 32,160	-€ 49,321	-€ 2,262	€ -	-€ 2,324	€ 3,625	-€ 231,201	€ 2,980	-€ 232,922
6	€ 25,986	€ 32,838	-€ 50,362	-€ 2,308	€ -	-€ 2,152	€ 4,003	-€ 227,198	€ 3,163	-€ 229,759
7	€ 26,613	€ 33,531	-€ 51,425	-€ 2,354	€ -	-€ 1,973	€ 4,393	-€ 222,805	€ 3,339	-€ 226,420
8	€ 27,256	€ 34,238	-€ 52,510	-€ 2,401	€ -	-€ 1,786	€ 4,798	-€ 218,007	€ 3,506	-€ 222,915
9	€ 27,914	€ 34,961	-€ 53,617	-€ 2,449	€ -	-€ 1,592	€ 5,216	-€ 212,791	€ 3,665	-€ 219,250
10	€ 28,588	€ 35,698	-€ 54,749	-€ 2,498	€ -	-€ 1,391	€ 5,649	-€ 207,142	€ 3,816	-€ 215,434
11	€ 29,278	€ 36,452	-€ 55,904	-€ 2,548	€ -	-€ 1,181	€ 6,097	-€ 201,045	€ 3,960	-€ 211,473
12	€ 29,984	€ 37,221	-€ 57,083	-€ 2,599	€ -	-€ 963	€ 6,560	-€ 194,485	€ 4,097	-€ 207,376
13	€ 30,708	€ 38,006	-€ 58,288	-€ 2,651	€ -	-€ 736	€ 7,040	-€ 187,445	€ 4,228	-€ 203,148
14	€ 31,449	€ 38,808	-€ 59,517	-€ 2,704	€ -	-€ 500	€ 7,536	-€ 179,909	€ 4,352	-€ 198,796
15	€ 32,209	€ 39,627	-€ 60,773	-€ 2,758	€ -	-€ 255	€ 8,049	-€ 171,860	€ 4,470	-€ 194,327
16	€ 32,986	€ 40,463	-€ 62,055	-€ 2,813	€ -	€ -	€ 8,581	-€ 163,279	€ 4,581	-€ 189,745
17	€ 33,782	€ 41,316	-€ 63,364	-€ 2,869	€ -	€ -	€ 8,865	-€ 154,414	€ 4,551	-€ 185,194
18	€ 34,598	€ 42,188	-€ 64,701	-€ 2,927	€ -	€ -	€ 9,158	-€ 145,256	€ 4,521	-€ 180,673
19	€ 35,433	€ 43,078	-€ 66,066	-€ 2,985	€ -	€ -	€ 9,460	-€ 135,796	€ 4,490	-€ 176,183
20	€ 36,289	€ 43,987	-€ 67,460	-€ 3,045	€ -	€ -	€ 9,771	-€ 126,025	€ 4,459	-€ 171,724
21	€ 37,165	€ 44,915	-€ 68,883	-€ 3,106	€ -	€ -	€ 10,090	-€ 115,935	€ 4,428	-€ 167,296
22	€ 38,062	€ 45,863	-€ 70,337	-€ 3,168	€ -	€ -	€ 10,420	-€ 105,515	€ 4,397	-€ 162,899
23	€ 38,981	€ 46,830	-€ 71,821	-€ 3,231	€ -	€ -	€ 10,759	-€ 94,756	€ 4,365	-€ 158,534
24	€ 39,922	€ 47,818	-€ 73,336	-€ 3,296	€ -	€ -	€ 11,108	-€ 83,648	€ 4,333	-€ 154,201
25	€ 40,885	€ 48,827	-€ 74,883	-€ 3,362	€ -	€ -	€ 11,467	-€ 72,181	€ 4,302	-€ 149,899
26	€ 41,872	€ 49,857	-€ 76,463	-€ 3,429	€ -	€ -	€ 11,837	-€ 60,343	€ 4,270	-€ 145,630
27	€ 42,883	€ 50,909	-€ 78,076	-€ 3,497	€ -	€ -	€ 12,218	-€ 48,125	€ 4,237	-€ 141,392
28	€ 43,918	€ 51,983	-€ 79,724	-€ 3,567	€ -	€ -	€ 12,610	-€ 35,515	€ 4,205	-€ 137,187
29	€ 44,978	€ 53,080	-€ 81,406	-€ 3,639	€ -	€ -	€ 13,014	-€ 22,501	€ 4,173	-€ 133,014
30	€ 46,064	€ 54,200	-€ 83,123	-€ 3,712	€ -	€ -	€ 13,429	-€ 9,072	€ 4,141	-€ 128,873
	€ 998,828	€ 1,220,983	-€ 1,872,551	-€ 84,787	-€ 245,800	-€ 25,744	-€ 9,072	-€ 4,829,516	-€ 128,873	



Variation of NPV		Fuel Price [€/l]			
		€ 0.40	€ 0.45	€ 0.50	€ 0.60
Discount rate [%]	3%	€ 163,519	€ 50,678	-	-
	4%	€ 102,141	€ 4,043	-	-
	5%	€ 51,293	-	-	-
	6%	€ 8,859	-	-	-

Variation of NPV		Electricity Price or Feed-in Tariff [€/kWh]			
		€ 0.10	€ 0.15	€ 0.17	€ 0.25
Discount rate [%]	3%	-	€ 120,223	€ 232,440	€ 681,310
	4%	-	€ 64,089	€ 161,437	€ 550,828
	5%	-	€ 17,590	€ 102,732	€ 443,299
	6%	-	-	€ 53,840	€ 354,052

Variation of NPV		Electricity Price or Feed-in Tariff [€/kWh]			
		€ 0.10	€ 0.15	€ 0.17	€ 0.25
Heat Value [€/kWh]	€ 0.06	-	-	-	€ 204,442
	€ 0.08	-	-	-	€ 309,762
	€ 0.10	-	-	€ 25,690	€ 415,081
	€ 0.12	-	€ 33,662	€ 131,010	€ 520,401

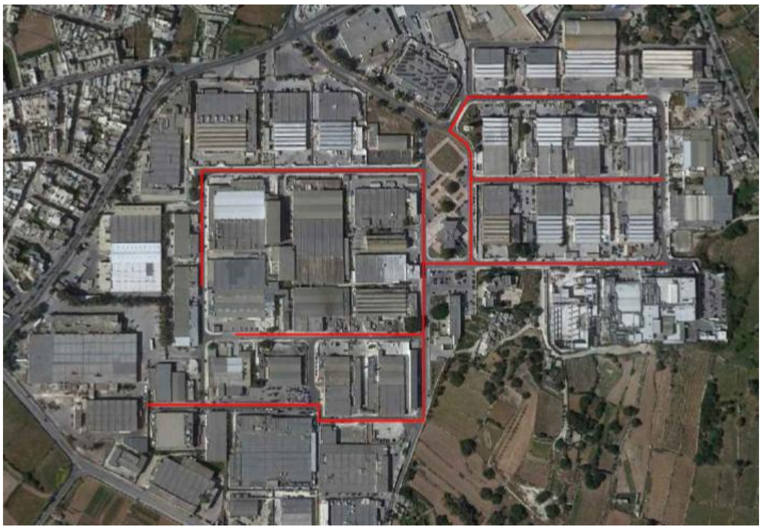
Variation of NPV		Specific Investment Cost [€/kWe]			
		€ 1,500	€ 2,000	€ 2,500	€ 3,000
Elec. price [€/kWh]	€ 0.10	-	-	-	-
	€ 0.15	€ 135,627	€ 76,012	€ 16,397	-
	€ 0.17	€ 232,975	€ 173,360	€ 113,745	€ 54,130
	€ 0.25	€ 622,366	€ 562,751	€ 503,136	€ 443,521

Variation of NPV		Electricity Price or Feed-in Tariff [€/kWh]			
		€ 0.10	€ 0.15	€ 0.17	€ 0.25
Heating use [%]	0%	-	-	-	-
	40%	-	-	-	€ 158,828
	80%	-	-	€ 39,782	€ 429,173
	100%	-	€ 77,606	€ 174,954	€ 564,345

5.1.3.3.2 District heating network

The analysis considered, as case study, the *Bulebel Industrial Estate*. In absence of actual consumption data about the specific area, the heating demand of the area started from the results of Sub-Task 1, proportioning the total heating energy demand for the industrial sector with the total industrial sites area.

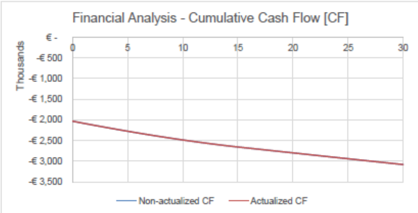
Considering the available data, the results and the hypothesis of Sub-Task 1, a CHP plant of **500 kWt** may cover approximately 15%-20% of the heating demand. The assumed layout of the district heating network, serving approximately 40 users, is reported in the following picture.



Line ID	Line Type	Nr of users	Thermal Power	Water Flow	DHN Diameter	DHN Price	Length	Total Price
	-	-	kWt	l/h	DN	€/m	m	€
1	*users*	**5**	66	2,839	32	€ 214	350	€ 74,900
2	*users*	**5**	66	2,839	32	€ 214	250	€ 53,500
3	Σ	10	133	5,679	50	€ 232	100	€ 23,200
4	*users*	**5**	66	2,839	32	€ 214	250	€ 53,500
5	Σ	15	199	8,518	50	€ 232	60	€ 13,920
6	*users*	**10**	133	5,679	50	€ 232	550	€ 127,600
7	Σ	25	331	14,196	65	€ 245	90	€ 22,050
8	*users*	**5**	66	2,839	32	€ 214	250	€ 53,500
9	Σ	30	398	17,036	65	€ 245	120	€ 29,400
10	*users*	**10**	133	5,679	50	€ 232	400	€ 92,800
							2,420	**€ 544,370**

Plant type

Year	Revenues [Electricity]	Savings [H&C]	Fuel cost	O&M cost	Investment	Financial costs	Cash Flow [CF]	Cumulative Non-actualized CF	Actualized CF	Net Present Value
0	€ -	€ -	€ -	€ -	-€ 2,032,866	€ -	-€ 2,032,866	-€ 2,032,866	-€ 2,032,866	-€ 2,032,866
1	€ 117,943	€ 100,168	-€ 225,312	-€ 19,203	€ -	-€ 24,394	-€ 50,798	-€ 2,083,664	-€ 50,798	-€ 2,083,664
2	€ 120,790	€ 102,281	-€ 230,066	-€ 19,587	€ -	-€ 23,176	-€ 49,757	-€ 2,133,421	-€ 49,757	-€ 2,133,421
3	€ 123,706	€ 104,439	-€ 234,920	-€ 19,978	€ -	-€ 21,909	-€ 48,662	-€ 2,182,083	-€ 48,662	-€ 2,182,083
4	€ 126,692	€ 106,643	-€ 239,876	-€ 20,378	€ -	-€ 20,591	-€ 47,510	-€ 2,229,593	-€ 47,510	-€ 2,229,593
5	€ 129,751	€ 108,892	-€ 244,937	-€ 20,785	€ -	-€ 19,221	-€ 46,300	-€ 2,275,893	-€ 46,300	-€ 2,275,893
6	€ 132,883	€ 111,190	-€ 250,105	-€ 21,201	€ -	-€ 17,796	-€ 45,029	-€ 2,320,922	-€ 45,029	-€ 2,320,922
7	€ 136,091	€ 113,536	-€ 255,381	-€ 21,625	€ -	-€ 16,314	-€ 43,693	-€ 2,364,615	-€ 43,693	-€ 2,364,615
8	€ 139,376	€ 115,931	-€ 260,769	-€ 22,058	€ -	-€ 14,772	-€ 42,292	-€ 2,406,907	-€ 42,292	-€ 2,406,907
9	€ 142,740	€ 118,377	-€ 266,271	-€ 22,499	€ -	-€ 13,169	-€ 40,821	-€ 2,447,728	-€ 40,821	-€ 2,447,728
10	€ 146,186	€ 120,875	-€ 271,889	-€ 22,949	€ -	-€ 11,502	-€ 39,278	-€ 2,487,007	-€ 39,278	-€ 2,487,007
11	€ 149,715	€ 123,425	-€ 277,625	-€ 23,408	€ -	-€ 9,768	-€ 37,660	-€ 2,524,667	-€ 37,660	-€ 2,524,667
12	€ 153,329	€ 126,029	-€ 283,482	-€ 23,876	€ -	-€ 7,964	-€ 35,964	-€ 2,560,631	-€ 35,964	-€ 2,560,631
13	€ 157,031	€ 128,688	-€ 289,463	-€ 24,353	€ -	-€ 6,089	-€ 34,187	-€ 2,594,818	-€ 34,187	-€ 2,594,818
14	€ 160,821	€ 131,403	-€ 295,570	-€ 24,840	€ -	-€ 4,138	-€ 32,325	-€ 2,627,143	-€ 32,325	-€ 2,627,143
15	€ 164,704	€ 134,175	-€ 301,806	-€ 25,337	€ -	-€ 2,110	-€ 30,375	-€ 2,657,518	-€ 30,375	-€ 2,657,518
16	€ 168,679	€ 137,006	-€ 308,174	-€ 25,844	€ -	€ -	-€ 28,332	-€ 2,685,850	-€ 28,332	-€ 2,685,850
17	€ 172,751	€ 139,897	-€ 314,676	-€ 26,361	€ -	€ -	-€ 28,389	-€ 2,714,239	-€ 28,389	-€ 2,714,239
18	€ 176,922	€ 142,848	-€ 321,315	-€ 26,888	€ -	€ -	-€ 28,433	-€ 2,742,672	-€ 28,433	-€ 2,742,672
19	€ 181,192	€ 145,862	-€ 328,094	-€ 27,426	€ -	€ -	-€ 28,465	-€ 2,771,138	-€ 28,465	-€ 2,771,138
20	€ 185,566	€ 148,939	-€ 335,016	-€ 27,974	€ -	€ -	-€ 28,485	-€ 2,799,622	-€ 28,485	-€ 2,799,622
21	€ 190,046	€ 152,082	-€ 342,084	-€ 28,534	€ -	€ -	-€ 28,490	-€ 2,828,113	-€ 28,490	-€ 2,828,113
22	€ 194,634	€ 155,290	-€ 349,301	-€ 29,105	€ -	€ -	-€ 28,482	-€ 2,856,595	-€ 28,482	-€ 2,856,595
23	€ 199,332	€ 158,567	-€ 356,671	-€ 29,687	€ -	€ -	-€ 28,459	-€ 2,885,053	-€ 28,459	-€ 2,885,053
24	€ 204,144	€ 161,912	-€ 364,196	-€ 30,280	€ -	€ -	-€ 28,420	-€ 2,913,474	-€ 28,420	-€ 2,913,474
25	€ 209,072	€ 165,328	-€ 371,880	-€ 30,886	€ -	€ -	-€ 28,366	-€ 2,941,840	-€ 28,366	-€ 2,941,840
26	€ 214,119	€ 168,816	-€ 379,726	-€ 31,504	€ -	€ -	-€ 28,294	-€ 2,970,134	-€ 28,294	-€ 2,970,134
27	€ 219,288	€ 172,378	-€ 387,737	-€ 32,134	€ -	€ -	-€ 28,205	-€ 2,998,339	-€ 28,205	-€ 2,998,339
28	€ 224,582	€ 176,015	-€ 395,918	-€ 32,776	€ -	€ -	-€ 28,098	-€ 3,026,437	-€ 28,098	-€ 3,026,437
29	€ 230,003	€ 179,728	-€ 404,271	-€ 33,432	€ -	€ -	-€ 27,972	-€ 3,054,409	-€ 27,972	-€ 3,054,409
30	€ 235,555	€ 183,520	-€ 412,800	-€ 34,101	€ -	€ -	-€ 27,825	-€ 3,082,234	-€ 27,825	-€ 3,082,234
	€ 5,107,645	€ 4,134,237	-€ 9,299,330	-€ 779,009	-€ 2,032,866	-€ 212,912	-€ 3,082,234	-€ 81,199,624	-€ 3,082,234	



Variation of NPV		Fuel Price [€/l] € 0.30	€ 0.40	€ 0.50	€ 0.60
Discount rate [%]	3%	-	-	-	-
	4%	-	-	-	-
	5%	-	-	-	-
	6%	-	-	-	-

Variation of NPV		CHP Unit Specific Investment Cost [€/kWe] € 1,200	€ 1,400	€ 1,600	€ 1,800
Elec. price [€/kWh]	€ 0.10	-	-	-	-
	€ 0.15	-	-	-	-
	€ 0.20	-	-	-	-
	€ 0.25	€ 1,010,040	€ 901,649	€ 793,258	€ 684,867

Variation of NPV		Electricity Price or Feed-in Tariff [€/kWh] € 0.10	€ 0.15	€ 0.20	€ 0.25
Discount rate [%]	3%	-	-	-	€ 1,297,557
	4%	-	-	-	€ 793,258
	5%	-	-	-	€ 375,804
	6%	-	-	-	€ 27,700

Variation of NPV		Network length [m] 0	500	1,500	2,500
Elec. price [€/kWh]	€ 0.10	-	-	-	-
	€ 0.15	-	-	-	-
	€ 0.20	€ 340,437	€ 182,100	-	-
	€ 0.25	€ 1,584,940	€ 1,426,603	€ 1,109,931	€ 793,258

Variation of NPV		Electricity Price or Feed-in Tariff [€/kWh] € 0.10	€ 0.15	€ 0.20	€ 0.25
Heat Price [€/kWh]	€ 0.06	-	-	-	€ 72,426
	€ 0.08	-	-	-	€ 579,713
	€ 0.10	-	-	-	€ 1,087,000
	€ 0.12	-	-	€ 349,783	€ 1,594,286

Variation of NPV		Electricity Price or Feed-in Tariff [€/kWh] € 0.10	€ 0.15	€ 0.20	€ 0.25
Heating use [%]	30%	-	-	-	-
	50%	-	-	-	-
	70%	-	-	-	€ 203,076
	90%	-	-	-	€ 675,222

5.2 Heat recovery

5.2.1 Industrial processes

Much of the energy required for industrial processes is ultimately emitted again to the environment in the form of heat. Where the emission is related to a flow of hot gases or liquids, then technologies exist to recover some of this heat. Heat flows from an activity, process or system may be seen by analogy to other emissions to the environment as two types:

- Fugitive sources, e.g. radiation through furnace openings, hot areas with poor or no insulation, heat dissipated from bearings.

- Specific flows, e.g.:
  - hot flue-gases;
  - exhaust air;
  - cooling fluids from cooling systems (e.g. gases, cooling water, thermal oil);
  - hot or cold product or waste product;
  - hot or cold water drained to a sewer.

These heat losses are often called **waste heat**, although the term should be 'surplus heat', as heat may be recovered from the specific heat flows for use in another process or system. The amount of useful work that can be obtained from a heat stream is called exergy, and is limited by thermodynamics. There are two levels of heat flow exergy:

1. Heat from hot streams such as hot flue-gases;
2. Heat from relatively cold streams (such as <80°C). These are more difficult to valorize, and the exergy of the heat may need to be upgraded.

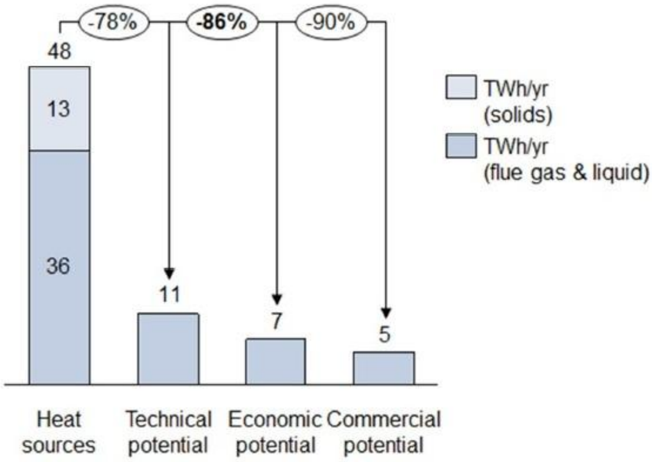
In order to identify the potential for recovery of heat from a certain industrial process it is crucial to have relevant, quantified information and knowledge of the processes from which the heat arises and into which the heat recovery is to be incorporated. The prime reason for difficulty and failure of waste heat recovery is lack of understanding. Errors and omissions are likely to have a more profound effect than, for example, an ill-judged choice of the type of heat exchanger. Apart from thermodynamic errors, it is the physical properties of a waste heat source which can lead to problems with whichever heat exchanger is chosen, if not fully investigated at the outset.

In order to estimate, although to a first approximation, the technical and economic potential of the heat recoverable from industrial process in Malta, reference is made to the results of a recent study carried on in the industrial sector of UK (London Imperial College, 2014).

In absence of data about industrial processes in Malta, the analysis considered this reference for calculating a first estimation of the technical and economic potential of heat recovery. In particular, the results of the study - in terms of ***indicators*** *of technical and economic potential starting from "heat sources" - were applied to the fossil fuels consumption in the industry sector.*

Nevertheless, it should be highlighted that, since this reference to the study may not be completely consistent with the local Maltese scenario, a detailed case-by-case study is the correct way to evaluate the actual technical feasibility of heat recovery from industrial processes.

The used methodology provided an innovative database describing "archetypal" characteristics of the waste heat sources and heat sinks at 73 of the largest UK industrial sites, initially developed and populated using literature sources. The contents of the databases were then refined through expert review, feedback from ten trade associations, and insights gained from 11 site visits and discussions with individual companies. Overall, the databases identify 48 TWh/yr industrial waste heat sources, i.e. around one sixth of overall UK industrial heat energy use.



United Kingdom: Potential for technical, economical and commercial heat recovery, compared to the available heat sources in industry sector

The **technical potential** includes contributions from on-site heat re-use, over-the-fence supply to another large industrial user and conversion to power. All heat-intensive industrial sectors examined (refineries, iron & steel, ceramics, glass, cement, chemicals, food and drink, paper and pulp) contribute to this potential. The technical potential is sensitive to industrial heat demand and supply, and CO_2 savings are sensitive to assumptions on avoided fuel use.

The table below reports the technical potential of heat recovery from industrial processes for Malta. The values are obtained applying the model developed in UK and summarized in the figure above to the fossil fuels used in the industry sector and obtained from the NEEAP 2014[46].

Malta heat demand from fossil fuels - Industry											
(toe)											
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Diesel	9,424	9,186	9,391	8,832	6,228	6,466	6,700	6,922	7,137	7,341	7,540
Biodiesel	139	172	233	166	145	155	169	160	159	158	160
Kerosene	181	120	154	123	123	123	123	123	123	123	123
Gasoil	5,846	5,192	5,302	5,700	5,933	6,162	6,386	6,613	6,830	7,036	7,238
Thin fuel oil	6,383	6,518	7,076	2,938	2,960	2,984	3,011	3,038	3,069	3,106	3,144
LPG/Propane	878	874	896	994	998	992	990	986	990	992	991
Total	**22,851**	**22,062**	**23,052**	**18,753**	**16,387**	**16,882**	**17,379**	**17,842**	**18,308**	**18,756**	**19,196**
Heat recovery technical potential	863.77	833.94	871.37	708.86	619.43	638.14	656.93	674.43	692.04	708.98	725.61

[46] (Malta's National Energy Efficiency Action Plan, 2014)

Malta heat demand from fossil fuels - Industry											
(GWh)											
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Diesel	109.60	106.83	109.22	102.72	72.43	75.20	77.92	80.50	83.00	85.38	87.69
Biodiesel	1.62	2.00	2.71	1.93	1.69	1.80	1.97	1.86	1.85	1.84	1.86
Kerosene	2.11	1.40	1.79	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Gasoil	67.99	60.38	61.66	66.29	69.00	71.66	74.27	76.91	79.43	81.83	84.18
Thin fuel oil	74.23	75.80	82.29	34.17	34.42	34.70	35.02	35.33	35.69	36.12	36.56
LPG/Propane	10.21	10.16	10.42	11.56	11.61	11.54	11.51	11.47	11.51	11.54	11.53
Total	**265.76**	**256.58**	**268.09**	**218.10**	**190.58**	**196.34**	**202.12**	**207.50**	**212.92**	**218.13**	**223.25**
Heat recovery technical potential	10.05	9.70	10.13	8.24	7.20	7.42	7.64	7.84	8.05	8.25	8.44

The most commonly used heat recovery techniques taken into account in the model are the following:

- Direct usage: heat exchangers make use of heat as it is in the surplus stream;
- Heat pumps upgrade the heat in relatively cold streams so that it can perform more useful work than could be achieved at its present temperature (i.e. an input of high quality energy raises the energy quality of the waste/surplus heat).
- Multistage operations such as multi-effect evaporation, steam flashing and combinations of the approaches already mentioned.

Because of its simplicity, low cost and versatility compared to the industrial sectors present, it is estimated that the direct heat recovery carried out by heat exchangers is the technology with the greatest opportunities for employment in Malta. A heat exchanger is a device in which energy is transferred from one fluid or gas to another across a solid surface. They are used to either heat up or cool down processes or systems. Heat transfer happens by both convection and conduction.

Discharge heat at relatively low temperatures such as 70 ºC, but can be up to 500 ºC can be found in many industrial sectors such as:

- chemicals including polymers;
- food and drink;
- paper and board;
- textiles and fabrics.

In this range of temperatures, the following heat recovery equipment (heat exchangers) can be used depending on the type of fluids involved (i.e. gas-gas, gas-liquid, liquid-liquid) and the specific application:

- rotating regenerator (adiabatic wheel);
- coil;
- heat pipe heat exchanger;
- tubular recovery;
- economizer;
- condensing economizer;
- spray condenser (fluid-heat exchanger);
- shell and tube heat exchanger;
- plate heat exchanger;
- plate and shell heat exchanger.

For the calculation of the economic potential and the identification of the matching between demand and supply of heat, the model used in UK cited study has also considered the use of Rankine engines and the use of pipeline for heat transport.

Rankine cycles are being used to convert heat to mechanical work, which can in turn be used to generate electricity. A widely applied example is the steam Rankine cycle, used in power stations to convert high temperature steam into electricity. Technologies that can convert heat from a lower temperature (90-500°C), into electricity are the Organic Rankine Cycle (ORC) and the Kalina cycle (which employs a solution of two fluids with different boiling points as working fluid). The efficiency of converting heat to electricity in an ORC ranges from about 8% for lower temperatures to 18% for higher temperatures. Kalina cycles can be more efficient than ORCs but due to their complexity are more suited for larger applications.

Heat transport by pipeline is widely used and mature technology for on-site, over-the-fence and for district heating. The limiting factor is the distance heat can be transported without significant losses of the enthalpy and against reasonable costs. The heat losses per kilometer are larger at elevated temperatures. Thicker and/or more expensive insulation can reduce the losses but at much higher costs. The study report distinguish between steam pipes and hot water pipes.

5.2.2 Delimara Power Station

Delimara Phase 3 – equipped with 8 x 17.1 MW diesel engine-driven generators plus a 13.5 MW steam turbine[47] for heat recovery from exhaust gases - is provided with two 8 MW_t multistage evaporators utilizing engine cooling water issuing at a temperature of approximately 92˚C for the production of evaporated water, with a return of approximately 51 GWh/y.

The steam turbine condenser uses the seawater cooling with a ΔT of 8°C. Considering the available data and information, the Delimara Power Station does not seem to provide significant amount of waste heat at a useful temperature, which may be used, through a district heating network, for heating purposes.

[47] (Malta's National Energy Efficiency Action Plan, 2014)

6 Sub-Task 4 – Economical Potential

All the studies already carried out in relation to the economic potential of CHP in Malta have identified several barriers to the spread of this technology in the country. Among these, it is important to remember those strictly context-dependent, related to infrastructure framework and climatic conditions of the island:

a. Currently Malta does not have a network of natural gas distribution (a feasibility study considering a number of distribution hubs is still underway).
b. The high level of insolation promotes the use of competing technologies such as solar photovoltaic, solar thermal, solar cooling.
c. The connection of the island with the European electricity grid, launched in April 2015, along with the new CCGT electricity generation plant at Delimara, fuelled with LNG, will contribute in the future to a lower cost of electricity.
d. The only "renewable" source available in Malta in order to fuel CHP is the biogas from waste.

In order to identify scenarios to be cost-benefit analysed, according to the guidance note on Directive 2012/27/EU (European Commision, 2013) point 33 and point 36: "only realistic scenarios need to be examined", the following scenarios were identified:

a. **Scenario 0 - Baseline Scenario**, point 33. The baseline scenario describes the existing situation and its likely evolution in the selected timeframe, if no parameters of the existing situation are changed, i.e. the business-as-usual or reference scenario. A critical element of the baseline scenario, and a key to a successful cost-benefit analysis, is to describe the heat and cooling demand within the geographical boundary as precisely as possible.

b. **Alternative Scenarios,** point 34, considering the relevant possibilities for how heating and cooling can be made more efficient.

For this purposes, several financial analysis including the **NPV – Net Present Value** calculation were developed, reported in the Annexes of this document. The analysis refers to the technical description presented with Sub-Task 3.

Each financial analysis is combined with a **sensitivity analysis**, for assessing the costs and benefits balance of the project based on different energy prices, discount rates and other variable factors having a significant impact on the outcome of the calculations. The aim is to evaluate how the investment NPV is influenced by the variations of factors - for example the fuel prices - characterized by uncertainty and variability. The proposed sensitivity analysis expresses the value of the NPV varying two parameters involved in the calculation and leaving the others to their original values.

As example, the results of the sensitivity analysis are present by means of tables similar to the one reported aside. The indication of "-" means that with the particular combination of the two parameters, the analysis gave a negative result for the NPV.

(Example)

Variation of NPV		*Electricity Price or Feed-in Tariff [€/kWh]*			
		€ 0.10	€ 0.15	€ 0.17	€ 0.25
Discount rate [%]	**3%**	-	€ *120,223*	€ *232,440*	€ *681,310*
	4%	-	€ *64,089*	€ *161,437*	€ *550,828*
	5%	-	€ *17,590*	€ *102,732*	€ *443,299*
	6%	-	-	€ *53,840*	€ *354,052*

6.1 Parameters of the analysis

The following tables report the parameters[48] used in the analysis, which are common between all the presented cases.

Economic Parameters			
Fuel Prices			
Marginal cost of electricity	€	0.105	/kWh
Avg cost of electricity - Services	€	0.179	/kWh
Avg cost of electricity - Industry	€	0.150	/kWh
LPG Fuel Price	€	0.96	/kg
Gasoil Fuel Price	€	1.05	/liter
Loan Parameters			
Percentage of financed capital		30%	%
Loan Duration		15	years
Cost of capital/Discount rate		4%	%
Other parameters			
Government taxes on profit		25%	%
Inflation rate applied to prices		2%	%
Yearly variation of fuel prices		0.7%	%
Yearly variation of electricity prices		1.0%	%

Reference estimated economic values for the thermal energy production[49]

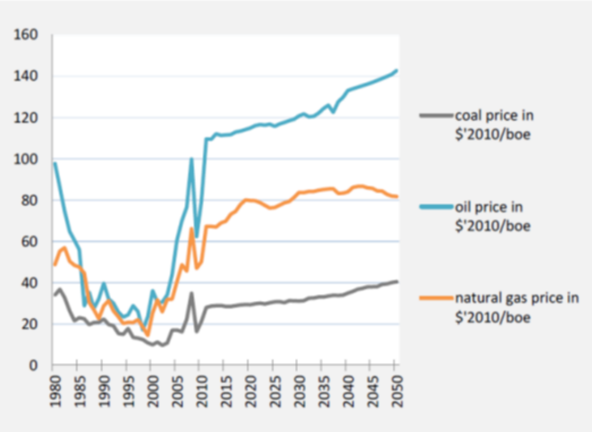
LPG			
Net calorific value		46.15	GJ/ton
		0.046	TJ/ton
		0.013	GWh/ton
		12.82	kWh/kg
Fuel density		0.5222	kg/l
Fuel Price	**€**	**0.96**	**/kg**
	€	**0.50**	**/liter**
Calorific Value		**6.69**	**kWh/l**
Conversion Efficiency		85%	
Heating Energy Price	**€**	**0.088**	**/kWh**

Gasoil			
Net calorific value		43.38	GJ/ton
		0.043	TJ/ton
		0.012	GWh/ton
		12.05	kWh/kg
Fuel density		0.8439	kg/l
Fuel Price	**€**	**1.05**	**/liter**
Calorific Value		**10.17**	**kWh/l**
Conversion Efficiency		85%	
Heating Energy Price	**€**	**0.121**	**/kWh**

The prices are here referred to the current year 2015. In the financial analysis they will BE updated – through the yearly variation coefficients - considering the assumption that all the described interventions will be realized starting from the year 2020.

[48] Electricity Price: Elaboration from the NSO database
[49] Calorific values and fuels density: (OECD, IEA, Eurostat, 2005). Price of LPG: elaboration of MEH, August 2015. Price of Gasoil: http://www.enemalta.com.mt/index.aspx?cat=2&art=7&art1=230, August 2015

FIGURE 6: FOSSIL FUEL IMPORT PRICES



The forecast estimation about **fuels** price was carried out with reference to the assumptions adopted in the **EU Energy Trends**[50] publication. The EU's Energy Trends publications present energy market scenarios for 2030 and 2050 based on current trends and policies. They highlight possible energy demand, **energy prices**, greenhouse gas emissions, and other potential developments.

6.2 Alternative Scenario #0 - Baseline Scenario

The baseline scenario describes the existing situation and its likely evolution in the selected timeframe, if no parameters of the existing situation are changed, i.e. the business-as-usual or reference scenario.

The calculation and the analysis of the heating and cooling demand for the Maltese Islands is reported within **Chapter 3**, while **Chapter 7** (Sub-Task 5 – Maps of heat loads) and the relative Annex describe its geographical distribution in the country. A likely evolution of the demand up to 2030 is reported in **Chapter 4** - Sub-Task 2 – Forecast of heating and cooling demand.

6.3 Alternative Scenario #1

In **Alternative Scenario 1** the only deepened hypothesis deals with machines fuelled with biogas from waste.

For what concerns the **Existing Biogas Facilities**, paragraph 5.1.3.1 showed how – considering the available data and information – the most cost-effective uses of the produced thermal energy, are the systems' internal processes. Hence, no financial analysis has been developed for this particular case.

As introduced in paragraph 5.1.3.2, the study proposes the use of the heat that can be recovered from **new potential biogas CHP facilities**.

[50] (European Commission, 2014)

ENERGY PRODUCTION	units	Plant type
Combined Heat and Power Plant		
Number of CHP units	-	1
CHP unit Thermal Power	kWt	290
CHP unit Electrical Power	kWe	250
CHP unit Fuel Consumption	m³/h	124
Operating Hours		
Heating operation hours	hh/y	3,960
Cooling operation hours	hh/y	0
Operating hours per year	**hh/y**	**3,960**
Yearly Energy Productions		
Thermal Energy - Heating	GWht/y	1.15
Thermal Energy - Cooling	GWht/y	0.00
Thermal Energy - Total	**GWht/y**	**1.15**
Gross Electricity Production	GWhe/y	0.99
Self-Consumption	%	10%
Net Electrical Energy	**GWhe/y**	**0.89**
Cooling Energy	**GWhc/y**	**0.00**
Useful Thermal Energy		
Heating Energy Use	%	98%
Heating Energy	GWht/y	1.13
Cooling Energy	GWht/y	0.00

SAVINGS & REVENUES	units	Plant type
Heating Energy Value	€/kWht	0.05
Heating Energy Revenues	€/y	€ 60,013
Cooling Energy Value	€/kWht	0.06
Cooling Energy Revenues	€/y	€ -
Electrical Energy Price	€/kWhe	0.11
Electrical Energy Revenues	€/y	€ 98,327

INVESTMENTS - CHP Plant	units	Plant type
CHP Plant		
Specific investment cost	€/kWe	€ 6,500
Investment cost	€	€ 1,625,000
INVESTMENTS - CHP Plant		**€ 1,625,000**

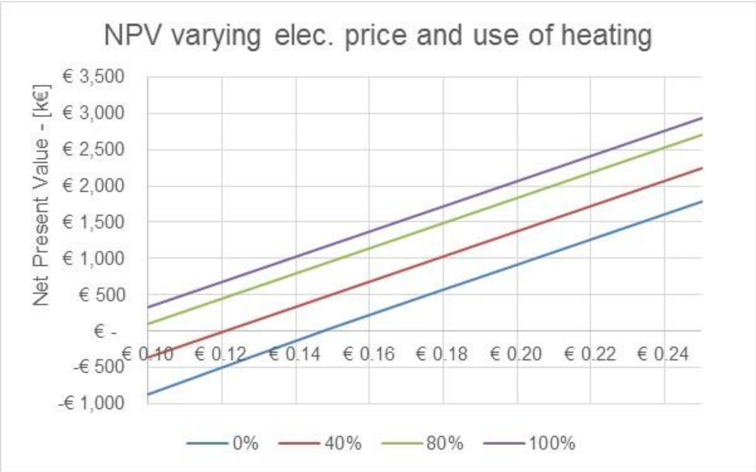
HEATING & COOLING NETWORK	units		Plant type 1
Heating and Cooling Network - Main line			
Heating - Water Flow	l/h		12,429
Heating - Diameter	DN		65
Specific Cost	€/m	€	245
H&C pipes length	m		1,500
Investment costs - Heating	€	€	367,500
Connections			
Number of users			20
Substation specific cost	€	€	9,000
Investment costs - Substation	€	€	180,000
Pipe connections	€	€	4,000
Total investment - Connections	€	€	80,000
INVESTMENTS - H&C NETWORK		**€**	**627,500**

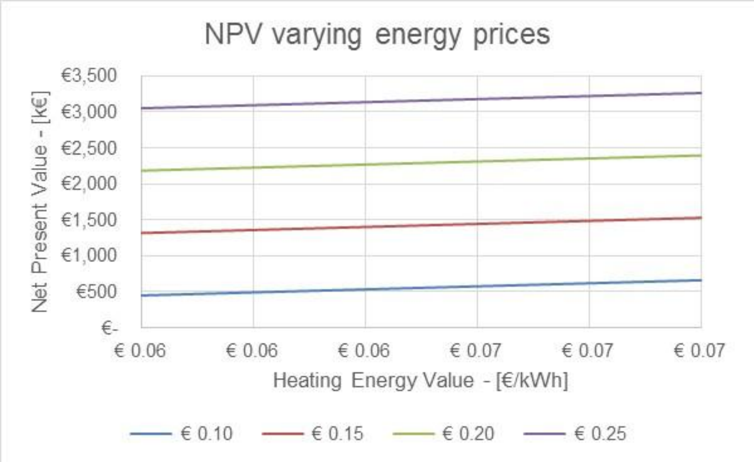
OPERATION & MAINTENANCE	units		Plant type
Fuel Consumption			
Specific fuel cost	€/m³		0.10
Yearly fuel consumption	m³/y		489,824
Total fuel yearly cost	€/y	€	48,982
CHP Plant			
Specific Maintenance cost	€/kWhe		0.01
Yearly Maintenance cost	€/y	€	270,580
Heating & Cooling network			
- Operation & Maintenance	€/m		0.80
- Repars	€/m		2.50
- Control and monitoring	€/MWt		500
Total Management costs H&C network:	€/y	€	5,095

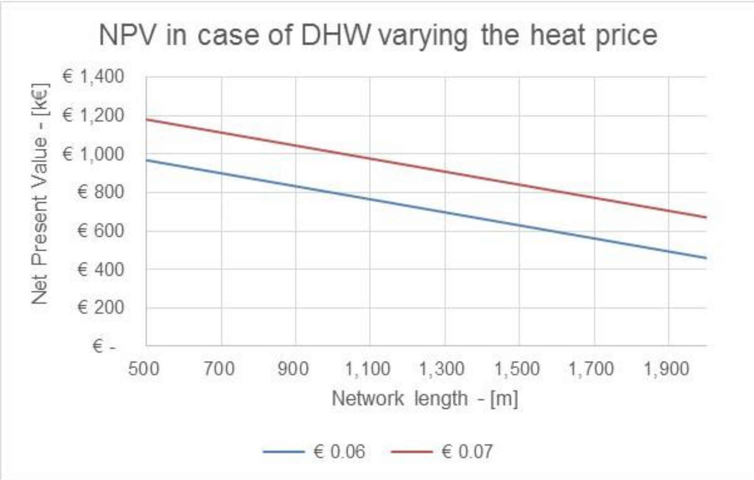
Cost-Benefit Analysis	units	Plant type
- Costs:		
+ Investments:	**€**	**2,252,500**
- CHP plant	€	1,625,000
- H&C Network	€	627,500
- Total financial costs on investment (for financing)	€	*235,915*
+ Yearly O&M costs:	**€**	**275,675**
- CHP plant	€	270,580
- Cooling units	€	-
- H&C Network	€	5,095
+ Yearly fuel costs:	**€**	**48,982**
- Benefits:	**€**	**158,340**
+ Yearly savings - Heating energy	€	60,013
+ Yearly savings - Cooling energy	€	-
+ Yearly revenues from electricity	€	98,327

Financial Parameters	units	Plant type
Net Present Value	€	€ 488,108
Simple payback time	years	13
Actualized payback time	years	18
Internal Rate of Return	%	6.07%

The following charts represent some of the main outputs of the sensitivity analysis.







6.4 Alternative Scenario #2

Through the **Alternative Scenario 2,** the economic potential of heat recovery in the industrial sector was instead estimated. The scenario is modular to other scenarios, meaning that it can be implemented individually or in combination with one of the other analysed scenarios.

The same methodology used to estimate the technical potential of industrial recoverable-heat, i.e. maintaining the same proportions between the heat demand of the UK industrial sector and UK technical potential of recoverable-heat, was performed for the identification of the economic potential.

Using the same proportions between the heat demand of the industrial sector UK and the identified economic potential of recoverable-heat has been considered legitimate because, as written in (London Imperial College, 2014)

*"The **economic potential** has been identified as those NPV positive projects which together provide the highest total NPV" and "financial analysis is performed on an annualised basis for the designated lifetime, as this provides the most flexibility when the actual year of implementation is not known".*

The economic feasibility of heat recovery measures depend on three main aspects:

- Investor key performance metrics;
- Energy and carbon prices: these impact the revenues by avoiding primary fuel use and the ongoing costs through power ancillary power consumption.
- Project costs: investment costs are a significant driver, especially given the short payback requirements.

Project costs are very site and facility specific, especially where heat recovery projects are integrated in existing facilities. Payback time may be extremely variable from a few months to ten years depending on the boundary conditions, the technologies used and the starting state of play. I.e. in the pulp and paper European industry, it has been shown that the payback time of the complex and different heat recovery systems was between one and about three years.

Malta heat demand from fossil fuels - Industry											
(toe)											
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Diesel	9,424	9,186	9,391	8,832	6,228	6,466	6,700	6,922	7,137	7,341	7,540
Biodiesel	139	172	233	166	145	155	169	160	159	158	160
Kerosene	181	120	154	123	123	123	123	123	123	123	123
Gasoil	5,846	5,192	5,302	5,700	5,933	6,162	6,386	6,613	6,830	7,036	7,238
Thin fuel oil	6,383	6,518	7,076	2,938	2,960	2,984	3,011	3,038	3,069	3,106	3,144
LPG/Propane	878	874	896	994	998	992	990	986	990	992	991
Total	**22,851**	**22,062**	**23,052**	**18,753**	**16,387**	**16,882**	**17,379**	**17,842**	**18,308**	**18,756**	**19,196**
Heat recovery technical potential	863.77	833.94	871.37	708.86	619.43	638.14	656.93	674.43	692.04	708.98	725.61
Heat recovery economic potential	**550.71**	**531.69**	**555.55**	**451.95**	**394.93**	**406.86**	**418.83**	**429.99**	**441.22**	**452.02**	**462.62**

Malta heat demand from fossil fuels - Industry											
(GWh)											
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Diesel	109.60	106.83	109.22	102.72	72.43	75.20	77.92	80.50	83.00	85.38	87.69
Biodiesel	1.62	2.00	2.71	1.93	1.69	1.80	1.97	1.86	1.85	1.84	1.86
Kerosene	2.11	1.40	1.79	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43
Gasoil	67.99	60.38	61.66	66.29	69.00	71.66	74.27	76.91	79.43	81.83	84.18
Thin fuel oil	74.23	75.80	82.29	34.17	34.42	34.70	35.02	35.33	35.69	36.12	36.56
LPG/Propane	10.21	10.16	10.42	11.56	11.61	11.54	11.51	11.47	11.51	11.54	11.53
Total	**265.76**	**256.58**	**268.09**	**218.10**	**190.58**	**196.34**	**202.12**	**207.50**	**212.92**	**218.13**	**223.25**
Heat recovery technical potential	10.05	9.70	10.13	8.24	7.20	7.42	7.64	7.84	8.05	8.25	8.44
Heat recovery economic potential	**6.40**	**6.18**	**6.46**	**5.26**	**4.59**	**4.73**	**4.87**	**5.00**	**5.13**	**5.26**	**5.38**

Driving forces for implementation of heat recovery from industrial processes can be:

- Reduction of energy costs, reduction of emissions and the often rapid return of investments;
- Improved process operation, e.g. reduction of surface contamination (in scrapped surface systems), improvement of existing equipment/flows, increased potential of maximum plant throughput
- Savings in effluent charges.

6.5 Alternative Scenario #3

The Scenario considers the realization of CHP Plants in the following types of buildings:

Type of building	Technical Description	CBA[51]	Fuel
Hospitals	§ 5.1.2.1	§ 6.5.1	Gasoil and LPG
Hotels	§ 5.1.2.2	§ 6.5.2	Gasoil and LPG
Residential buildings	§ 5.1.1	§ 0	LPG
Industry	§ 5.1.3.3	§ 0	LPG

6.5.1 Hospitals

For the hospitals sector, three different **reference CHP Plants** were then sized, starting from the thermal load profiles, for three different types of hospital:

- **Type 1:** Hospital with about nr.150 beds;
- **Type 2:** Hospitals with about nr.500 beds;
- **Type 3:** Hospitals with about nr.800 beds.

[51] Cost Benefit Analysis

6.5.1.1 Gasoil

The cost-benefit analysis (CBA) is reported in the following tables.

ENERGY PRODUCTION	units	Plant type 1	Plant type 2	Plant type 3
Combined Heat and Power Plant				
Number of CHP units	-	1	1	1
CHP unit Thermal Power	kWt	45	220	400
CHP unit Electrical Power	kWe	35	210	380
CHP unit Fuel Consumption	l/h	9	49	92
Total installed thermal power	**kWt**	**45**	**220**	**400**
Total installed electrical power	**kWe**	**35**	**210**	**380**
CHP unit Fuel Consumption	**l/h**	**9**	**49**	**92**
Cooling Units				
Coefficient of Performance	-	-	-	0.7
Nominal cooling capacity	kWc	0	0	280
Operating Hours				
Heating operation hours	hh/y	3,035	3,035	3,035
Cooling operation hours	hh/y	0	0	2,440
Operating hours per year	**hh/y**	**3,035**	**3,035**	**5,475**
Yearly Energy Productions				
Thermal Energy - Heating	GWht/y	0.14	0.67	1.21
Thermal Energy - Cooling	GWht/y	0.00	0.00	0.98
Thermal Energy - Total	**GWht/y**	**0.14**	**0.67**	**2.19**
Gross Electricity Production	GWhe/y	0.11	0.64	2.08
Self-Consumption	%	5%	5%	5%
Net Electrical Energy	**GWhe/y**	**0.10**	**0.61**	**1.98**
Cooling Energy	**GWhc/y**	**0.00**	**0.00**	**0.68**
Useful Thermal Energy				
Distribution Efficiency	%	98%	98%	98%
Heating Energy	GWht/y	0.13	0.65	1.19
Cooling Energy	GWht/y	0.00	0.00	0.67

SAVINGS & REVENUES	units	Plant type 1	Plant type 2	Plant type 3
Heating Energy Value	€/kWht	0.13	0.13	0.13
Heating Energy Revenues	€/y	€ 16,835	€ 82,302	€ 149,641
Cooling Energy Value	€/kWht	0.07	0.07	0.07
Cooling Energy Revenues	€/y	€ -	€ -	€ 46,516
Electrical Energy Price	€/kWhe	0.11	0.11	0.11
Electrical Energy Revenues	€/y	€ 11,136	€ 66,819	€ 218,116

INVESTMENTS - CHP Plant	units	Plant type 1	Plant type 2	Plant type 3
CHP Plant				
Specific investment cost	€/kWe	€ 2,600	€ 1,900	€ 1,700
Investment cost	€	€ 91,000	€ 399,000	€ 646,000
Cooling Units				
Specific investment cost	€/kWc	250	250	250
Investment cost	€	€ -	€ -	€ 70,000
Cooling Towers				
Specific investment cost	€/kWc	100	100	100
Investment cost	€	€ -	€ -	€ 28,000
Civil and plant works				
Thermal Plant connection	€/kWt	50	50	50
Investment cost	€	€ 2,250	€ 11,000	€ 20,000
Electrical Plant connection	€/kWe	80	90	100
Investment cost	€	€ 2,800	€ 18,900	€ 38,000
INVESTMENTS - CHP Plant		**€ 96,050**	**€ 428,900**	**€ 802,000**

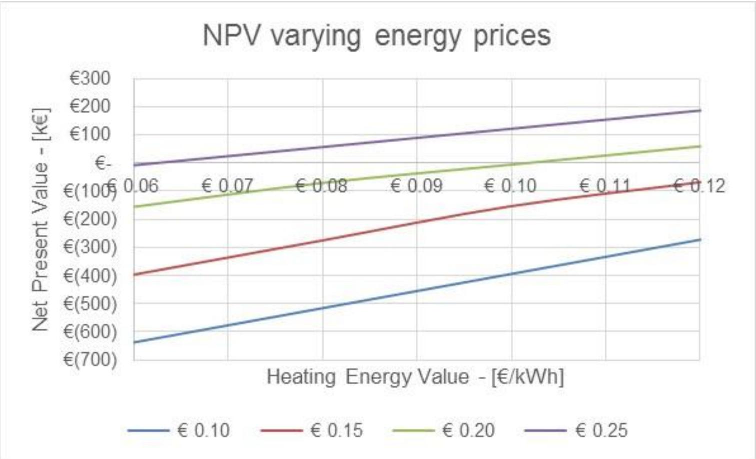
OPERATION & MAINTENANCE	units	Plant type 1	Plant type 2	Plant type 3
Fuel Consumption				
Specific fuel cost	€/liter	1.09	1.09	1.09
Yearly fuel consumption	l/y	27,063	147,272	505,395
Total fuel yearly cost	€/y	€ 29,425	€ 160,125	€ 549,499
CHP Plant				
Specific Maintenance cost	€/kWhe	0.01	0.01	0.01
Yearly Maintenance cost	€/y	€ 1,009	€ 6,055	€ 19,765
Cooling Units				
Specific Maintenance cost	€/kWc	4.00	4.00	4.00
Yearly Maintenance cost	€/y	€ -	€ -	€ 1,120

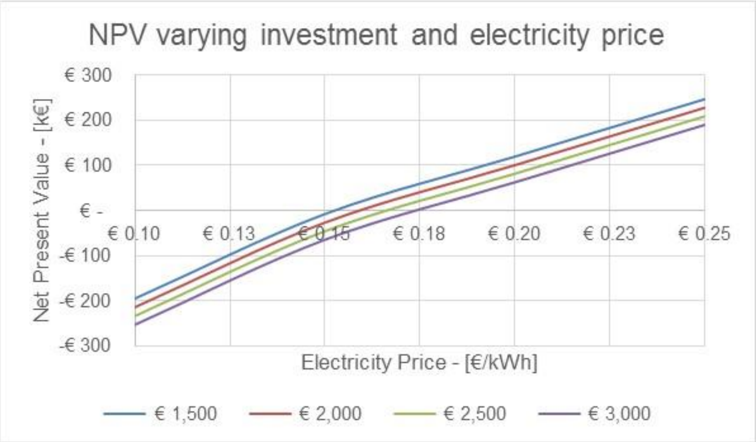
Cost-Benefit Analysis	units	Plant type 1	Plant type 2	Plant type 3
- Costs:				
+ Investments:		**€ 96,050**	**€ 428,900**	**€ 802,000**
- CHP plant		€ 96,050	€ 428,900	€ 802,000
- H&C Network		€ -	€ -	€ -
- Total financial costs on investment (for financing)		€ *10,060*	€ *44,921*	€ *83,997*
+ Yearly O&M costs:		**€ 1,009**	**€ 6,055**	**€ 20,885**
- CHP plant		€ 1,009	€ 6,055	€ 19,765
- Cooling units		€ -	€ -	€ 1,120
- H&C Network		€ -	€ -	€ -
+ Yearly fuel costs:		**€ 29,425**	**€ 160,125**	**€ 549,499**
- Benefits:		**€ 27,971**	**€ 149,121**	**€ 414,273**
+ Yearly savings - Heating energy		€ 16,835	€ 82,302	€ 149,641
+ Yearly savings - Cooling energy		€ -	€ -	€ 46,516
+ Yearly revenues from electricity		€ 11,136	€ 66,819	€ 218,116

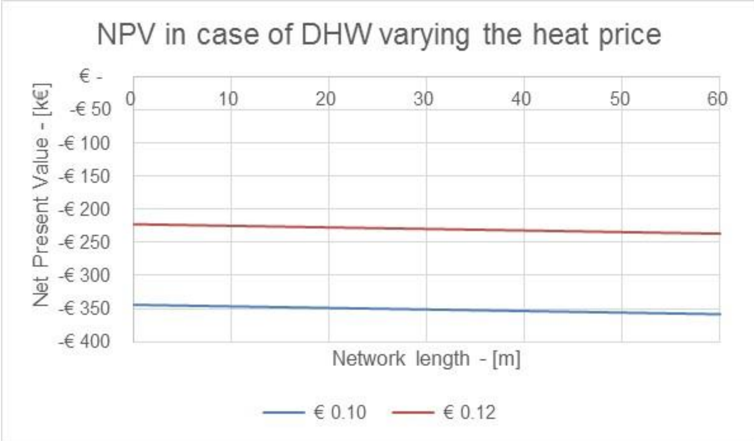
Financial Parameters	units	Plant type 1	Plant type 2	Plant type 3
Net Present Value	€	-€ 187,488	-€ 1,065,769	-€ 7,375,371
Simple payback time	years	-	-	-
Actualized payback time	years	-	-	-
Internal Rate of Return	%	-	-	-

Primary Energy Savings	units	Plant type 1	Plant type 2	Plant type 3
Yearly fuel consumption	l/y	27,063	147,272	505,395
	kWh/y	275,224	1,497,733	5,139,766
Annual overall efficiency	%	86.29%	85.01%	81.06%
Heat efficiency of the cogeneration	%	49.62%	44.58%	42.61%
Electrical efficiency of the cogeneration	%	36.67%	40.43%	38.45%
Reference value for separate heat production	%	90%	90%	90%
Reference value for separate electricity production	%	50%	50%	50%
Primary Energy Savings	%	22.16%	23.31%	19.52%

The following charts represent some of the main outputs of the sensitivity analysis.






NPV in case of DHW varying the heat price
Net Present Value - [k€]
€ -
-€ 50
-€ 100
-€ 150
-€ 200
-€ 250
-€ 300
-€ 350
-€ 400
0
10
20
30
40
50
60
Network length - [m]
€ 0.10
€ 0.12

6.5.1.2 LPG

The cost-benefit analysis (CBA) is reported in the following tables.

ENERGY PRODUCTION	units	Plant type 1	Plant type 2	Plant type 3
Combined Heat and Power Plant				
Number of CHP units	-	1	1	1
CHP unit Thermal Power	kWt	45	220	400
CHP unit Electrical Power	kWe	35	210	380
CHP unit Fuel Consumption	l/h	14	78	149
Total installed thermal power	**kWt**	**45**	**220**	**400**
Total installed electrical power	**kWe**	**35**	**210**	**380**
CHP unit Fuel Consumption	**l/h**	**14**	**78**	**149**
Cooling Units				
Coefficient of Performance	-	-	-	0.7
Nominal cooling capacity	kWc	0	0	280
Operating Hours				
Heating operation hours	hh/y	3,035	3,035	3,035
Cooling operation hours	hh/y	0	0	2,440
Operating hours per year	**hh/y**	**3,035**	**3,035**	**5,475**
Yearly Energy Productions				
Thermal Energy - Heating	GWht/y	0.14	0.67	1.21
Thermal Energy - Cooling	GWht/y	0.00	0.00	0.98
Thermal Energy - Total	**GWht/y**	**0.14**	**0.67**	**2.19**
Gross Electricity Production	GWhe/y	0.11	0.64	2.08
Self-Consumption	%	5%	5%	5%
Net Electrical Energy	**GWhe/y**	**0.10**	**0.61**	**1.98**
Cooling Energy	**GWhc/y**	**0.00**	**0.00**	**0.68**
Useful Thermal Energy				
Distribution Efficiency	%	98%	98%	98%
Heating Energy	GWht/y	0.13	0.65	1.19
Cooling Energy	GWht/y	0.00	0.00	0.67

SAVINGS & REVENUES	units	Plant type 1	Plant type 2	Plant type 3
Heating Energy Value	€/kWht	0.13	0.13	0.13
Heating Energy Revenues	€/y	€ 16,835	€ 82,302	€ 149,641
Cooling Energy Value	€/kWht	0.07	0.07	0.07
Cooling Energy Revenues	€/y	€ -	€ -	€ 46,516
Electrical Energy Price	€/kWhe	0.11	0.11	0.11
Electrical Energy Revenues	€/y	€ 11,136	€ 66,819	€ 218,116

INVESTMENTS - CHP Plant	units	Plant type 1	Plant type 2	Plant type 3
CHP Plant				
Specific investment cost	€/kWe	€ 2,600	€ 1,900	€ 1,700
Investment cost	€	€ 91,000	€ 399,000	€ 646,000
Cooling Units				
Specific investment cost	€/kWc	250	250	250
Investment cost	€	€ -	€ -	€ 70,000
Cooling Towers				
Specific investment cost	€/kWc	100	100	100
Investment cost	€	€ -	€ -	€ 28,000
Civil and plant works				
Thermal Plant connection	€/kWt	50	50	50
Investment cost	€	€ 2,250	€ 11,000	€ 20,000
Electrical Plant connection	€/kWe	80	90	100
Investment cost	€	€ 2,800	€ 18,900	€ 38,000
INVESTMENTS - CHP Plant		**€ 96,050**	**€ 428,900**	**€ 802,000**

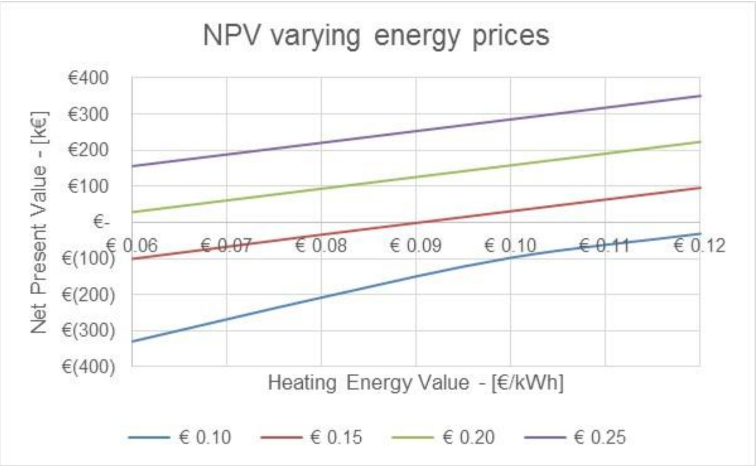
OPERATION & MAINTENANCE	units	Plant type 1	Plant type 2	Plant type 3
Fuel Consumption				
Specific fuel cost	€/liter	0.52	0.52	0.52
Yearly fuel consumption	l/y	43,735	237,999	816,742
Total fuel yearly cost	€/y	€ 22,644	€ 123,223	€ 422,865
CHP Plant				
Specific Maintenance cost	€/kWhe	0.01	0.01	0.01
Yearly Maintenance cost	€/y	€ 1,009	€ 6,055	€ 19,765
Cooling Units				
Specific Maintenance cost	€/kWc	4.00	4.00	4.00
Yearly Maintenance cost	€/y	€ -	€ -	€ 1,120

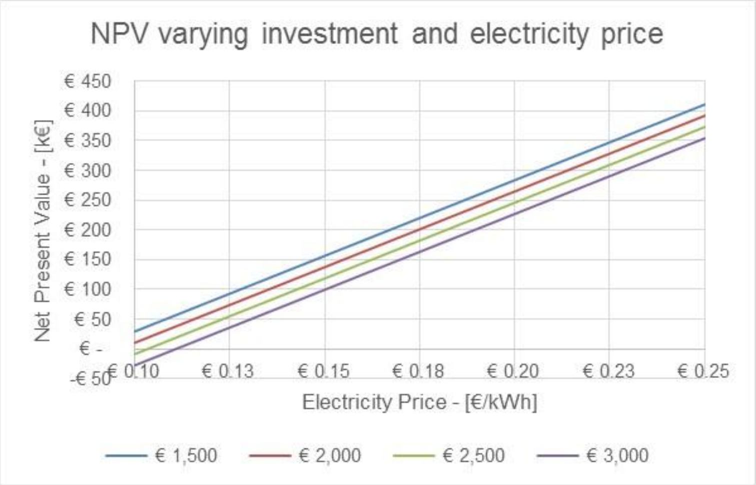
Cost-Benefit Analysis	units	Plant type 1	Plant type 2	Plant type 3
- Costs:				
+ Investments:		**€ 96,050**	**€ 428,900**	**€ 802,000**
- CHP plant		€ 96,050	€ 428,900	€ 802,000
- H&C Network		€ -	€ -	€ -
- Total financial costs on investment (for financing)		€ *10,060*	€ *44,921*	€ *83,997*
+ Yearly O&M costs:		**€ 1,009**	**€ 6,055**	**€ 20,885**
- CHP plant		€ 1,009	€ 6,055	€ 19,765
- Cooling units		€ -	€ -	€ 1,120
- H&C Network		€ -	€ -	€ -
+ Yearly fuel costs:		**€ 22,644**	**€ 123,223**	**€ 422,865**
- Benefits:		**€ 27,971**	**€ 149,121**	**€ 414,273**
+ Yearly savings - Heating energy		€ 16,835	€ 82,302	€ 149,641
+ Yearly savings - Cooling energy		€ -	€ -	€ 46,516
+ Yearly revenues from electricity		€ 11,136	€ 66,819	€ 218,116

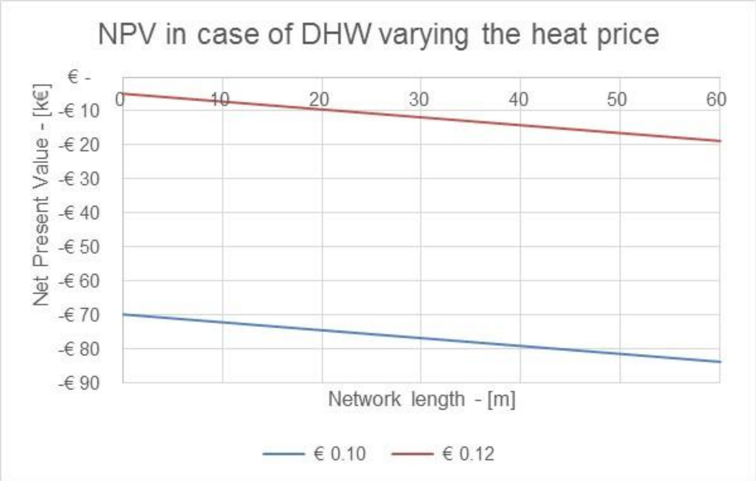
Financial Parameters	units	Plant type 1	Plant type 2	Plant type 3
Net Present Value	€	€ 13,870	€ 96,026	-€ *1,622,231*
Simple payback time	years	18	18	-
Actualized payback time	years	27	25	-
Internal Rate of Return	%	4.90%	5.36%	-

Primary Energy Savings	units	Plant type 1	Plant type 2	Plant type 3
Yearly fuel consumption	l/y	43,735	237,999	816,742
	kWh/y	292,799	1,593,370	5,467,963
Annual overall efficiency	%	81.11%	79.91%	76.20%
Heat efficiency of the cogeneration	%	46.64%	41.90%	40.05%
Electrical efficiency of the cogeneration	%	34.47%	38.00%	36.15%
Reference value for separate heat production	%	90%	90%	90%
Reference value for separate electricity production	%	50%	50%	50%
Primary Energy Savings	%	17.19%	18.41%	14.38%

The following charts represent some of the main outputs of the sensitivity analysis.







6.5.2 Hotels

For the hotels sector, three different **reference CHP Plants** were then sized, starting from the thermal load profiles, for three different types of hotels:

- **Type 1:** 25-99 rooms;
- **Type 2:** 100-249 rooms;
- **Type 3:** 250 or more.

6.5.2.1 Gasoil

The cost-benefit analysis (CBA) is reported in the following tables.

ENERGY PRODUCTION	units	Plant type 1	Plant type 2	Plant type 3
Combined Heat and Power Plant				
Number of CHP units	-	1	1	1
CHP unit Thermal Power	kWt	45	120	320
CHP unit Electrical Power	kWe	35	110	300
CHP unit Fuel Consumption	l/h	9	27	74
Total installed thermal power	**kWt**	**45**	**120**	**320**
Total installed electrical power	**kWe**	**35**	**110**	**300**
CHP unit Fuel Consumption	**l/h**	**9**	**27**	**74**
Cooling Units				
Coefficient of Performance	-	-	-	0.7
Nominal cooling capacity	kWc	0	0	224
Operating Hours				
Heating operation hours	hh/y	1,700	1,700	1,700
Cooling operation hours	hh/y	0	0	1,952
Operating hours per year	**hh/y**	**1,700**	**1,700**	**3,652**
Yearly Energy Productions				
Thermal Energy - Heating	GWht/y	0.08	0.20	0.54
Thermal Energy - Cooling	GWht/y	0.00	0.00	0.62
Thermal Energy - Total	**GWht/y**	**0.08**	**0.20**	**1.17**
Gross Electricity Production	GWhe/y	0.06	0.19	1.10
Self-Consumption	%	5%	5%	5%
Net Electrical Energy	**GWhe/y**	**0.06**	**0.18**	**1.04**
Cooling Energy	**GWhc/y**	**0.00**	**0.00**	**0.44**
Useful Thermal Energy				
Distribution Efficiency	%	98%	98%	98%
Heating Energy	GWht/y	0.07	0.20	0.53
Cooling Energy	GWht/y	0.00	0.00	0.43

SAVINGS & REVENUES	units	Plant type 1	Plant type 2	Plant type 3
Heating Energy Value	€/kWht	0.13	0.13	0.13
Heating Energy Revenues	€/y	€ 9,430	€ 25,146	€ 67,055
Cooling Energy Value	€/kWht	0.07	0.07	0.07
Cooling Energy Revenues	€/y	€ -	€ -	€ 29,771
Electrical Energy Price	€/kWhe	0.11	0.11	0.11
Electrical Energy Revenues	€/y	€ 6,238	€ 19,605	€ 114,861

INVESTMENTS - CHP Plant	units	Plant type 1	Plant type 2	Plant type 3
CHP Plant				
Specific investment cost	€/kWe	€ 2,600	€ 2,100	€ 1,800
Investment cost	€	€ 91,000	€ 231,000	€ 540,000
Cooling Units				
Specific investment cost	€/kWc	250	250	250
Investment cost	€	€ -	€ -	€ 56,000
Cooling Towers				
Specific investment cost	€/kWc	100	100	100
Investment cost	€	€ -	€ -	€ 22,400
Civil and plant works				
Thermal Plant connection	€/kWt	50	50	50
Investment cost	€	€ 2,250	€ 6,000	€ 16,000
Electrical Plant connection	€/kWe	80	90	100
Investment cost	€	€ 2,800	€ 9,900	€ 30,000
INVESTMENTS - CHP Plant		**€ 96,050**	**€ 246,900**	**€ 664,400**

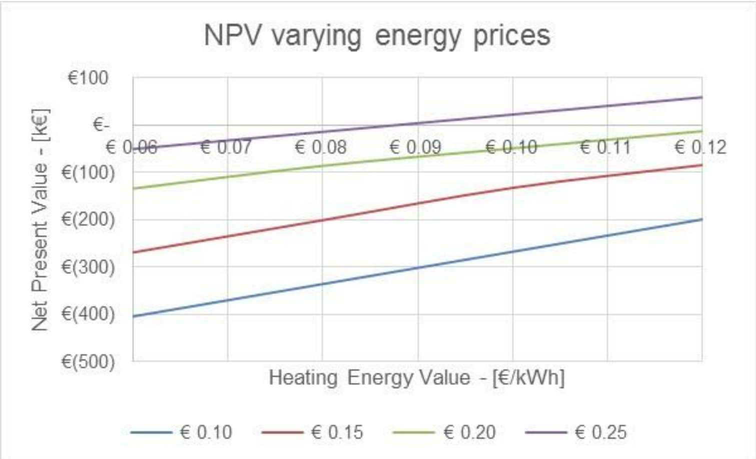
OPERATION & MAINTENANCE	units	Plant type 1	Plant type 2	Plant type 3
Fuel Consumption				
Specific fuel cost	€/liter	1.09	1.09	1.09
Yearly fuel consumption	l/y	15,159	46,091	271,336
Total fuel yearly cost	€/y	€ 16,482	€ 50,113	€ 295,015
CHP Plant				
Specific Maintenance cost	€/kWhe	0.01	0.01	0.01
Yearly Maintenance cost	€/y	€ 565	€ 1,777	€ 10,408
Cooling Units				
Specific Maintenance cost	€/kWc	4.00	4.00	4.00
Yearly Maintenance cost	€/y	€ -	€ -	€ 896

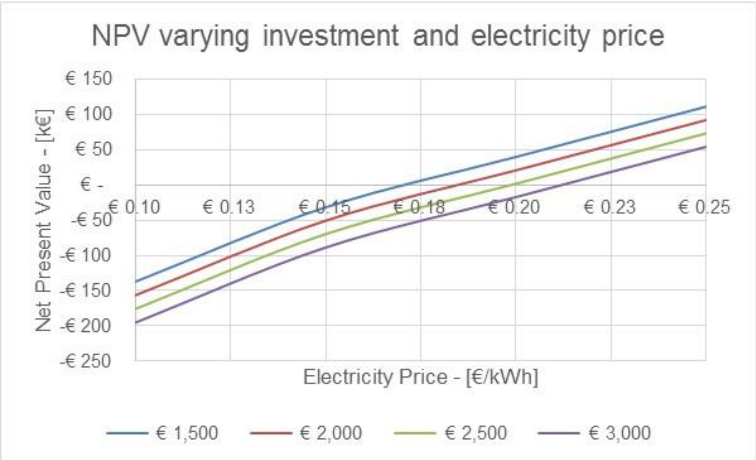
Cost-Benefit Analysis	units	Plant type 1	Plant type 2	Plant type 3
- Costs:				
+ Investments:		**€ 96,050**	**€ 246,900**	**€ 664,400**
- CHP plant		€ 96,050	€ 246,900	€ 664,400
- H&C Network		€ -	€ -	€ -
- Total financial costs on investment (for financing)		€ *10,060*	€ *25,859*	€ *69,586*
+ Yearly O&M costs:		**€ 565**	**€ 1,777**	**€ 11,304**
- CHP plant		€ 565	€ 1,777	€ 10,408
- Cooling units		€ -	€ -	€ 896
- H&C Network		€ -	€ -	€ -
+ Yearly fuel costs:		**€ 16,482**	**€ 50,113**	**€ 295,015**
- Benefits:		**€ 15,667**	**€ 44,750**	**€ 211,686**
+ Yearly savings - Heating energy		€ 9,430	€ 25,146	€ 67,055
+ Yearly savings - Cooling energy		€ -	€ -	€ 29,771
+ Yearly revenues from electricity		€ 6,238	€ 19,605	€ 114,861

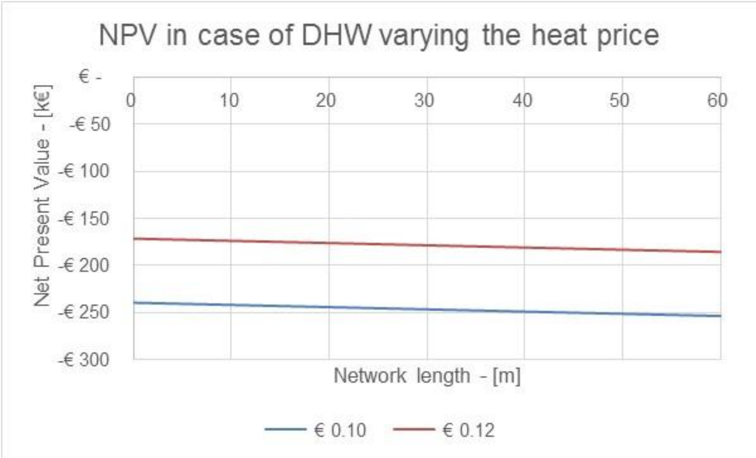
Financial Parameters	units	Plant type 1	Plant type 2	Plant type 3
Net Present Value	€	-€ 151,693	-€ 543,398	-€ 4,714,277
Simple payback time	years	-	-	-
Actualized payback time	years	-	-	-
Internal Rate of Return	%	-	-	-

Primary Energy Savings	units	Plant type 1	Plant type 2	Plant type 3
Yearly fuel consumption	l/y	15,159	46,091	271,336
	kWh/y	154,162	468,734	2,759,435
Annual overall efficiency	%	86.29%	81.42%	80.07%
Heat efficiency of the cogeneration	%	49.62%	43.52%	42.35%
Electrical efficiency of the cogeneration	%	36.67%	37.90%	37.72%
Reference value for separate heat production	%	90%	90%	90%
Reference value for separate electricity production	%	50%	50%	50%
Primary Energy Savings	%	22.16%	19.46%	18.36%

The following charts represent some of the main outputs of the sensitivity analysis.






NPV in case of DHW varying the heat price
Net Present Value - [k€]
€ -
-€ 50
-€ 100
-€ 150
-€ 200
-€ 250
-€ 300
0
10
20
30
40
50
60
Network length - [m]
€ 0.10
€ 0.12

6.5.2.2 LPG

The cost-benefit analysis (CBA) is reported in the following tables.

ENERGY PRODUCTION	units	Plant type 1	Plant type 2	Plant type 3
Combined Heat and Power Plant				
Number of CHP units	-	1	1	1
CHP unit Thermal Power	kWt	45	120	320
CHP unit Electrical Power	kWe	35	110	300
CHP unit Fuel Consumption	l/h	14	44	120
Total installed thermal power	**kWt**	**45**	**120**	**320**
Total installed electrical power	**kWe**	**35**	**110**	**300**
CHP unit Fuel Consumption	**l/h**	**14**	**44**	**120**
Cooling Units				
Coefficient of Performance	-	-	-	0.7
Nominal cooling capacity	kWc	0	0	224
Operating Hours				
Heating operation hours	hh/y	1,700	1,700	1,700
Cooling operation hours	hh/y	0	0	1,952
Operating hours per year	**hh/y**	**1,700**	**1,700**	**3,652**
Yearly Energy Productions				
Thermal Energy - Heating	GWht/y	0.08	0.20	0.54
Thermal Energy - Cooling	GWht/y	0.00	0.00	0.62
Thermal Energy - Total	**GWht/y**	**0.08**	**0.20**	**1.17**
Gross Electricity Production	GWhe/y	0.06	0.19	1.10
Self-Consumption	%	5%	5%	5%
Net Electrical Energy	**GWhe/y**	**0.06**	**0.18**	**1.04**
Cooling Energy	**GWhc/y**	**0.00**	**0.00**	**0.44**
Useful Thermal Energy				
Distribution Efficiency	%	98%	98%	98%
Heating Energy	GWht/y	0.07	0.20	0.53
Cooling Energy	GWht/y	0.00	0.00	0.43

SAVINGS & REVENUES	units	Plant type 1	Plant type 2	Plant type 3
Heating Energy Value	€/kWht	0.13	0.13	0.13
Heating Energy Revenues	€/y	€ 9,430	€ 25,146	€ 67,055
Cooling Energy Value	€/kWht	0.07	0.07	0.07
Cooling Energy Revenues	€/y	€ -	€ -	€ 29,771
Electrical Energy Price	€/kWhe	0.11	0.11	0.11
Electrical Energy Revenues	€/y	€ 6,238	€ 19,605	€ 114,861

INVESTMENTS - CHP Plant	units	Plant type 1	Plant type 2	Plant type 3
CHP Plant				
Specific investment cost	€/kWe	€ 2,600	€ 2,100	€ 1,800
Investment cost	€	€ 91,000	€ 231,000	€ 540,000
Cooling Units				
Specific investment cost	€/kWc	250	250	250
Investment cost	€	€ -	€ -	€ 56,000
Cooling Towers				
Specific investment cost	€/kWc	100	100	100
Investment cost	€	€ -	€ -	€ 22,400
Civil and plant works				
Thermal Plant connection	€/kWt	50	50	50
Investment cost	€	€ 2,250	€ 6,000	€ 16,000
Electrical Plant connection	€/kWe	80	90	100
Investment cost	€	€ 2,800	€ 9,900	€ 30,000
INVESTMENTS - CHP Plant		**€ 96,050**	**€ 246,900**	**€ 664,400**

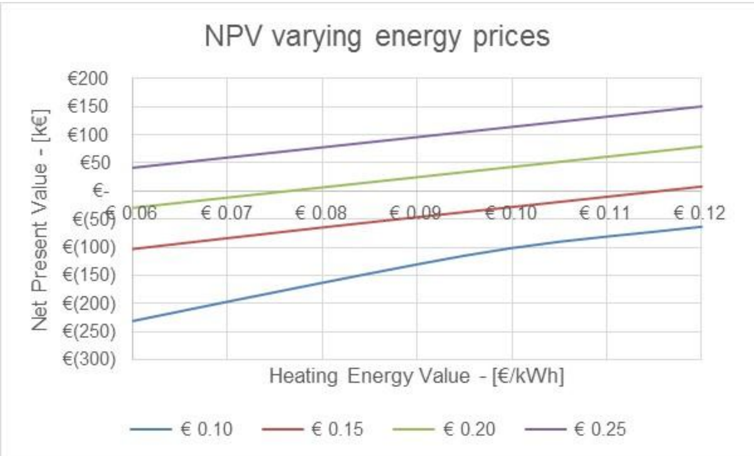
OPERATION & MAINTENANCE	units	Plant type 1	Plant type 2	Plant type 3
Fuel Consumption				
Specific fuel cost	€/liter	0.52	0.52	0.52
Yearly fuel consumption	l/y	24,497	74,485	438,492
Total fuel yearly cost	€/y	€ 12,683	€ 38,564	€ 227,028
CHP Plant				
Specific Maintenance cost	€/kWhe	0.01	0.01	0.01
Yearly Maintenance cost	€/y	€ 565	€ 1,777	€ 10,408
Cooling Units				
Specific Maintenance cost	€/kWc	4.00	4.00	4.00
Yearly Maintenance cost	€/y	€ -	€ -	€ 896

Cost-Benefit Analysis	units	Plant type 1	Plant type 2	Plant type 3
- Costs:				
+ Investments:	**€**	**96,050**	**€ 246,900**	**€ 664,400**
- CHP plant	€	96,050	€ 246,900	€ 664,400
- H&C Network	€	-	€ -	€ -
- Total financial costs on investment (for financing)	€	*10,060*	€ *25,859*	€ *69,586*
+ Yearly O&M costs:	**€**	**565**	**€ 1,777**	**€ 11,304**
- CHP plant	€	565	€ 1,777	€ 10,408
- Cooling units	€	-	€ -	€ 896
- H&C Network	€	-	€ -	€ -
+ Yearly fuel costs:	**€**	**12,683**	**€ 38,564**	**€ 227,028**
- Benefits:	**€**	**15,667**	**€ 44,750**	**€ 211,686**
+ Yearly savings - Heating energy	€	9,430	€ 25,146	€ 67,055
+ Yearly savings - Cooling energy	€	-	€ -	€ 29,771
+ Yearly revenues from electricity	€	6,238	€ 19,605	€ 114,861

Financial Parameters	units	Plant type 1	Plant type 2	Plant type 3
Net Present Value	€	-€ 38,025	-€ 137,258	-€ 1,625,535
Simple payback time	years	27	-	-
Actualized payback time	years	-	-	-
Internal Rate of Return	%	1.05%	-0.39%	-

Primary Energy Savings	units	Plant type 1	Plant type 2	Plant type 3
Yearly fuel consumption	l/y	24,497	74,485	438,492
	kWh/y	164,006	498,665	2,935,636
Annual overall efficiency	%	81.11%	76.53%	75.26%
Heat efficiency of the cogeneration	%	46.64%	40.91%	39.81%
Electrical efficiency of the cogeneration	%	34.47%	35.63%	35.45%
Reference value for separate heat production	%	90%	90%	90%
Reference value for separate electricity production	%	50%	50%	50%
Primary Energy Savings	%	17.19%	14.31%	13.15%

The following charts represent some of the main outputs of the sensitivity analysis.



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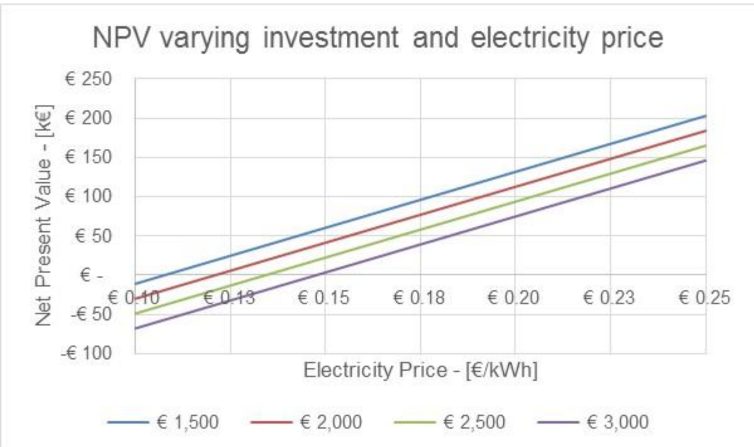
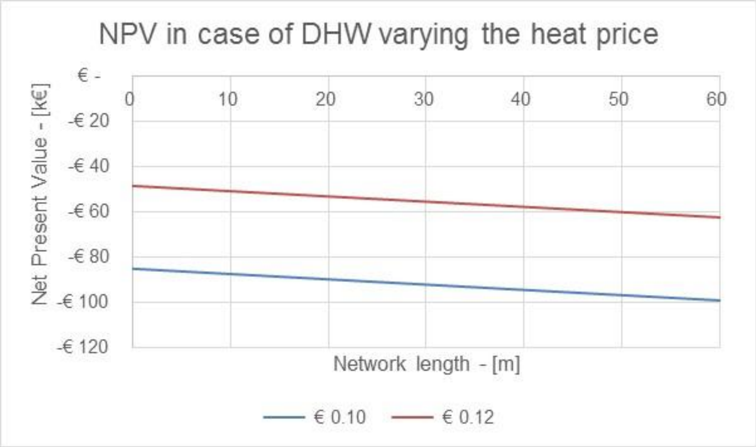



NPV in case of DHW varying the heat price
Net Present Value - [k€]
€ -
-€ 20
-€ 40
-€ 60
-€ 80
-€ 100
-€ 120
0
10
20
30
40
50
60
Network length - [m]
€ 0.10
€ 0.12

6.5.3 Residential

The cost-benefit analysis (CBA) is reported in the following tables.

ENERGY PRODUCTION	units	Plant type
Combined Heat and Power Plant		
Number of CHP units	-	1
CHP unit Thermal Power	kWt	12.50
CHP unit Electrical Power	kWe	5.50
CHP unit Fuel Consumption	l/h	2.96
Operating Hours		
Heating operation hours	hh/y	2,162
Cooling operation hours	hh/y	0
Operating hours per year	**hh/y**	**2,162**
Yearly Energy Productions		
Thermal Energy - Heating	GWht/y	0.03
Thermal Energy - Cooling	GWht/y	0.00
Thermal Energy - Total	**GWht/y**	**0.03**
Gross Electricity Production	GWhe/y	0.01
Self-Consumption	%	5%
Net Electrical Energy	**GWhe/y**	**0.01**
Cooling Energy	**GWhc/y**	**0.00**
Useful Thermal Energy		
Heating Energy Use	%	98%
Heating Energy	GWht/y	0.03
Cooling Energy	GWht/y	0.00

SAVINGS & REVENUES	units		Plant type
Heating Energy Value	€/kWht		0.13
Heating Energy Revenues	€/y	€	3,331
Electrical Energy Price	€/kWhe		0.11
Electrical Energy Revenues	€/y	€	1,246

INVESTMENTS - CHP Plant	units		Plant type
CHP Plant			
Specific investment cost	€/kWe	€	4,300
Investment cost	€	€	23,650
Civil and plant works			
Thermal Plant connection	€/kWt		100
Investment cost	€	€	1,250
Electrical Plant connection	€/kWe		100
Investment cost	€	€	550
INVESTMENTS - CHP Plant		**€**	**25,450**

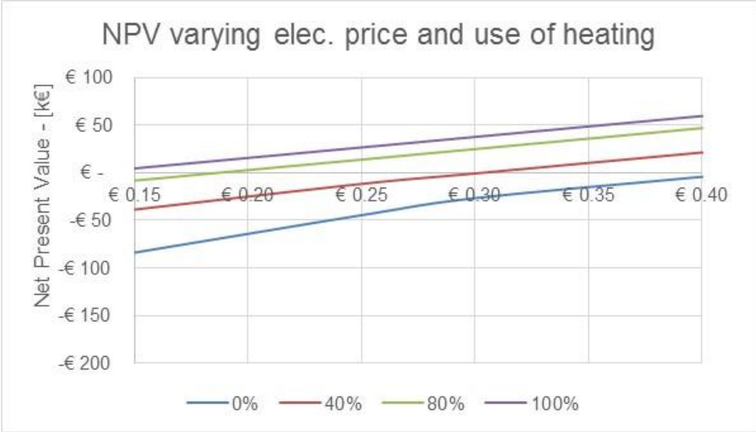
OPERATION & MAINTENANCE	units		Plant type
Fuel Consumption			
Specific fuel cost	€/liter		0.52
Yearly fuel consumption	l/y		6,393
Total fuel yearly cost	€/y	€	3,310
CHP Plant			
Specific Maintenance cost	€/kWhe		0.01
Yearly Maintenance cost	€/y	€	113

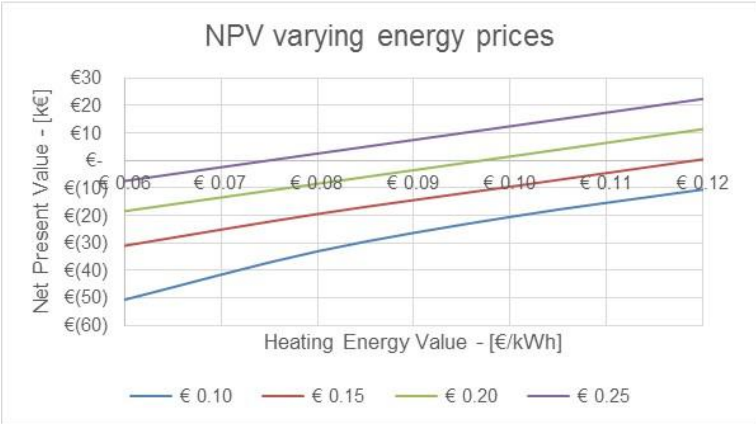
Cost-Benefit Analysis	units		Plant type
- Costs:			
+ Investments:		**€**	**25,450**
- CHP plant		€	25,450
- H&C Network		€	-
- *Total financial costs on investment (for financing)*		*€*	*2,666*
+ Yearly O&M costs:		**€**	**113**
- CHP plant		€	113
- Cooling units		€	-
- H&C Network		€	-
+ Yearly fuel costs:		**€**	**3,310**
- Benefits:		**€**	**4,577**
+ Yearly savings - Heating energy		€	3,331
+ Yearly savings - Cooling energy		€	-
+ Yearly revenues from electricity		€	1,246

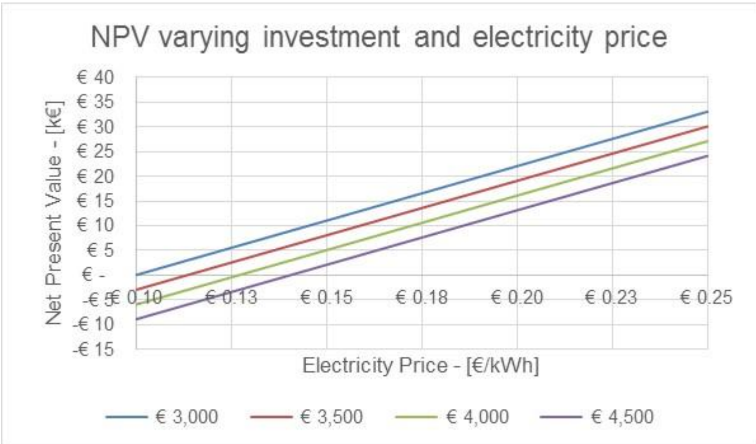
Financial Parameters	units		Plant type
Net Present Value	€	-€	*5,406*
Simple payback time	years		23
Actualized payback time	years		-
Internal Rate of Return	%		2.32%

Primary Energy Savings	units	Plant type
Yearly fuel consumption	l/y	6,393
	kWh/y	42,801
Annual overall efficiency	%	89.52%
Heat efficiency of the cogeneration	%	63.13%
Electrical efficiency of the cogeneration	%	26.39%
Reference value for separate heat production	%	90%
Reference value for separate electricity production	%	50%
Primary Energy Savings	%	18.65%

The following charts represent some of the main outputs of the sensitivity analysis.







Based on the assumption made within this paragraph, the table below contains also an estimation of the **Levelized Cost Of Energy** of a micro-CHP unit applied to the residential sector.

Parameters		
Life of the system *n*	20	years
Discount rate *r*	4%	
Specific Cost (CHP Unit + Plant)	€ 4,627	€/kWe

Variables name reference

LCOE: Levelized Cost Of *Energy*

It: Investment expenditures in the year t
Mt: Operations and maintenance expenditures in the year t
Ft: Fuel expenditures in the year t
Et: *Energy* generation in the year t
r: Discount rate
n: Life of the system

$$\mathrm{LCOE} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

LCOE\Part1 $\sum_{t=1}^{n} \frac{I_t+M_t+F_t}{(1+r)^t}$ 73,962 €

LCOE\Part2 $\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}$ 513,393 kWh

LCOE $\frac{\sum_{t=1}^{n} \frac{I_t+M_t+F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$ **0.144 €/kWh**

	Expenditures					*Energy*	
t (year)	**Investment** It	**O&M** Mt	**Fuel** Ft	**TOTAL** It+Mt+Ft	**TOTAL** It+Mt+Ft **Disc.**	**Energy** Et	**Energy** Et **Disc.**
	€	€	€	€	**€**	*kWh/y*	***kWh/y***
1	€ 25,450	€ 113	€ 3,310	€ 28,873	**€ 27,762**	37,776	**36,323**
2		€ 115	€ 3,333	€ 3,448	**€ 3,188**	37,776	**34,926**
3		€ 118	€ 3,357	€ 3,474	**€ 3,088**	37,776	**33,583**
4		€ 120	€ 3,380	€ 3,500	**€ 2,992**	37,776	**32,291**
5		€ 122	€ 3,404	€ 3,526	**€ 2,898**	37,776	**31,049**
6		€ 125	€ 3,427	€ 3,552	**€ 2,807**	37,776	**29,855**
7		€ 127	€ 3,451	€ 3,579	**€ 2,720**	37,776	**28,707**
8		€ 130	€ 3,476	€ 3,605	**€ 2,634**	37,776	**27,603**
9		€ 132	€ 3,500	€ 3,632	**€ 2,552**	37,776	**26,541**
10		€ 135	€ 3,524	€ 3,659	**€ 2,472**	37,776	**25,520**
11		€ 138	€ 3,549	€ 3,687	**€ 2,395**	37,776	**24,539**
12		€ 140	€ 3,574	€ 3,714	**€ 2,320**	37,776	**23,595**
13		€ 143	€ 3,599	€ 3,742	**€ 2,248**	37,776	**22,687**
14		€ 146	€ 3,624	€ 3,770	**€ 2,177**	37,776	**21,815**
15		€ 149	€ 3,650	€ 3,799	**€ 2,109**	37,776	**20,976**
16		€ 152	€ 3,675	€ 3,827	**€ 2,043**	37,776	**20,169**
17		€ 155	€ 3,701	€ 3,856	**€ 1,980**	37,776	**19,393**
18		€ 158	€ 3,727	€ 3,885	**€ 1,918**	37,776	**18,647**
19		€ 161	€ 3,753	€ 3,914	**€ 1,858**	37,776	**17,930**
20		€ 165	€ 3,779	€ 3,944	**€ 1,800**	37,776	**17,241**
					€ 73,962		513,393

The LCOE - levelized cost of **electricity** – measured in €/kWh - is the net present value of the unit cost of electricity over the lifetime of a generating asset. It is a first-order economic assessment of the cost competitiveness of an electricity-generating system that incorporates all costs over its lifetime: initial investment, operations and maintenance, cost of fuel, cost of capital.

Nevertheless, differently from this standard definition of the LCOE, the analysis proposed considers the unit cost of all the **energy** produced by the CHP unit (thermal and electrical energy) rather than just the electricity. With this assumption, the analysis refers to the acronym "LCOE" as the Levelized Cost Of Energy. The rule used for the calculation is the following:

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

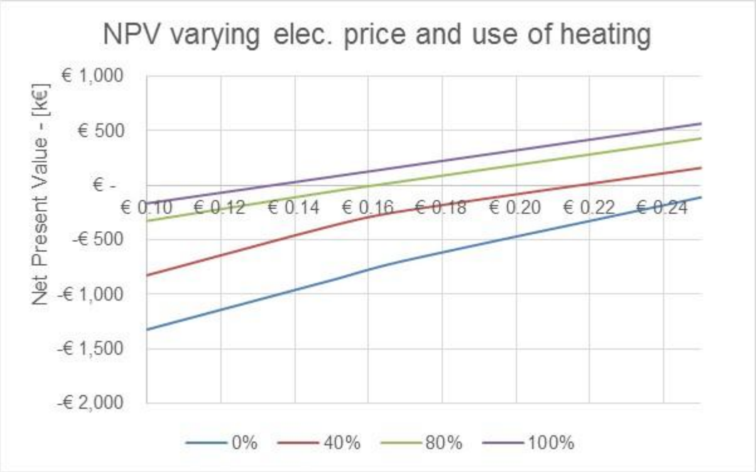
Where:

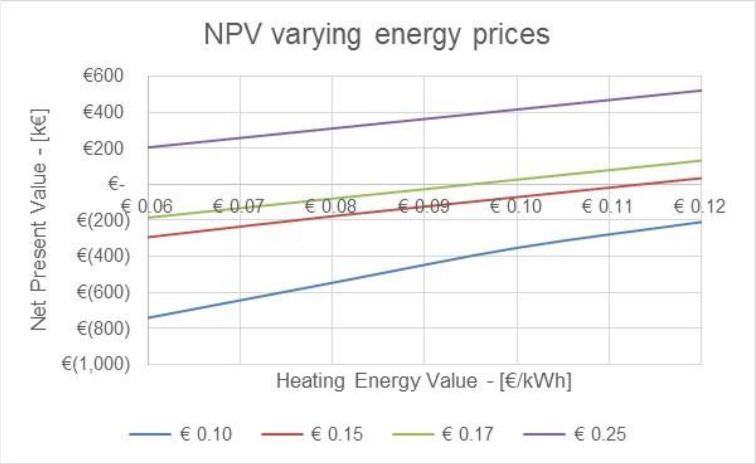
I_t: Investment expenditures in the year t
M_t: O&M: Operations and maintenance expenditures in the year t
F_t: Fuel expenditures in the year t
E_t: Energy generation in the year t
r: Discount rate
n: Life of the system

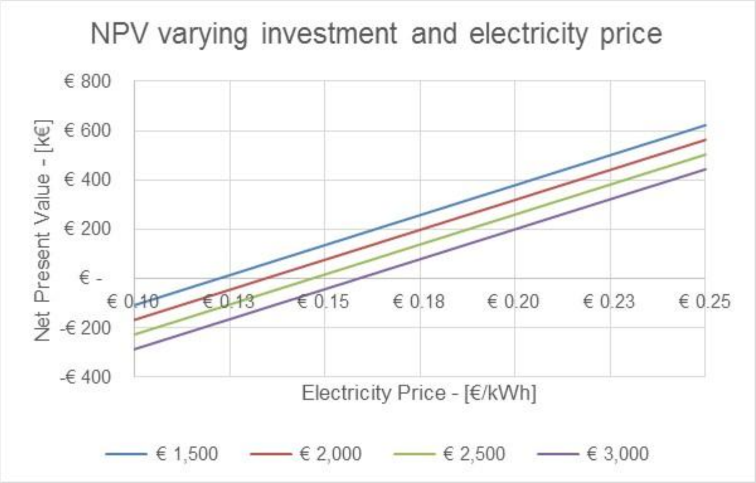
6.5.4 Industry

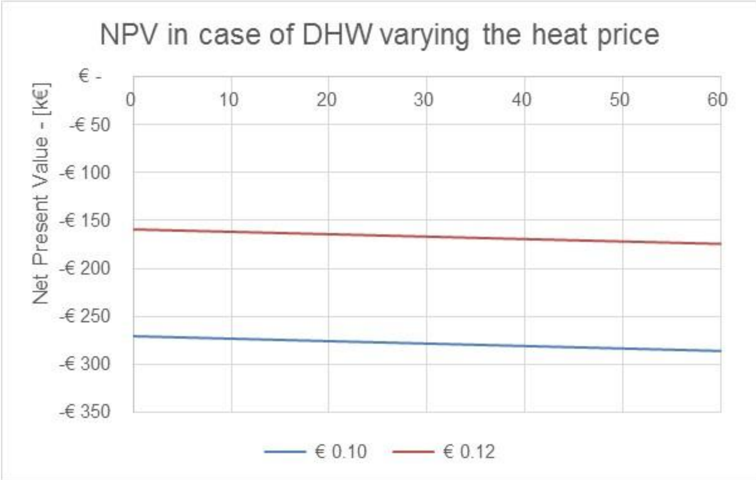
6.5.4.1.1 Single industry CHP unit

The analysis (already introduced in 5.1.3.3.1) aimed to give a general evaluation in order to highlight cases and possibilities in the industry sector that can make the CHP installations viable in a cost-effective way.. The following charts represent some of the main outputs of the sensitivity analysis.








NPV in case of DHW varying the heat price
Net Present Value - [k€]
€ -
-€ 50
-€ 100
-€ 150
-€ 200
-€ 250
-€ 300
-€ 350
0
10
20
30
40
50
60
€ 0.10
€ 0.12

6.5.4.1.2 District heating network

The analysis refers to the case study presented in 5.1.3.3.2.

ENERGY PRODUCTION	units		Plant type
Combined Heat and Power Plant			
Number of CHP units	-		1
CHP unit Thermal Power	kWt		530
CHP unit Electrical Power	kWe		500
CHP unit Fuel Consumption	l/h		193
Total installed thermal power	**kWt**		**530**
Total installed electrical power	**kWe**		**500**
CHP unit Fuel Consumption	**l/h**		**193**
Operating Hours			
Heating operation hours	hh/y		2,250
Cooling operation hours	hh/y		0
Operating hours per year	**hh/y**		**2,250**
Yearly Energy Productions			
Thermal Energy - Heating	GWht/y		1.19
Thermal Energy - Cooling	GWht/y		0.00
Thermal Energy - Total	**GWht/y**		**1.19**
Gross Electricity Production	GWhe/y		1.13
Self-Consumption	%		5%
Net Electrical Energy	**GWhe/y**		**1.07**
Cooling Energy	**GWhc/y**		**0.00**
Useful Thermal Energy			
Heating Energy Use	%		95%
Heating Energy	GWht/y		1.13
Cooling Energy	GWht/y		0.00

SAVINGS & REVENUES	units		Plant type
Heating Energy Price	€/kWht		0.09
Heating Energy Revenues	€/y	€	100,168
Cooling Energy Value	€/kWht		0.06
Cooling Energy Revenues	€/y	€	-
Electrical Energy Price	€/kWhe		0.11
Electrical Energy Revenues	€/y	€	117,943

INVESTMENTS - CHP Plant	units		Plant type
CHP Plant			
Specific investment cost	€/kWe	€	1,600
Investment cost	€	€	800,000
Cooling Units			
Specific investment cost	€/kWc		250
Investment cost	€	€	-
Cooling Towers			
Specific investment cost	€/kWc		100
Investment cost	€	€	-
Civil and plant works			
Fuel tanks	litres		100,000
Specific Investment	€/litre		0.84
Investment cost	€	€	84,000
Thermal Plant connection	€/kWt		50
Investment cost	€	€	26,500
Electrical Plant connection	€/kWe		80
Investment cost	€	€	40,000
INVESTMENTS - CHP Plant		**€**	**950,500**

HEATING & COOLING NETWORK	units		Plant type 1
Heating and Cooling Network - Main line			
Heating - Water Flow	l/h		*see DHN analysis*
Heating - Diameter	DN		*see DHN analysis*
Average Specific Cost	€/m	€	225
H&C pipes length	m		2,500
Investment costs - Heating	€	€	562,366
Investment costs - Cooling	€	€	-
Connections			
Number of users			40
Substation specific cost	€	€	9,000
Investment costs - Substations	€	€	360,000
Pipe connections	€	€	4,000
Total investment - Connections	€	€	160,000
INVESTMENTS - H&C NETWORK		**€**	**1,082,366**

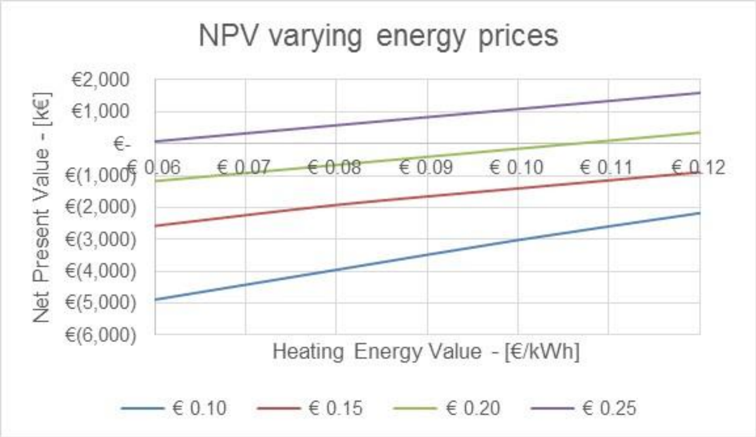
OPERATION & MAINTENANCE	units		Plant type
Fuel Consumption			
Specific fuel cost	€/liter		0.52
Yearly fuel consumption	l/y		435,178
Total fuel yearly cost	€/y	€	225,312
CHP Plant			
Specific Maintenance cost	€/kWhe		0.01
Yearly Maintenance cost	€/y	€	10,688
Cooling Units			
Specific Maintenance cost	€/kWc		4.00
Yearly Maintenance cost	€/y	€	-
Heating & Cooling network			
- Operation & Maintenance	€/m		0.80
- Repairs	€/m		2.50
- Control and monitoring	€/MWt		500
Total Management costs H&C network:	€/y	€	8,515

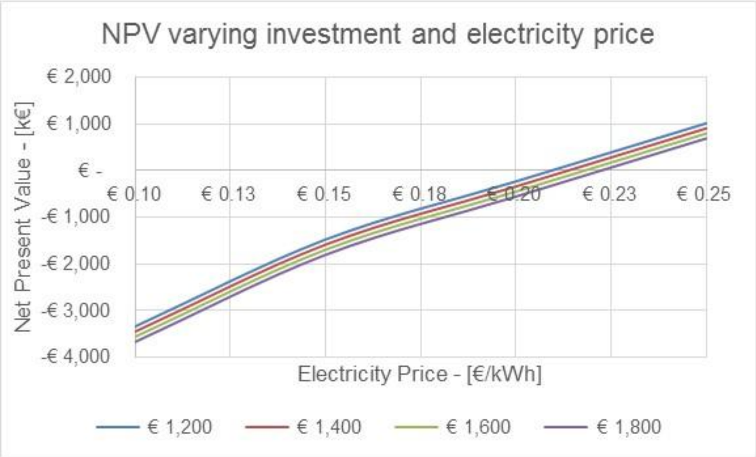
Cost-Benefit Analysis	units	Plant type
- Costs:		
+ Investments:	**€**	**2,032,866**
- CHP plant	€	950,500
- H&C Network	€	1,082,366
- Total financial costs on investment (for financing)	*€*	*212,912*
+ Yearly O&M costs:	**€**	**19,203**
- CHP plant	€	10,688
- Cooling units	€	-
- H&C Network	€	8,515
+ Yearly fuel costs:	**€**	**225,312**
- Benefits:	**€**	**218,111**
+ Yearly savings - Heating energy	€	100,168
+ Yearly savings - Cooling energy	€	-
+ Yearly revenues from electricity	€	117,943

Financial Parameters	units	Plant type
Net Present Value	€	-€ 3,082,234
Simple payback time	years	-
Actualized payback time	years	-
Internal Rate of Return	%	-

Primary Energy Savings	units	Plant type
Yearly fuel consumption	l/y	435,178
	kWh/y	2,913,452
Annual overall efficiency	%	77.61%
Heat efficiency of the cogeneration	%	40.93%
Electrical efficiency of the cogeneration	%	36.68%
Reference value for separate heat production	%	90%
Reference value for separate electricity production	%	50%
Primary Energy Savings	%	15.86%

The following charts represent some of the main outputs of the sensitivity analysis.





6.6 Financial Analysis conclusions

Combined Heat and Power (CHP). Currently Malta does not have a network of natural gas distribution (a feasibility study considering a number of distribution hubs is still underway), so the assessment considered the installation of **LPG** or **Gasoil** fueled units.

The analysis introduced theoretical "Plant types", identified as typical applications starting from the calculation carried out within Sub-Task 1 about the heating and cooling demand. A **financial analysis** was developed for each "Plant types" in the different sectors, for assessing the economic feasibility of the investment. Each financial analysis has been combined with a **sensitivity analysis**, for evaluating the costs and benefits balance of the projects based on different energy prices, discount rates and other variable factors having a significant impact on the outcome of the calculations. The aim was to evaluate how the final result of the investment was influenced by the variations of factors - for example the fuel prices – that can be characterized by uncertainty and variability.

The economic potential analysis confirmed difficulties for the cogeneration, eventually associated to district heating or cooling, in having positive NPV of the investments. As already stated by (CODE2 Cogeneration Observatory and Dissemination Europe, July 2014), this is mainly due to[52]:

- Low thermal loads and low heat/power ratios required;

[52] (CODE2 Cogeneration Observatory and Dissemination Europe, July 2014), page 11 and 17.

- The non-connection of residences and industrial sites to the natural gas grid. This force the use of expensive and high taxed fuels for cogeneration (LPG, Diesel), reducing the spark spread, with higher emission factors in the atmosphere.

Nevertheless, based on the current available data in terms of fuel cost, the sensitivity analysis showed how the LPG-fuelled applications of CHP seem to offer more opportunities of cost-effectiveness, especially when the use of the heating energy produced by the CHP unit is maximized.

A key element for the economic feasibility is the value of the electrical energy produced. For this reason, the sensitivity analysis highlighted different results of the investments varying the economic value of the electricity produced.

In ascending order it was considered a value close to the "marginal cost" of electricity, another ones similar to the purchasing cost of electricity, and a last one – the highest value - which may be associated to an eventual "**feed-in tariff"**. The opportunity of directly **self-consuming** significant amounts to the electricity produced (for example in the case of hospitals, hotels or industries) is definitely a good opportunity to improve investment results. The implementation of a "feed-in tariff" scheme on the electricity produced or fed into the grid by CHP installation, is another opportunity to boost investments.

It is worth recalling that the assessment of the actual technical and economic feasibility of the interventions must be carried out with a detailed case-by-case analysis in order to:

- Evaluate the real technical feasibility of interventions based on the technical and safety regulation constraints and the availability of necessary spaces for the installation.
- Identify the optimal size of the plant based on the actual energy needs of the buildings;
- Perform a financial analysis for the specific case.

The technical and economic potential analysis has also examined the feasibility of a district heating network, applied to an industrial area. In this case, the supply and installation costs of the network in an existing urban context, which is charged on total investment, makes more difficult the economic viability of the investment, which would require the implementation of significant support measures and incentives.

In all the cases examined, they are not to be underestimated the technical issues related to the LPG or Gasoil supply tanks for the CHP unit, with a necessary capacity increasing with the size of the installations.

Combined Heat and Power (CHP) from biogas. As highlighted by (CODE2 Cogeneration Observatory and Dissemination Europe, July 2014) and according to the report "Malta Indicative National Energy Efficiency Target for 2020 in accordance with Article 3 of Directive 2012/27/EU", *"one of the potential sectors for the development of CHP is the waste sector"*.

- For what concerns the **existing biogas facilities** (infrastructures using bio-waste already installed and operating in the islands) the analysis of the available data showed that currently the thermal energy produced by these plants is mostly used for the systems' internal processes. Furthermore, the very limited amount of thermal energy available for a possible export does not seem sufficient to justify the realization of infrastructures, such as district heating networks, for exporting the produced thermal energy. Exception is the plant of Sant'Antnin (Marsascala) where the heat is also already delivered to a nearby swimming pool.

- Regarding the **new potential biogas facilities**, Assignment I – Task 2 – Sub-Task 6 identified the possibility for the creation of three new *Mechanical Biological Treatment* plants (MBTs) producing biogas for fueling three CHP units with electrical and thermal power respectively of **250** and **290 kW**. The CHP plants may serve – through a district heating network - industrial areas needing thermal energy for winter heating and for industrial processes demand. In this case, the return of investment is made easier by the avoided costs for conferring MSW, estimated within Task 2 – Sub-Task 6, and due to an improved waste management strategy. Starting from the overall production potential (approximately 3,960 hours per year), the profitability of the investment depends, in addition to energy prices, on the amount of useful thermal energy that effectively will be delivered to the users.

Heat Recovery. In absence of data about **industrial processes**, the technical and economic potential of the heat recoverable from industrial process in Malta has referred to the results of a recent study carried on in the industrial sector of UK. Considering this reference, the technical and economic potentials were estimated – for the year 2015 - in approximately **7.4** and **4.7 GWh**. Nevertheless, since this reference to the study may not be completely consistent with the local Maltese scenario, a detailed case-by-case study is the correct way to evaluate the actual technical feasibility of heat recovery from industrial processes.

Concerning the **Delimara Power Station**, considering the available data and information, it does not seem to provide significant amount of waste heat at a useful temperature, which may be used, through a district heating network, for heating purposes.

Some possible supporting measures for supporting the technologies described in this chapter could be:

- **Feed-in tariffs**, for the net (or total) electricity generated by the CHP plants;
- The possibility (in absence of a feed-in tariff scheme) of **self-consuming** the electricity produced by the generation plants;
- Tax and excises reduction polices on **fuel price**;
- **White certificates**[53], also known as “Energy Efficiency Certificates” (EEC): tradable instruments giving proof of the achievement of end-use energy savings through energy efficiency improvement initiatives (see paragraph 8.1.2.1 for further details).
- **Tax rebates** for those building renovations including sustainable heating and cooling;
- **Low interest revolving funds**, aiming to reduce the cost of capital for energy efficiency investments.

[53] http://www.gse.it/en/White%20Certificates/Pages/default.aspx

6.7 Economic Cost Benefit Analysis

6.7.1 Alternative Scenarios

Sub-Task 4 identified several Alternative Scenarios, considering relevant possibilities for how heating and cooling can be made more efficient. Considering all the hypothesis and assumptions made within Sub-Task 3 and 4, these scenarios can be summarized as follows:

- **Alternative Scenario 1** deals with machines fuelled with biogas from waste:
  a. *Existing Biogas Facilities*: infrastructures using bio-waste already installed and operating in the islands;
  b. *New potential biogas facilities:* projects making use of biogas from waste management, which potentially may be implemented.

- **Alternative Scenario 2** estimates the economic potential of heat recovery in the industrial sector.

- **Alternative Scenario 3** considers the realization of CHP Plants in the following types of buildings:

Type of building	Fuel
Hospitals	Gasoil and LPG
Hotels	Gasoil and LPG
Residential buildings	LPG
Industry	LPG

6.7.2 Financial analysis

Several financial analysis including the **NPV – Net Present Value** calculation were developed in Sub-Task 4, referred to the technical description presented with Sub-Task 3. With the aim of evaluating how the investment NPV is influenced by the variations of factors - for example the fuel prices - characterized by uncertainty and variability, each financial analysis is combined with a **sensitivity analysis**. The sensitivity analysis assesses the costs and benefits balance of the project based on different energy prices, discount rates and other variable factors having a significant impact on the outcome of the calculations.

The following tables summarize the main results of the **financial analysis** in terms of Net Present Value for each Alternative Scenario. The reported values are the results of the starting analysis, developed with the parameters introduced within Sub-Task 4.

Alternative Scenario 1

Alternative Scenario 1 Fuel: **Biogas**	**Net Present Value** *Mln€*
New potential biogas facilities	0.488

Alternative Scenario 2. In absence of data about **industrial processes**, the technical and economic potential of the heat recoverable from industrial process in Malta was obtained through a statistical approach. The analysis provided an economic potential (total yearly recoverable heat through *NPV positive projects*) of approximately **4.7 GWh**.

Alternative Scenario 3

Alternative Scenario 3	**Net Present Value**		
Fuel: **LPG**	Plant Type 1 *Mln€*	Plant Type 2 *Mln€*	Plant Type 3 *Mln€*
Hospitals	0.014	0.096	-1.622
Hotels	-0.038	-0.137	-1.626
Residential buildings	-0.005	-	-
Industry	-0.129	-	-

Alternative Scenario 3	**Net Present Value**		
Fuel: **Gasoil**	Plant Type 1 *Mln€*	Plant Type 2 *Mln€*	Plant Type 3 *Mln€*
Hospitals	-0.187	-1.066	-7.375
Hotels	-0.152	-0.543	-4.714
Residential buildings	-	-	-
Industry	-	-	-

6.7.3 Economic analysis

The following paragraphs report the methodology and the main results of the **economic analysis**. Starting for the performed financial analysis, some adjustments have to be introduced in the analysis to reflect a **social perspective**:

- The prices of inputs (including labour) are gross of **direct taxes** in the financial analysis but should be net of taxes within the economic analysis. On the contrary, the economic analysis should be conducted gross of **subsidies** because they are a cost for the society[54].

[54] Subsidies were not considered in the economic analysis since they are currently not present in the national policy for the heating technologies considered in Sub-Task 3 and 4.

- It is required to estimate and include in the analysis the externalities or impacts on **society welfare**. These are not taken into account in the financial analysis as they do not generate a real cash flow for investors.

Starting from the results of Sub-Task 3 and 4 (technical and economic potential) the economic analysis was carried out considering a realistic set of more likely installations selected within the overall potential. For this reason, the economic analysis was focused on a limited part of the investments introduced within **Alternative Scenarios 1** and **3**. This considered configuration is represented in the following table[55].

	Number of installations			
	Plant Type 1	Plant Type 2	Plant Type 3	**Total**
Alternative Scenario 1				
New potential biogas facilities	3	-	-	**3**
Alternative Scenario 3				
Hospitals	0	0	1	**1**
Hotels	12	7	1	**20**
Residential buildings	0	-	-	**0**
Industry	0	-	-	**0**

The economic analysis identifies, for each Alternative Scenario, cumulative **Economic Net Present Values**, considering the set of investments reported in table and the methodological approach presented in the next paragraph.

6.7.3.1 Micro-economic evaluations

6.7.3.1.1 Methodological approach

The **cost** and **benefit** elements considered in the economic analysis are described within the following two tables.

In the calculation of the Economic Net Present Value, the Social discount rate (SDR) was considered. The **Social Discount Rate** (SDR) reflects the social view on how future benefits and costs should be valued against present ones. For the programming period 2014-2020, the European Commission[56] suggests using two benchmark social discount rates: **5%** for the Cohesion countries and 3% for the others.

[55] The numbers reported in the table are a subset of the technical potential calculated within Sub-Task 3. CHP units were considered as fueled by LPG.
[56] (European Commision, 2014)

<table>
<tr><th colspan="2">COSTS</th></tr>
<tr><td>Capital cost</td><td>Capital cost of heating and cooling supply are the same that were accounted for in the financial analysis but considering them net of direct taxes.</td></tr>
<tr><td>Operation and maintenance costs</td><td>Operation and maintenance costs of heating and cooling supply are the same that were accounted for in the financial analysis but considering them net of direct taxes.</td></tr>
<tr><td>Fuel costs</td><td>Fuel and electricity costs are the same that were accounted for in the financial analysis but considering them net of direct taxes.</td></tr>
<tr><td>Loss of revenues from electricity production</td><td>Negligible, not considered in the analysis</td></tr>
<tr><td>Environmental and health externalities</td><td>Energy production causes different types of environmental impacts as a consequence of the emission of pollution; land occupation and resources consumption (fuels, water, etc.) during the energy production process. These kinds of impacts generate a loss of welfare on society. In the construction of new CHP plants, the damage caused by both energy products obtained as an output (so, heat and electricity) has to be accounted for. Damage factors in (Alberici, et al., 2014) provide the information required.

Production of Heat
<table>
<tr><th>Technologies</th><th>Environmental damage
(EUR2012 / MWh_{th})</th></tr>
<tr><td>CHP -Bio (Heat)</td><td>4.3</td></tr>
<tr><td>CHP -Natural gas (Heat)</td><td>11.7</td></tr>
<tr><td>CHP -Hard coal (Heat)</td><td>24.1</td></tr>
<tr><td>CHP -Waste (Heat)</td><td>10.1</td></tr>
</table>

Production of Electricity[57]
<table>
<tr><th>Technologies</th><th>Environmental damage
(EUR2012 / MWh_{el})</th></tr>
<tr><td>CHP -Bio (Heat)</td><td>15</td></tr>
<tr><td>CHP -Natural gas (Heat)</td><td>37</td></tr>
<tr><td>CHP -Hard coal (Heat)</td><td>95</td></tr>
<tr><td>CHP -Waste (Heat)</td><td>35</td></tr>
</table>
</td></tr>
<tr><td>Impact of energy dependency</td><td>Impact on the economy caused by increases of imported fuel prices. Beyond the complexity of the relationship between fuel prices and economic activity, the additional fuel volumes associated to the Scenarios are very low and so the economic impact on energy prices can be considered negligible.</td></tr>
</table>

[57] Estimations from (Alberici, et al., 2014)

BENEFITS	
Revenues from selling electricity	They are the same as in the financial analysis
Residual value	Not considered in the analysis
Impact on reliability of the system operation	Negligible, not considered in the analysis
Macroeconomic impact	See paragraph "Macro-economic evaluations"

As a result of the considerations reported above, the following tables[58] summarize the parameters used in the economic analysis.

LPG Parameters			
Fuel density		0.522	kg/l
Fuel Price	€	0.50	/liter
	€	0.96	/kg
	€	957	€/t
Excise duties on LPG	€	38.94	€/t

Discount and Taxes rates	
Direct Tax flat-rate	35%
Financial Discount Rate (FDR)	4%
Social Discount Rate (SDR)	5%
Estimation of excise duties on LPG *(as % of the total fuel price)*	4%

Damage factors for CHP energy production			
(Estimation from Alberci et al., 2014)			
CHP from Biogas			
Damage factor for electricity	€	15,000	€/GWhe
Damage factor for heat	€	4,000	€/GWhth
CHP from LPG			
Damage factor for electricity	€	40,000	€/GWhe
Damage factor for heat	€	12,000	€/GWhth

6.7.3.1.2 Results

The results of the calculations for Alternative Scenarios 1 and 3 shown in sections 6.7.3.2 and 6.7.3.3 contain the following:

- The Cumulative Financial Analysis, expressing overall **Financial Net Present Values** for the Scenarios;
- The Cumulative Economic Analysis, expressing overall **Economic Net Present Values** for the Scenarios. The analysis considers, as introduced above:

    a. Costs:
        i. Capital cost, operation and maintenance costs and fuel costs net of **direct taxes**.
        ii. Environmental and health **externalities**, calculated with the factors proposed by Alberici et al., 2014.

[58] For the estimations on the excise duties on LPG (European Commission, 2015)

b. Benefits: **revenues** as they are in the financial analysis.

6.7.3.2 Macro-economic evaluations

There is substantial literature evidence of the positive outcome for GDP growth and employment derived from increases on energy efficiency. The assessment of the macro-economic impact of energy efficiency measures was made using the estimations made by NE – Nomisma Energia[59] and it is reported in the following table.

	Cumulative Production *Mln€*	**Cumulative Added Value** *Mln€*	**Cumulative Employment** *Full-time units*
Alternative Scenario 1	12.6	5.4	42
Alternative Scenario 3	3.67	1.58	13

6.7.3.3 Conclusions

As conclusion of the Economic Cost Benefit Analysis, the following table compares, for the chosen configuration including investments within Alternative Scenarios 1 and 3, the values of:

- Financial Net Present Values, calculated in Sub-Task 4;
- Economic Net Present Values, calculated as introduced in 6.7.3.1;
- Macroeconomic impact, as introduced in 6.7.3.2.

	Financial Net Present Value *Mln€*	**Economic** Net Present Value *Mln€*	**Cumulative Added Value** *Mln€*
Alternative Scenario 1	1.46	8.57	5.4
Alternative Scenario 3	-4.66	1.38	1.58

[59] Assignment I – Task 2 – Sub-Task 3

7 Sub-Task 5 – Maps of heat loads

The maps represent at territorial level the results of the previous developed Sub-Tasks. In particular, the consumption maps were created considering different breakdowns:

- Final Energy Consumption and Heating and Cooling Energy Demand;
- Energy uses introduced above (space heating and cooling, water heating);
- Energy sources associated to the various uses (i.e. electricity, fossil fuels etc.);
- Sectors of application (residential, industry and services);
- Geographical location (subdivision considering the 68 Maltese local councils).

The reference results for building the maps are the ones obtained for the different sectors in 3.2.1.4 (residential), 3.2.2.3 (services), and 3.2.3.3 (industry). These national estimated energy quantities, were thus allocated to the different local councils.

This breakdown was done on the basis of indicators, often called “surrogate variables” or “proxies”, which can represent the distribution of the “weight” of the overall amounts in the territory. The “total” value was switched to the “local” value proportioning the total value on the basis of this surrogate variable.

For the **residential sector**, the surrogate variables were chosen within the dataset given by the Census 2011[60]. Basically, the chosen variables were the numbers of households owning the different types of energy equipment for heating and cooling used for converting the different energy sources into useful energy. For each energy use and sources, the table reports the data used as surrogate variable.

Energy Uses & Sources	**Surrogate Variable** *Number of Households owning:*
Heating	
Fossil Fuels	Heaters
Solid Biomass	Fireplace
Electric Heating	Heaters
Heating (Air Conditioning)	Air Conditioning
Cooling	
Electricity	Air Conditioning
Water Heating	
Fossil Fuels	Heaters
Solar Thermal	Solar Water Heater
Electricity	Water Heater

For the industry and services sector, the overall energy amounts were transposed into “local” values using the electricity consumption at councils’ level as surrogate variable. The values were obtained as an elaboration of the 2013 database provided by NSO.

[60] (National Statistics Office, 2014)

The following table contains the complete set of variables that was uploaded on the Malta GIS maps at councils' level. The GIS database associates a value for each variable to the all geographic elements being part of the map.

Energy Demand		Residential	Services	Industry
Heating				
	Fossil Fuels	ED_RES_H_FF	ED_SER_H_FF	-
	Solid Biomass	ED_RES_H_SolidBiomass	-	-
	Electricity	ED_RES_H_ELEC	ED_SER_H_ELEC_AC	ED_IND_H_ELEC_AC
	Total	**ED_RES_H**	**ED_SER_H**	**ED_IND_H**
Cooling				
	Electricity	**ED_RES_C**	**ED_SER_C**	**ED_IND_C**
Water Heating				
	Fossil Fuels	ED_RES_WH_FF	ED_SER_WH_FF	ED_IND_WH_FF
	Solar Thermal	ED_RES_WH_STh	ED_SER_WH_STh	ED_IND_WH_STh
	Electricity	ED_RES_WH_ELEC	ED_SER_WH_ELEC	ED_IND_WH_ELEC
	Total	**ED_RES_WH**	**ED_SER_WH**	**ED_IND_WH**
TOTAL		**ED_RES_TOT**	**ED_SER_TOT**	**ED_IND_TOT**

The name of each variable is structured into different fields as follows:

1	_	2	_	3	_	4

1. Type of Energy: ED = (Heating and Cooling) Energy Demand

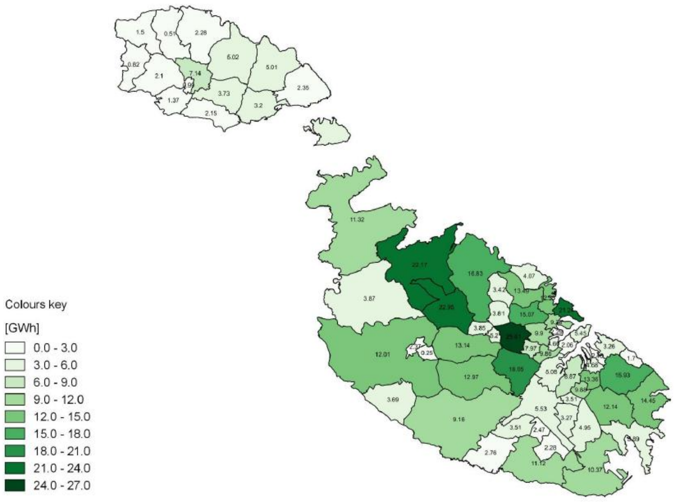
2. Sector:
    - Res = Residential
    - Ind = Industry
    - Ser = Services

3. Energy Use:
    - H = Heating
    - C = Cooling
    - WH = Water Heating

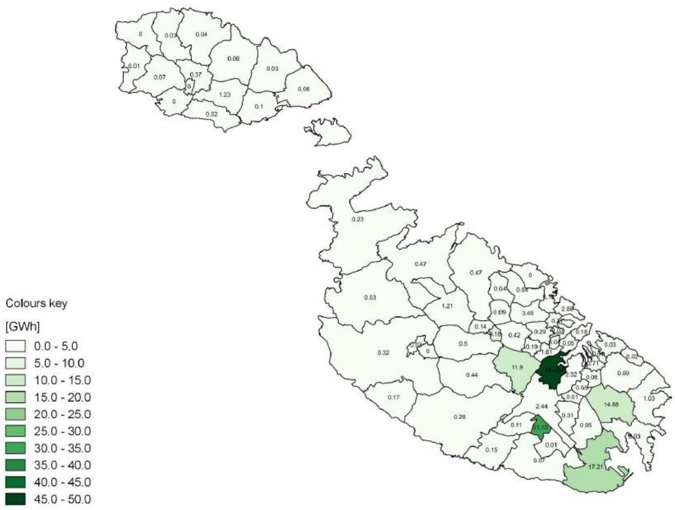
4. Energy Source:
    - FF = Fossil Fuels
    - Solid Biomass
    - ELEC = Electricity
    - STh = Solar Thermal

The results were uploaded into the GIS map provided by MEH. The following maps were produced within Sub-Task 5.

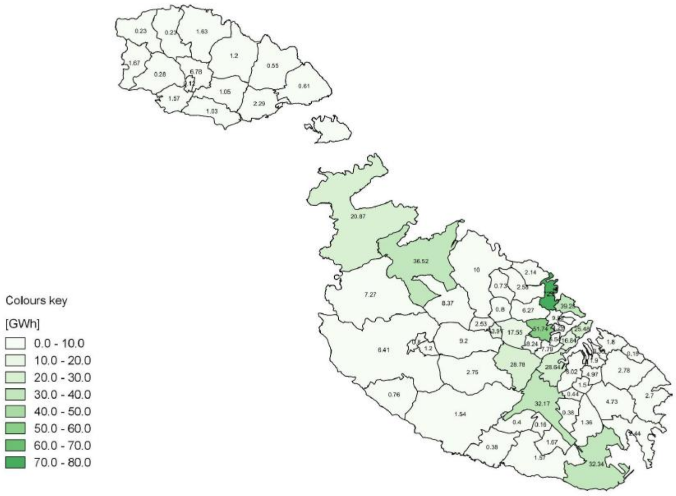
Residential Sector – Energy Demand – TOTAL



Industry Sector – Energy Demand – TOTAL



Services Sector – Energy Demand – TOTAL



8 Sub-Task 6 – Strategies, policies and measures

This report is part of the work developed for the “Energy Roadmap - Towards achieving decarbonisation for the Maltese Islands”. In particular, it deals with efficient heating and cooling strategies, policies and measures that may be adopted up to 2020 and up to 2030.

As titled in the 2015 report of the *Energy Efficiency Financial Institutions Group (EEFIG)*[61], energy efficiency is the first fuel for the EU economy. Energy efficiency is one of the most cost effective ways to enhance security of energy supply, and to reduce emissions of greenhouse gases and other pollutants. The energy system and society as a whole need to become significantly more energy efficient. Improving energy efficiency is a priority in all decarbonisation scenarios presented in the Energy Roadmap 2050 and therefore the prime focus should remain on energy efficiency in this context.

This makes energy efficiency investments strategically important due to high levels of energy imports, energy price instability and the need for Europe, and for Malta, to transition to a competitive low carbon and resilient economy.

With the European legislation recently adopted - namely with the Renewable Energy Directive, the Energy Performance of Buildings Directive, and the Energy Efficiency Directive - the European Commission has created a comprehensive European framework for an efficient and sustainable heating and cooling sector.

The combination of improved end-use performance – in particular in buildings and industrial processes – and optimised heating and cooling supply, notably via more intelligent use of efficient technologies such as cogeneration and district heating and cooling, would allow for a more cost-effective energy transition.

In relation to this, also in Malta, it is crucial to identify the optimal balance between investments aimed at reducing heat and cool demand and providing more efficient, sustainable and affordable supply solutions.

[61] (The Energy Efficiency Financial Institutions Group, 2015)

National and local authorities have a key role in creating the market framework and instruments, and ensuring that these help in achieving their energy efficiency and decarbonisation goals in buildings, cities and industries.

Based on the results and forecasts coming especially from sub task 4, the present document further reports about strategies, policies and measures Malta can realistically adopt within 2020 and 2030, distinguishing between solutions aiming at reducing heat and cool demand and those relating to more affordable and sustainable supply.

8.1 Strategies and policies for efficient heating and cooling

The chapter presents a series of possible strategies and policies the Government of Malta may adopt in a near future in relation to efficient heating and cooling.

Strategies and policies here refer specifically to legislative obligations, financial instruments, supporting tools and policies to be implemented in order to promote the diffusion in Malta of efficient heating and cooling solutions.

As stated earlier, energy efficiency is the first fuel because it is competitive, cost effective to produce; it is widely available and delivers multiple benefits to project hosts and national economies.

This concretely means more action is needed from central and local government, business and consumers to make the transformation happen.

Governments have the option to put in place necessary structural reforms, exercise fiscal responsibility, provide regulatory certainty and boost investment in support of jobs and growth. In this context, obligations may be set and encouragement should go for the greater use of high-efficiency cogeneration and district heating and cooling network development.

8.1.1 Reducing heat and cool demand

New buildings and service: For new buildings, services and products, the European Commission set clear rules. Article 6 and Annex III of the EED (2012/27/EU) establish energy efficiency requirements in public procurement. Products purchased by central governments should be of high energy-efficiency performance in so far as that is consistent with cost-effectiveness, economical feasibility, wider sustainability, technical suitability as sufficient competition and as referred to in Annex III of the EED. Annex III provides details on what is to be considered the high energy-efficiency performance for some particular products as well as in case of services and buildings. Public bodies at national and local levels shall be encouraged (i) to purchase only products, services and buildings with high energy-efficiency performance, and (ii) include efficient heating and cooling criteria in their regulatory tools (i.e. building codes, residential plans, etc.) whenever they plan, build and renovate industrial or residential areas.

Stakeholder forum. In order to set out a shared framework for solving the problem of ensuring there is affordable, secure and low carbon heating and cooling, the Government could launch a stakeholder forum. By engaging all the key actors (businesses, consumers, local authorities, etc.) in the process of identifying areas where heat and cool demand could be reduced, would lead to the set out of a shared vision of the energy future in Malta. A future with secure supplies of low carbon and renewable energy at affordable prices, which would support the growth of a strong and competitive economy.

Energy Audits. In order to get a complete picture over the potential of savings for heating and cooling in the business, industrial and commercial sectors, the Government could promote energy audits by providing funds partly covering the price of them or identify financial incentives for those businesses making the decision to carry them out.

8.1.2 Providing sustainable supply

Central government could adopt a number of initiatives, instruments, and financial tools in order to foster the diffusion of efficient heating and cooling solutions e.g.: bonus/benefits (i.e. faster time to get building permissions or similar, tax rebates, etc.) to those building renovations including RES systems installations providing sustainable heating and cooling (i.e. solar thermal, heat pumps, CHP, etc.).

The following are a few fiscal incentives and other schemes recently adopted in Italy and in Germany in order to boost the supply of efficient heating and cooling as follows.

8.1.2.1 White Certificates in Italy

The so-called "White Certificates" (*Titoli di Efficienza Energetica, TEE*) represent increases in energy efficiency that have to be achieved by final distributors of natural gas and electricity. The "white certificates" were introduced at the national level in order to promote interventions aimed at efficiency in final consumption of energy. The mechanism is based on the obligations of power and natural gas distributors to reach annual energy savings objectives set by the Ministerial Decree 20 July 2004 and Ministerial Decree 21 December 2007. Italy was the first country to use this mechanism. Each TEE emitted represents one tonne of oil equivalent (TOE) saved for each year of duration over the useful life of the intervention. The TEEs can also be commercially traded.

The energy savings objectives are expressed in terms of tonnes of oil equivalent (TOE). Each TEE certifies the implementation of savings of primary energy equivalent to one TOE, or approximately 5.3 MWh of electricity and nearly 1,200 Nm^3 of natural gas. Thus, any interventions by final consumers that save energy can earn rights to white certificates, which are issued by the Energy Markets Manager on the basis of communication from the AEEG certifying the savings implemented. The subjects authorised to request White Certificates are the distributors of electricity and gas with more than 50,000 final customers, subjects with energy managers under ex Law 10/91 (industrial consumers that consume more than 10,000 toe/year and service sector and public administrations registering more than 1,000 toe/year of consumption) and Energy Service Companies (ESCos). There are three different methods to evaluate the savings implemented through energy efficiency interventions: 1) standardised; 2) analytical and 3) consumptive.

8.1.2.2 Renewable Energy for Heating & Cooling Support Scheme - Italy

The Ministerial Decree of 28 December 2012 (the so-called “Renewable Energy for Heating & Cooling Support Scheme”) implemented Legislative Decree no. 28 of 3 Mar. 2011 on a scheme of support for small-scale projects of energy efficiency improvement and production of thermal energy from renewables. Gestore dei Servizi Energetici - GSE S.p.A. is the body in charge of implementing and managing the scheme, as well as of awarding financial incentives. Eligible projects concern:

- energy efficiency improvements in existing building envelopes (thermal insulation of walls, roofs and floors, replacement of doors, windows and shutters, installation of solar screens);
- replacement of existing systems for winter heating with more efficient ones (condensing boilers);
- replacement and, in some cases, construction of new renewable-energy systems (heat pumps, biomass boilers, heaters and fireplaces, solar thermal systems, including those based on the solar cooling technology).

The new decree also introduces - subject to specific requirements - incentives for energy auditing and energy certification associated with the above projects.

The support is granted on the basis of the type of project and on the improvement of the energy performance of the building which may be achieved and/or on the energy which may be produced by renewable-energy systems. The incentive (contribution to the costs incurred for the project) will be paid in yearly instalments over a variable support period (2 to 5 years), depending on the projects.

The decree allocates funds for a maximum yearly cumulative disbursement of € 200 million for projects implemented or to be implemented by public administrations and a yearly cumulative disbursement of € 700 million for projects implemented by private parties.

60 days after reaching the above limits, no new applications for support will be accepted. Public administrations may “book” incentives for their projects under a special procedure. The yearly cumulative disbursement allocated for public administrations opting for this procedure will not exceed € 100 million (50% of the € 200 million allocation for public administrations). Two categories of projects are eligible for the incentives introduced by the Ministerial Decree 28 Dec. 2012:

- energy efficiency improvement projects;
- small-scale projects concerning systems for production of thermal energy from renewables and high-efficiency systems.

The incentive will be limited to the portion of the project exceeding the one required for complying with the obligation of integrating renewables into new buildings and existing buildings subject to major renovations (as per Legislative Decree 28/11) and for obtaining the building licence.

The incentives may be awarded for projects benefiting from other non-government incentives which may be cumulated, in accordance with the applicable national and EU legislation.

8.1.2.3 Tax rebate programme - Italy

The Italian tax rebate programme (55% - now 65%) refers since 2007 to energy-efficiency interventions in buildings (windows, solar thermal, horizontal opaque structures/floors/roofs, vertical opaque structures/walls, heating, combined interventions or others).

The 55% tax rebate has shown to be one of the most effective incentive schemes for energy efficiency measures in buildings in Italy. ENEA, the national entity for energy and environment, tracks RES and EE developments and operates the website for application to the 55% tax rebate; the Tax Administration (Agenzia delle Entrate) processes the applications and awards the tax rebates. Among the main benefits of the incentive programme (based on CRESME (2010) estimates for Italy)

- Stimulus to economy --11.8% of total investment value
- est. 4,979.6 jobs/year
- Energy cost savings €369.8 million
- Fiscal returns €383.5 million
- Increase in rents for improved property €580.58 million
- Support to productive fabric
- Incentive to technological innovation
- Improvement of Energy mix.

In terms of tangible benefits, only for the Emilia-Romagna region, during 2007-2011, the initiative has nominally saved a cumulative total of 951 GWh per year of energy (mostly natural gas) and avoided emitting a total of 202.56 kt of CO2 into the atmosphere.

8.1.2.4 CHP law in Germany

Germany passed a CHP law in summer 2012, with a target of 25% of generated electricity to come from CHP installations by 2020 (up from 14.5% in 2010).

The KWKG (combined heat and power law) features a series of policy instruments to more effectively tap into the national potential for cogeneration:

- Support for cogenerated electricity through differentiated bonus (premium) payments depending on the capacity of the CHP plant. In short, bonuses for new and refurbished plants will range between 1.8 and 5.41 cents/kWh (see table below). It should be noted that the bonus received by CHP operators is complemented by payment from DSOs on the basis of both the avoided purchase cost of electricity from the generation mix and the distribution grid losses;
- The total level of support to the sector is capped to € 750 million/year;

- Micro CHP up to 50 kW electricity operators (defined as mini-CHP in Germany) will be able to choose between receiving support for 10 years and 30,000 full operating hours;
- Micro CHP up to 2 kW electricity operators (very small CHP in Germany) can opt for a one-time payment equivalent to the amount of 30,000 full time operating hours;
- Reaffirmation of the priority access rule for cogenerated electricity (in full parity with renewable energy sources);
- Promotion of the construction and expansion of heating and cooling networks operated with heat from CHP plants. Heating networks will receive €100 per meter, up to 40% of investment for pipelines below 100 mm in diameter and up to 30% for pipelines above 100 mm in diameter;
- Support for heat storage infrastructure by € 250/m^3, up to 30% of investment costs and capped at €5 million.

Supporting scheme to CHP installations in Germany

elektr. power (proportional*)	Bonus per kWh	Support duration
≤ 50 kW	5,41 Cent optional for ≤ 2 kW: one times payment for 30.000 foh**	10 years or optional 30.000 foh**
≤ 250 kW	4 Cent	30.000 foh
≤ 2000 kW	2,41 Cent	
> 2000 kW	1,8 Cent	
from 2013 for ETS plants	2,1 Cent	

New measures might be put in place if CHP market development trajectory is not on track for achieving the 25% target by 2025.

8.2 Overview on potential policies and measures up to 2020 and to 2030

The above mentioned efficient heating and cooling measures and policies, combined with economic potentials of measures investigated in Subtask 4, can be reported in the following table showing proposals for 2020 and 2030 horizons in Malta.

Within 2020 timeframe, readily implemented measures (not requiring specific efforts at legislative or technological level) have been taken into account.

On the other hand, measures and policies needing a more complex framework to be implemented (i.e. the creation of supporting/financial schemes for the promotion of energy efficient heating and cooling systems by the central Government are planned to be put in place within 2030 timeframe.

UP TO 2020

Preparation of a **set of policies/supporting schemes** in favour of **heat recovery measures (either from industrial processes or within** existing **electricity production processes)**.

In relation to Sub-Tasks 3 and 4, in order to promote High-efficiency CHP systems, **preparation of a set of incentives/supporting schemes both in terms of:**

- **feed-in tariffs;**
- favourable fuels (LPG and gasoil) **price policies** (i.e. reduced fuel price for tertiary or residential sector making use of it for High-Efficiency Cogeneration).

More and more public bodies at local levels undertaking and implementing green procurement policies**:** only products, services and buildings with high energy-efficiency performance are actually purchased.

A shared vision of energy future in Malta**. A stakeholder forum with key actors engaged (businesses, consumers, local authorities, etc.)** in order to identify areas for reducing heat and cool demand has been held.

National, regional and local authorities to adopt **efficient heating and cooling criteria in their regulatory instruments** whenever they plan, build and renovate industrial or residential areas.

Energy audits campaign launched by the Government and targeted to businesses and residences.

Government to set a **system of benefits/bonus** (i.e. on permitting or in the form of tax rebates) to those building renovations including RES systems installations providing sustainable heating and cooling (i.e. solar thermal, heat pumps, CHP, etc.).

Replacement of old **boilers** with new **condensing** ones for small businesses buildings (tertiary, hospitality sector especially).

High efficiency heat pumps for households, services and industry sectors.

Implementation of a number of **cool roofing pilot cases** (reflective roof products can reduce buildings' energy use by up to 50%).

According to results reported by the European project “CODE2” (CODE2 Cogeneration Observatory and Dissemination Europe, July 2014), in order to boost CHP systems diffusion, **structure a value chain support programme in co-operation with industry** (training, exchange of experiences, quality standard labels, financial schemes, marketing, awareness raising actions, etc.).

UP TO 2030

Set of policies/supporting schemes in favour of **heat recovery measures** (either from industrial processes or within existing electricity production processes) **actually in place**.

In relation to sub tasks 3 and 4, **set of incentives/supporting schemes both in terms of feed-in tariffs** (i.e. for biogas use from biogas facilities, those existing and new ones) **and concerning favourable fuels** (LPG and gasoil) **price policies actually in place**.

Concrete diffusion of CHP plants, based on the available connection to the pipeline which will supply the methane-gas to the Maltese Islands. In case of non-feasibility through methane-gas, diffusion of gasoil or LPG fuelled CHP plants.

Diffusion of micro-CHP systems on residential and small businesses buildings, according to safety regulations in the light of possible methane gas to the Maltese inland fuels market.

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Intelligent Energy Europe Projects database:
http://ec.europa.eu/energy/intelligent/projects/en

BLUE AP (2012-2015, LIFE+ (LIFE11 ENV/IT/119))
www.blueap.eu

CORDIS - FP7 and earlier programmes Projects and Results:
http://cordis.europa.eu/projects/home_en.html

MAIN (2013-2015, MED Programme)
www.med-main.eu

ODYSSEE MURE Project: http://www.odyssee-mure.eu/

SMART MED PARKS (2013-2015, MED Programme)
www.smartmedparks.eu

INSTITUTIONS:

European Commission: http://ec.europa.eu

EU law and other public EU documents: http://eur-lex.europa.eu/

Concerted Action – European Performance of Buildings: http://www.epbd-ca.eu/

Emilia Romagna Region (Italy) - Regional Operational Programme of the European Regional Development Fund: http://fesr.regione.emilia-romagna.it

ENEA (Italy): http://www.enea.it/en/home?set_language=en&cl=en

Eurostat: http://ec.europa.eu/eurostat

European Commission - Joint Research Centre: https://ec.europa.eu/jrc/

GSE (Italy): http://www.gse.it/en/Pages/default.aspx

IEA - International Energy Agency: www.iea.org

Malta Enterprise: http://www.maltaenterprise.com/

Malta Ministry for Energy and Health: http://energy.gov.mt/

Managenergy: http://www.managenergy.net/news/articles/594

MEPA - Malta Environment & Planning Authority: www.mepa.org.mt

National Statistics Office – Malta: http://nso.gov.mt/en/Pages/NSO-Home.aspx

ARMS ltd - https://www.smartutilities.com.mt

OTHER WEBSITES AND ON-LINE RESOURCES:

GIS of the Malta Environment and Planning Authority: http://mapserver.mepa.org.mt

QGIS: http://qgis.org/en/site/

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