Comprehensive Assessment on the Potential for Efficiency in Heating and Cooling in Malta

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THE ENERGY & WATER AGENCY

GOVERNMENT OF MALTA
MINISTRY FOR THE ENVIRONMENT, ENERGY AND REGENERATION OF THE GRAND HARBOUR

This report was drawn up in line with the requirements of Article 25 of Directive (EU) 2023/1791 on energy efficiency, as well as in full compliance with the specifications detailed in Annexes X and XI of the same Directive.

The report has been commissioned and overseen by the Energy and Water Agency which falls within the remit of the Government of Malta Ministry for the Environment, Energy and Regeneration of the Grand Harbour, and developed with the support of Ernst & Young Limited and Altern Limited.

The new strategies, interventions and policy measures presented in this report are being proposed by the contractor for consideration by the Government of Malta and are not to be construed as expressing the opinion of the Government of Malta. Specific interventions and/or measures which are deemed appropriate may be considered for inclusion in the updated NECP.

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List of Abbreviations

ASHP	Air Source Heat Pumps
B/C	Benefit-to-Cost Ratio
BCA	Building & Construction Authority
BTU	British Thermal Unit
CBA	Cost Benefit Analysis
CDD	Cooling Degree Days
CHP	Combined Heat & Power
COP	Coefficient of Performance
CPI	Consumer Price Index
DCF	Discounted Cash Flow
DHW	Domestic Hot Water
EC	European Commission
EED	Energy Efficiency Directive
EER	Energy Efficiency Ratio
EEZ	Exclusive Economic Zone
EIB	European Investment Bank
ENPV	Economic Net Present Value
EPBD	Energy Performance of Buildings Directive
ERR	Economic Rate of Return
ETS	Emission Trading System
EU	European Union
EWA	Energy Water Agency
EY	Ernst & Young
F&B	Food & Beverage
FDR	Financial Discount Rate
FNPV	Financial Net present value
FRR	Financial Rate of Return
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GSHP	Ground Source Heat Pump
GVA	Gross Value Added
GWh	Gigawatt hour
HDD	Heating Degree Days
LAU	Local Administrative Unit
LCDS	Low Carbon Development Strategy
LPG	Liquified Petroleum Gas
LTRS	Long-Term Renovation Strategy
MDB	Malta Development Bank
MDH	Mater Dei Hospital
MS	Member States
MTA	Malta Tourism Authority

NECP	National Energy Climate Plan
NZEB	Nearly Zero Energy Building
kWh	Kilowatt hour
NSO	National Statistics Office
NPV	Net Present Value
Mtoe	Million tonnes of oil equivalent
PAM	Policies and Measures
PV	Photovoltaic
REWS	Regulator for Energy and Water Services
ROI	Return on Investment
R&I	Research & Innovation
RRF	Recovery & Resilience Facility
SAMOC	Sir Anthony Mamo Oncology Hospital
SDR	Social Discount Rate
SWH	Solar Water Heater
TFF	Thermal Treatment Facility
TMVA	Thermostatic Mixing Valve Manufacturers Association
VRF	Variable Refrigerant Flow
WHR	Waste Heat Recovery
ZEB	Zero Energy Building

Executive Summary

This executive summary captures the key findings and recommendations from the comprehensive assessment of heating and cooling energy demand as mandated by the Energy Efficiency Directive. The assessment includes an extensive analysis of energy consumption patterns within residential, industrial and services sectors, projecting future demands and identifying opportunities for efficiency improvements through intervention measures for the Maltese Islands. This analysis was carried out in line with the requirements of Article 25 of Directive (EU) 2023/1791 on energy efficiency, as well as in full compliance with the specifications detailed in Annexes X and XI of the same Directive. This study serves as an update to the 2020 report titled 'Comprehensive Assessment of the potential for efficient heating and cooling, including the overall final and useful energy used for heating and cooling purposes, in the Maltese Islands,' submitted in accordance with Article 14 of the Energy Efficiency Directive 2012/27/EU.

The report is split into four parts as follows:

- Part I provides an overview of the useful and final heating and cooling energy consumption in Malta. The chosen base year for the analysis was 2022, and data for all sectors under assessment (these being the residential, industrial and services sectors) was extracted accordingly. Energy consumption profile data was used, including information on the energy sources and technologies used to satisfy the demand. This section also includes a high-level forecast of the heating and cooling demand for the next 30 years, which takes into consideration relevant existing policy initiatives and measures. Maps of the Maltese national territory are also included, identifying areas of high energy density for heating and cooling.

- Part II reports on Malta's current objectives, strategies and policy measures relevant to the field of heating and cooling. These are aligned with Malta's Low Carbon Development Strategy for 2050 (published 2021), the Long-Term Renovation Strategy for 2050 (published 2021), the Sustainable Development Strategy for 2050 (published 2022), the Draft National Strategy for the Environment for 2050 (published 2022), the Draft Update to the National Energy and Climate Plan (published 2023), and the Minimum Energy Performance Requirements in Buildings (Technical Document F) (published 2024).

- Part III of the study builds on the findings from Part 1, encompassing an evaluation of low-carbon, energy-efficient heating and cooling technologies appropriate for deployment within the national context. This was assessed through a Cost-Benefit Analysis framework, which rigorously examined the upper limits of various technologies to determine their technical viability under prevailing climatic conditions and resource availability. In conducting the economic analysis, a standard baseline is compared against multiple alternative scenarios, with consideration given to the inclusion of external cost factors.

- Part IV builds on the conclusions of Part III, and identifies the intervention measures whose financial and economic potential gave positive results in the Cost-Benefit analysis carried out. These can be summarized as follows:

    - Replacing domestic electric water heaters with heat pump water heaters or solar water heaters, using either a centralised or decentralised approach;

    - Replacing domestic electric water heaters with a combination of PV panels and electric water heaters;

    - Replacing domestic LPG heaters with air-to-air heat pumps, in conjunction with the replacement of LPG cookers and ovens with their electric counterparts;

    - Replacing low-efficiency fuel-fired boilers in hotels with either high-efficiency condensing boilers powered with biofuels, or heat pump water heaters;

    - Replacing water- and air-cooled chillers in hotels with counterparts having heat-recovery functions;

    - Replacing ageing, low-efficiency climate-control systems (based on air-to-air heat pumps) with new, high-efficiency systems before the end of their technical lifetime, in restaurants and small (2&3-star) hotels.

  Furthermore, this segment of the report provides recommended policy interventions for the heating and cooling sector that could be enacted at the national level. These interventions are designed to promote the uptake of cost-efficient technologies that curb the overall demand for heating and cooling services through increased efficiency. Additionally, the report includes recommendations for policy measures aimed at fulfilling heating and cooling demands through more sustainable approaches.

This report provides a strategic framework for decision makers to undertake concerted actions that have the ability to deliver sustained positive outcomes for both economic growth and environmental preservation. The scope of the analysis encompasses the residential, industrial and services sectors. Consumption data within each sector was disaggregated by energy source, including electricity, fuels, and other categories. The tables below present a summary of the resulting final and useful energy demand for each of the three sectors described:

Final Energy Consumption for all three sectors in 2022

Sector	Space Cooling	Space Heating	Water Heating	Total
	GWh	GWh	GWh	GWh
Residential	207.15	123.32	287.06	617.54
Industry	59.070	5.700	4.460	69.23
Services	243.13	189.03	87.19	519.35
Total	**509.35**	**318.05**	**378.71**	**1,206.12**

Useful Energy Consumption for all three sectors in 2022

Sector	Space Cooling	Space Heating	Water Heating	Total
	GWh	GWh	GWh	GWh
Residential	638.04	340.96	258.36	1,237.35
Industry	244.18	20.25	4.00	394.35
Services	809.08	663.61	76.29	1,548.98
Total	**1,691.29**	**1024.81**	**338.65**	**3,180.67**

As can be seen from the summary tables, the final energy consumption for heating and cooling purposes (defined as the energy supplied to the final consumer) in 2022 totalled to 1,206 GWh. Of this total, the residential sector used 617 GWh for heating and cooling purposes, followed by the services sector, with a consumption of 519 GWh, with the industry sector is the least consuming sector overall with 69 GWh. The highest end use in the residential sector is water heating, whilst space cooling represents the highest end use for the services sector. Within the industry sector, space cooling again represents the highest end use for heating and cooling, with space and water heating being significantly lower in comparison. It is evident from these results that the long and hot summer season in Malta is driving the high consumption for cooling purposes, particularly in the services sector.

The interventions proposed for the residential, hotel, and restaurant sectors, which by extension could also be relevant to other services sector, all lead to economically favourable outcomes. The benefits these technologies provide to society at large outweigh the costs associated with their implementation, resulting in enhanced heating and cooling efficiency across Malta. The primary driver of these benefits is the increased energy efficiency for heating and cooling purposes, which in turn lowers operational expenses for both households and businesses through reduced energy bills. Centralised alternatives for new buildings are particularly recommended for their ability to benefit from the economies of scale. Additionally, these technologies contribute to a decrease in GHG emissions, which, when valued in economic terms, further amplify the overall benefits.

A significant number of these interventions, such as the shift towards heat pumps and solar systems in place of conventional energy solutions, also support an increase in the use of renewable energy. Owing to Malta's densely populated urban areas and limited space for large-scale installations, this shift is particularly crucial for Malta to overcome its unique challenges in deploying renewable energy. The proposed measures provide renewable energy solutions that are well-suited to Malta's urban and climatic context, and are adaptable for use in both single and multi-family dwellings. They are also applicable to various business establishments, regardless of size, enhancing their potential for widespread adoption. However, despite the anticipated economic benefits, the substantial initial capital outlay required for certain interventions (especially within the residential sector), might discourage private investors. This is due to significant initial costs associated with new, more efficient technologies. In the absence of government financial incentives, the adoption rate of these energy-saving technologies is expected to remain low. As such, it is recommended that current incentive measures for the residential sector be maintained, and where possible, extended to accommodate new emerging technologies and equitably reach more households.

Most service sector interventions exhibit a favourable financial net present value, suggesting financial viability without government subsidies. However, high initial costs may hinder private investment, particularly when efficient upgrades replace functioning but less efficient technology before its lifespan ends. The cost recovery, dependent on operational savings, may take time. Without incentives, the shift to cleaner technologies might be postponed until older technologies are obsolete. It is thus advisable for the government to consider financial support, from grants to blended instruments like loan guarantees for more favourable lending terms, to facilitate this transition.

With regards to the industrial sector, the sector's contribution to the total heating and cooling energy requirements is relatively small. This is primarily because the bulk of the energy consumption in the manufacturing industry is for industrial processes, which fall outside the purview of this heating and cooling assessment. When exploring options to optimize heating and cooling in these industries, such as the adoption of cogeneration and trigeneration systems, it will be crucial to collect precise data on the existing technologies employed by each firm and their particular uses. Nevertheless, strategies like upgrading boilers and heat pumps, which have been considered for different entities in the service sector, might be adapted for industrial applications.

Introduction

In accordance with Article 25 and Annexes X and XI of Directive EU 2023/1791 (EU) on energy efficiency, this comprehensive assessment report aims to provide a detailed analysis of the current and projected energy demand for heating and cooling across various economic sectors, as well as in households, in Malta. This is the third report of its kind being submitted to the European Commission (EC).

Integral to this assessment is the energy efficiency first principle, which serves as an overarching approach across all sectors, informing policy, planning, and investment decisions. This principle, which recognizes energy efficiency as an energy source in its own right, is embedded within the fabric of the Directive and is therefore inherently considered throughout the assessment.

The significance of heating and cooling in the overall energy consumption portfolio is undeniable, as these processes are pivotal for maintaining comfort within buildings and for operational purposes. This report examines the energy consumption patterns within different sectors. It adopts a multi-dimensional approach to evaluation, by taking into account a range of elements that encompass technical, economic and environmental aspects, amongst others, thereby offering a holistic view of the heating and cooling landscape in Malta.

This assessment not only identifies the sectors with significant energy demand for heating and cooling but also explores targeted intervention measures for these sectors that are designed to increase energy efficiency, reduce greenhouse gas emissions, and align with the overarching goals of the European Green Deal and the Fit for 55. Furthermore, this assessment covers the obligation to carry out an assessment of Malta's potential of energy from renewable sources and the use of waste heat and cold in the heating and cooling sector, as required by Article 23 1b of Directive (EU) 2023/2412 as regards the promotion of energy from renewable sources.

Reducing carbon emissions and enhancing the efficiency of Malta's heating and cooling systems present considerable challenges. Malta's climate is distinguished by hot, dry summers and cool winters with an average annual rainfall of 592mm. Temperatures in July and August reach an average max of 32°C and only drop to around 15 -17°C during December to February.[1] Currently, Malta holds the record for the highest population density in Europe, despite being the smallest Member State in the European Union (EU) by population count. When comparing the years 2022 and 2001, Malta saw the most significant rise in population density, from 1,245 to 1,657 individuals per square kilometre.[2] The National Statistics Office (NSO) reported that, as per the latest national census, Malta's usual resident population reached 519,562 in 2021,

[1] Malta weather – Met Office. https://www.metoffice.gov.uk/weather/travel/holiday-weather/europe/malta
[2] Eurostat (2023), Demograph of Europe, Demography of Europe – 2023 edition - Eurostat (europa.eu)

marking a significant increase of over 100,000 compared to the 417,432 residents noted in the 2011 Census.[3]

Economically, Malta has evolved significantly since the mid-1960s, transitioning from an economy that was once heavily dependent on the British colonial administration to one that is market-oriented, with a focus on high-value-added activities within the services sector, especially in financial services and tourism. Facing the hurdles of a limited domestic market and the logistical constraints of being an island, the Maltese economy nevertheless benefits from a favourable climate and a capable workforce. Despite its small size, Malta's economy is highly diversified and responsive to global market trends. Economic growth in Malta hinges on the promotion of domestic investment and the attraction of foreign direct investment. The backbone of Malta's economic activity is bolstered by pivotal industries including manufacturing, tourism, and critical high value-added services like finance, business, information technology, and remote gaming. The average annual real Gross Domestic Product (GDP) growth rate between 2012 and 2022 was roughly 5%, compared to a Euro area average of 0.5%. In 2023, Malta's real GDP was projected to be €15.5 billion,[4] which is more than double what it was two decades ago.

These developments in Malta's social, economic and demographic landscape inevitably had an impact on the country's energy demands. At a European level, there is a clear drive towards climate neutrality by 2050. Malta's National Energy and Climate Plan (NECP) sets out the country's national objectives and commitments for 2030, aimed at supporting the collective objectives of the EU. This comprehensive assessment provides an in-depth insight into the sector-specific energy needs for heating and cooling and explores possible measures for intervention.

This report is structured to follow the components specified in Annex X of the Energy Efficiency Directive. Part I provides an overview of the current state of energy consumption in Malta, detailing usage across the residential, industry, and service sectors. Part II outlines the existing policy measures and their contribution to national efficiency targets. Part III presents a thorough analysis of the economic potential for efficiency improvements, evaluating a range of intervention measures and technological solutions across various sectors. Part IV proposes new strategies and policy measures, designed to steer forthcoming initiatives to improve the efficiency of heating and cooling in Malta.

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[3] NSO (2023), Census of Population and Housing 2021, NSO Malta | Census of Population and Housing 2021: Final Report: Population, migration and other social characteristics - NSO Malta (gov.mt)

[4] NSO (2024), Gross Domestic Product Q4/2023, NSO Malta | Gross Domestic Product: Q4/2023 - NSO Malta (gov.mt)

Part I – Overview of Heating and Cooling

1.1 Introduction

This section describes in detail the useful energy demand and the final energy consumption for heating and cooling for all sectors in Malta, with a comprehensive analysis of the following:

- the amount of useful energy and quantification of final energy consumption per year for the residential, industrial and services sectors.

- the estimated and identified current heating and cooling demand from the final energy consumption per year for the residential, industrial and services sectors.

- the shares of energy from renewable energy sources from waste heat over the past five years

- a map covering the entire Maltese territory that presents the heating and cooling demands covering all sectors.

- a forecast of demand for heating and cooling for the next 30 years for the residential, industrial and services sectors.

For the purpose of this assessment, the year 2022 is being used as the reference year for all consumption data and the base year for all calculations. The analysis builds up on different data sets published by the NSO, made available by the Energy and Water Agency (EWA), Enemalta and other government entities/authorities, as well as extensive local and international market research into technologies and energy uses within the different sectors. In instances where direct data was not available, indirectly derived data was used with the necessary assumptions, methodologies and extrapolation which have been formulated specifically for the objectives of this task.

The heating and cooling assessment has been carried out at a national level according to different sectors, that is:

- the Residential sector;

- the Services sector which is further sub-divided into several sub-sectors; and

- the Industry sector which was also sub-divided into sub-sectors.

Other sectors, including the agricultural sector, have not been taken into consideration for the purpose of this study since none of them consume more than 5% of the total national useful energy consumption.

The assessment carried out for each different sector identified builds upon an evaluation of the real measured and verified consumption data of electricity and estimated sectoral consumption of fuel used in the Maltese islands. This data was further analysed to estimate the consumption related to space heating, space cooling and hot water generation per sector as well as industrial processes, where applicable. The exercise also identifies the energy sources and technologies generally employed to cover these energy demands.

1.2 Overview of the Final Energy Consumption for the Maltese Islands

According to the latest available data from the NSO, Malta's total energy consumption has exhibited a steady increase over the past decade. Factors such as population growth, economic development, and changing lifestyles have contributed to this trend. Additionally, Malta's reliance on imported fossil fuels for energy generation further impacts its consumption patterns.

Malta's final energy consumption increased relatively stable, from 5,982 GWh in 2018 to 6,878 GWh to 2022.[5] The final energy consumption by sector and fuel for 2022 are shown in Figure 1 and Figure 2, respectively. Fossil fuels constituted the largest share of this consumption (54.6%), reflecting Malta's historical dependence on imported fuels.

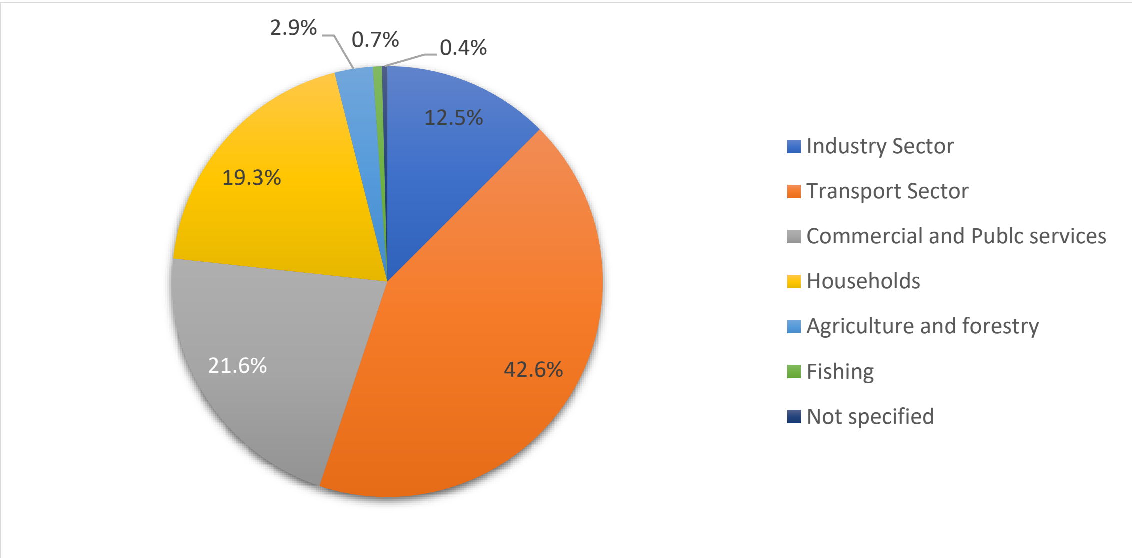

Figure 1 - Malta's Final energy consumption by sector

[5] Eurostat_Energy statistics (ten00123)

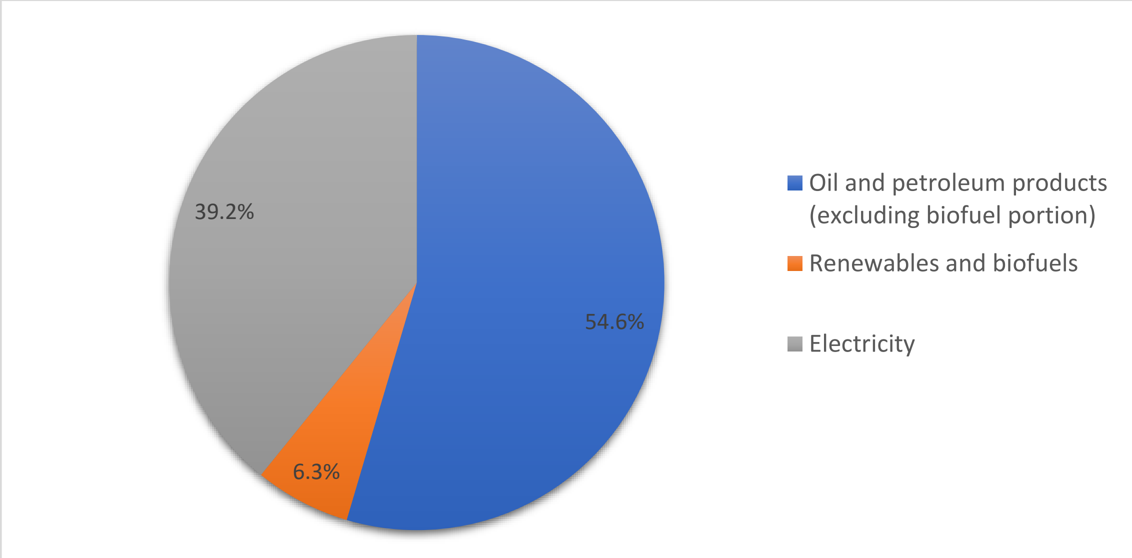

Figure 2 - Malta's final energy consumption by fuel use

The transport sector is shown as the largest consumer; however, since it lacks direct consumption from spatial heating, spatial cooling, and water heating, this was excluded from the report, focusing instead on the household, commercial and public services, and industry sectors. A more detailed explanation of the main sector follows.

- **Residential Sector**: The residential sector emerged as one of the primary consumers to energy consumption in Malta. This includes energy usage in households for spatial heating, water heating, spatial cooling, cooking, lighting, and appliances, amongst others.

- **Commercial and Services Sector:** This sector includes the commercial entities and public service and encompasses a wide range of establishments such as offices, hotels, restaurants, elderly care homes, shops, schools, hospitals, and government buildings. Thus, this sector emerges as one of the primary contributors to energy consumption in Malta. Energy consumption in this sector accounts for activities like spatial heating, water heating, spatial cooling, cooking, lighting, and operation of equipment and machinery, amongst others.

- **Industry Sector:** The industry sector represents another major consumer of energy in Malta, covering manufacturing plants, factories, production facilities, mining, quarrying and construction. Energy-intensive processes, machinery operation, and heating are among the primary drivers of energy consumption in this sector.

Other sectors which contribute to energy consumption, but to a much less extent are agriculture (2.9%), fishing (0.7%) and other sectors (not specified) (0.4%); in all, these sectors contribute to less than 5% of the Maltese islands total energy consumption.

1.3 Residential Sector

The resident population in Malta has more than doubled over the last century. An increase in population from 417,432 in 2011 to 519,562 in 2021[6] was observed; a 24.5 percentage increase in just 10 years making it the largest decade long growth recorded to date. Details in relation to the population and households' distribution between Malta and Gozo as well as the different districts are presented in Table 1. From Table 1, it can be deduced that the Northern Harbour and Southern Harbour areas account for 46.83% of the total population in Malta. By extension of the above, as the population increased from 2011, so has the households' stock, as can be seen from the 2021 data published by NSO.

Table 1 - Population and household data for Malta for the year 2021, Data Source - NSO Census 2021

	Population	Main Residential Dwellings/ Number of Households
Maltese Islands	519,562	215,691
Malta	480,275	199,339
Gozo and Comino	39,287	16,352
Southern Harbour	86,009	34,482
Northern Harbour	157,297	69,071
South Eastern District	77,948	31,457
Western District	65,266	25,188
Northern District	93,755	39,141

Building on the preceding table, historical data can be extrapolated and represented as seen in Figure 3 which highlights the predominantly linear growth trend of households across the Maltese islands, with occasional fluctuations of varying magnitudes corresponding to population growth in specific years.

[6] NSO (2023), Census of Population and Housing 2021, NSO Malta | Census of Population and Housing 2021: Final Report: Population, migration and other social characteristics - NSO Malta (gov.mt)

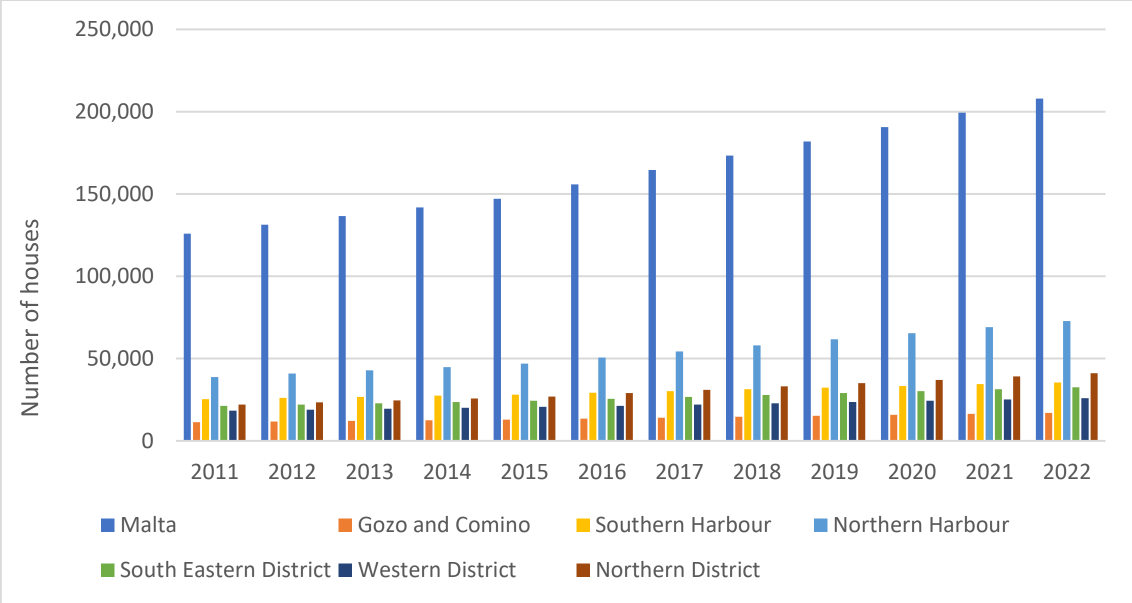

Figure 3 - Number of households in Malta between 2011 and 2022. Source: NSO Census 2021 for 2011-2021; Extrapolation for 2022.

Data in relation to energy consumption was collected and analysed to define the heating and cooling demand in the residential sector. In the interest of understanding the general energy consumption of households in Malta throughout the calendar year one must understand that typically, households use energy to cover a baseload which includes lighting, domestic appliances, plug-in loads and cooking while excluding energy demands for water heating alongside space heating in winter and space cooling in summer. In contrast to many other European countries, most Maltese homes lack central heating systems, relying instead on portable electricity or fuel-based heaters or air-to-air heat pumps (typically of split unit type) for warmth. While some households use traditional wood-burning stoves and fuel space heating systems, electric heating is more prevalent. Most of the energy demand for households related to water heating, space cooling and lighting is covered by electricity.

Liquefied Petroleum Gas, more commonly known as LPG, is the predominant fossil fuel used in the residential sector and plays an essential role in terms of space heating and cooking consumption. It is assumed that the amount of LPG used for water heating in the residential sector is negligible. Hence, for the purposes of this assessment, both electricity and LPG will be considered to determine the heating and cooling demand in the residential sector. Biomass accounted to 10% of the total LPG consumption, while heating gasoil only accounted to 0.4 GWh in 2022; thus these are considered to be negligible in residential use.

The main sources of data related to energy consumption in the residential sector in Malta used for this study are:

- Total Annual Electricity Consumption in the Residential Sector as reported in the Eurostat Energy Balance;[7]

- Sample of hourly Electricity Consumption as provided by EWA based on meter data;

- LPG Consumption in the Residential Sector as reported by the NSO in the Eurostat Energy Balance;

- Data in relation to quantities of installed systems for heating, cooling and domestic hot water as published in the NSO 2021 Census Volume 2.

1.3.1 Electrical Consumption for Residential Sector

The hourly electricity consumption data from a sample of approximately 158,000 households for 2022 was analysed and extrapolated to achieve the total yearly electricity consumption in the residential sector which was 1,006.5 GWh.[8]
Table 2 displays the monthly breakdown of residential consumption, derived from hourly data collected from a sample of 158,000 households.

Table 2 - Estimated Monthly Residential Electricity Consumption in 2022

Month	Consumption (GWh)
January	90.58
February	79.57
March	88.58
April	70.32
May	69.61
June	89.40
July	115.42
August	114.38
September	91.36
October	67.16
November	62.75
December	67.38
Total (2022)	1,006.50

The total residential electricity consumption for the years 2018 to 2022 and the related percentage increase between the years is shown in Table 3. It shows the gradual increase during the past five years, resulting in an overall increase of 27.55% from 2018 to 2022. The total yearly electricity consumption in the residential sector is shown in Figure 4.

[7] Eurostat_Simplified Energy balance 2022 (nrg_ba)
[8] NSO, Electricity Supply: 2022 – NR 176/2023. https://nso.gov.mt/electricity-supply-2022/

Table 3 - Yearly Electrical Consumption for the year 2022. Source: Eurostat Energy Balance[9]

	2018	2019	2020	2021	2022
Yearly Consumption (GWh)	789.10	855.20	888.70	947.80	1,006.50
Yearly increase (GWh)		66.10	33.50	59.10	58.70
Yearly % increase		8.37%	3.92%	6.65%	6.19%

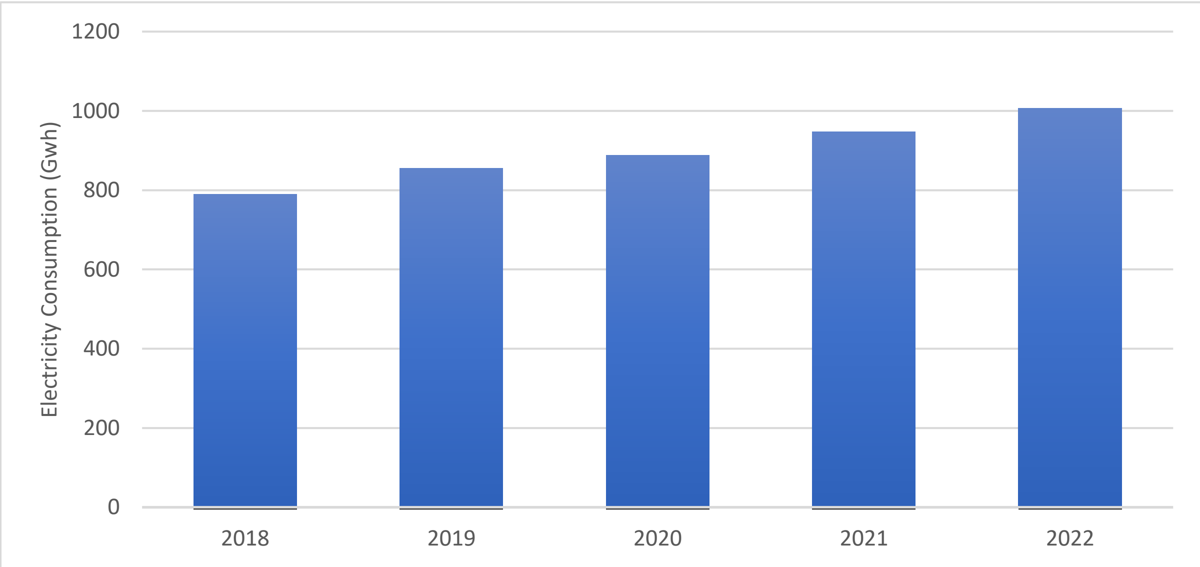

Figure 4 - Total Yearly Electrical Consumption between 2018 and 2022 for the Residential Sector. Data source: Eurostat Energy Balance

Figure 5 presents the monthly residential consumption and the average monthly temperature during 2022, which clearly shows the effect of seasonality on energy consumption during the summer months, particularly in July and August, where the energy consumption to cater for the cooling demand reaches a peak. A smaller winter peak can be observed in January as a result of the heating load, which corresponds to the lowest average monthly temperature.

[9] Eurostat_Complete Energy Balance (nrg_bal_c)

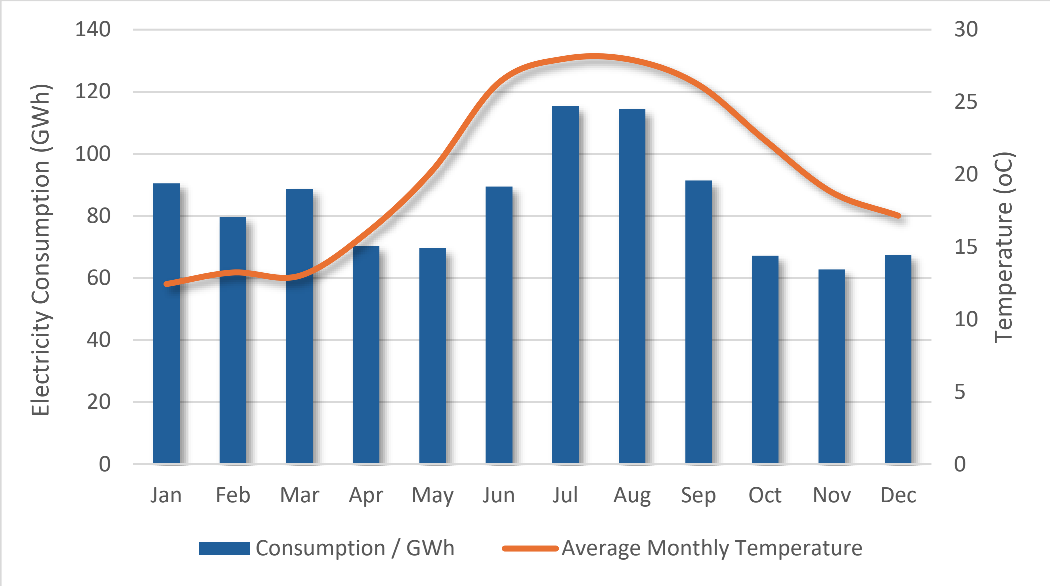

Figure 5 - Monthly Electrical Consumption for the Residential Sector in 2022. Data source: EWA

Based on the data available in the 2021 Census, the occupancy rate per households was calculated to be 2.41 people per household. The resident population in 2022 as reported by NSO is 542,051.[10] Assuming that the occupancy rate does not vary on an annual period, the number of households is estimated to be 225,027. Considering a total yearly energy consumption in the residential sector of 1,006.50 GWh, the average consumption per household is 4,472.78 kWh. The monthly electricity consumption values shown in Table 2 were divided by the number of households and days per month in order to calculate a daily consumption value per household. The results are shown in Table 4.

Table 4 - Average Daily Electricity Consumption per household during 2022

Month	Average daily consumption per household (kWh)
January	12.98
February	12.63
March	12.70
April	10.42
May	9.98
June	13.24
July	16.55
August	16.40
September	13.53
October	9.63
November	9.29
December	9.66

[10] NSO, Population and migration: 2012-2022. nso.gov.mt/intercensal-population-revisions-2012-2021

1.3.1.1 Water Heating

- The daily thermal demand for Domestic Hot Water (DHW) heating was calculated through the parameters presented in
- Table 5. The data presented in
- Table 5 was obtained from the following sources:

- European Commission. (2013). Commission Decision of 21 May 2013 establishing the ecological criteria for the award of the EU Ecolabel for sanitary tapware (2013/250/EU). Official Journal of the European Union.

- Technical Document F Part 1: Households Minimum Energy Performance and Building Envelope Requirements (Section 5.4)

- Healthline Article published 20 May 2020. "How long should you shower?"

- Mix of hot to cold water, deduced by assumption.

- Thermostatic Mixing Valve Manufacturers Association (TMVA). Recommended Code of Practice for Safe Water Temperatures (Section 4.2.2).

- NSO Census of Population and Housing 2021, Households Characteristics, Final Report Volume 2.

Table 5 - Data for Calculating Residential Hot Water Generation

Parameter for DHW Calculation	Value
Flow rate per shower per min (litres)	8[11]
Avg. time per shower per person (minutes)	8[12]
Mix of hot to cold water (%)	50%
Initial water Temperature (°C)	Average Daily Air Temperature
Water Heater temperature (deg Celsius)	60[13]
Litres of hot water per shower	32
Residents per household	2.41
Electric Water heater efficiency	0.9

By assuming the daily average temperature as the starting point for water temperature, the estimated average thermal requirement for DHW in the residential sector in 2022 was determined to be 324.39 GWh.

[11] Directive 2013/250/EU for LN 145/6 – European Union Journal of 21 May 2013
[12] Shower Frequency - https://www.healthline.com/health/shower-time#shower-frequency
[13] Schedule 3 of L.N. 5 of 2006 – Public Health Act, 2003 (ACT NO. XIII of 2003)

Solar Water Heating

Government has been providing financial support for solar water heaters (SWH) to be installed in households for over a decade. Based on data reported in Malta's SHARES tool and given the lack of data available on solar water heaters in the non-residential sector, it is being assumed that all solar water heaters in Malta are installed within the residential sector.

The total energy generated by solar water heaters in 2022 resulted to 37.33 GWh.[14] This was distributed on a monthly basis by using the average monthly irradiation values. The following factors have been considered to calculate the monthly production:

- Calculating the average monthly solar irradiation in kWh/m^2/month for the period 2010-2020.[15]

- 15,039 installed solar water heaters in the residential sector.[16]

The monthly distribution of energy generation by SWH in 2022 is presented Table 6

Table 6 - Calculated Monthly Hot Water Generation through solar water heaters for 2022

Month	Estimated Monthly Solar Thermal Energy in 2022 (GWh)
January	2.25
February	2.49
March	3.19
April	3.48
May	3.80
June	3.82
July	4.09
August	3.94
September	3.25
October	2.77
November	2.16
December	2.08
Total	**37.33**

- The total DHW demand per household was calculated based on the parameters presented in

[14] Eurostat Data for 2022_Complete Energy Balance (nrg_bal_c)
[15] PVGIS-SARAH2 - https://re.jrc.ec.europa.eu/pvg_tools/en/#PVP
[16] NSO (2023), Census of Population and Housing 2021, NSO Malta | Census of Population and Housing 2021: Final Report: Population, migration and other social characteristics - NSO Malta (gov.mt)

Table 5 which results in a total of 1,442 kWh/year/household. The total demand is partially covered through SWH with the remaining hot water needs of households being met by electric boilers with an assumed efficiency of 0.9.

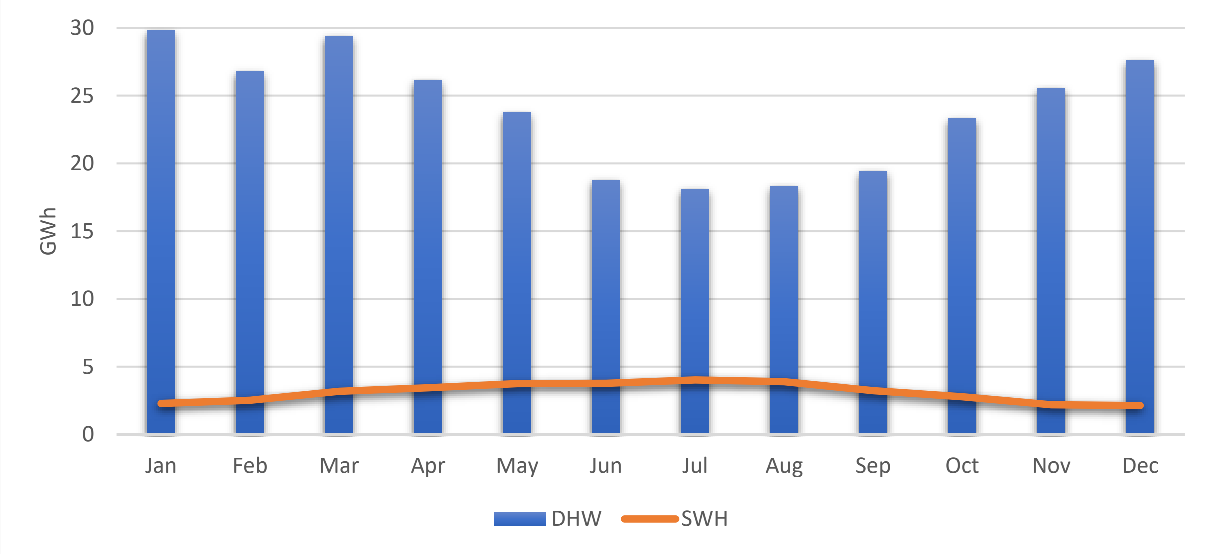

Figure 6 - Monthly Residential Hot Water Demand and Solar Water Heaters Generation in 2022

Figure 6 highlights the discrepancy between SWH and electric water heaters when it comes to hot water generation. Based on the data available and assumption considered for the hot water generation, such as the boiler temperature, the initial water temperature, and the volume of water per shower, solar water heaters covered 11.5% of the total residential hot water demand during 2022. The relatively low proportion, considering favourable solar irradiation levels, is due to the building scenario in the Maltese islands, with the ever-increasing trend of residents living in apartments rather than terraced houses, and not owning or having access to their own roof, which poses a challenge for the installation of SWH. The installation of heat pump water heaters in households only started very recently after the Government issued financial incentives for the adoption of such technology. Since the uptake of this scheme is still rather low, it has been excluded from the analysis. It should also be noted that water heating demand is much less in the summer months mainly due to a higher initial temperature of water.

1.3.1.2 Other End Uses

The hourly electricity consumption data from a sample of approximately 158,000 households for 2022[17] was analysed and extrapolated to calculate the baseload for the residential sector. The data was correlated to the heating and cooling requirements during the different months based on the heating degree days (HDD) and cooling degree days (CDD)[18] for Malta for 2022. The daily consumption profile for the electricity used for space heating and cooling was then determined using the following formula:

---

[17] Sample of hourly Electricity Consumption as provided by EWA.

[18] Data from Maltese Meteorologic Office as provided by EWA.

$$
\begin{aligned}
&Total\ Daily\ Electical\ Consumption \\
&\qquad = [Electricial\ Consumption\ for\ Heating\ and\ Cooling\ ] \\
&\qquad + [Electical\ Baseload] + [Electrical\ \ Consumption\ for\ Hot\ water]
\end{aligned}
$$

In this section, the baseload of a household refers to the other loads that do not include spatial heating, spatial cooling or water heating. This includes powering white goods, cooking appliances and lighting.

Hot water demand covered by electric boilers and solar water heaters was considered. Based on the daily consumption values and HDD and CDD, the annual baseload per household was calculated to be 1,925 kWh/household/year.

The monthly electricity consumption figures for the baseload, hot water, space heating and space cooling are presented in Table 7.

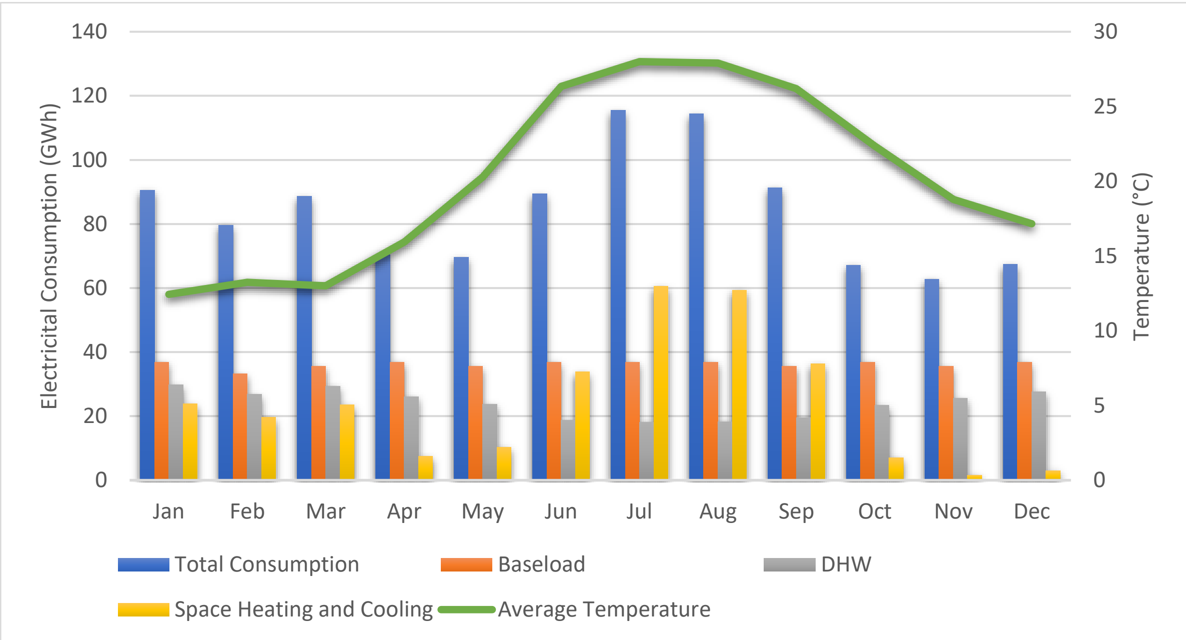

Figure 7 - Monthly profile of electrical energy distribution split by energy use for baseload, hot water and space heating and cooling, in the residential sector during 2022

Table 7 - Residential monthly consumption distribution between baseload, hot water and spatial cooling and heating, in GWh

Month	**Total Electrical Consumption**	Electrical Consumption for Baseload	Electrical Consumption for Domestic Hot Water	Electrical Consumption for Space Heating	Electrical Consumption for Space Cooling
January	**90.50**	36.80	29.83	23.87	0.00
February	**79.65**	33.24	26.81	19.59	0.00
March	**88.58**	35.61	29.41	23.55	0.00
April	**70.32**	36.80	26.11	7.41	0.00
May	**69.61**	35.61	23.74	0.00	10.25
June	**89.40**	36.80	18.77	0.00	33.84
July	**115.42**	36.80	18.11	0.00	60.51
August	**114.38**	36.80	18.33	0.00	59.25
September	**91.36**	35.61	19.45	0.00	36.30
October	**67.16**	36.80	23.34	0.00	7.01
November	**62.75**	35.61	25.52	1.61	0.00
December	**67.38**	36.80	27.64	2.94	0.00
Grand Total	**1,006.50**	**433.31**	**287.06**	**78.97**	**207.16**

From the above calculations, the final energy for space heating and cooling generated by electrical means in the residential sector is shown in Figure 8.

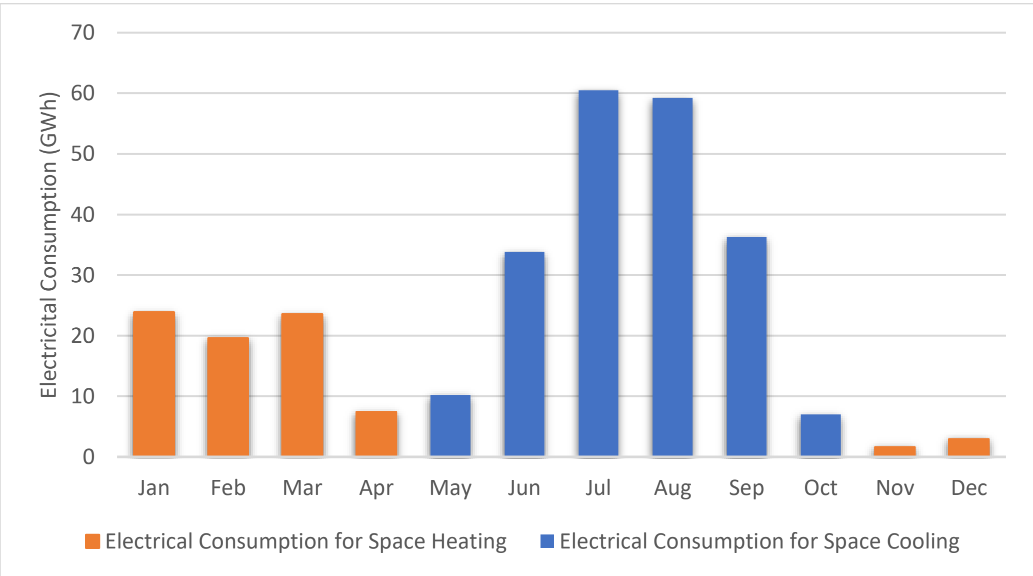

Figure 8 - Final Electrical Energy Consumed for Space Heating and Cooling in 2022 for the Residential Sector

Figure 9 shows the percentage distribution between the electricity consumption for the baseload, domestic hot water, space heating and space cooling in Maltese households during 2022.

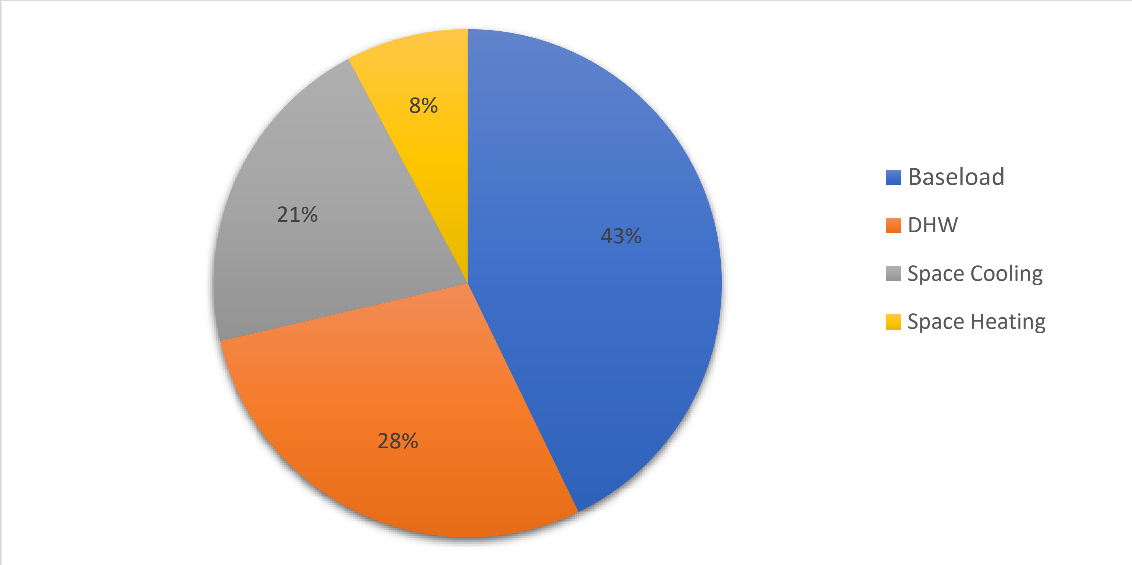

Figure 9 - Electricity consumption by end-use in the residential sector during 2022

The electricity consumption for space heating can be attributed to electrical resistance heaters and air-to-air heat pumps. To determine the useful energy in the residential sector for electricity, the conversion efficiency of the different types of technologies being used was applied. Based on the data collected through the latest national Census, market trends observed and industry analysis, it was assumed that the space heating demand in the residential sector through electricity is covered primarily by air-to-air heat pumps. Table 8 summarises the efficiency parameters used for converting final electrical energy into useful energy.

Table 8 - Efficiency values for residential technologies used for heating and cooling

Technology	Efficiency
Electrical water heaters	0.90
Heat pumps, COP	3.84
Heat pumps, EER	3.08

The Coefficient of Performance (COP)and the Energy Efficiency Ratio (EER) values for heat pumps were obtained through market research and data available through samples of energy performance certificates for the residential sector.

In the analysis of residential heat pump systems, we have examined both the COP and the EER values. Consequently, the values obtained for COP and EER through the research and analysis are highly comparable and effectively synonymous for residential heat pump systems. However, it's crucial to acknowledge that these values may not directly translate across sectors. Variations in operating conditions and usage patterns exist between residential, commercial, and industrial sectors, necessitating consideration of averaged COP and EER values when applying them outside of the residential sector. This recognition ensures a more accurate assessment of energy performance in diverse sectors and underscores the need for tailored evaluations in different contexts.

Based on the average values for COPs and EERs presented in Table 8 the useful energy for space heating and space cooling and hot water generated by electricity in the residential sector has been calculated and is shown in Table 9.

Table 9 - Final and useful electrical energy for the residential sector in 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Electricity	Spatial Cooling	Heat Pumps	207.15	3.08	638.04
	Spatial Heating	Heat Pumps	78.97	3.84	303.26
	Water Heating	Electric Boilers	287.06	0.90	258.36
	Total		**573.19**		**1,199.65**

1.3.2 Fuel Consumption for Residential Sector

LPG, a mixture of butane and propane, is the main fossil fuel used in the residential sector. In 2022, 13 GWh[19] of Solid Biofuels was consumed in the residential sector for heating purposes which can be considered as negligible compared to LPG.

A fuel consumption survey across all sectors indicates that 25kg cylinders are primarily used in the economic sector, while 10kg cylinders are predominantly consumed in the residential sector. The consumption of 12kg and 15kg LPG cylinders, as well as bulk LPG, was allocated to the residential and economic sectors based on the survey findings. In 2022, the total LPG consumption in the residential sector was 142.26 GWh. This was primarily used for spatial heating and cooking, with water heating by LPG considered to be negligible. This was distributed on a monthly basis in Table 10, based on data of sales of LPG Cylinders during each month.

Table 10 - Estimated Monthly LPG Consumption attributed to the Residential Sector for 2022

Year 2022	Total (MT)	LPG Use (GWh)
January	1,579.96	20.19
February	1,277.56	16.32
March	1,872.25	23.92
April	840.60	10.74
May	657.26	8.40
June	594.80	7.60
July	571.89	7.31
August	667.89	8.53
September	657.01	8.40
October	682.50	8.72
November	762.88	9.75
December	968.74	12.38
Total	**11,133.33**	**142.26**

[19] Eurostat Data for 2022_Complete Energy Balance (nrg_bal_c)

Based on the information presented in Table 10 it is clear that from January to April and between November and December, LPG usage increases drastically. Given that this coincides with the winter months, it can therefore be deduced that the additional LPG is used for domestic space heating.

Figure 10 depicts the quarterly LPG consumption in GWh for cooking and heating purposes in the residential sector. To note that Figure 10 depicts the LPG consumption in quarterly terms, since the data used relates to the total sales of LPG cylinders (rather than consumption) and this could lead to a household buying an amount of LPG in one month while consuming in other months.

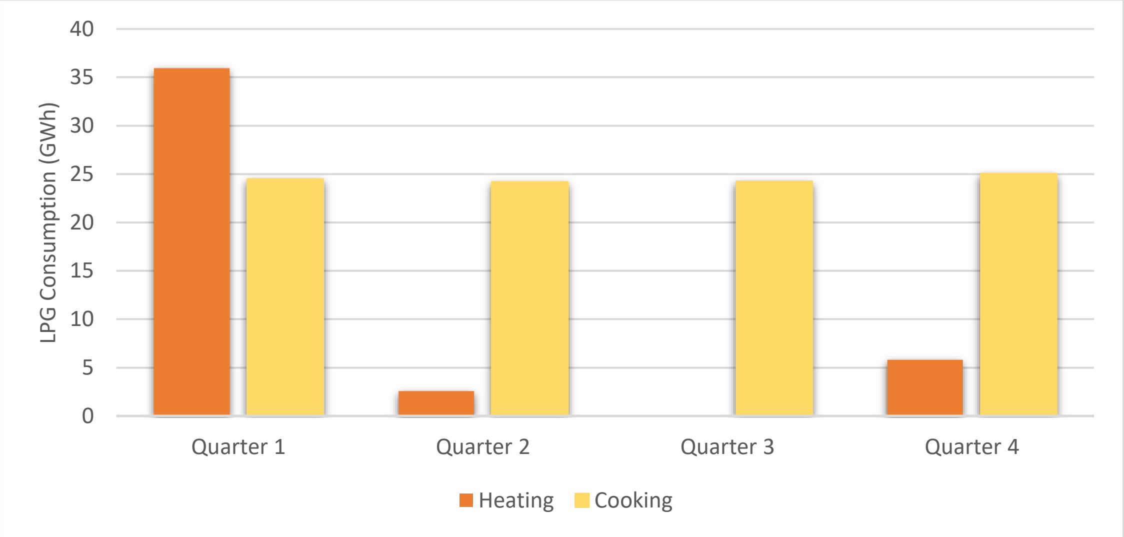

Figure 10 - Quarterly LPG use in GWh for heating and cooking in the residential sector during 2022

The monthly LPG (in tons) for cooking and space heating was converted to GWh and is shown in Table 11.

Table 11 - Monthly LPG use for cooking and space heating in GWh in the residential sector (2022)

Year 2022	Total (MT)	Heating (MT)	Cooking (MT)
January	1,579.96	941.41	638.56
February	1,277.56	639.00	638.56
March	1,872.25	1,233.69	638.56
April	840.60	202.04	638.56
May	657.26	0.00	657.26
June	594.80	0.00	594.80
July	571.89	0.00	571.89
August	667.89	0.00	667.89
September	657.01	0.00	657.01
October	682.50	0.00	682.50
November	762.88	124.32	638.56
December	968.74	330.19	638.56
Total	**11,133.33**	**3,470.64**	**7,662.69**

Figure 11 shows the percentage distribution between the use of LPG for cooking and heating during 2022.

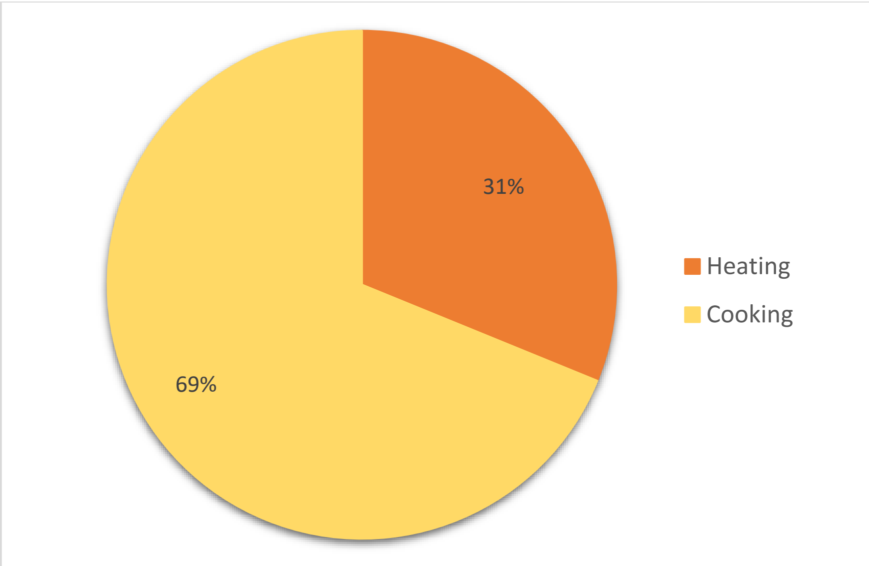

Figure 11 - LPG Consumption Percentage Distribution between heating and cooking in 2022

From the above calculations, the final and useful energy for space heating and cooking generated by LPG in the residential sector can be seen in the Table 12. An efficiency coefficient of 0.85 was used for gas heating systems based on market research and data available for the technology.

Table 12 - Final and Useful Energy for LPG use in the residential sector during 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
	Spatial Cooling		0.00		0.00
Fuel	Spatial Heating	Gas Heater	44.35	0.85	37.70
	Water Heating		0.00		0.00
	Total		44.35		37.70

1.3.3 Total Final and Useful energy for Residential Sector

Considering the data, methodologies and assumptions presented in this section, a summary of the final and useful energy of space heating, space cooling and water heating for the residential sector is presented in Table 13.

Table 13 - Total final and useful energy for the residential sector in 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Electricity	Spatial Cooling	Heat Pumps	207.15	3.08	638.04
	Spatial Heating	Heat Pumps	78.97	3.84	303.26
	Water Heating	Electric Boilers	287.06	0.9	258.36
			573.19		**1,199.65**
Fuel	Spatial Cooling		0.00		0.00
	Spatial Heating	Gas Heater	44.35	0.85	37.70
	Water Heating		0.00		0.00
			44.35		**37.70**
Total	Spatial Cooling		207.15		638.04
	Spatial Heating		123.32		340.96
	Water Heating		287.06		258.36
		Total	**617.54**		**1,237.35**

Figure 12 and Figure 13 present a complete overview of the distribution of the final and useful energy consumption for the residential sector for spatial heating, spatial cooling and water heating, whilst Figure 14 and Figure 15 show the energy distribution for both final and useful energy for the residential sector.

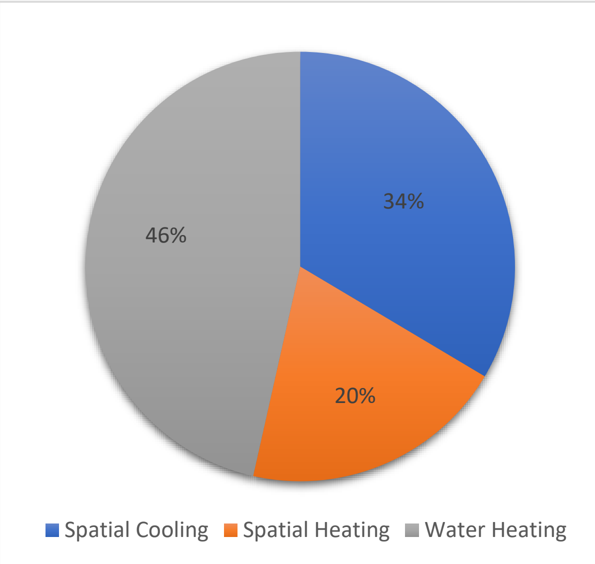

Figure 12 - Final energy consumption by end-use

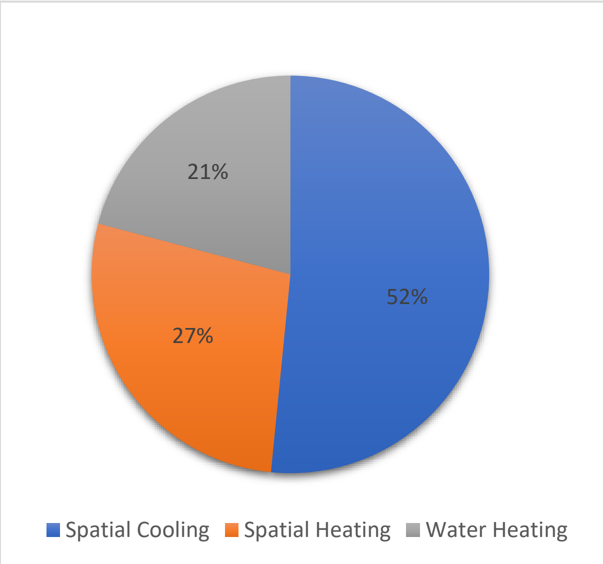

Figure 13 - Useful energy consumption by end-use

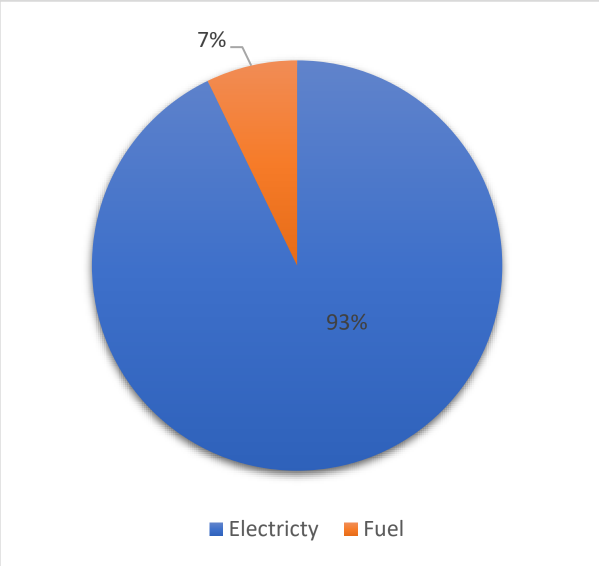

Figure 14 - Final energy consumption by source

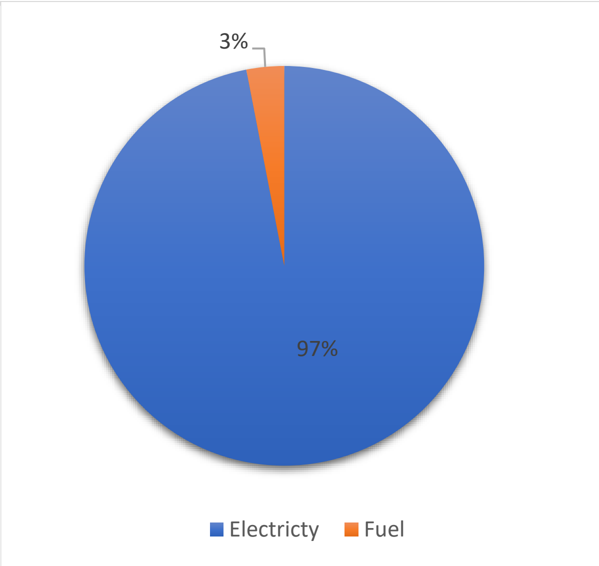

Figure 15 - Useful energy consumption by source

1.4 Industry Sector

Over the past few decades, Malta has witnessed substantial economic development and diversification. The industrial sector, encompassing activities such as quarrying, mining, construction, and manufacturing, plays a pivotal role in the nation's economic structure. It significantly contributes to job creation, GDP, high-value trade, and attracting foreign investments.

The manufacturing industry has been a cornerstone of Malta's economy since its industrialization began in the 1950s, initially emerging as a low-cost manufacturing hub. Over time, the sector has undergone remarkable growth and transformation, evolving into an industry known for high-value goods, continuous innovation, and maintaining a competitive edge. In 2022, industry (excluding manufacturing), accounted for around 9% of Malta's GVA, establishing itself as a key economic driver.[20] Despite challenges such as the COVID-19 pandemic, the manufacturing sector in Malta has consistently achieved annual growth. In 2022, the sector provided full-time employment to 22,723 individuals and part-time work to an additional 3,445.[21]

The manufacturing landscape in Malta is now highly diversified, with enterprises specializing in automotive and electronic components, injection moulding, medical devices, pharmaceuticals, precision engineering, and food production. Many of these companies operate within a network of industrial estates across the islands, managed by INDIS Malta Ltd.

[20] Eurostat, Gross Value Added in chain-linked volumes (2015), ESA 2010.
[21] NSO, Registered Employment: August 2022.

The construction industry on the Maltese islands represents another key segment of the industrial landscape. Over the last ten years, this sector has experienced considerable expansion, becoming an essential component of Malta's economy. The nation's economic climate, bolstered by a flourishing tourism industry and a growing services sector, has a direct influence on the construction sector, propelling the broader economy. A dynamic real estate market underpins the construction industry in Malta, with growth drivers including population growth, tourism appeal, and foreign investment, all of which have spurred a wave of building projects. These projects encompass residential developments, commercial buildings, hotel accommodation, and infrastructural enhancements. Malta has also made substantial investments in public infrastructure, such as improvements to the transportation network, port facilities, and public transportation systems.

In terms of its contribution towards the economy, the construction sector is estimated to directly account for roughly 4% of the total GVA.[22] The sector is directly responsible for a range of jobs and trade skills. Between 2014 and 2021, the construction sector directly accounted for 5.9% of the total workforce. In 2022, there were 17,679 full-time employees in the construction sector (NACE F), with an additional 2,716 working part-time within the sector.[23] Mining and quarrying, a sector which is strongly linked to the construction industry, accounted for approximately another 400 employees.

The following sections of the report cover a detailed analysis of the heating and cooling requirements of the following sub-categories within the industry sector:

- NACE Code B – Mining and quarrying
- NACE Code C – Manufacturing
- NACE Code F – Construction

[22] NSO, National Accounts.
[23] NSO, Registered Employment: August 2022.

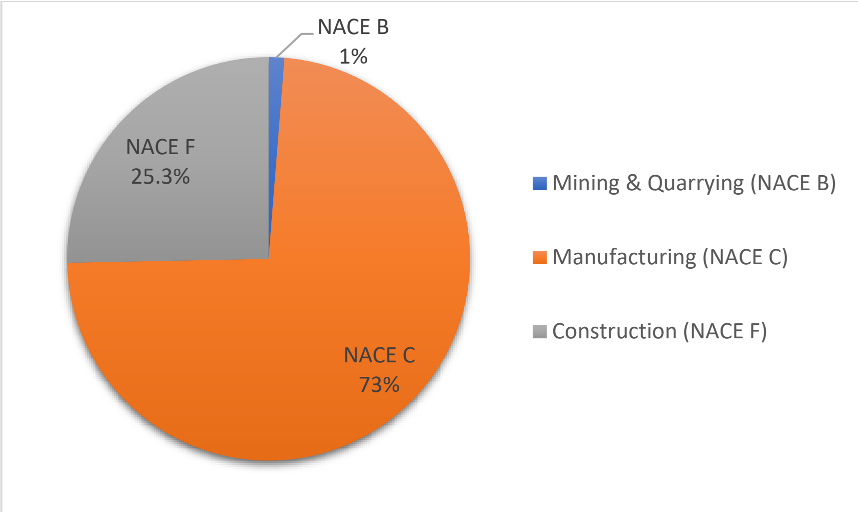

Figure 16 - Total Energy consumption of the industry sector by NACE in 2022 [24]

Figure 16 represents the total energy consumption trends used in the industry sector in 2022, excluding fuels used for transport. It highlights that the manufacturing sector, classified under NACE Code C, is the predominant energy user in the industry, responsible for a significant 73% of the total energy consumption of the industry sector. By contrast, the construction sector, under NACE F, accounts for 25% of the industry's total energy use. It is important to note that there are no mining activities in Malta, and therefore the energy usage of NACE B, is consumed by quarrying activities. The energy requirements for quarrying activities make up a minor fraction (1%) of the total energy consumption within the Maltese industrial sector.

The main sources of data used to assess the heating and cooling demand within the industrial sector for the base year 2022 include:

- Annual electricity consumption for each sector as per Eurostat Data;[25]
- Aggregated 2022 hourly electricity consumption data from a representative number of meters from each NACE; and
- Fuel consumption for the industry sector provided by the EWA.

Since the purpose of this study is to perform an assessment on the heating and cooling demand in Malta, fuel use for transport was not factored in the energy consumption throughout the survey. Detailed analysis was performed on electricity and fuel consumption for water heating, space heating and space cooling for each NACE.

Given the nature of the industry sub-sectors, the energy consumption for NACE B (Quarrying) and NACE F (Construction) were analysed together due to their similar operation. On the other

[24] Eurostat_Complete energy balances (nrg_bal_c)
[25] Eurostat_Supply, transformation and consumption of electricity (nrg_cb_e)

hand, NACE C (Manufacturing) has been analysed separately to provide a better understanding of the heating and cooling requirements within the manufacturing industry.

1.4.1 Quarrying and Construction (NACEs B and F)

This section analyses the electrical and fuel consumption for NACE codes B and F. As mentioned earlier, there is no mining activity in Malta, thus NACE B is only referring to quarrying. In 2022, the total energy consumption in NACE B was 10.8 GWh, whilst 217.8 GWh was consumed in NACE F. Figure 17 provides the ratio of the total fuel consumption and electricity consumption of these two sectors.

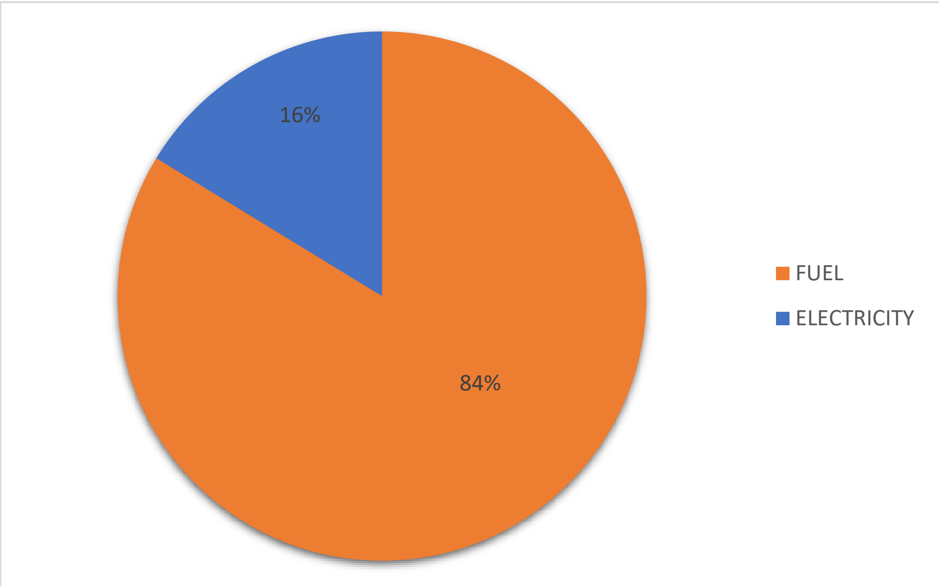

Figure 17 - Total Energy Consumption of NACE B and F[26] in 2022

[26]Eurostat_Complete energy balances (nrg_bal_c)

1.4.1.1 Electricity Consumption in Quarrying and Construction

The total monthly electricity for 2022 for NACE codes B and F is shown in Figure 18.

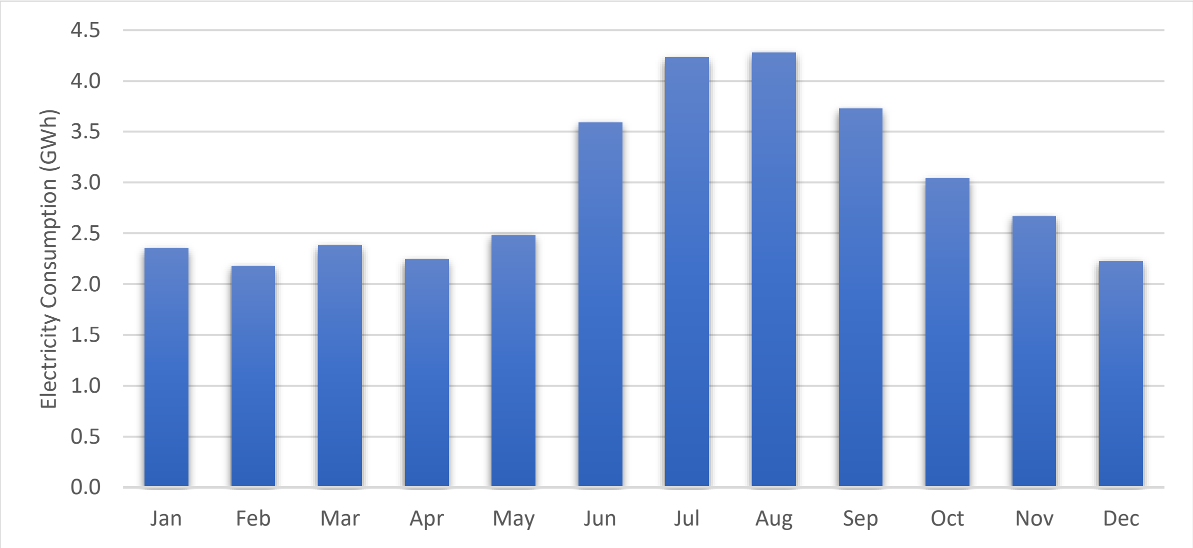

Figure 18 - Monthly electricity consumption for NACE codes B and F for the year 2022

2022 hourly data from a sample number of electricity consumption meters for companies in NACE codes B and F was aggregated to develop monthly consumption profiles. These profiles were then scaled up to meet the final electricity consumption of both NACEs and used to define the monthly electricity baseload. The data available for the base year 2022 highlighted the predominance of the cooling demand covered by electricity during the period between June and October.

Considering the lower spatial heating demands during the months of January to April corresponds primarily to the sectors' baseload, which was used to determine daily average baseload values that was then applied for the rest of the months to define the baseload throughout the year.

This methodology has limited applicability to segregate the heating demand from the baseload in this sector. In fact, this methodology has identified higher heating demand in November rather than December, despite December having higher HDDs. This is likely because December's lower overall electricity consumption, due to fewer working days, masks the actual heating demand. Limitations in data segregation and assumptions made to calculate the baseload for 2022 make it difficult to isolate heating demands during those months.

Given the year-round utilization of electrically powered processing equipment, the baseload remains relatively stable. The electrical energy consumption during non-cooling periods can therefore be attributed to the sector's baseload (i.e. electrical energy required for the companies' operations including electric machinery, plants and office areas and excluding space cooling).

Given the nature of the operations and limited segregated data available within the quarrying and construction industries, the hot water consumption and spatial heating are assumed to be minimal and any heating requirements in offices within the sectors are considered as part of the baseload.

Figure 19 shows the monthly baseload, electrical energy to cover the space heating and cooling demand and the total electricity consumption for NACE codes B and F during 2022. Figure 20 focuses on the monthly electrical consumption for space cooling, whilst indicating the presence of some electricity consumption for space heating in November (and minor consumption for December).

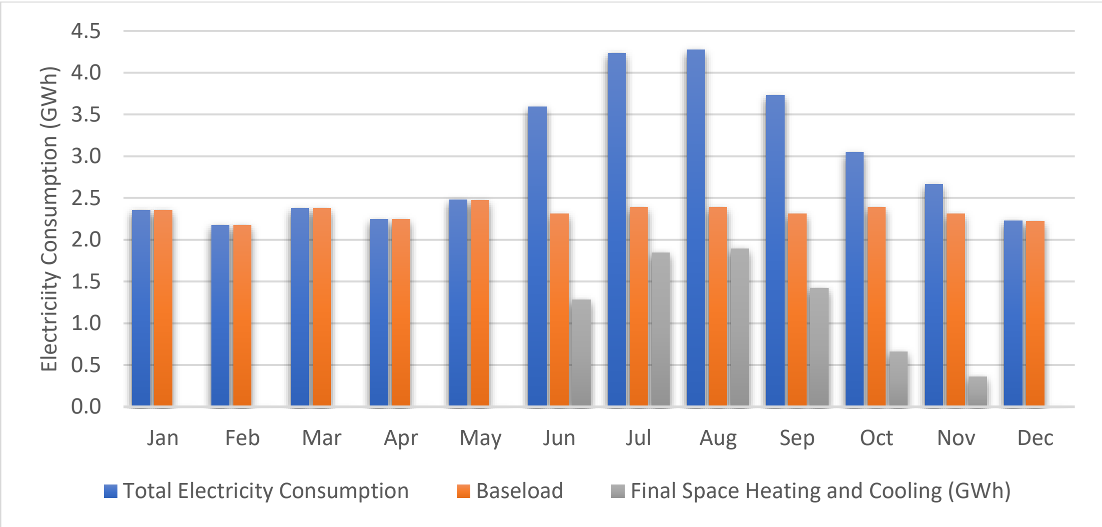

Figure 19 - Monthly electricity consumption distribution split between the baseload and heating/cooling for NACE codes B&F during 2022

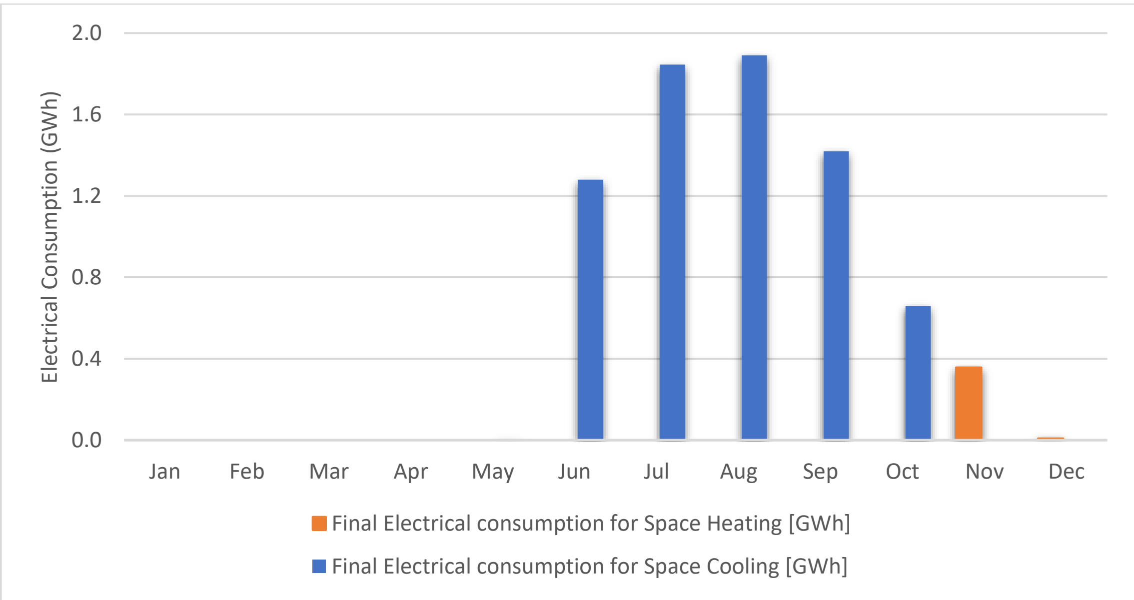

Figure 20 - Monthly final electrical energy for space heating and cooling for NACE codes B&F during 2022

The monthly electricity consumption figures for the baseload, space heating and space cooling within NACE B and F are presented in Table 14.

Table 14 - Monthly electrical consumption distribution for baseload, space heating and space cooling during 2022

Month (2022)	Total Electrical Consumption (GWh)	Electrical Consumption for Baseload (GWh)	Final Electrical Consumption for Space Heating (GWh)	Final Electrical Consumption for Space Cooling (GWh)
January	2.35	2.35	0.00	0.00
February	2.17	2.17	0.00	0.00
March	2.38	2.38	0.00	0.00
April	2.24	2.24	0.00	0.00
May	2.48	2.47	0.00	0.00
June	3.59	2.31	0.00	1.28
July	4.23	2.39	0.00	1.85
August	4.28	2.39	0.00	1.89
September	3.73	2.31	0.00	1.42
October	3.05	2.39	0.00	0.66
November	2.67	2.31	0.36	0.00
December	2.23	2.22	0.01	0.00
Grand Total	**35.40**	**27.93**	**0.37**	**7.10**

It is important to note that due to the transient nature of construction sites related to NACE B & F, the adoption of low-capacity heat pumps is prevalent. Space heating and cooling requirements within the quarrying and construction sectors are therefore mainly characterised by conventional split-unit air-conditioning systems for small offices and plant rooms on site. Based on the average values for COPs and EERs for such systems presented in the previous section of the report, the useful energy for space heating and space cooling generated by electricity in these sub-sectors has been calculated and is shown in Table 15.

Table 15 - Final and useful electrical energy for NACE B&F in 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Electricity NACE B&F	Spatial Cooling	Heat Pumps	7.10	3.08	21.87
	Spatial Heating	Heat Pumps	0.37	3.84	1.40
	Water Heating		0.00		0.00
	Total		**7.47**		**23.27**

1.4.1.2 Fuel Consumption for Quarrying and Construction

The data for fossil fuel consumption data in NACE B & F was provided by EWA.[27] The yearly fuel consumption between 2018 and 2022 is shown in Figure 21.

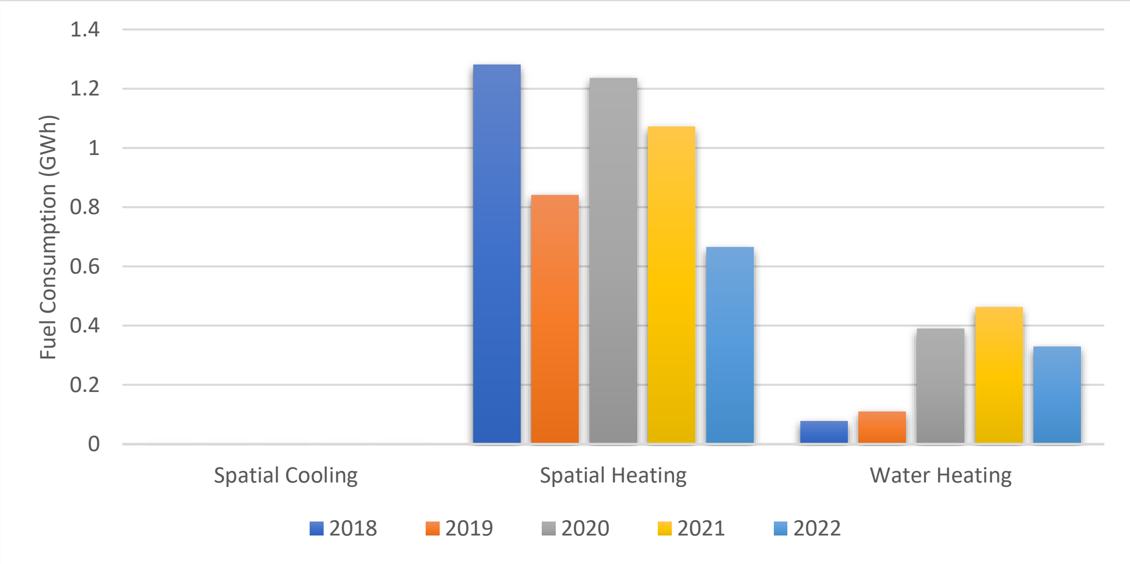

Figure 21 - Yearly fuel consumption summary for 2018 – 2022 for quarrying and construction sub-sectors (NACEs B&F)

The fossil fuel consumption during 2022 was further split by fuel type and end use as shown in Table 16.

Table 16 - Fossil Fuel Consumption for mining, quarrying and construction for 2022

Fuel Type	Fuel Use	Consumption (tons)	Conversion Factor (GWh/ton)	Final Energy (GWh)
Diesel	Spatial Cooling	0.00	0.01194	0.00
	Spatial Heating	0.00		0.00
	Water Heating	7.08		0.09
Gasoil	Spatial Cooling	0.00	0.01194	0.00
	Spatial Heating	54.27		0.65
	Water Heating	0.00		0.00
LPG	Spatial Cooling	0.00	0.01278	0.00
	Spatial Heating	1.32		0.02
	Water Heating	19.10		0.24
Total	**Spatial Cooling**			**0.00**
	Spatial Heating			**0.67**

[27] Fuel Consumption Data in each NACE provided by EWA.

Fuel Type	Fuel Use	Consumption (tons)	Conversion Factor (GWh/ton)	Final Energy (GWh)
	Water Heating			**0.33**

The distribution between the different types of fuel in both NACEs are shown in Figure 22.

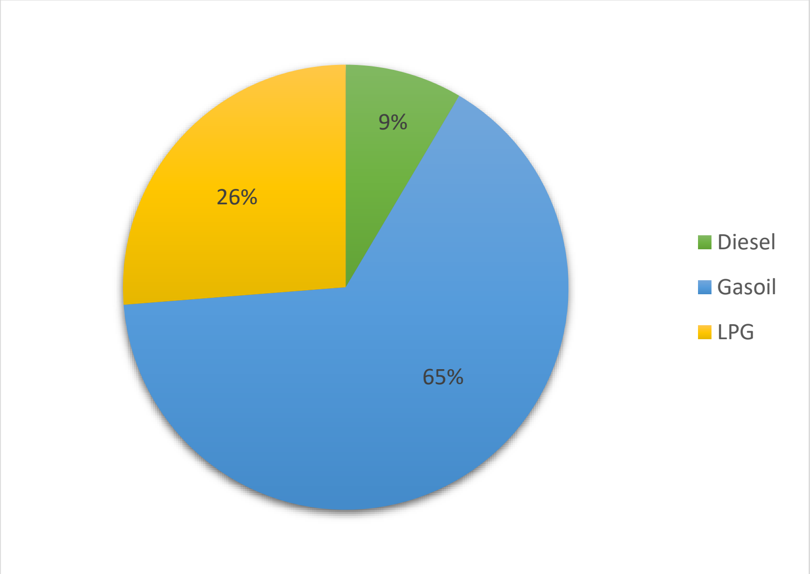

Figure 22 - Fuel consumption distribution in NACE B&F by type in 2022

The data included in Table 16 and the graphical representation in Figure 22 shows that gasoil was the mostly used fossil fuel in 2022 in NACEs B & F, followed by LPG and then diesel. These fuels are used to generate hot water and for space heating, as can be seen in Figure 23.

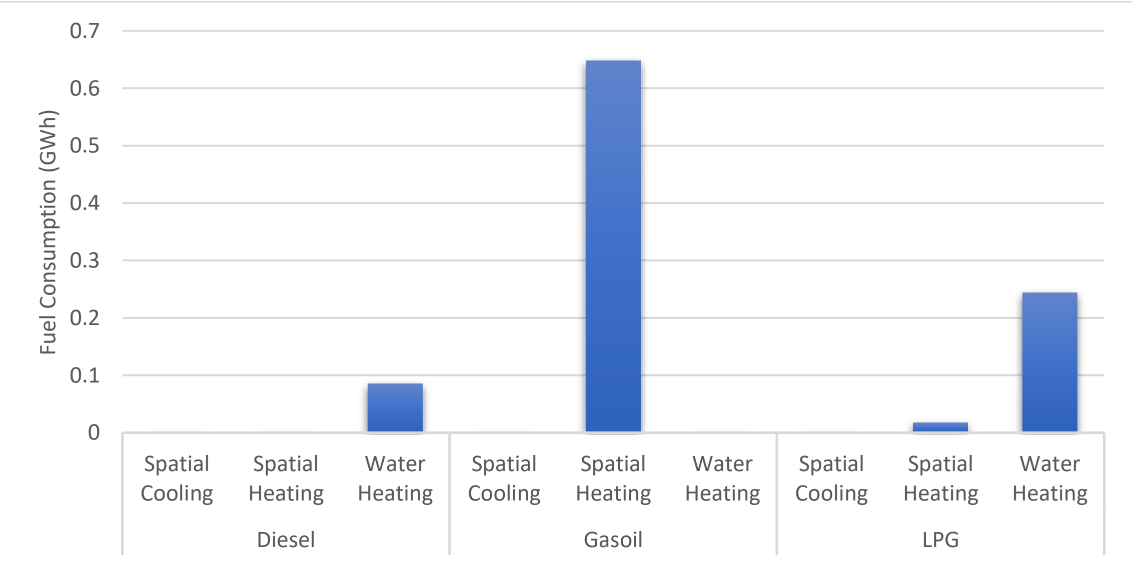

Figure 23 - Fuel Consumption by end use in NACE B and NACE F for Heating and Cooling Demand in 2022

On the basis of the data indicated above, Figure 24 shows the percentage distribution of the fossil fuel end uses in NACEs B & F, for space heating and water heating. There is no fuel being consumed for space cooling in these sectors.

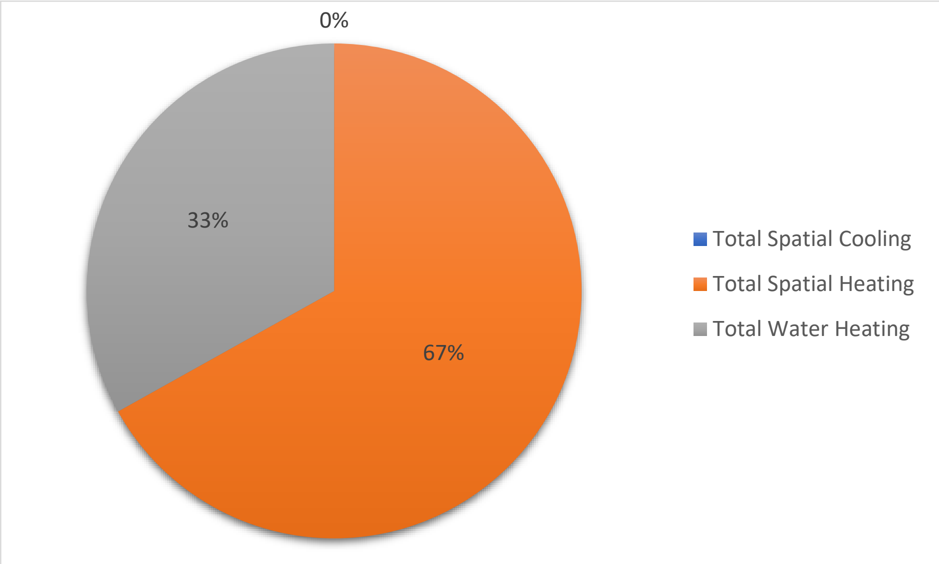

Figure 24 - Percentage Fossil Fuel distribution in the mining, quarrying and construction sub-sector in 2022

From the above calculations, the final and useful energy for hot water generation, space heating and cooling generated by fossil fuels are presented in the Table 17. An efficiency coefficient of 0.85 for fuel-fired boilers was used, based on market research and data available for the technology.

Table 17 - Final and Useful Energy for fossil fuel use in NACE B&F during 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Fuel (NACE B&F)	Spatial Cooling	Fuel Fired Boilers	0.00	0.85	0.00
	Spatial Heating	Fuel Fired Boilers	0.67	0.85	0.57
	Water Heating	Fuel Fired Boilers	0.33	0.85	0.28
	Total		**0.99**		**0.84**

1.4.2 Manufacturing

The electricity and fuel consumption for the manufacturing sector (NACE C) is analysed in this section. The manufacturing sector's hot water demand includes a broader range of activities apart from sanitary purposes; some examples include hot water used for cleaning processes or product sterilization. Due to the higher temperatures required in larger industries, fossil fuels are most likely to be the primary source for water heating in this sector.

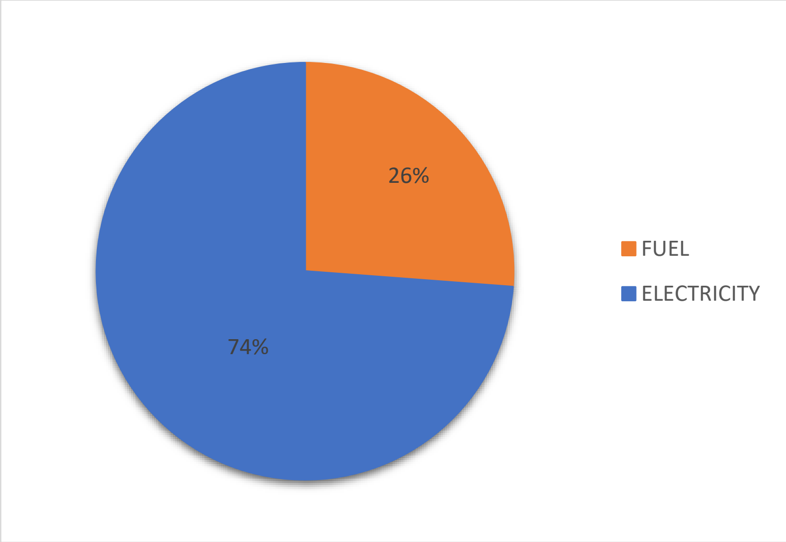

Figure 25 - Total Energy Consumption in NACE C

1.4.2.1 Electricity Consumption in Manufacturing

The total monthly electricity for manufacturing in 2022 is shown in Figure 26.

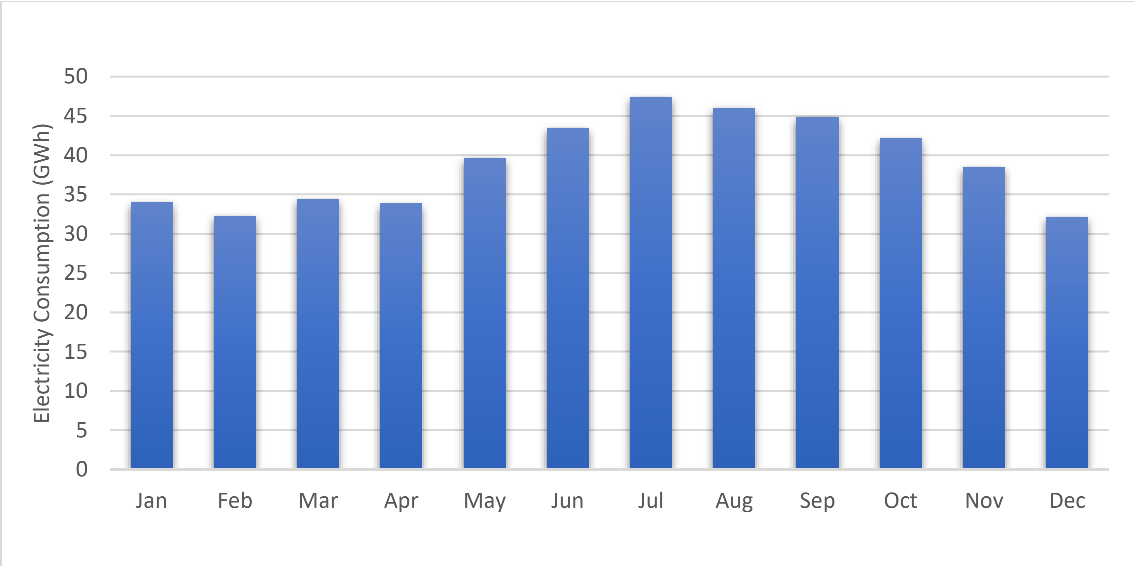

Figure 26 - Monthly electricity consumption for NACE code C for the year 2022

The hourly data and the derived monthly electricity consumption from a representative sample were analysed to define the electricity baseload of companies in NACE C. Figure 26 shows a clear increase in electricity consumption from May to October, which is being attributed to cooling requirements. The electricity consumption during the months of December to April corresponds primarily to the sectors' baseload. This was used to determine daily average electricity baseload values that was then applied for the rest of the months to define a constant baseload throughout the year.

Minimum spatial heating demand was identified during the month of November, which can be attributed to heating requirements based on HDD values during the month. However, it is important to note that due to lack of data segregation, electricity consumption for spatial heating could not be identified in the other winter months, possibly leading to overestimation of the electricity baseload. Given the year-round utilization of electrical energy for the manufacturing companies' operations, the baseload remains relatively stable throughout the year.

Figure 27 shows the monthly baseload, electrical energy to cover the heating and cooling demand and the total electricity consumption for NACE C during 2022 while Figure 28 shows the monthly electrical consumption for space heating and cooling.

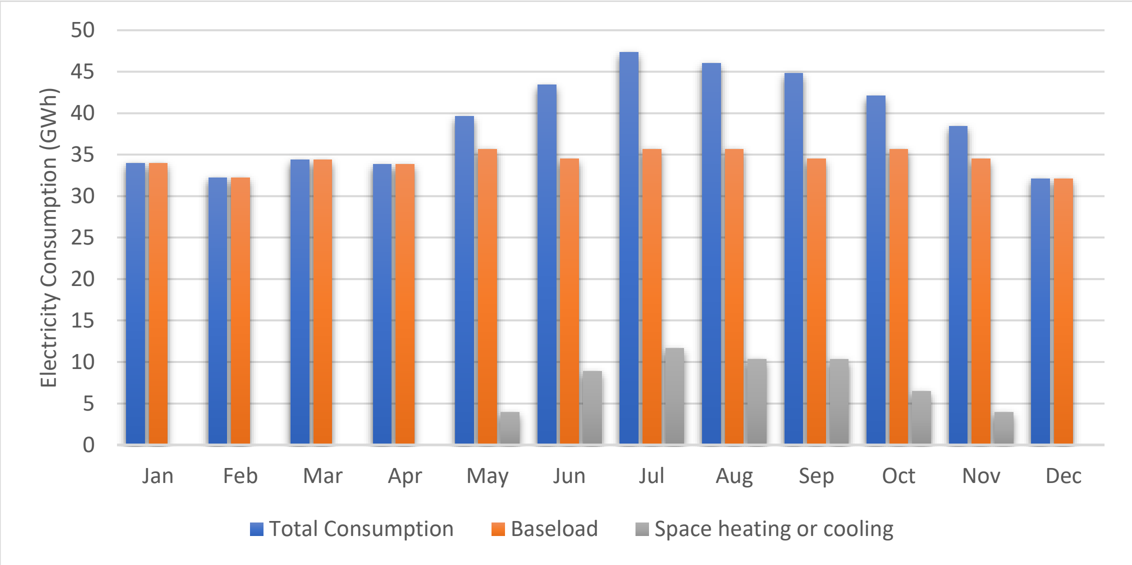

Figure 27 - Monthly electricity consumption distribution between the baseload and heating/cooling for NACE C during 2022

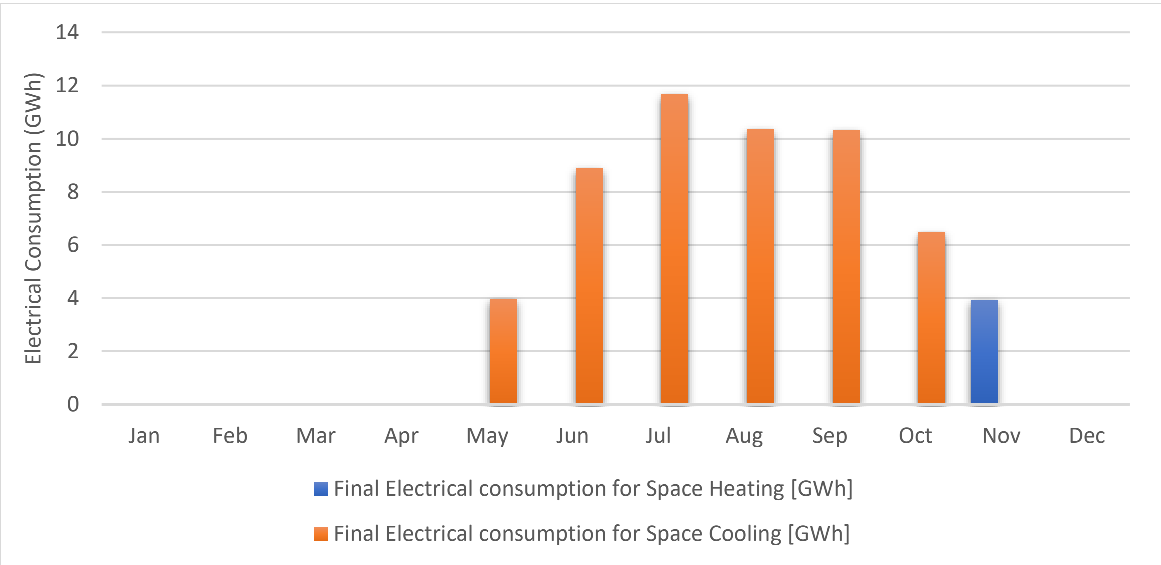

Figure 28 - Monthly Electrical Energy Consumption for space heating and cooling for NACE C during 2022

It is being assumed that space heating and cooling requirements within the manufacturing industry is characterised by centralised Variable Refrigerant Flow (VRF) HVAC systems. Heating and cooling requirements for industrial processes are generally covered by chillers, however, as explained above, these have been considered as part of the baseload and are therefore not considered as part of the space heating and cooling demand. Based on the average values for COPs and EERs for such systems installed across sample buildings and market research, the useful energy for space heating and space cooling generated by electricity in the manufacturing sub-sector has been calculated and is shown in
Table 18.

Table 18 - Final and useful electrical energy for NACE C in 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Electricity NACE C	Spatial Cooling	Heat Pumps	51.63	4.3	222.02
	Spatial Heating	Heat Pumps	3.92	4.5	17.65
	Water Heating		0.00		0.00
	Total		**55.55**		**239.66**

1.4.2.2 Fuel Consumption for Manufacturing

The fossil fuel consumption data for NACE C was provided by EWA. The yearly fuel consumption between 2018 and 2022 is shown in Figure 29.

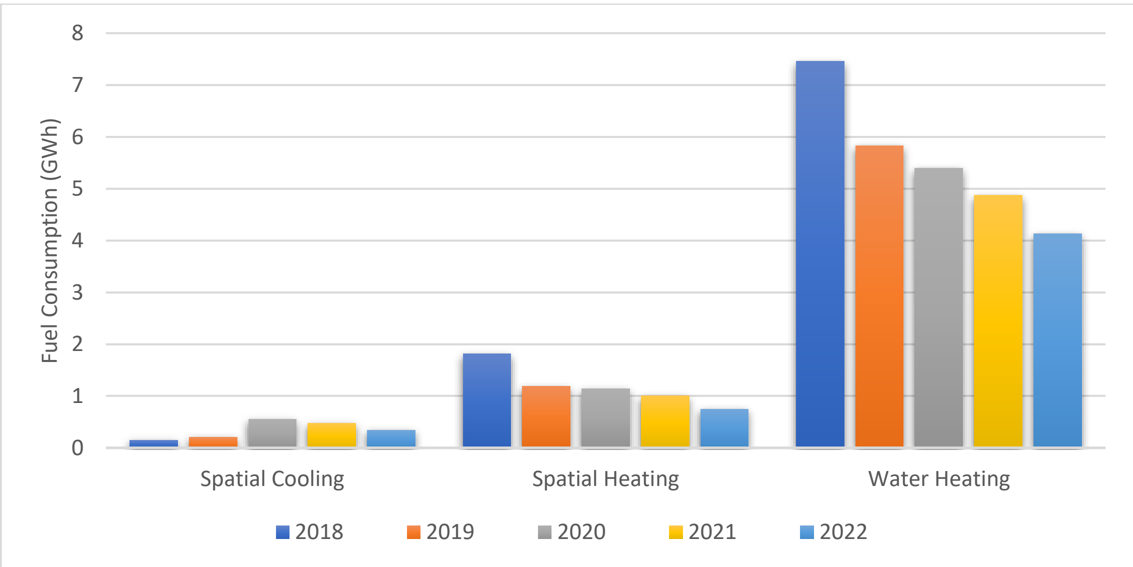

Figure 29 - Manufacturing sector (NACE C) yearly fuel consumption summary for 2018 – 2022

The fossil fuel consumption during 2022 was further split by fuel type and end use as shown in Table 19.

Table 19 - Fossil Fuel Consumption for manufacturing sub-sector for 2022

Fuel Type	Fuel Use	Fuel Consumption (tons)	Conversion Factor (GWh/ton)	Final Energy Consumption (GWh)
Diesel	Spatial Cooling	11.44	0.0119	0.14
	Spatial Heating	0.00		0.00
	Water Heating	0.00		0.00
Gasoil	Spatial Cooling	16.76	0.0119	0.20
	Spatial Heating	59.31		0.71
	Water Heating	150.13		1.79
Kerosene	Spatial Cooling	0.00	0.0122	0.00
	Spatial Heating	0.00		0.00
	Water Heating	156.12		1.91
LPG	Spatial Cooling	0.35	0.0128	0.00
	Spatial Heating	3.12		0.04
	Water Heating	33.92		0.43
Total	**Spatial Cooling**			**0.34**
	Spatial Heating			**0.75**
	Water Heating			**4.13**

Table 19 and Figure 30 present data indicating that in 2022, gasoil and kerosene are the predominant fossil fuels utilized to meet heating and cooling requirements in NACE C, with some LPG and diesel also being used. The primary application of these fuels is to produce hot water as shown in Figure 31.

It is important to underline that the main use of fuel in the manufacturing sector is for industrial processes, which accounts for almost 97% of the total fuel consumption. However, industrial processes are not being considered within the scope of the heating and cooling assessment.

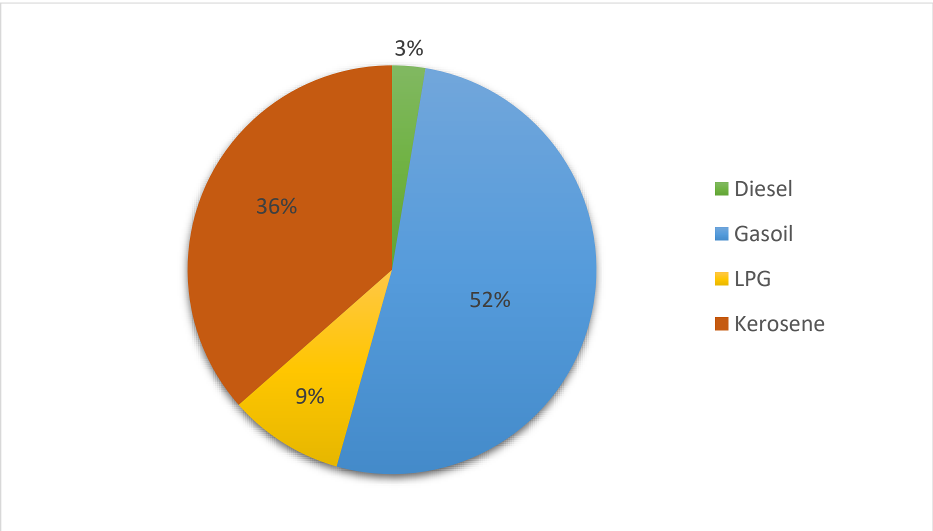

Figure 30 - Fuel consumption for Heating and Cooling Purposes in NACE C by Fuel type in 2022

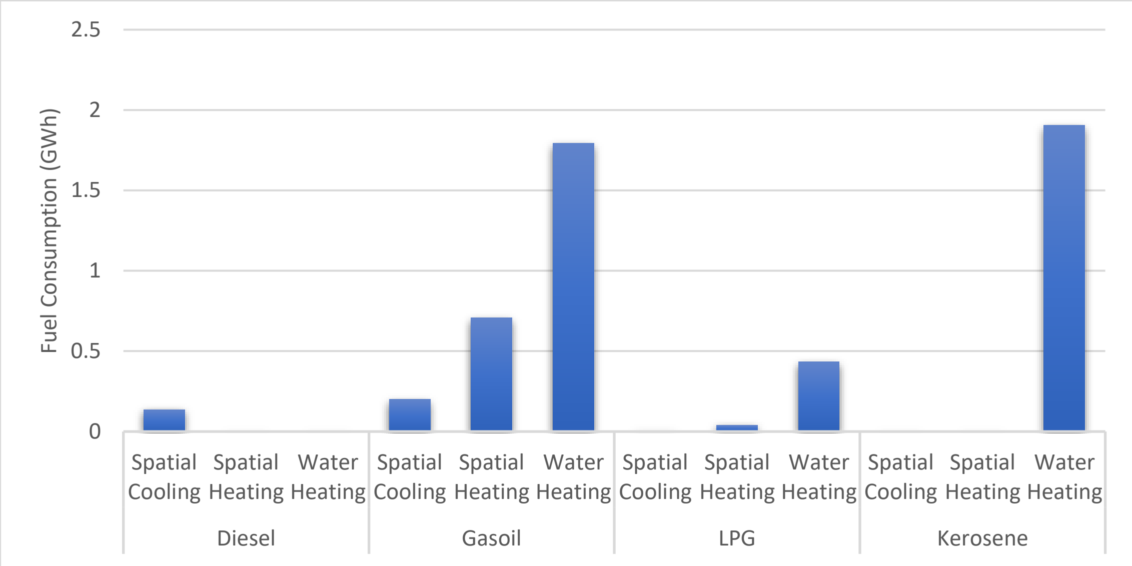

Figure 31- Fossil Fuel Consumption for Heating and Cooling Purposes by end-use in NACE C in 2022

From the above calculations, the final and useful energy for hot water generation, space heating and cooling generated by fossil fuels can be seen in Table 20. The efficiency coefficients used for fuel-fired boilers were based on market research and data available for the technology.

Table 20 - Final and Useful Energy for fossil fuel use in NACE C during 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Fuel (NACE C)	Spatial Cooling	Fuel Fired Boilers	0.34	0.85	0.29
	Spatial Heating	Fuel Fired Boilers	0.75	0.85	0.64
	Water Heating	Fuel Fired Boilers	4.13	0.9	3.72
	Total		5.22		4.64

1.4.3 Industry Sector Summary

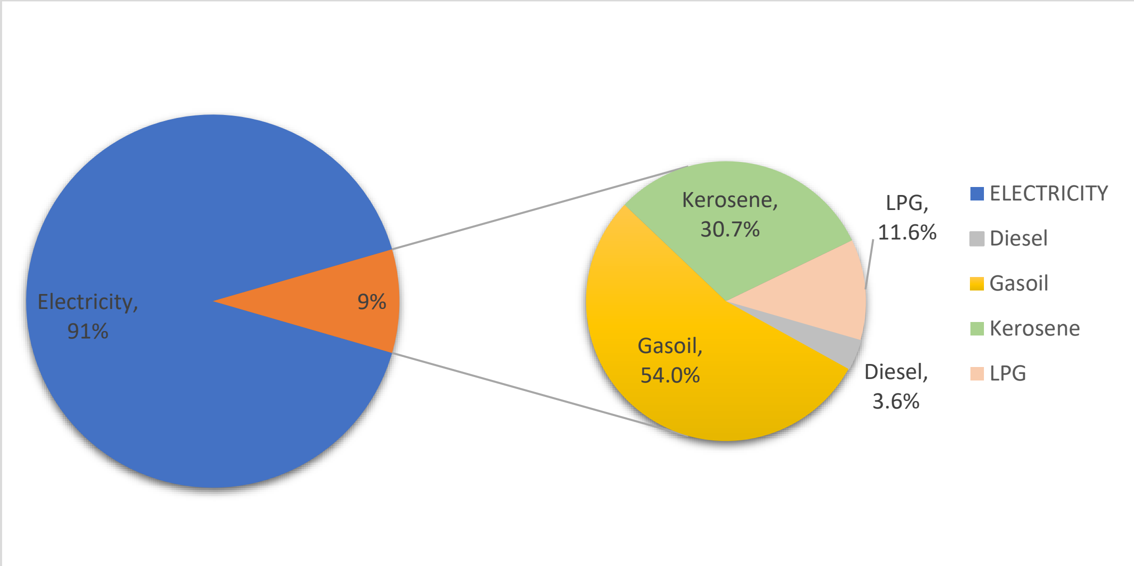

Figure 32 illustrates that 91% of the total heating, cooling and water heating demand in the industry sector is obtained from electricity, with the other 9% derived from fossil fuels.

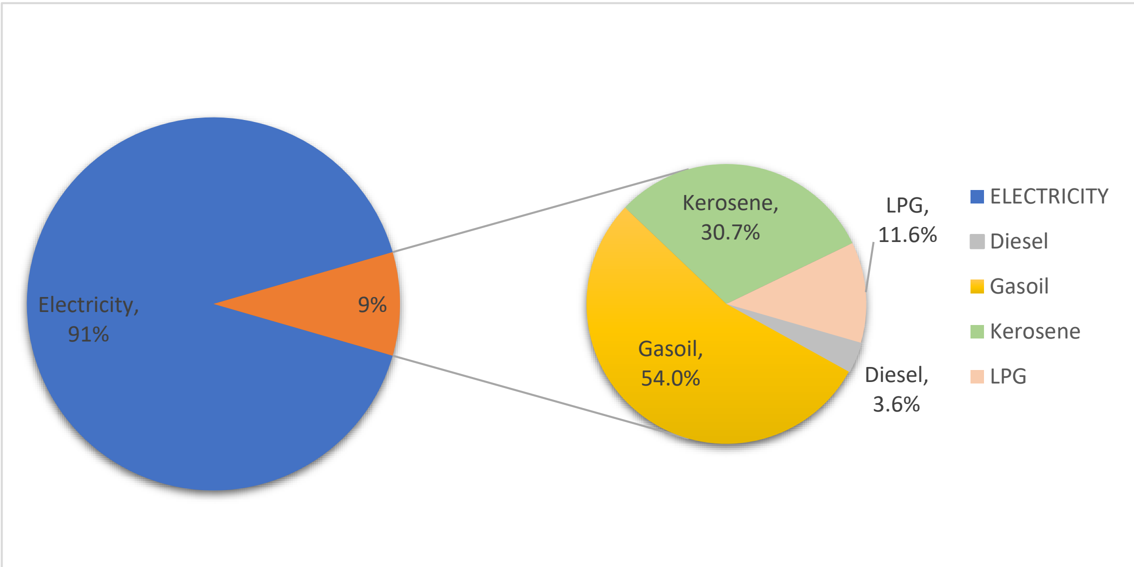

Figure 32 - Energy Consumption for Heating and Cooling Requirements in the Industry Sector in 2022.

1.4.3.1 Electrical Consumption in Industry Sector

In 2022, the total electricity usage in the industrial sector amounts to 503.6 GWh, as per Eurostat Energy Balance. Moreover, hourly electricity consumption data for the same year was collected from a selection of electricity meters corresponding to the specified NACE codes. This information was compiled and projected to generate a monthly consumption pattern for the entire sector.

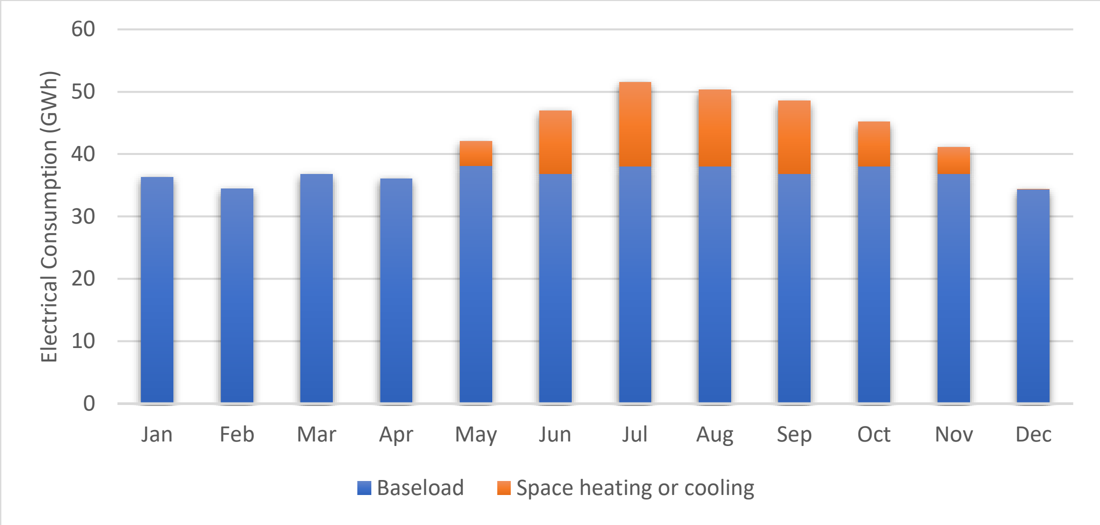

Figure 33 - Industry Sector (NACEs B, F and C) Monthly Electricity Consumption in 2022

Considering the overall electricity consumption of the industry sector (including all sub-categories), the distribution between the baseload and electrical energy used for space heating and cooling is shown in Figure 33.

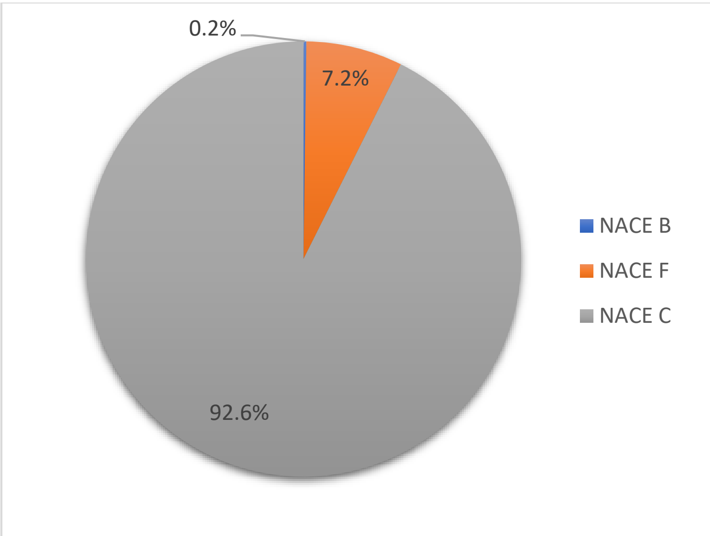

Figure 34 - Electrical energy consumption distribution between the Industry sub-sectors for the year 2022

The total electricity consumption distribution between the three industry sub-categories is shown in Figure 34. The main consumer in terms of electrical energy consumption is manufacturing (92.6%), followed by construction (7.2%) and quarrying with less than 1%. Peaks in the final energy required for space conditioning through electricity can be observed during the summer months for all sub-categories within the industrial sector. Table 21 shows the final energy consumption and useful energy for space heating and cooling for the industry sector, based on the conversion factors for technologies used predominantly in the different sub-sectors.

Table 21 - Final and useful electrical energy for heating and cooling for the industrial sector

	End Use	Technology	Final Energy (GWh/a)	Conversion Factor	Useful Energy (GWh/a)
Electricity (NACE B&F)	Spatial Cooling	Heat Pumps	7.10	3.08	21.87
	Spatial Heating	Heat Pumps	0.37	3.84	1.40
	Water Heating		0.00		0.00
Electricity (NACE C)	Spatial Cooling	Heat Pumps	51.63	4.3	222.02
	Spatial Heating	Heat Pumps	3.92	4.5	17.65
	Water Heating		0.00		0.00
	Total		**63.02**		**262.94**

1.4.3.2 Fuel Consumption in the Industry Sector

The fuel consumption for the industry sub-sectors for the base year 2022 has been analysed in further detail and a summary of the consumption per fuel type is presented in Table 22.

Table 22 - Fossil fuel consumption used for heating and cooling in the industry sector in 2022 per fuel type and NACE code (Source: EWA)

Fuel Type	Fuel Use	Industry Sub-Sectors		
		Mining, Quarrying and Construction (NACE B & F) GWh	Manufacturing (NACE C) GWh	Total GWh
Diesel	Spatial Cooling	0.00	0.14	0.14
	Spatial Heating	0.00	0.00	0.00
	Water Heating	0.08	0.00	0.08
Gasoil	Spatial Cooling	0.00	0.20	0.20
	Spatial Heating	0.65	0.71	1.36
	Water Heating	0.00	1.79	1.79
LPG	Spatial Cooling	0.00	0.00	0.00
	Spatial Heating	0.02	0.04	0.06
	Water Heating	0.24	0.43	0.68
Kerosene	Spatial Cooling	0.00	0.00	0.00
	Spatial Heating	0.00	0.00	0.00
	Water Heating	0.00	1.91	1.91
Total	**Spatial Cooling**	**0.00**	**0.34**	**0.34**
	Spatial Heating	**0.67**	**0.75**	**1.41**
	Water Heating	**0.33**	**4.13**	**4.46**

According to the information in Table 22, gasoil emerges as the most consumed fuel type across all industry sectors for the various NACE codes, with kerosene being the second most used. Figure 35, Figure 36 and Figure 37 depict the proportional breakdown of fuel usage for space heating, space cooling, and water heating. Additionally, these figures illustrate the division of fuel types utilized in the quarrying and construction sectors (NACE codes B & F) versus the manufacturing sector (NACE code C) for the year 2022.

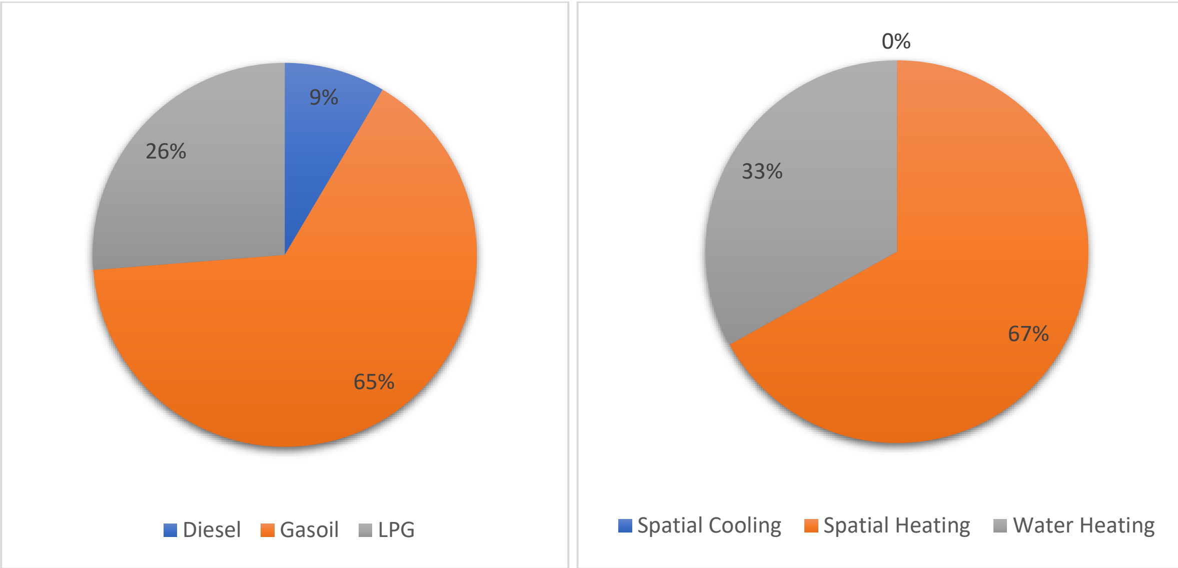

Figure 35 - Fuel consumption by type (left) and end-use (right) for Heating and Cooling purposes in the quarrying and construction sectors for 2022 (NACE B & F)

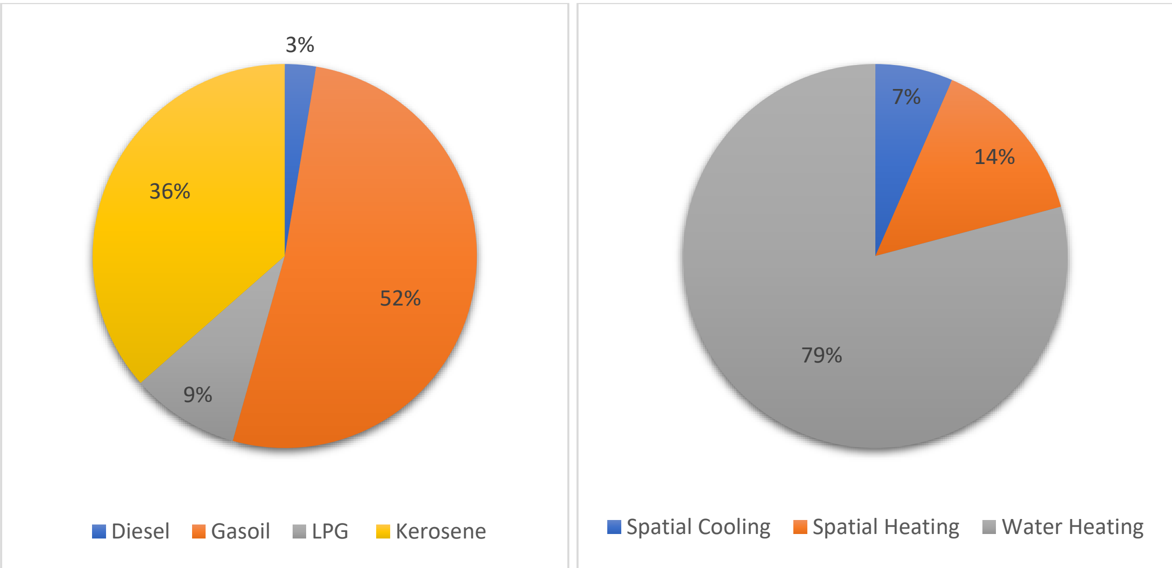

Figure 36 - Fuel consumption by type (left) and end-use (right) for Heating and Cooling purposes in the manufacturing sector for 2022 (NACE C)

Considering fuel consumption for heating and cooling purposes, Figure 35 shows that space heating is the primary energy use in terms of fuel consumption for NACE codes B & F (67%) while Figure 36. shows that water heating is the main fuel consumer for NACE code C (79%). Gasoil represents the primary fuel type used for heating and cooling purposes in all sectors, accounting for 65% in NACE codes B & F and 46% in NACE code C. A small amount of fuel is used for space cooling purposes which can be attributed to manufacturing companies requiring humidity control for the processes.

The total percentage distribution between the fuel consumption end use and fuel type used for the industry sector for heating and cooling is shown in Figure 37.

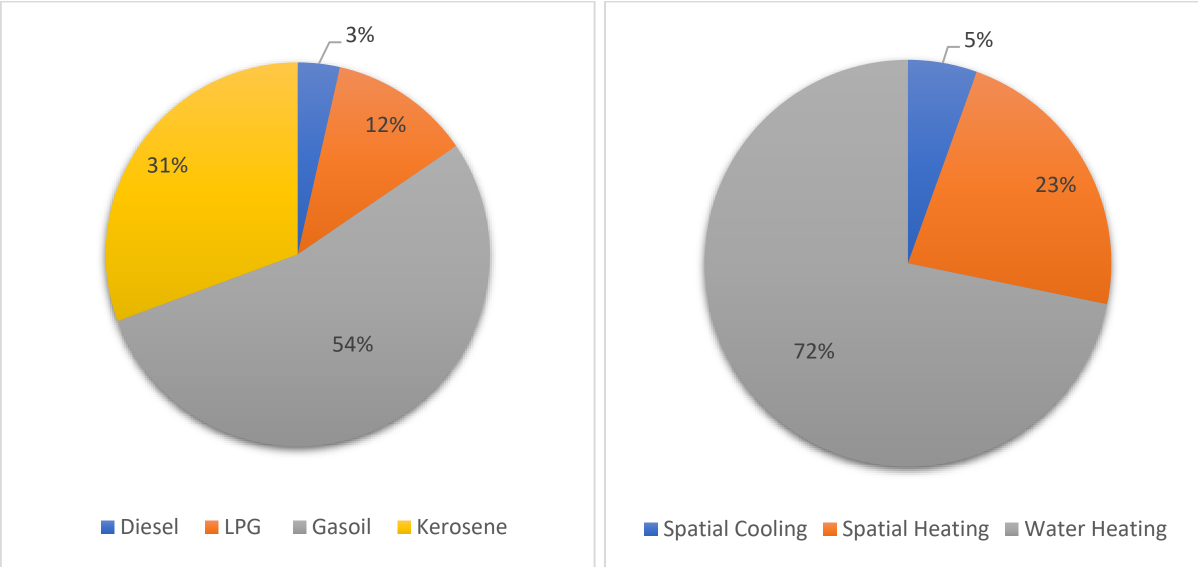

Figure 37 - Fuel consumption by fuel type (left) and end use (right) used for Heating and Cooling Purposes in the industry sector for 2022

The distribution of fuel for different end use within the industry sector during 2022 is summarised in Table 23. Fuel-fired boilers are the most common technology used for the space heating and hot water generation. A conversion of factor of 0.85 was applied for boiler technology to calculate the useful energy for space cooling, space heating and water heating in the industrial sector.

Table 23 - Final and useful fuel consumption for the industrial sector

	End Use	Technology	Final Energy (GWh)	Conversion Factor	Useful Energy (GWh)
Fuel (NACE B&F)	Spatial Cooling	Fuel Fired Boilers	0.00	0.85	0.00
	Spatial Heating	Fuel Fired Boilers	0.67	0.85	0.57
	Water Heating	Fuel Fired Boilers	0.33	0.85	0.28
Fuel (NACE C)	Spatial Cooling	Fuel Fired Boilers	0.34	0.85	0.29
	Spatial Heating	Fuel Fired Boilers	0.75	0.85	0.64
	Water Heating	Fuel Fired Boilers	4.13	0.9	3.72
Total			6.21		5.49

1.4.4 Total Final and Useful Energy for Heating and Cooling in the Industry Sector

Following the presentation of data, methodologies, and assumptions in the previous sections for the energy consumption in relation to heating and cooling in the industry sector, the total final and useful energy for the sector is presented in Table 24.

Table 24 - Summary of the final and useful energy in the industry sector by energy source and use for 2022

Sector	NACE	Type of Use	Total Final Energy in GWh	Total Useful Energy in GWh
Industry	B & F	Spatial Cooling	7.10	21.87
		Spatial Heating	1.03	1.97
		Water Heating	0.33	0.28
	C	Spatial Cooling	51.97	222.31
		Spatial Heating	4.67	18.28
		Water Heating	4.13	3.72
	Total	Spatial Cooling	59.07	244.18
		Spatial Heating	5.70	20.25
		Water Heating	4.46	4.00

Figure 38 to Figure 41 present a complete overview of the distribution between the final and useful energy consumption for the industry sector.

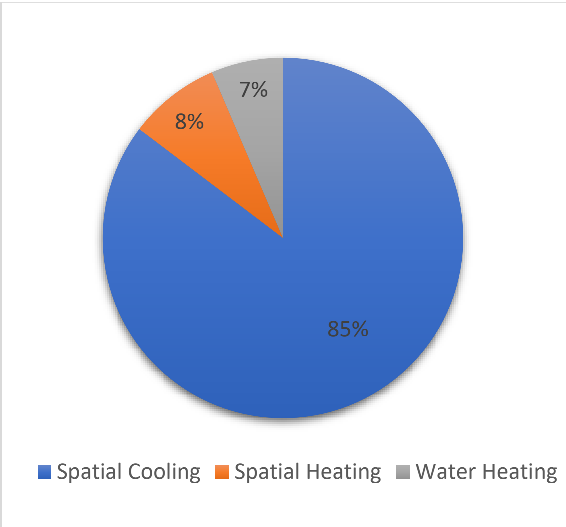

Figure 38 - Final Energy Consumption by End-Use in 2022

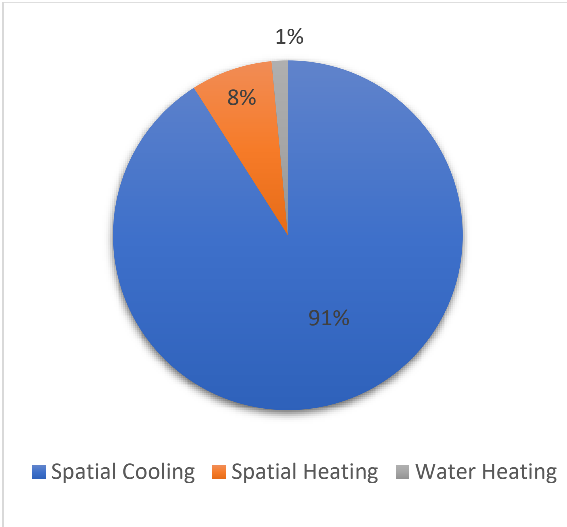

Figure 39 - Useful Energy Consumption by End-Use in 2022

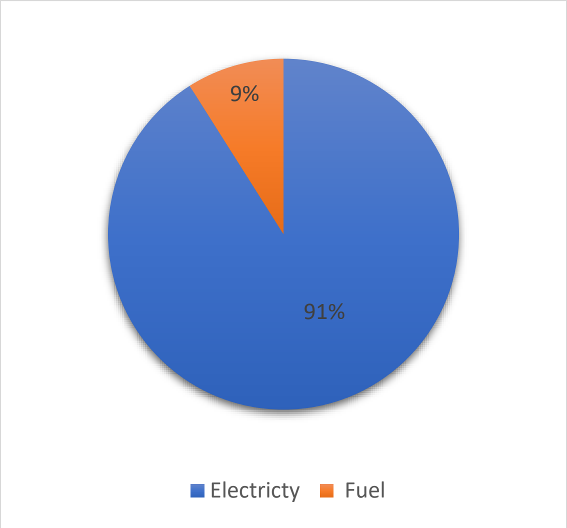

Figure 40 - Final Energy Consumption by Source

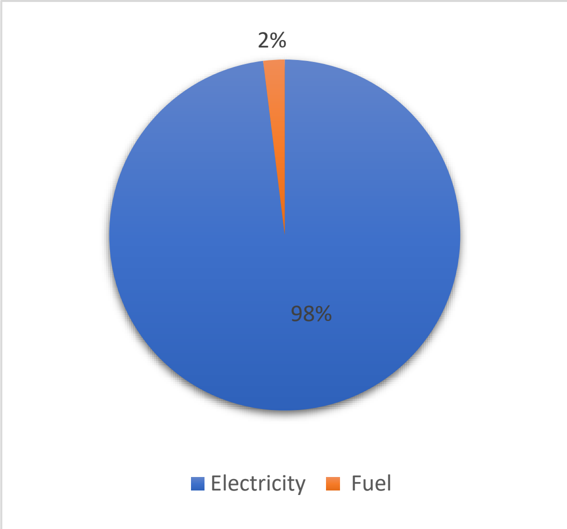

Figure 41 - Useful Energy Consumption by Source

1.5 Commercial and Services Sector

Over the years, Malta has undergone a significant economic shift, transitioning successfully into an economy predominantly driven by services. This broad-based economic growth in Malta has been spearheaded by the strong performance of service-oriented sectors, especially those that are regulated. This surge in service sector activity has also spurred an increase in job opportunities. In 2022, services contributed to over three-quarters of Malta's gross value added.[28]

This contribution is driven by a diverse range of sub-sectors, with wholesale and retail trade, transport, storage, and logistics forming the core of the domestic market. Tourism is a vital component of Malta's economy, with spending by tourists reaching approximately €2 billion in 2022, as reported by the NSO.[29] The economic impact of tourism is evident in sectors such as hospitality, travel agencies, airlines, and other forms of passenger transport, as well as in the food service and entertainment industries that cater to tourists. Moreover, the information and communication sector, together with the financial and insurance industries, as well as the remote gaming sector, enhance Malta's technological and economic framework. The real estate sector, along with professional and administrative services, also contributes significantly to this economic expansion.

As evident from the above, the services sector in Malta is highly diverse, comprising numerous branches, each with distinct demand patterns and energy requirements. Although these branches have different energy intensities, due to the varying nature of the services provided, their basic energy process structures are similar.

[28] Eurostat_National accounts aggregates by industry (up to NACE*64)
[29] NSO, Inbound Tourism: December 2023 – NR 025/2024. https://nso.gov.mt/inbound-tourism-december-2023/

In this analysis, the commercial and services sector is divided into several categories: hotels, food and beverage establishments, hospitals, residential care facilities, and a variety of commercial spaces such as public buildings, offices, retail shops, schools, among others, as illustrated in the following table. It should be highlighted that energy load and consumption can differ significantly across these sub-sectors, owing to their distinct operational patterns.

Table 25 - Service categories forming part of this analysis

Sector	Sub-Sector
Commercial and Services	Hotels
	Food and Beverage
	Hospitals
	Residential Care Homes
	Other Commercial Buildings (public buildings, schools, retail, etc.)

The commercial and services sector typically uses electrical energy for water heating, space heating, space cooling, lighting, equipment, and cooking, among other purposes. Fossil fuels are primarily used for water heating, space heating, and cooking.

The main sources of data on energy consumption for the services sector in Malta for the base year 2022 have been obtained from the following entities:

- Aggregated hourly electricity consumption data from a representative number of meters from each NACE provided by EWA.

- Fuel consumption for sector provided by EWA.

The fuel consumption data for the services sector in 2022 was derived from the Fuel Consumption Survey provided by EWA. This data includes the distribution of fuels used for each sub-sector, specifically for space heating and hot water generation. More specifically, fossil fuel consumption data is categorized into:

1. NACE I55 - Accommodation

2. NACE Q86.1 - Hospitals

3. NACE Q87 - Residential care homes

4. NACE I56 - Food and Beverage services

5. NACEs E, G-U - Other Commercial and services sub-sectors (including retail, schools and others)

This data is provided according to the type of fossil fuel consumed for the base year 2022.

Regarding electricity consumption, in the absence of specific data on electricity usage for space heating and cooling in the services sector, the methodologies explained below for each sub-sector were used to estimate and determine these consumptions.

1.5.1 Accommodation Sub-Sector (NACE I55)

Tourism is a major component of the services sector. The number of hotels and collective accommodation establishments in Malta increased by 17.8% in 2022 compared to the previous year. [30] The total hotel guests for year 2022 amounted to 1,812,834, resulting in a total of 8,204,068 nights spent, with the largest share of guests staying in 4-star hotels.[31,32]

This sector is highly seasonal, with peaks in the number of guest nights always observed during the summer period. The number of guest nights during the different quarters for 2019 till 2022 is shown in Figure 42. A significant decrease in the overall number of guest nights can be observed during 2020 and 2021, due to shutdowns imposed by the COVID-19 pandemic.

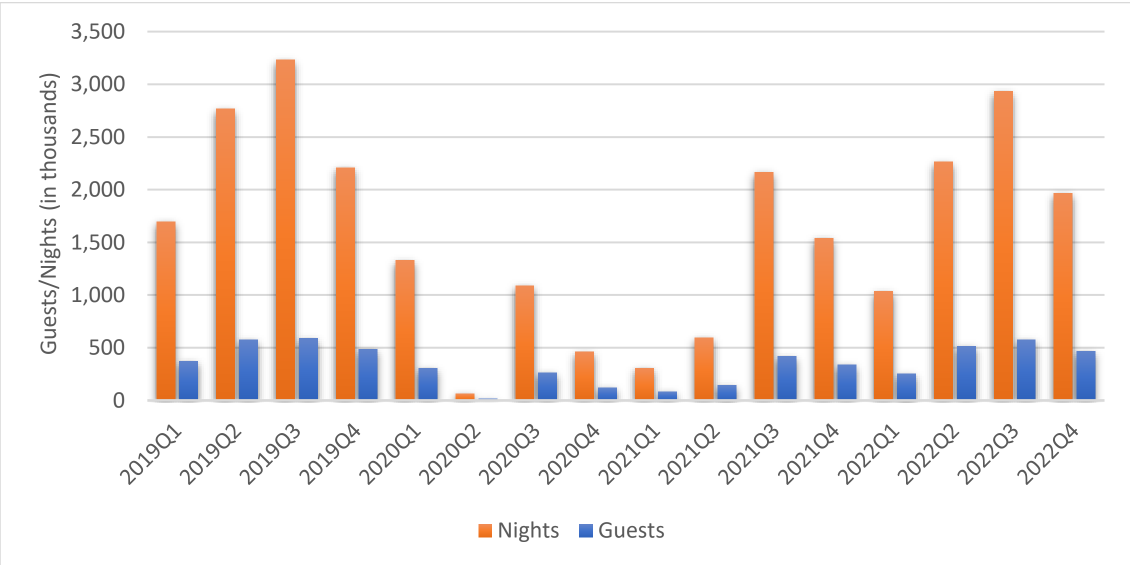

Figure 42 - Total Guests and Nights spent, NSO (Collective Accommodation Establishments)

The sector employed 6,863 full-timers in the summer of 2022, with another 2,145 employed on a part-time basis.[33] The hotel sector in Malta consists of a number of hotels in different categories namely 5-Star, 4-Star, 3-Star, 2-Star, guesthouses and hostels. In total, there are 394[34] establishments registered with the Malta Tourism Authority (MTA).[35]

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[30] NSO, Collective Accommodation Establishment: Q4/2022 – NR 040/2023 https://nso.gov.mt/collective-accommodation-establishments-q4-2022/

[31] ibid.

[32] ibid.

[33] NSO, Registered Employment: August 2022: NR083/2023 https://nso.gov.mt/registered-employment-august-2022-2/

[34] MTA Licensing - https://www.mta.com.mt/en/licensing

[35] The list of registered establishments with MTA excludes holiday premises.

Hotel facilities in Malta are among the top consumers in terms of energy consumption in the services sector. Based on data from energy audits and market studies, the main energy end-uses in the accommodation sector are space heating and cooling in guest rooms and common spaces, hot water, preparation of meals, pools and spa facilities and laundry. There are several factors that affect the energy consumption throughout the year, the main variable being seasonality. Different technologies for heating and cooling are present in the establishments, including boilers, chillers, VRFs and split units. A detailed overview of the heating and cooling demand in hotels covered by both electricity and fossil fuels is presented in the following sections.

1.5.1.1 Electrical Consumption in Hotels

Due to the hotels' seasonality and yearly fluctuations, the calculations for the hotel sub-sector have been based on hourly electrical consumption profiles for a representative sample of hotels. The hourly data provided was studied and extrapolated to reach the total consumption for NACE I55 (Accommodation) provided by NSO. The total electricity consumption during 2022 for the hotels' sub-sector amounted to 144.8 GWh. The monthly electricity consumption is shown in Figure 43. As anticipated, a peak in the consumption can be observed during the summer period, with the highest consumption registered in August.

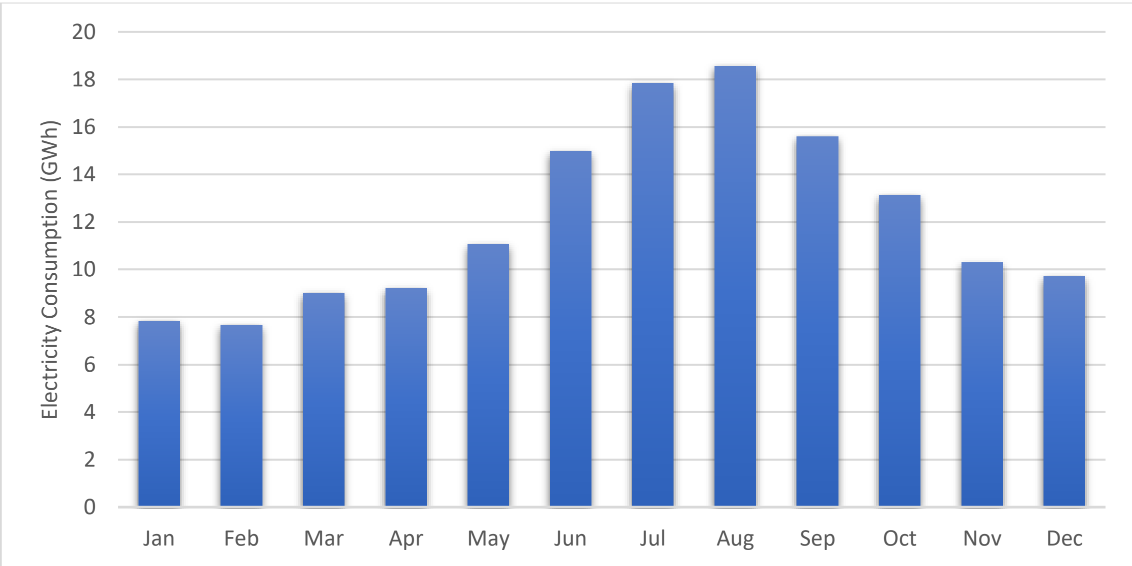

Figure 43 - Monthly Electricity Consumption in 2022 for the hotels sub-sector (NACE 155)

In order to calculate the baseload for hotels in Malta, reference was made to publications issued by studies carried out in European Union Countries.[36] [37] [38]These studies, together with

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[36] Analysis of Energy Consumption in the Hotel Sector and Feasibility study for the installation of SOFC-Based Cogeneration Systems - https://webthesis.biblio.polito.it/18842/1/tesi.pdf

[37] Assessment of Cyprus and Greece Hotels – https://www.oeb.org.cy/wp-content/uploads/2021/04/AI.1-Report-on-characteristics-of-the-hotel-industry-in-Cyprus-and-Greece_v41-1.pdf

[38] Analysis on energy use by European hotels: online survey and desk research -

data collected from energy audits of Malta-based companies shows that that the baseload for the hotel industry is 40%. This accounts for the energy requirements of lighting, office equipment, ventilation, cooking and other systems used within hotels. Hence a percentage of 40% is being applied on the monthly electricity consumption. Thus it is being assumed that the baseload varies per month in line with the monthly electricity consumption. This method ensures that the calculation accurately reflects the monthly variations usage within hotels.

1.5.1.1.1 Water Heating

In this assessment, the total hot water demand in relation to NACE I55 has been calculated through the parameters presented in Table 26.

Table 26 - DHW Calculation Parameters

Parameter for DHW Calculation	Value
Flow rate per shower per min (litres)	24[39]
Avg. time per shower per person (minutes)	10[40]
Mix of hot water to cold water	50%
Initial water temperature (°C)	Average Daily Air Temperature
Water heater temperature (°Celsius)	62[41]
Litres of hot water per shower	120
Total number of nights spent in 2022	8,204,068[42]
Electric water heater efficiency	0.9[43]

The hot water demand produced by electricity was determined by subtracting the water heating by means of fossil fuels, for which data has been provided by EWA, from the hot water demand, as shown in the formula below. Given the availability of annual fossil fuel consumption data for water heating, monthly fuel consumption was proportionally allocated based on the corresponding monthly hot water demand.

$$DHW\ by\ Electricity = Total\ DHW\ demand - DHW\ by\ fossil\ fuels$$

The resulting monthly hot water demand by source is shown in Table 27. The results obtained in the table below reflect the total DHW demand calculated from assumptions considered in Table 26 above. Then, the monthly DHW from fuel was calculated based on fuel consumption data provided by EWA and an estimation through a ratio based on the calculated demand. The

http://www.nezeh.eu/assets/media/fckuploads/file/Reports/10.HESreserch.pdf

[39] Hot Water Plumbing System, A. Bhatia, B.E., 2020 - Hot Water Plumbing Systems (pdhonline.com)
[40] Hot Water Plumbing System, A. Bhatia, B.E., 2020 - Hot Water Plumbing Systems (pdhonline.com)
[41] Schedule 3 of L.N. 5 of 2006 – Public Health Act, 2003 (ACT NO. XIII of 2003)
[42] NSO - NSO NR-40-2023-Tbl-2
[43] B2.3.3.2 – Hot Water Storage -SBEM Technical Manual - https://www.uk-ncm.org.uk/filelibrary/SBEM-Technical-Manual_v5.2.g_20Nov15.pdf

DHW by electricity was determined by deducing the DHW from fuel out of the DHW total demand.

Table 27 - Monthly hot water demand by source

Month	DHW Total Demand (GWh)	DHW by electricity (GWh)	DHW by Fuel (GWh)
January	1.86	0.75	1.10
February	2.61	1.06	1.55
March	3.40	1.38	2.02
April	4.96	2.01	2.95
May	4.82	1.96	2.86
June	4.58	1.86	2.72
July	5.22	2.12	3.10
August	5.79	2.35	3.44
September	4.69	1.91	2.79
October	5.19	2.11	3.08
November	4.17	1.69	2.48
December	3.47	1.41	2.06
Total	**50.76**	**20.60**	**30.16**

The daily consumption profile for the electricity used for space heating and cooling in the hotel sub-sector has been determined using the below formula:

Total Daily Consumption for Heating or Cooling = Total Daily Consumption – Baseload – DHW

The baseload workings were further elaborated to assess such baseload in relation to the number of occupants per night in hotels. Figure 44, shows the electrical baseload distribution based on the guest night occupancy; the latter has been obtained from the Quarterly Hotel Occupancy surveys carried out by NSO. This shows the correlation between the baseload and the number of guest nights reflecting the hotels' occupancy, indicating a peak in the months of July – October, being Malta's tourism peak season for hotel occupancy. The baseload electricity consumption in this sector is referring to all other loads, which do not pertain to either water heating, spatial cooling or spatial heating, but relates to lighting systems, pumping systems and electric cooking equipment. The monthly electricity consumption figures for the baseload, space heating and space cooling are presented in Table 28.

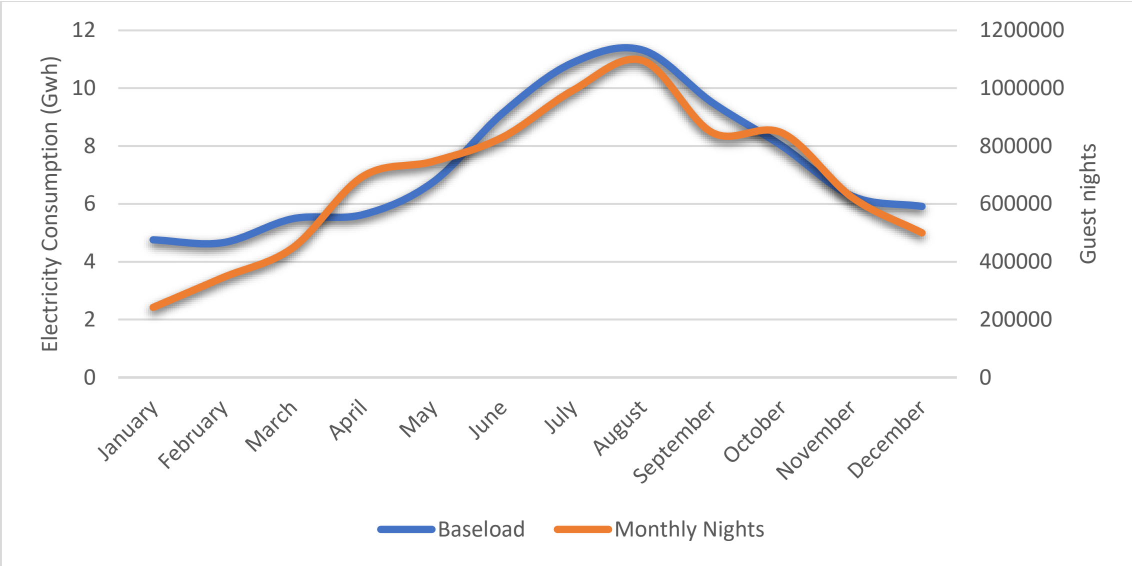

Figure 44 - Hotels' monthly baseload electricity consumption in relation to guest nights during 2022

Table 28 - Monthly electrical consumption distribution for baseload, space heating and space cooling during 2022

	Total Electricity Consumption (GWh)	Electrical Consumption for Baseload (GWh)	Final Electricity Consumption for Domestic Hot Water (GWh)	Final Electricity Consumption for Space Heating (GWh)	Final Electricity Consumption for Space Cooling (GWh)
January	7.80	3.12	0.754	3.93	0.00
February	7.64	3.06	1.058	3.53	0.00
March	9.00	3.60	1.381	4.02	0.00
April	9.23	3.69	2.011	3.53	0.00
May	11.06	4.42	1.956	0.00	4.68
June	14.99	6.00	1.860	0.00	7.13
July	17.84	7.14	2.118	0.00	8.59
August	18.57	7.43	2.348	0.00	8.79
September	15.58	6.23	1.905	0.00	7.45
October	13.12	5.25	2.105	0.00	5.77
November	10.29	4.11	1.691	4.48	0.00
December	9.70	3.88	1.408	4.41	0.00
Total	144.83	57.93	20.60	23.90	42.41

The overall final electricity consumption for space heating and cooling during 2022 amounts to 66.3 GWh. Figure 45 shows the total electrical consumption in hotels on a monthly basis, as well as the baseload and the electrical consumption for space heating and cooling and water heating. From the above calculations, the final energy for space heating and cooling generated by electrical means in the hotel sub-sector is shown in Figure 46.

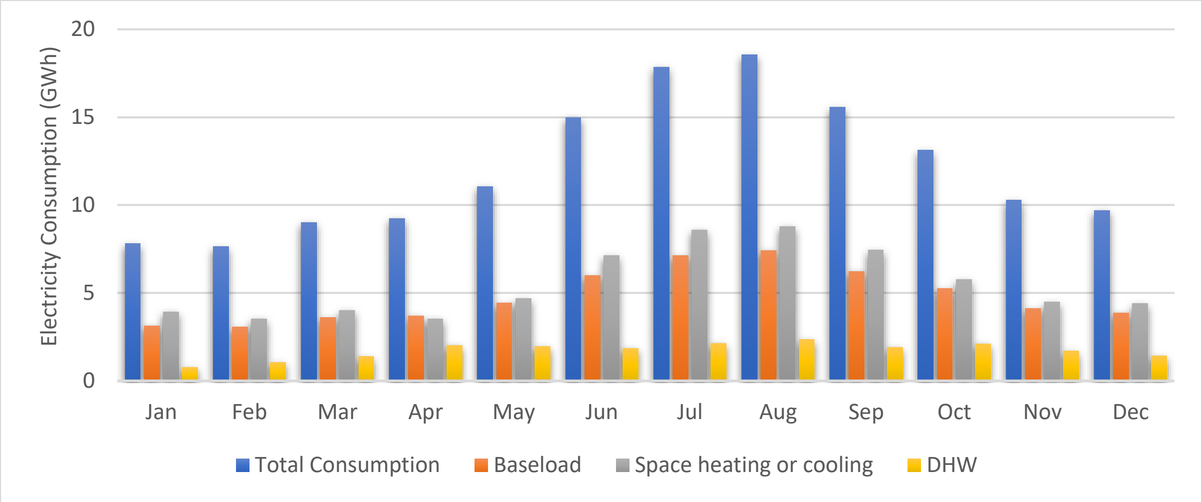

Figure 45 - Yearly profile of electrical energy distribution between energy use for baseload, space heating and cooling and water heating

From the above calculations, the final energy for space heating and cooling generated by electrical means in the hotel sub-sector is shown in Figure 46.

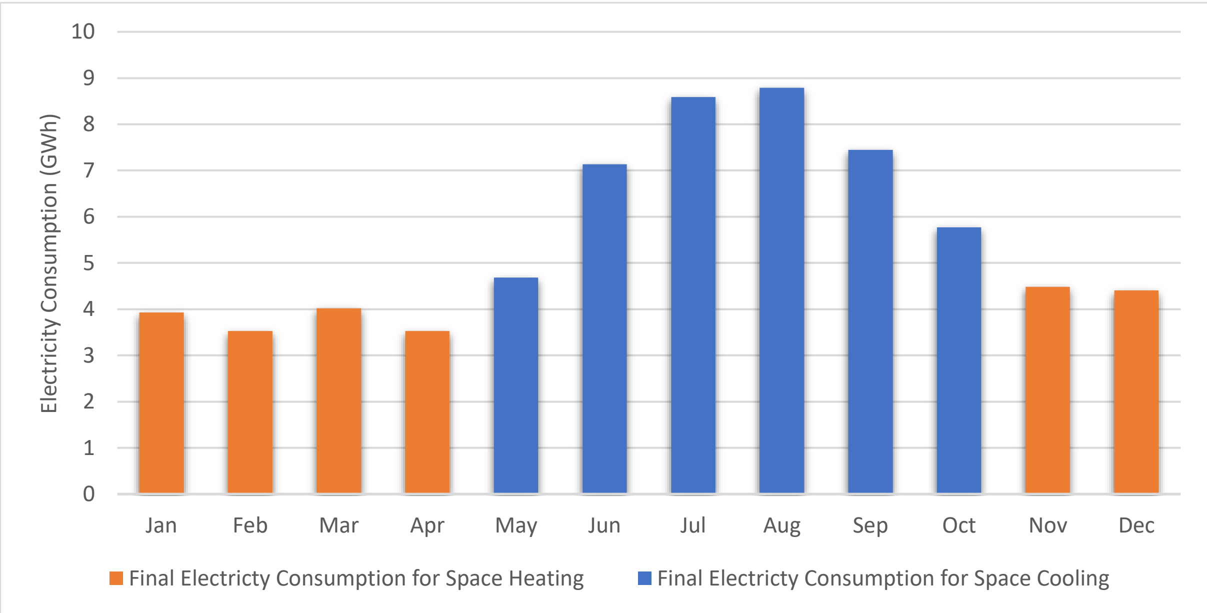

Figure 46 - Final electrical energy consumed for space heating and cooling in 2022 for the hotels sub-sector

The values of COPs and EERs have been based on market research from several energy audits, where the results show that the most common technologies in hotels in Malta are variable refrigerant volume air conditioners (VRVs) and chillers. Thus, based on the average values for COPs and EERs presented in the table hereunder, the useful energy generated by electricity in the hotel sub-sector has been calculated for space heating and space cooling.

Table 29 - Final and useful electrical energy for the hotels sub-sector in 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Electricity (NACE I55)	Spatial Cooling	Heat Pumps	42.41	4.3	182.35
	Spatial Heating	Heat Pumps	23.90	4.5	107.54
	Water Heating	Electric Boilers	20.60	0.9	18.54
	Total		**86.90**		**308.42**

1.5.1.2 Fuel Consumption in Hotels

The fossil fuel consumption data for the hotel sector was provided by EWA. The yearly fuel consumption in hotels between 2018 and 2022 is shown in Figure 47.

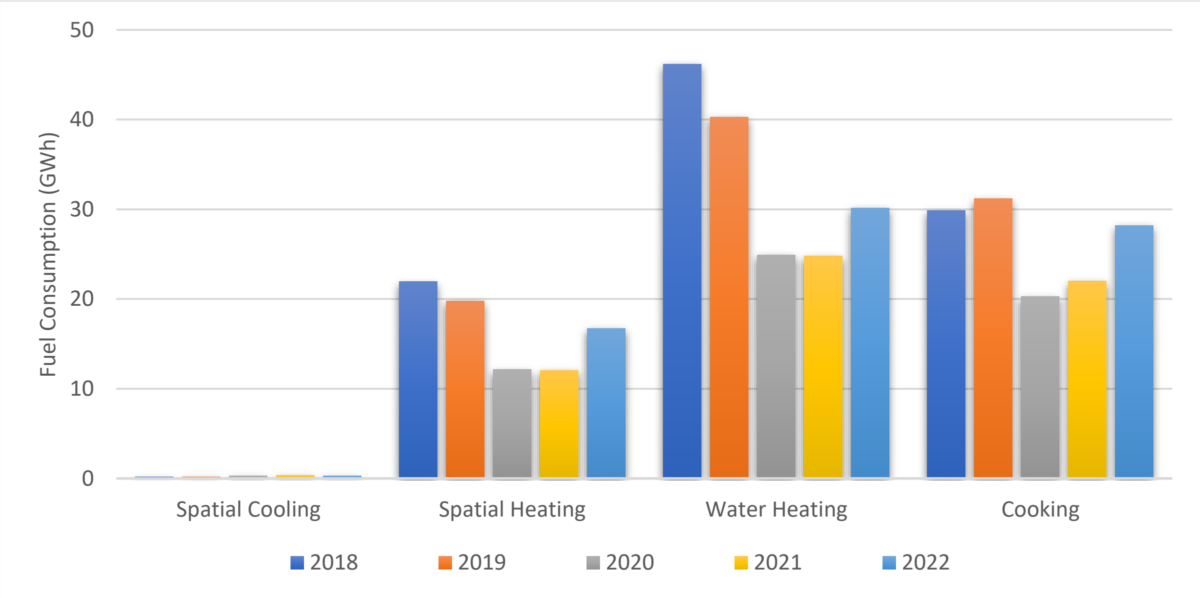

Figure 47 - Fossil fuel consumption by end use in hotels, 2018 - 2022

The fossil fuel consumption during 2022 for water heating and spatial heating/cooling was further split by fuel type and end use as shown in Table 30. From the data included in Table 30 and the graphical representation in Figure 48, it is clear that during 2022, LPG is the mostly used fossil fuel in hotels, followed by gasoil. The two fossil fuel types are mainly used to generate hot water and for space heating. Additionally, LPG is also used for cooking, as can be seen in Figure 48.

Table 30 - Fossil fuel consumption by fuel-type in hotels in 2022

Fuel Type	Fuel Use	Consumption (Tons)	Conversion Factor (GWh/Ton)	GWh
Diesel	Spatial Cooling	0.00	0.01194	0.00
	Spatial Heating	588.87		7.03
	Water Heating	122.18		1.46
	Cooking	0.00		0.00
Fuel Oil	Spatial Cooling	18.75	0.01111	0.21
	Spatial Heating	207.86		2.31
	Water Heating	521.92		5.80
	Cooking	0.00		0.00
Gasoil	Spatial Cooling	0.00	0.01194	0.00
	Spatial Heating	417.7		4.99
	Water Heating	614.41		7.34
	Cooking	0.00		0.00
LPG	Spatial Cooling	4.70	0.01278	0.06
	Spatial Heating	188.01		2.40
	Water Heating	1,217.89		15.56
	Cooking	2,207.41		28.21
Total	**Spatial Cooling**			**0.27**
	Spatial Heating			**16.74**
	Water Heating			**30.16**
	Cooking			**28.21**

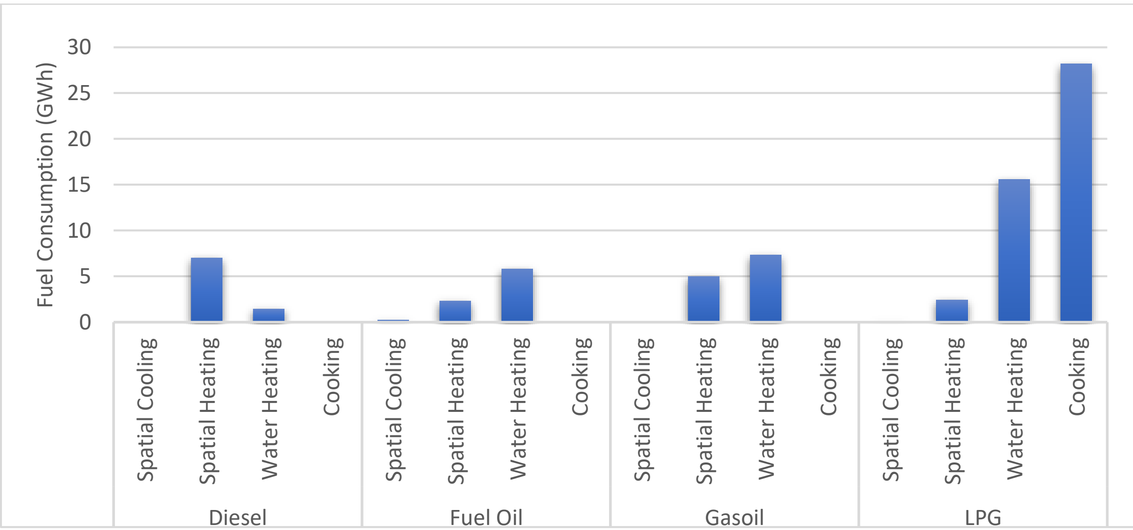

Figure 48 - Fossil Fuel Consumption for accommodation services for each type of fossil fuel in 2022

Based on the data indicated above, Figure 49 shows the percentage distribution of the fossil fuel used in hotels by end-use, namely space cooling, space heating, water heating and cooking. From the above calculations, the final and useful energy for hot water generation, space heating and cooling generated and cooking by fossil fuels in the hotel sub-sector can be analysed in Table 31. An efficiency coefficient of 0.85 for fuel-fired boilers was used, based on market research and data available for the technology. To give a more comprehensive overview, fuel consumption for cooking was also covered by the analysis. An efficiency coefficient of 0.65 was used.

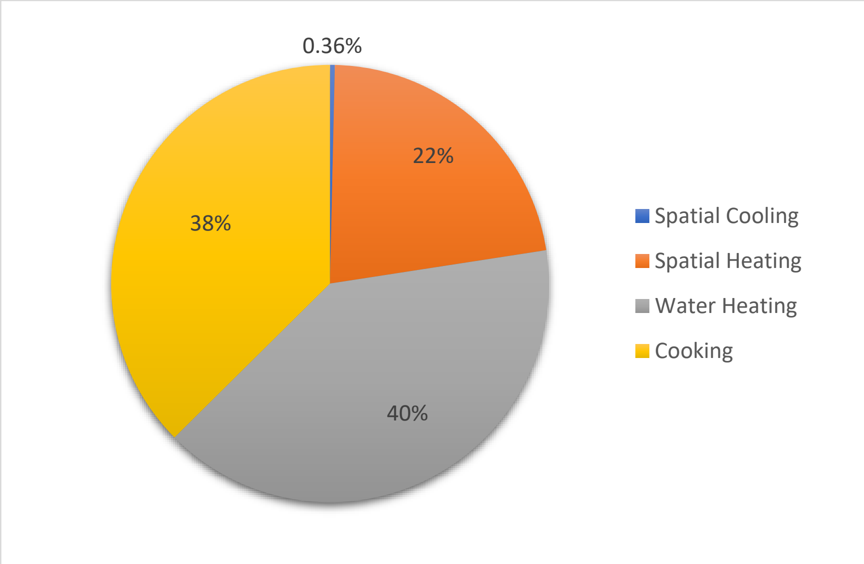

Figure 49 - Percentage Fossil Fuel distribution in the accommodation sub-sector in 2022

Table 31 - Final and Useful Energy for fossil fuel use in the hotel sub-sector during 2022

	End Use	Technology	Final Energy (GWh/a)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh/a)
Fuel (NACE I55)	Spatial Cooling	Fuel Fired Boilers	0.27	0.85	0.23
	Spatial Heating	Fuel Fired Boilers	16.73	0.85	14.22
	Water Heating	Fuel Fired Boilers	30.16	0.85	25.64
	Cooking	Cooking Appliances	28.21	0.65	18.33
	Total		**75.37**		**58.42**

1.5.1.3 Total and Useful Energy for Hotels

Table 32 depicts the total final and useful energy for hotels, split by different energy source types and by end use. Figure 50 to Figure 53 present a complete overview of the distribution between the final and useful energy consumption for the hotel sub-sector. It is important to note that in this section, cooking has been excluded from the final overview since the study focuses on spatial cooling, heating and water heating only.

Table 32 - Total final and useful energy for the hotels sub-sector in 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Electricity (NACE I55)	Spatial Cooling	Heat Pumps	42.41	4.3	182.35
	Spatial Heating	Heat Pumps	23.90	4.5	107.54
	Water Heating	Electric Boilers	20.60	0.9	18.54
		Sub-total (electricity)	**86.90**		**308.42**
Fuel (NACE I55)	Spatial Cooling	Fuel Fired Boilers	0.27	0.85	0.23
	Spatial Heating	Fuel Fired Boilers	16.73	0.85	14.22
	Water Heating	Fuel Fired Boilers	30.16	0.85	25.64
		Sub-total (fuel)	**47.16**		**40.09**
Total	**Spatial Cooling**		**42.68**		**182.58**
	Spatial Heating		**40.63**		**121.76**
	Water Heating		**50.76**		**44.17**
	Total		**134.06**		**348.51**

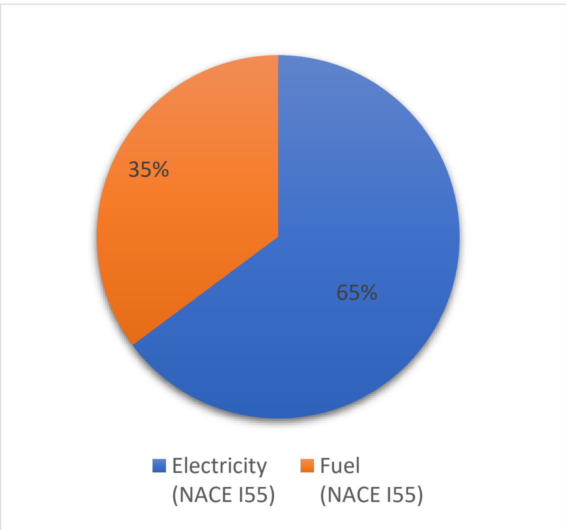

Figure 50 - Final Energy consumption by source

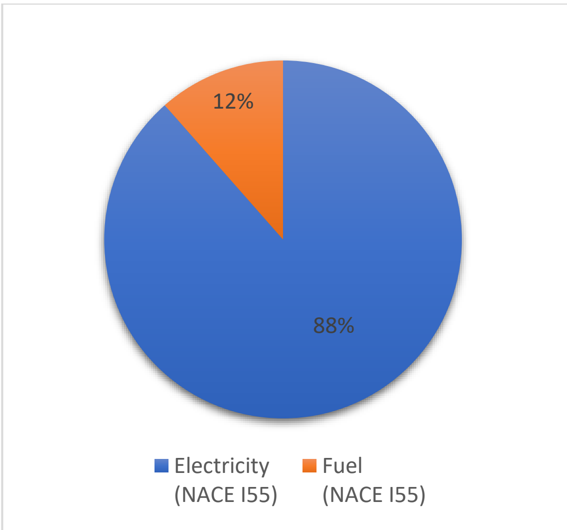

Figure 51 - Useful Energy consumption by source

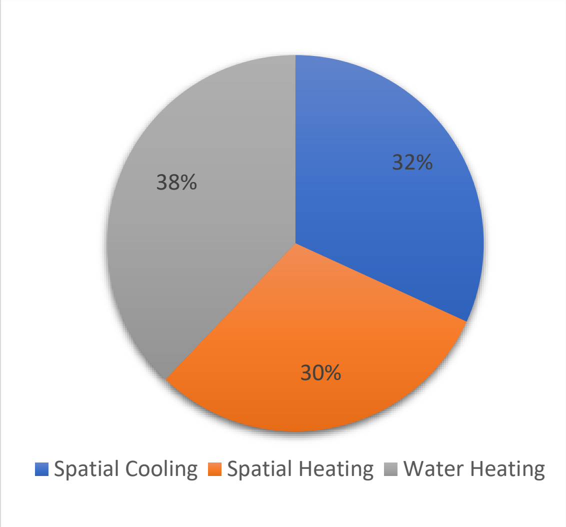

Figure 52 - Final energy consumption by end-use

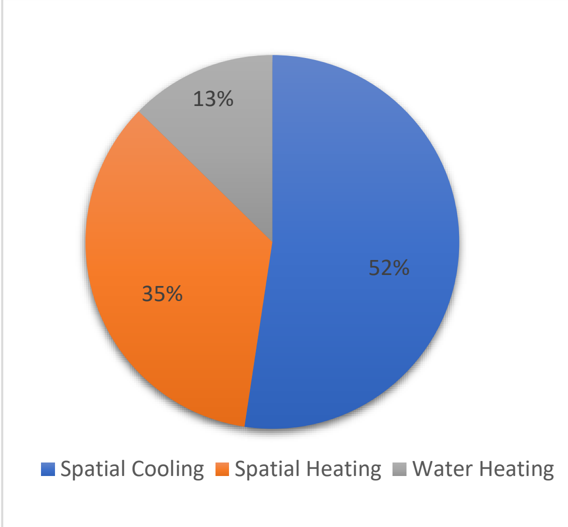

Figure 53 - Useful Energy Consumption by Source

1.5.2 Food and Beverage Services Sub-Sector (NACE I56)

Information released by the MTA indicates that there are over 2,600 establishments in Malta engaged in food and beverage (F&B) service operations. Table 33 below provides a condensed overview of services related to food and beverage.[44] Subsequent sections offer an in-depth analysis of the heating and cooling requirements for F&B activities, encompassing energy consumption from both electric and fossil fuel sources.

Table 33- List of establishments in the F&B sub-sector

Type of F&B service	Number of licenses
Restaurants	837
Snack Bars	1,077
Take-aways	188
Kiosks	56
Bars	480
Total	2,674

1.5.2.1 Electrical Consumption in the Food and Beverage Sector

The calculations for the F&B sub-sector have been based on hourly electrical consumption profiles for a sample of such premises, as provided by EWA. The hourly data provided was studied and extrapolated to reach the total consumption for NACE I56 provided by NSO. The total electricity consumption during 2022 for the F&B sub-sector amounted to 64.94GWh. The monthly electricity consumption is shown in Figure 54. A peak in the consumption can be observed during the summer period, with the highest peaks observed in July and August.

[44] https://www.mta.com.mt/en/licensing

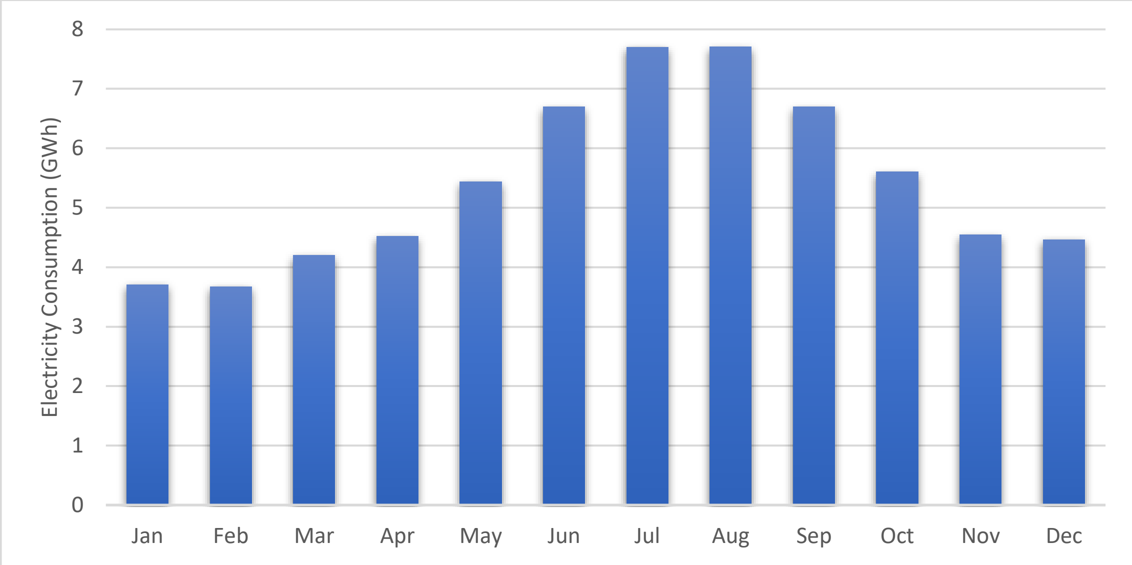

Figure 54 - Monthly Electricity Consumption in 2022 for NACE 156

From studies published by University of Malta[45] and other studies published by other EU Member States,[46] it transpires that restaurants have 50% of their total electricity consumption dedicated to HVAC systems, which would include spatial cooling and heating, ventilation and water heating.

1.5.2.1.1 Water Heating

The electrical energy demand for hot water was calculated based on the number of establishments related to the food and beverage sector and similar assumptions were used for the amount of hot water required, daily water temperature and water temperature for 2022 as done for the residential sector.

[45] Prioritising Energy Efficiency Measures in Maltese Restaurants – https://www.um.edu.mt/library/oar/bitstream/123456789/55785/1/Prioritising_energy_efficiency_measures_in_Maltese_restaurants_2019.pdf

[46] Analysis of Energy Consumption in the Food Service Sector – Manuel Coutinho Almeida, June 2018

Table 34 - DHW Calculation Parameters

Parameter for DHW Calculation	Value
Flow rate per wash basin per min (litres)	10[47]
Avg. time per wash basin per person (minutes)	10
Initial water Temperature (°C)	Average Daily Air Temperature
Water Heater temperature (°C)	31[48]
Litres of hot water per wash basin	100
Total number of establishments	2674[49]
Electric Water heater efficiency	0.9[50]

Based on this method, a total of 1.238GWh of electrical energy was estimated to be required to cover the hot water demand in 2022. This was calculated by subtracting the DHW produced by fuel consumption from the total DHW demand.

DHW by Electricity = Total DHW demand – DHW by fossil fuels

Table 35 - DHW monthly demand

Month	**Total DHW Demand (GWh)**	**DHW from Electricity (GWh)**	**DHW from Fuel (GWh)**
January	0.200	0.180	0.016
February	0.169	0.156	0.013
March	0.190	0.175	0.015
April	0.154	0.142	0.012
May	0.113	0.104	0.009
June	0.047	0.044	0.004
July	0.032	0.029	0.003
August	0.033	0.030	0.003
September	0.049	0.045	0.004
October	0.091	0.084	0.007
November	0.125	0.115	0.010
December	0.146	0.134	0.012
Total	**1.345**	**1.238**	**0.107**

[47] Development of European Ecolabel and Green Public Procurement Criteria for Sanitary Tapware – Taps and Showerheads - https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/contentype/product_group_documents/1581682812/1st%20draft_Technical_background_report_Criteria_for_taps_and_showerheads.pdf

[48] Schedule 3 of L.N. 5 of 2006 – Public Health Act, 2003 (ACT NO. XIII of 2003)

[49] MTA Licensing - https://www.mta.com.mt/en/licensing

[50] B2.3.3.2 – Hot Water Storage -SBEM Technical Manual - https://www.uk-ncm.org.uk/filelibrary/SBEM-Technical-Manual_v5.2.g_20Nov15.pdf

Studies on the F&B industry indicate that 50% of total electricity consumption is attributed to the HVAC system, encompassing spatial cooling and heating, water heating, and ventilation.[51,52,53] A 50% ratio was applied to the monthly electricity consumption to estimate values related to the HVAC systems. The DHW demand was calculated on the values indicated in Table 34 and subtracted the monthly HVAC and DHW values from the total electricity consumption, thereby acquiring the monthly values for spatial cooling and heating. At this stage, while the baseload has not yet been determined, spatial cooling and heating, water heating, and total electricity consumption is determined. The baseload is then derived by subtracting the values for DHW and spatial cooling and heating from the total electricity consumption. The daily consumption profile for the electricity used for space heating and cooling in the food and beverage sub-sector has been determined using the below formula:

Total Daily Consumption for Heating or Cooling = HVAC – DHW

The electricity consumption that remained after the removal of the spatial cooling and heating and hot water was attributed to the baseload. Figure 55 shows the total electrical consumption of NACE I56 in Malta, together with the applicable monthly baseload, monthly hot water demand and monthly spatial cooling and heating consumption. The monthly electricity consumption figures for the baseload, hot water, space heating and space cooling are presented in Table 36.

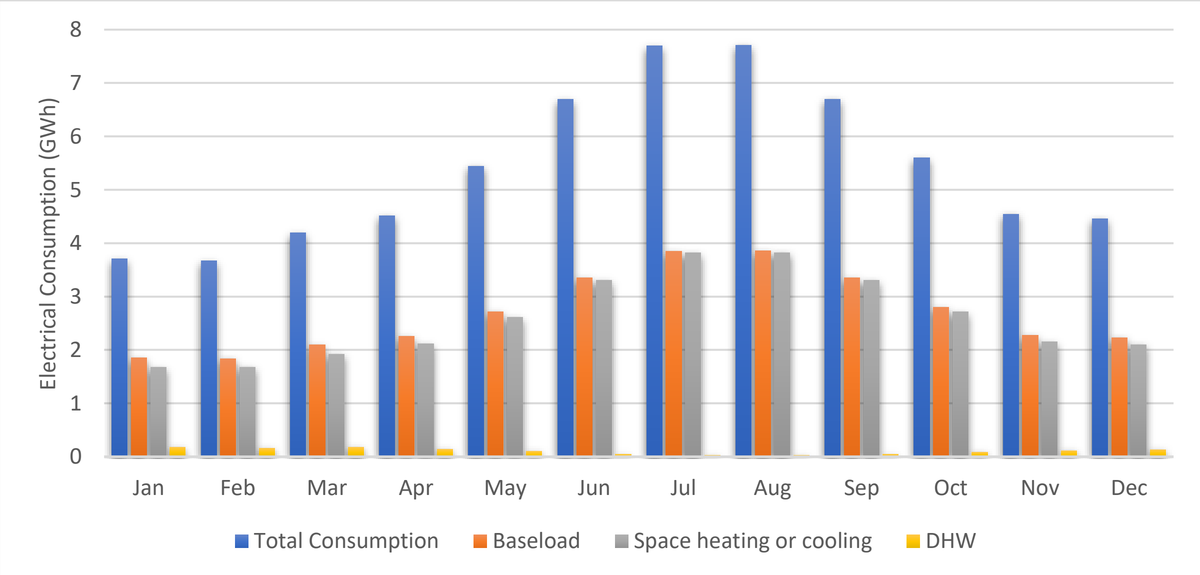

Figure 55 - Monthly total electricity consumption, hot water, spatial heating & cooling and baseload in the F&B sub-sector for the year 2022 (NACE156)

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[51] Prioritising Energy Efficiency Measures in Maltese Restaurants – Felix Noel Barbara, et.al., 2019.

[52] Restaurants Energy Consumption Statistics and High Cost of Energy - https://solutions.rdtonline.com/blog/restaurant-energy-consumption-statistics

[53] Analysis of energy consumption in the food service sector (Manuel Coutinho Almeida) - June 2018

Table 36 - Monthly electrical consumption distribution for baseload, hot water, space heating and space cooling during 2022

Month (2022)	Total Electricity Consumption (GWh)	Electrical Consumption for Baseload (GWh)	Electrical Consumption for DHW (GWh)	Final Electricity Consumption for Space Heating (GWh)	Final Electricity Consumption for Space Cooling (GWh)
January	3.71	1.85	0.18	1.67	0.00
February	3.67	1.83	0.16	1.68	0.00
March	4.20	2.10	0.17	1.92	0.00
April	4.52	2.26	0.14	2.12	0.00
May	5.44	2.72	0.10	0.00	2.62
June	6.70	3.35	0.04	0.00	3.31
July	7.70	3.85	0.03	0.00	3.82
August	7.71	3.85	0.03	0.00	3.82
September	6.70	3.35	0.05	0.00	3.30
October	5.60	2.80	0.08	0.00	2.72
November	4.54	2.27	0.11	2.16	0.00
December	4.46	2.23	0.13	2.10	0.00
Total	**64.94**	**32.47**	**1.24**	**11.65**	**19.59**

The overall final electricity consumption for space heating and cooling during 2022 amounts to 31.23GWh. Figure 56 shows the total monthly electrical consumption attributed to space heating and cooling.

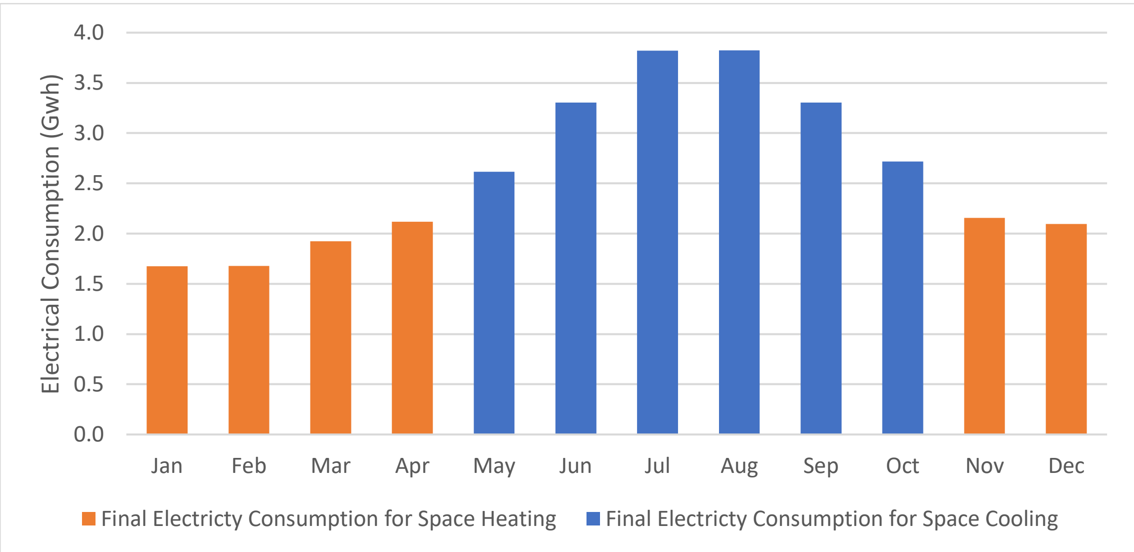

Figure 56 - Final electrical energy consumed for space heating and cooling in 2022 for the F&B sub-sector (NACE I56)

Based on the average values for COPs and EERs presented in the previous section (residential) of the report, the useful energy for space heating and space cooling and hot water generated by electricity in the F&B sub-sector has been calculated and is shown in Table 37.

Table 37 - Final and useful electrical energy for NACE I56 in 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Electricity (NACE I56)	Spatial Cooling	Heat Pumps	19.59	3.08	60.33
	Spatial Heating	Heat Pumps	11.65	3.84	44.72
	Water Heating	Electric Boilers	1.24	0.90	1.11
	Total		**32.47**		**106.16**

1.5.2.2 Fuel Consumption in the Food and Beverage Sub-sector (NACE I56)

The fossil fuel consumption data for the F&B sector was provided by EWA. The yearly fuel consumption in F&B sector between 2018 and 2022 is shown in Figure 57.

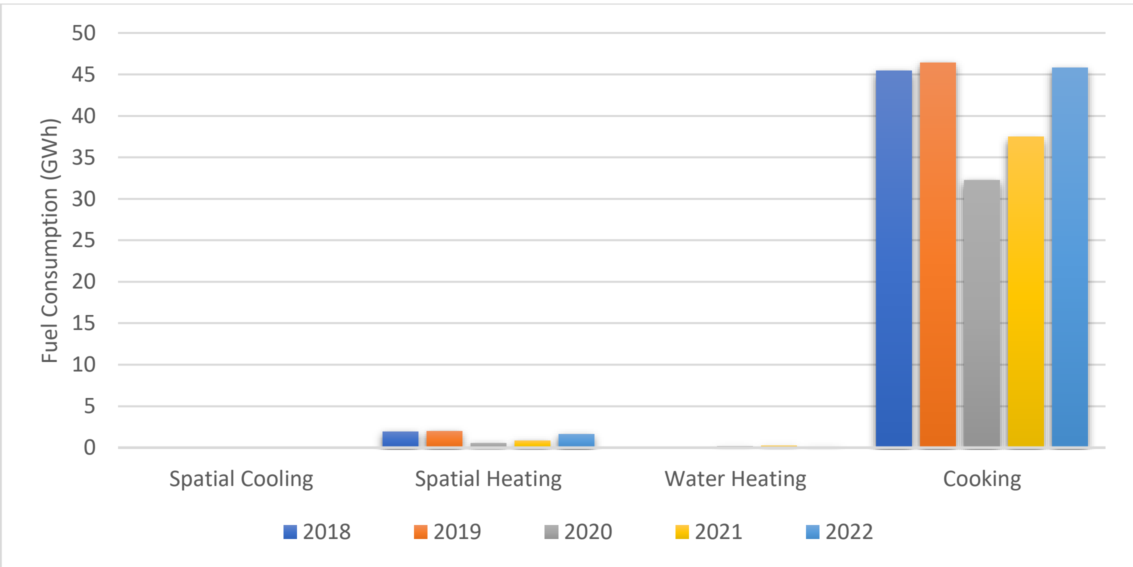

Figure 57 - Fossil fuel consumption in NACE I56 sub-sector by end use 2018 – 2022

Figure 57 demonstrates that fuel usage in this sub-sector was predominantly for cooking. The same figure also shows a decrease in fuel consumption from 2020 to 2021, attributable to the closure periods resulting from the COVID-19 pandemic. The fossil fuel consumption during 2022 was further split by fuel type and end use as shown in Table 38.

Table 38 - Fossil Fuel Consumption in NACE I56 for 2022

Fuel Type	Fuel Use	Consumption (Tons)	Conversion Factor (GWh/ton)	GWh/annum
Diesel	Spatial Cooling	0.00	0.01194	0.00
	Spatial Heating	0.00		0.00
	Water Heating	0.96		0.01
Fuel Oil	Spatial Cooling	0.94	0.01111	0.01
	Spatial Heating	5.85		0.07
	Water Heating	0.00		0.00
LPG	Spatial Cooling	0.00	0.01278	0.00
	Spatial Heating	119.73		1.53
	Water Heating	7.49		0.10
	Cooking	3,586.87		45.83
Total	**Spatial Cooling**			**0.01**
	Spatial Heating			**1.60**
	Water Heating			**0.11**
	Cooking			**45.83**

Table 38 reveals that LPG is most commonly used fuel within this sub-sector. Figure 58 further illustrates that LPG is primarily used for cooking, with some LPG consumed for space heating purposes. Figure 59 shows the percentage distribution of the fossil fuel end uses in the F&B sub-sector, namely space cooling, space heating, water heating and cooking.

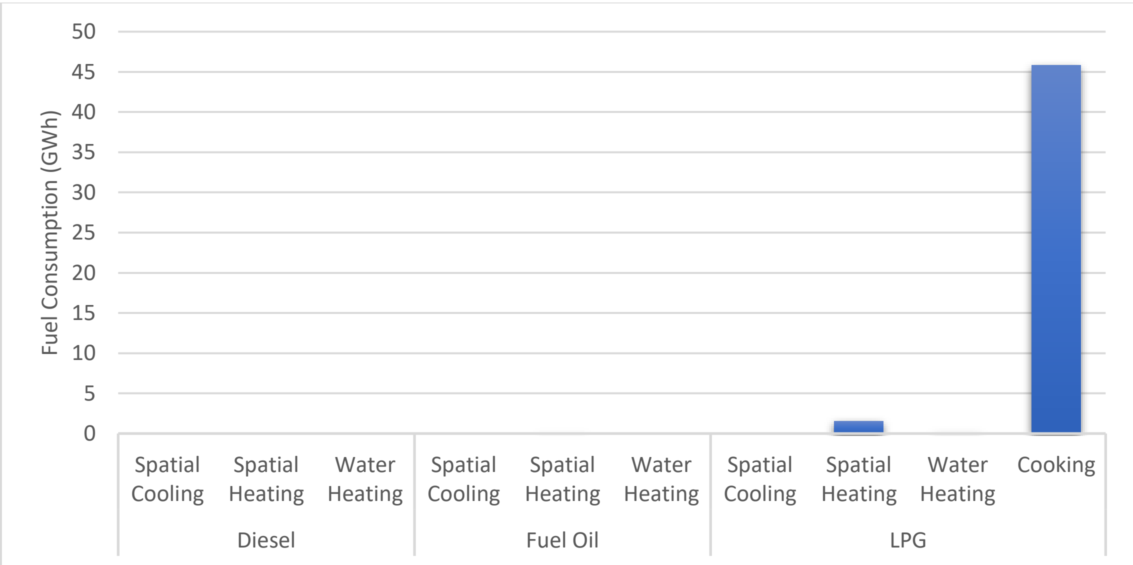

Figure 58 - Fossil Fuel Consumption for the F&B sub-sector (NACE 156) for each type of fossil fuel in 2022

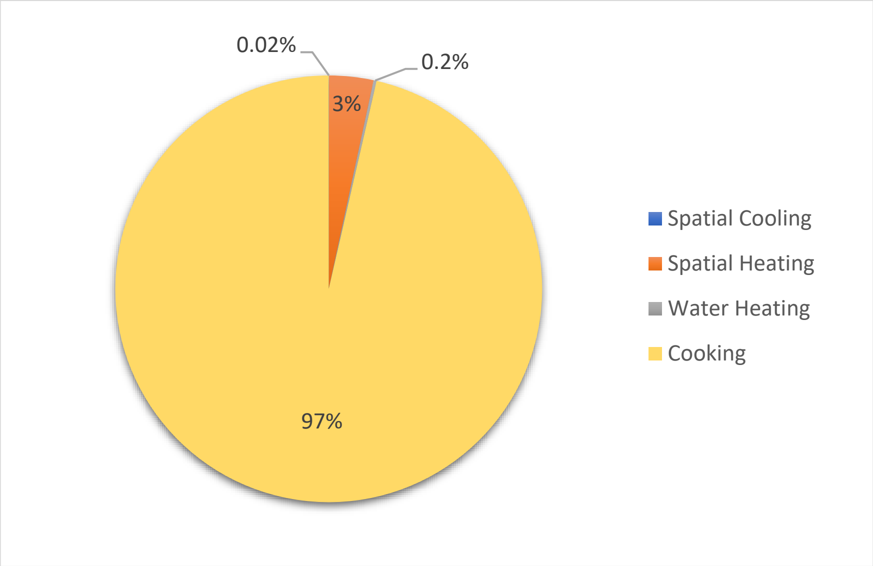

Figure 59 - Percentage Fossil Fuel distribution in NACE I56 in 2022

From the above calculations, the final and useful energy for hot water generation and space heating generated by fossil fuels in the F&B sub-sector are presented in Table 39. An efficiency coefficient of 0.85 for fuel-fired boilers was used and an efficiency coefficient of 0.65 for cooking appliances, based on market research and data available for the technology.

Table 39 - Final and Useful Energy for fossil fuel use in the F&B sub-sector during 2022

End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Spatial Cooling	Fuel Fired Boilers	0.01	0.85	0.01
Spatial Heating	Fuel Fired Boilers	1.59	0.85	1.36
Water Heating	Fuel Fired Boilers	0.11	0.85	0.09
Cooking	Cooking Appliances	45.83	0.65	29.79
	Total	47.54		31.25

1.5.2.3 Total and Useful Energy for F&B Sub-Sector

Table 40 depicts the total final and useful energy for the F&B sub-sector, split by different energy source types and by end use.

Table 40 - Total final and useful energy for NACE I56 in 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Electricity (NACE I56)	Spatial Cooling	Heat Pumps	19.59	3.08	60.33
	Spatial Heating	Heat Pumps	11.65	3.84	44.72
	Water Heating	Electric Boilers	1.24	0.90	1.11
			32.47		**106.16**
Fuel (NACE I56)	Spatial Cooling	Fuel Fired Boilers	0.01	0.85	0.01
	Spatial Heating	Fuel Fired Boilers	1.59	0.85	1.36
	Water Heating	Fuel Fired Boilers	0.11	0.90	0.10
			1.71		**1.46**
Total	Spatial Cooling		19.60		60.34
	Spatial Heating		13.24		46.07
	Water Heating		1.34		1.21
		Total	**34.18**		**107.63**

Figure 60 to Figure 63 present a complete overview of the distribution between the final and useful energy consumption for the F&B sub-sector for heating and cooling.

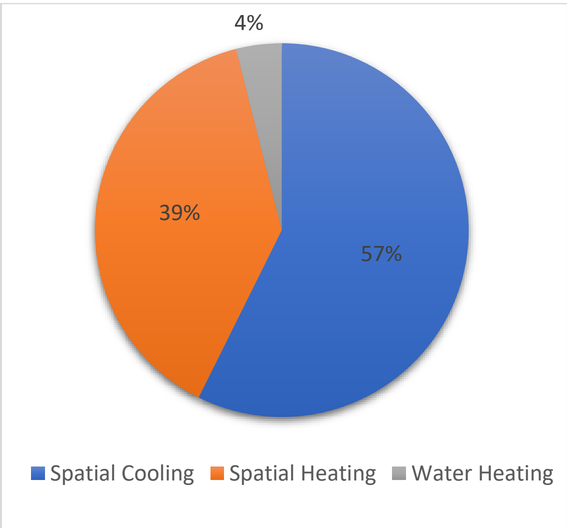

Figure 60 - Final Energy consumption by end-use

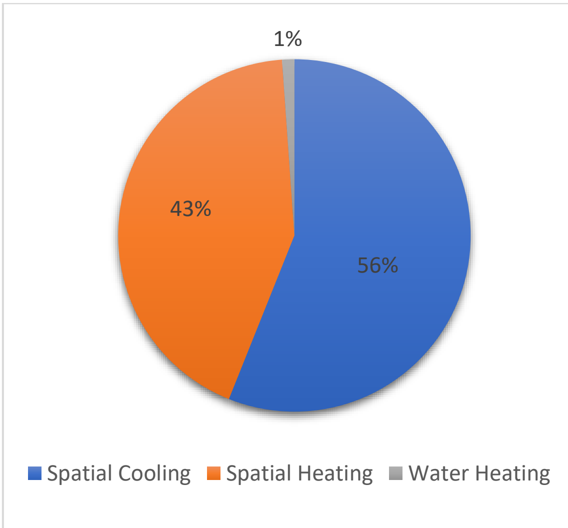

Figure 61 - Useful Energy consumption by end-use

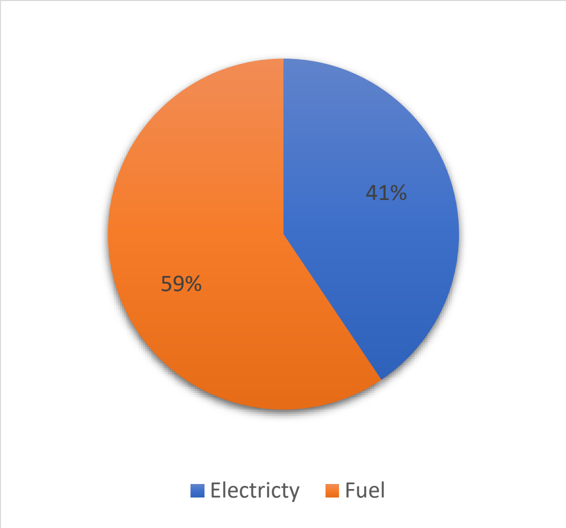

Figure 62 - Final Energy consumption by end-use

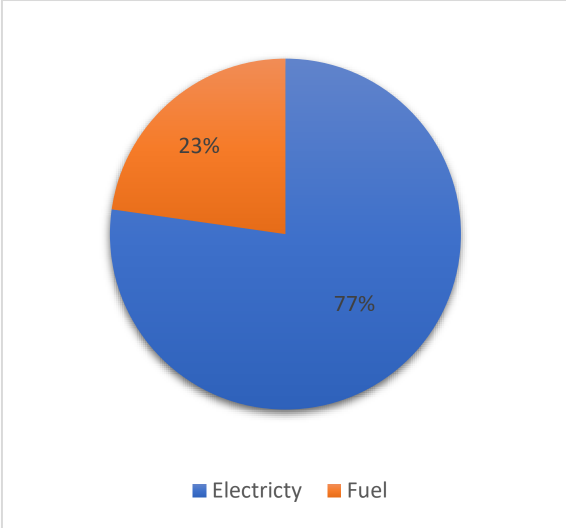

Figure 63 - Useful Energy consumption by end-use

1.5.3 Hospitals Sub-Sector (NACE Q86.1)

The hospital sector in Malta consists of several hospitals around the island, with the largest one being the Government-run Mater Dei hospital (MDH). The other hospitals on the island include both public and private hospitals. The total number of beds reported by Eurostat in 2021 was 2,149[54], whilst for the year 2022 the number of beds provided by EWA was 2,158.

1.5.3.1 Electrical Consumption in the Hospitals Sub-sector

The calculations for the hospitals sub-sector are based on hourly electrical consumption profiles for a sample of buildings provided by EWA. This analysis excludes the largest hospital on the Maltese Islands, MDH, which alone had a total electricity consumption of 42.67 GWh in 2022. MDH is considered an outlier compared to the other hospitals due to its significantly larger size and the extensive range of processes and operations it carries out, which are not performed in other hospitals. Additionally, MDH already has advanced equipment and its own energy efficiency improvement program. The data analysed in the following sections is based on other private and public hospitals.

Out of the total electricity consumption for MDH, 2.31 GWh were used for spatial heating, 1.16 GWh were used for water heating, 5.06 GWh were used for spatial cooling. The value of 5.06 GWh was obtained by assuming that 80% of the total electricity consumption is attributed to the baseload (34.17 GWh) and thus spatial cooling was found by subtracting the spatial heating, water heating and baseload from the total electricity consumption of MDH.[55]

Spatial Cooling = Total Electricity Consumption – Baseload – Spatial Heating – Water Heating

[54] Eurostat_Hospital beds by function and type of care (hlth_rs_bds) https://ec.europa.eu/eurostat/databrowser/view/hlth_rs_bds1/default/table?lang=en
[55] Mater Dei Energy Audit – Data extracted by EWA

MDH operates with 14 air-cooled chillers exclusively for cooling, boasting an EER of 3.15, as verified from factory acceptance tests. Additionally, MDH employs four water-cooled chillers in a unique heat pump configuration, achieving a combined EER of 4.3 (1.6 for cooling and 2.7 for heating).

The Sir Anthony Mamo Oncology Centre (SAMOC), which falls within the MDH premises, utilizes four air-cooled chillers solely for cooling, with an EER of 3.05. SAMOC also feeds into MDH's heating circuit until its own two heat pump chillers are operational. It has four water-cooled chillers (typically two active and two on standby) functioning in heat pump mode throughout the year to cater for both domestic hot water and spatial heating. In exceptional days in summer, usually during a heatwave, these chillers are used to provide additional cooling capacity. The domestic hot water circuit is connected via a plate heat exchanger on the condenser side of these chillers, ensuring no heat is wasted to the atmosphere.

For spatial heating, MDH operates with water-cooled chillers supplying heat through a plate heat exchanger. Due to the hospital's all fresh air ventilation units, dehumidification and reheat loads remain high, sometimes peaking in mild winters. Currently, 60% of this demand is met by the water-cooled chillers, with the remaining 40% covered by boilers.

The total electricity consumption in 2022 for the other hospitals (excluding MDH) amounted to 21.11 GWh. The hourly electricity data provided was studied and extrapolated to reach the total consumption for NACE Q86.1 provided by NSO, less the consumption of MDH. The monthly electricity consumption is shown in Figure 64. A peak in the consumption can be observed during the summer period, with the highest peaks observed between July and August.

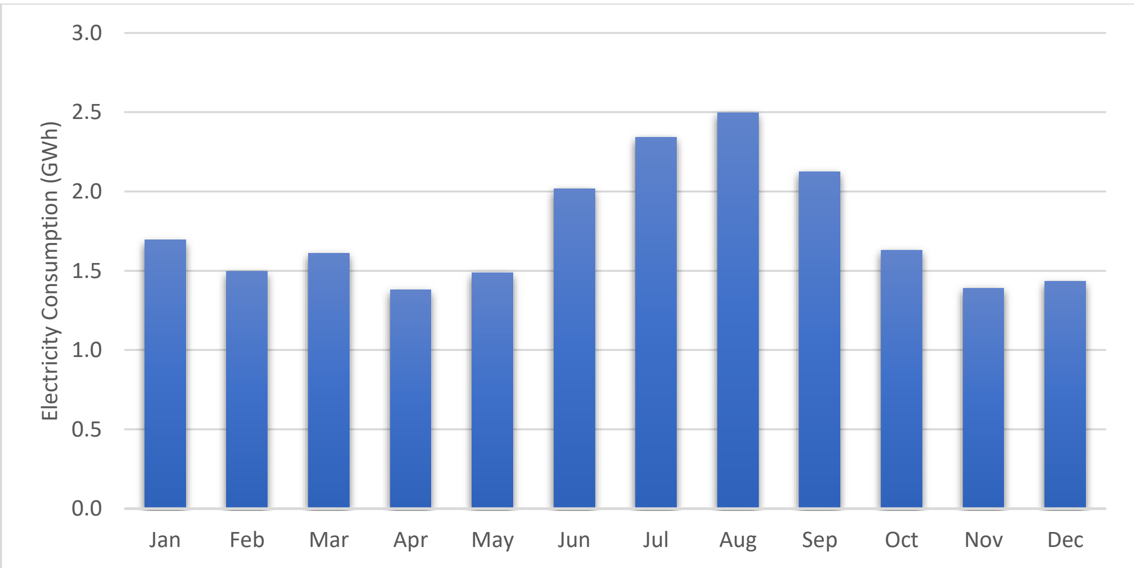

Figure 64 - Monthly Electricity Consumption in 2022 for the hospitals sub-sector excluding Mater Dei Hospital

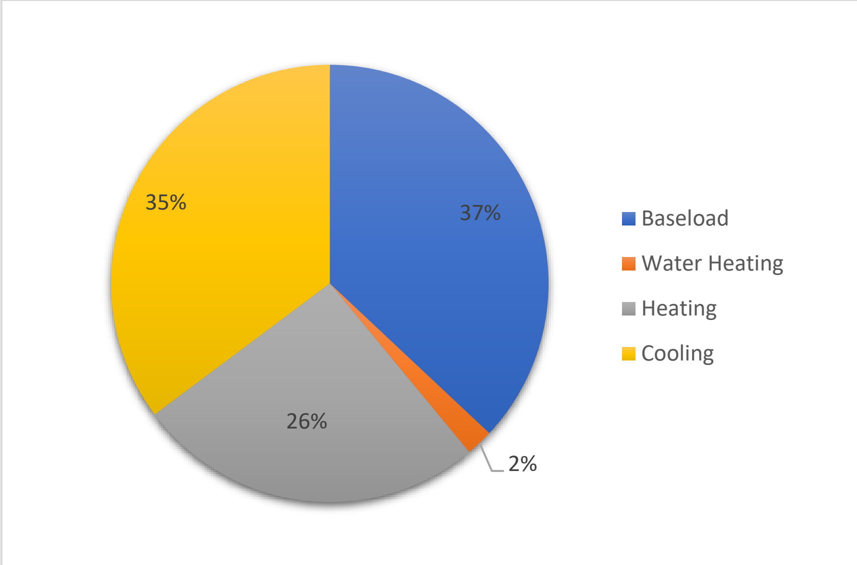

Figure 65 - NACE 86.1 electricity distribution excluding Mater Dei Hospital

A detailed analysis of energy audits performed in public hospitals (excluding MDH) during 2022 shows that 37% of the total electricity consumption can be attributed to the baseload while 2% is used for water heating. Given that public hospitals represent over 90% of the total bed capacity in Malta, these ratios were applied to the total electricity consumption of public and private hospitals. The remaining consumption is attributed to spatial heating and cooling. The electrical energy demand for hot water, based on the ratios explained above, translates to a total of 0.42 GWh of electrical energy in 2022. The daily consumption profile for the electricity used for space heating and cooling in the hospitals sub-sector has been determined using the below formula:

$$\textit{Total Daily Consumption for Heating/Cooling} = \textit{Total Daily Consumption} - \textit{Baseload} - \textit{Hot water}$$

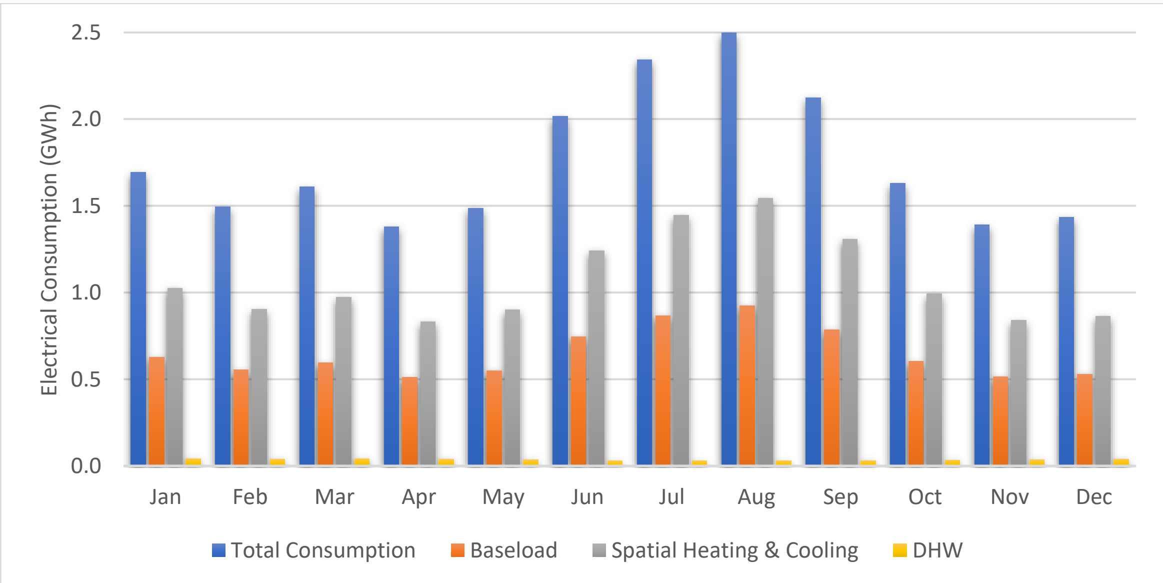

Figure 66 - Monthly total electricity consumption, DHW and baseload in the hospitals sub-sector for the year 2022

The monthly electricity consumption figures for the baseload, hot water, space heating and space cooling are presented in Table 41.

Table 41 - Monthly electrical consumption distribution for baseload, hot water, space heating and space cooling in NACE Q86.1 during 2022

Month (2022)	Total Electricity Consumption (GWh)	Electrical Consumption for Baseload (GWh)	Final Electrical consumption for DHW (GWh)	Final Electrical Consumption for Spatial Heating (GWh)	Final Electrical Consumption for Spatial Cooling (GWh)
January	1.694	0.627	0.042	1.025	0.000
February	1.496	0.553	0.037	0.905	0.000
March	1.610	0.596	0.042	0.973	0.000
April	1.381	0.511	0.038	0.832	0.000
May	1.487	0.550	0.036	0.000	0.901
June	2.018	0.747	0.030	0.000	1.241
July	2.344	0.867	0.030	0.000	1.447
August	2.498	0.924	0.030	0.000	1.544
September	2.124	0.786	0.030	0.000	1.308
October	1.631	0.603	0.034	0.000	0.993
November	1.390	0.514	0.036	0.840	0.000
December	1.433	0.530	0.038	0.865	0.000
Grand Total	**21.105**	**7.809**	**0.422**	**5.440**	**7.434**

The overall final electricity consumption for space heating and cooling during 2022 amounts to 12.87 GWh. From the above calculations, the final energy for space heating and cooling generated by electrical means in the hospitals sub-sector is shown in Figure 67.

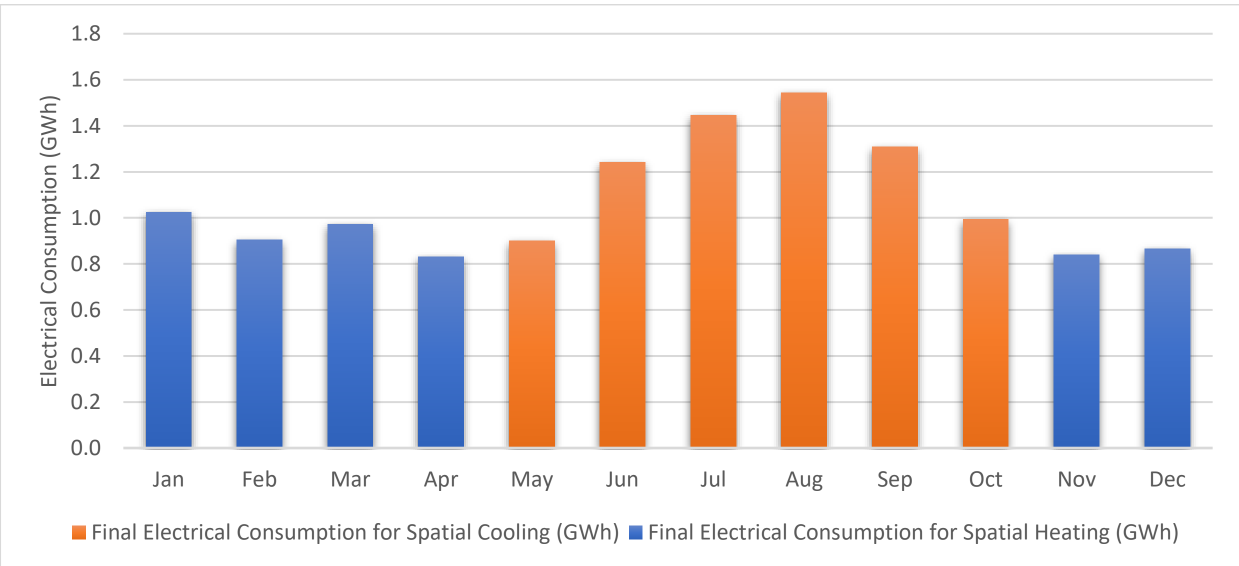

Figure 67 - Final electrical energy consumed for space heating and cooling in 2022 for the hospitals

Based on the average values for COPs and EERs presented in the previous section of the report, a weighted average has been given to the values of the COP and EERs since through energy audits carried out for a number of hospitals showed that a mix of split and VRFs systems exist. The useful energy for space heating and space cooling and hot water generated by electricity in the hospitals sub-sector has been calculated and is shown in Table 42.

Table 42 - Final and useful electrical energy for the hospitals sub-sector in 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Electricity (NACE Q86.1 excl. Mater Dei Hospital)	Spatial Cooling	Heat Pumps	7.43	3.58	26.62
	Spatial Heating	Heat Pumps	5.44	4.34	23.61
	Water Heating	Electric Boilers	0.42	0.90	0.38
			13.30		**50.60**
Electricity (Mater Dei Hospital)	Spatial Cooling	Heat Pumps	5.06	3.15	15.94
	Spatial Heating	Heat Pumps	2.31	4.3	9.93
	Water Heating	Electric Boilers	1.16	4.3	4.99
			8.53		**30.86**
Total Electricity Consumption (NACE Q86.1)	**Spatial Cooling**	**Heat Pumps**	**12.49**	**3.41**	**42.56**
	Spatial Heating	**Heat Pumps**	**7.75**	**4.32**	**33.54**
	Water Heating	**Electric Boilers**	**1.58**	**3.40**	**5.37**
			21.82		**81.47**

1.5.3.2 Fuel Consumption in the Hospitals Sub-sector

The fossil fuel consumption data for the hospitals sector was provided by EWA. Yearly fuel consumption in hospitals between 2018 and 2022 is shown in Figure 68.

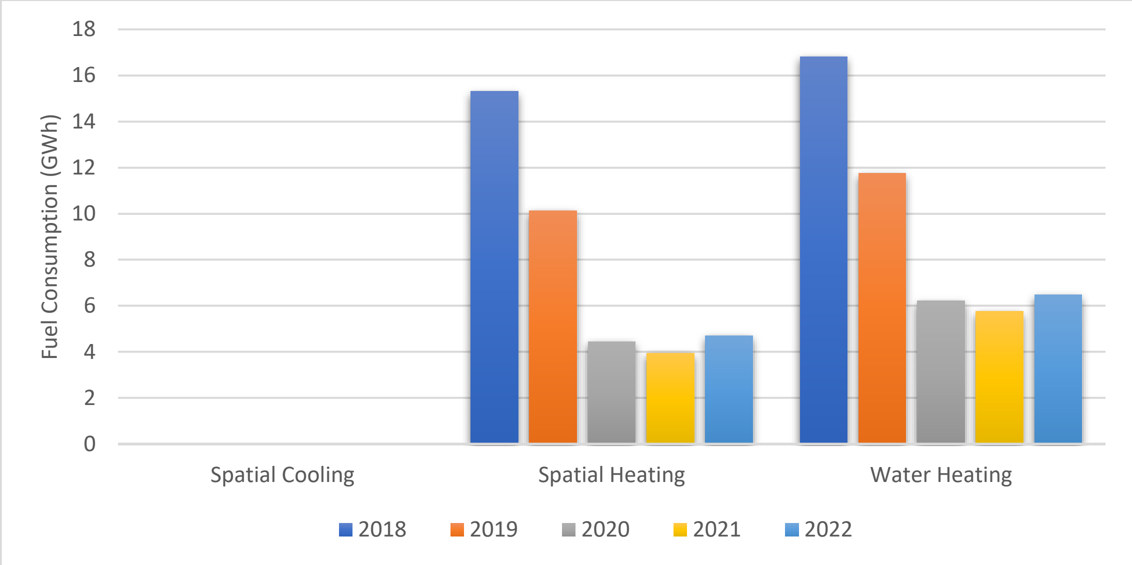

Figure 68 - Fossil fuel consumption in NACE Q86.1 by end use 2018 – 2022

The fossil fuel consumption during 2022 was further split by fuel type and end-use as shown in Table 43.

Table 43 - Fossil Fuel Consumption in hospitals for 2022

Fuel Type	Fuel Use	Consumption (Tons)	Conversion Factor (GWh/Ton)	GWh
Diesel	Spatial Cooling	0.00	0.01194	0.00
	Spatial Heating	0.00		0.00
	Water Heating	0.00		0.00
Fuel Oil	Spatial Cooling	0.00	0.01111	0.00
	Spatial Heating	0.00		0.00
	Water Heating	0.00		0.00
Gasoil	Spatial Cooling	0.00	0.01194	0.00
	Spatial Heating	343.43		4.10
	Water Heating	343.43		4.10
LPG	Spatial Cooling	0.00	0.01278	0.00
	Spatial Heating	46.65		0.60
	Water Heating	186.61		2.38
Total	**Spatial Cooling**			**0.00**
	Spatial Heating			**4.70**
	Water Heating			**6.49**

The percentage distribution between the different types of fuel used in the hospitals sub-sector is shown in Figure 69. From the fuel consumption data, 7% of the fuel consumption has been allocated to cooking but for the case of hospitals, cooking has been omitted from the study, since most of the hospitals in the Malta subcontract the catering service.

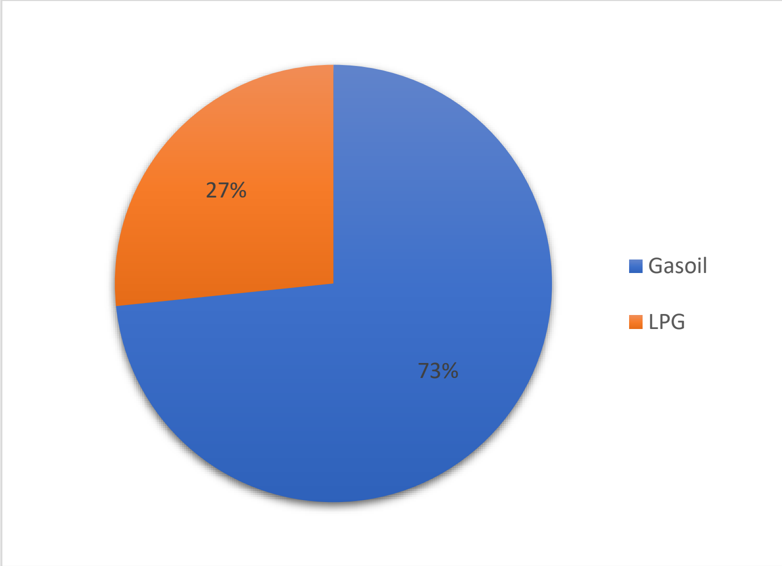

Figure 69 - Fossil Fuel Consumption for hospitals for 2022 (NACE Q86.1)

The information presented in Table 43 and Figure 69 indicates that that in 2022, gasoil was the predominant fossil fuel used in the hospitals sub-sector, followed by LPG as the second most utilized. As depicted in Figure 70, these types of fossil fuels are primarily used to generate hot water and space heating within the hospitals sub-sector.

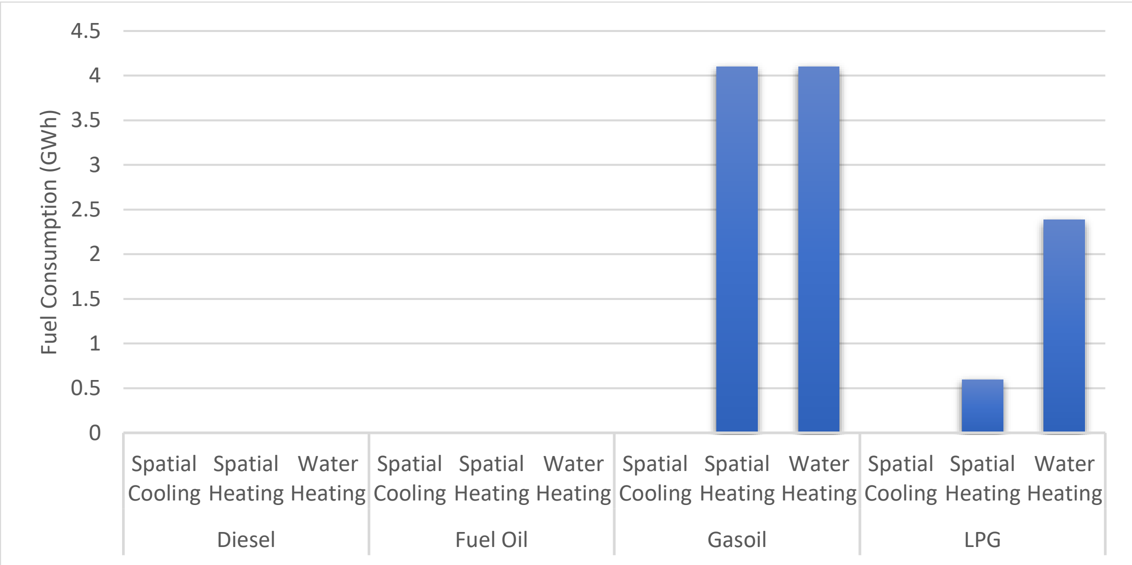

Figure 70 - Fossil Fuel Consumption for the for heating and cooling in 2022 (NACE Q.86.1)

On the basis of the data indicated above, Figure 71 shows the percentage distribution of the fossil fuel end uses in the hospitals sub-sector, namely space cooling, space heating and water heating.

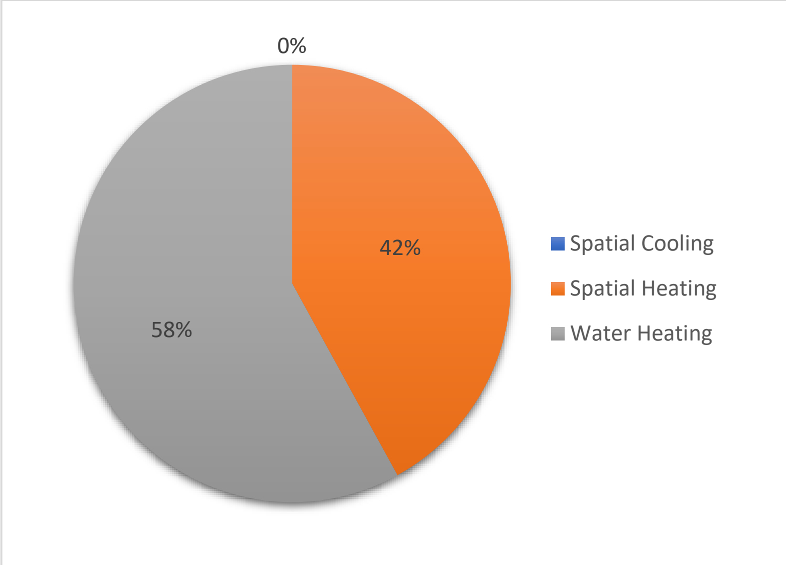

Figure 71 - Percentage Fossil Fuel distribution in the hospitals sub-sector in 2022

From the above calculations, the final and useful energy for hot water generation and space heating generated by fossil fuels in the hospitals sub-sector can be seen in the Table 44. An efficiency coefficient of 0.92 for fuel-fired boilers was used, based on market research and data available for the technology and the sector.

Table 44 - Final and Useful Energy for fossil fuel use in the hospitals sub-sector during 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Fuel (NACE Q86.1)	Spatial Cooling	Fuel Fired Boilers	0.00		0.00
	Spatial Heating	Fuel Fired Boilers	4.70	0.92	4.32
	Water Heating	Fuel Fired Boilers	6.49	0.92	5.97

1.5.3.3 Total and Useful Energy for Hospitals Sub-Sector

Table 45 depicts the total final and useful energy for the hospitals sub-sector, split by different energy source types and by end use.

Table 45 - Total final and useful energy for the hospitals sub-sector in 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Electricity (NACE Q86.1)	Spatial Cooling	Heat Pumps	12.44	3.58/3.15	42.56
	Spatial Heating	Heat Pumps	7.80	4.34/4.3	33.54
	Water Heating	Electric Boilers	1.58	4.3/0.9	5.37
			21.82		**81.47**
Fuel (NACE Q86.1)	Spatial Cooling	Fuel Fired Boilers	0.00		0.00
	Spatial Heating	Fuel Fired Boilers	4.70	0.92	4.32
	Water Heating	Fuel Fired Boilers	6.49	0.92	5.97
			11.18		**10.29**
Total	Spatial Cooling		12.44		44.54
	Spatial Heating		12.50		38.19
	Water Heating		8.07		7.39
		Total	**33.00**		**91.76**

Figure 72 to Figure 75 present a complete overview of the distribution between the final and useful energy consumption for the hospitals sub-sector.

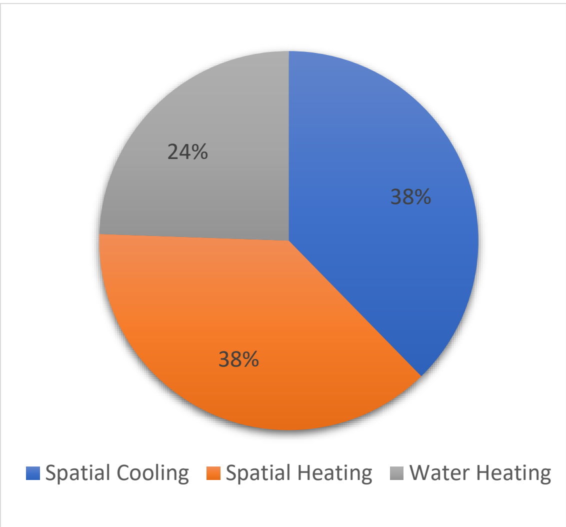

Figure 72 - Final energy consumption by end-use for spatial cooling, heating and water heating

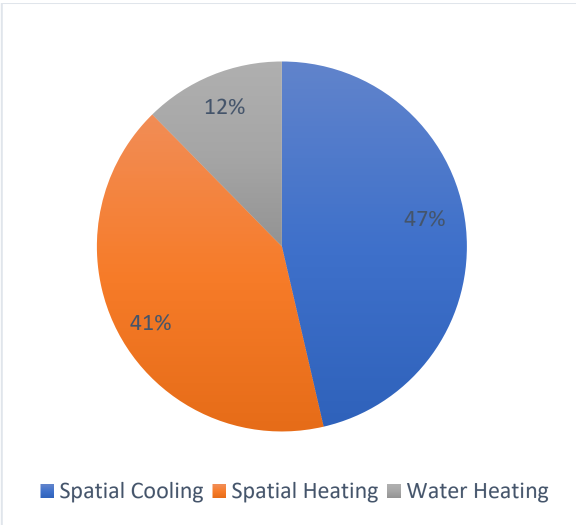

Figure 73 - Useful energy consumption by end-use for spatial cooling, heating and water heating

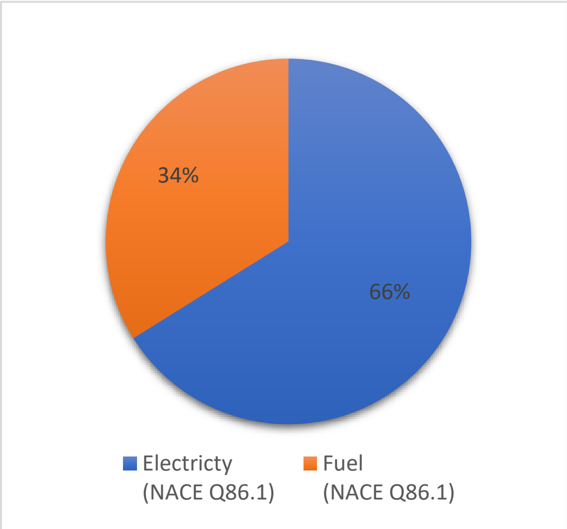

Figure 74 - Final energy consumption by end-use

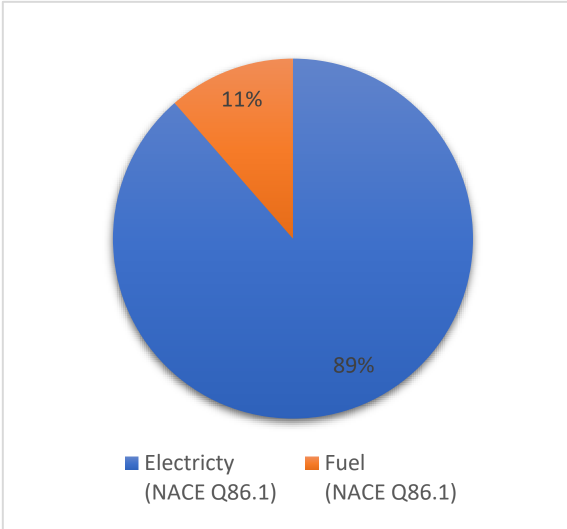

Figure 75 - Useful energy consumption by end-use

1.5.4 Residential Care (NACE Q87)

Historically, Malta had a predominantly youthful demographic profile, but this shifted dramatically in the latter part of the 20th century.[56] Between 1985 and 2020, the proportion of the population aged 65 and over in Malta rose from 9.9% to 18.9%.[57] Given this demographic shift, the already high demand for residential care homes is anticipated to increase further in the future. This section addresses the energy requirements of residential care such as elderly residential care and residential nursing care, classified under NACE Q87.

1.5.4.1 Electrical Consumption in the Residential Care Sub-sector

The calculations for the residential care sub-sector have been based on hourly electrical consumption profiles for a sample of buildings provided by EWA. The hourly data provided was studied and extrapolated to reach the total consumption for NACE Q87. The total electricity consumption during 2022 for the residential care sub-sector amounted to 15.35 GWh. The monthly electricity consumption is shown in Figure 76. Consumption reaches its peak in the summer months, with August experiencing the highest demand.

[56] Measuring and Modelling Demographic Trends in Malta: Implications for Ageing Policy by Prof. M. Formosa
[57] National Strategic Policy for Active Ageing 2023 – 2030

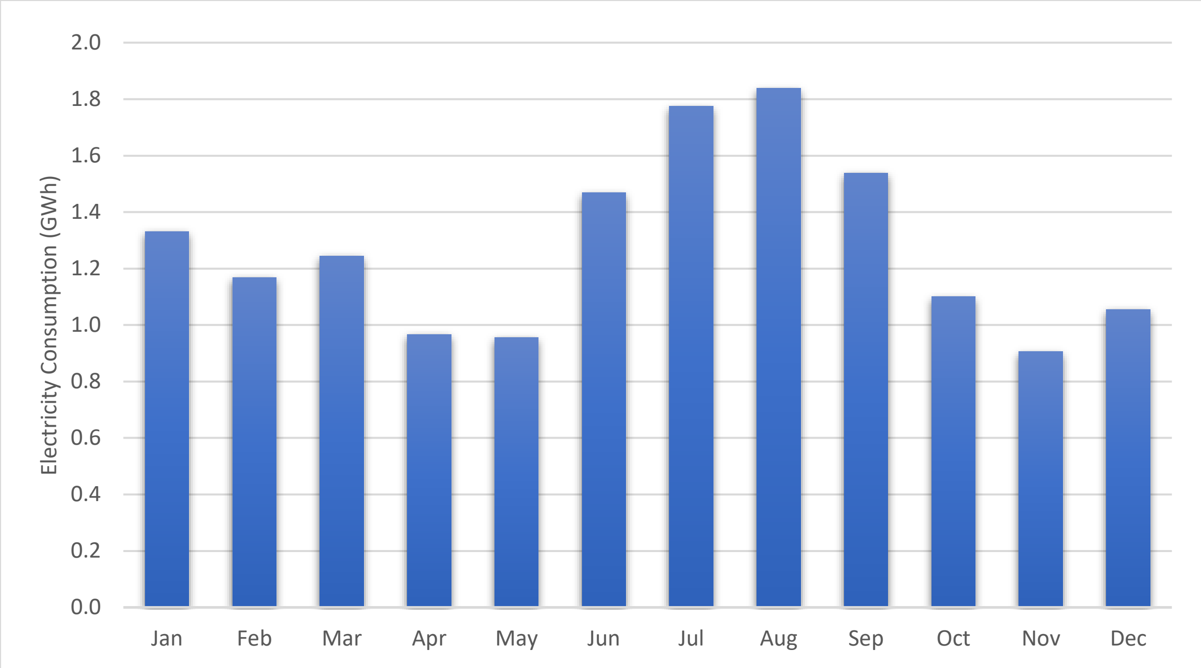

Figure 76 - Monthly Electricity Consumption in 2022 for the residential care sub-sector

The highest peaks in the total electricity consumption during 2022 can be observed during the summer months, followed by smaller peaks during the winter period. The hourly data was further analysed to understand the correlation between the heating and cooling requirements during the different months. HDD and CDD for Malta for 2022 were analysed to define the heating and cooling energy requirements of buildings through electricity as done for the previous two sub-sectors. The energy demand for DHW was calculated based on the number of beds in residential care homes. Data provided by EWA shows that the number of beds in the residential care in Malta during 2022 was 6,090. Table 46 details the additional parameters considered when calculating the total energy required for DHW in 2022.

Table 46 - DHW Calculation Parameters

Parameter	**Value**
Flow rate per shower per minute (l/min)	7[58]
Average time per shower per person (minutes)	20
Mix of hot to cold water (%)	50
Boiler set temperature C	65[59]
Litre of hot water per shower	70
Water system efficiency	0.9
Number of beds	6,090

[58] Benchmarks & Best Practice Flow Rates - https://greenhealthcare.ie/wp-content/uploads/2020/09/Benchmarks-Factsheet-New.pdf

[59] Legionella – The Impact on the Care Home Sector - https://legionellaandfiresafe.co.uk/legionella-the-impact-on-the-care-home-sector/

Table 47 - DHW calculated monthly consumption

Month	Demand (GWh)	DHW produced by Electricity (GWh)	DHW produced by Fuel (GWh)
January	0.896	0.066	0.830
February	0.797	0.059	0.738
March	0.887	0.066	0.821
April	0.810	0.060	0.750
May	0.762	0.057	0.706
June	0.638	0.047	0.590
July	0.631	0.047	0.584
August	0.632	0.047	0.586
September	0.640	0.048	0.593
October	0.727	0.054	0.673
November	0.763	0.057	0.706
December	0.816	0.061	0.755
Total	**8.999**	**0.668**	**8.331**

In 2022, the total fuel consumption for water heating in the residential care was 8.33 GWh. The monthly fuel consumption was distributed throughout each year based on the monthly calculated hot water demand. The additional 0.67 GWh of hot water demand was achieved by electricity. The daily consumption profile for the electricity used for space heating and cooling in the residential care sub-sector has been determined using the below formula:

$$\text{Total Daily Consumption for Heating or Cooling} = \text{Total Daily Consumption} - \text{Baseload} - \text{Hot water}$$

Based on the daily consumption values and HDD/CDD days, the baseload was calculated by analysing the monthly consumption in which April, May and November was assumed as the baseload months. The average consumption across these three months was calculated to obtain the daily average, which was identified as 0.0054 GWh per day. Applying this number to each month, the total electrical consumption attributed to the baseload is calculated to be 1.98GWh.

A typical baseload for residential care homes is assumed to include lighting systems, ventilation systems, electrical kitchen equipment and other similar equipment, excluding space heating, space cooling and water heating. The electricity consumption that remained after the removal of the baseload and hot water was attributed to heating and cooling. Figure 77 shows the total electrical consumption for NACE Q87 in Malta together with the applicable baseload and hot water and spatial cooling and heating on a monthly basis. The monthly electricity consumption figures for the baseload, hot water, space heating and space cooling are presented in Table 48.

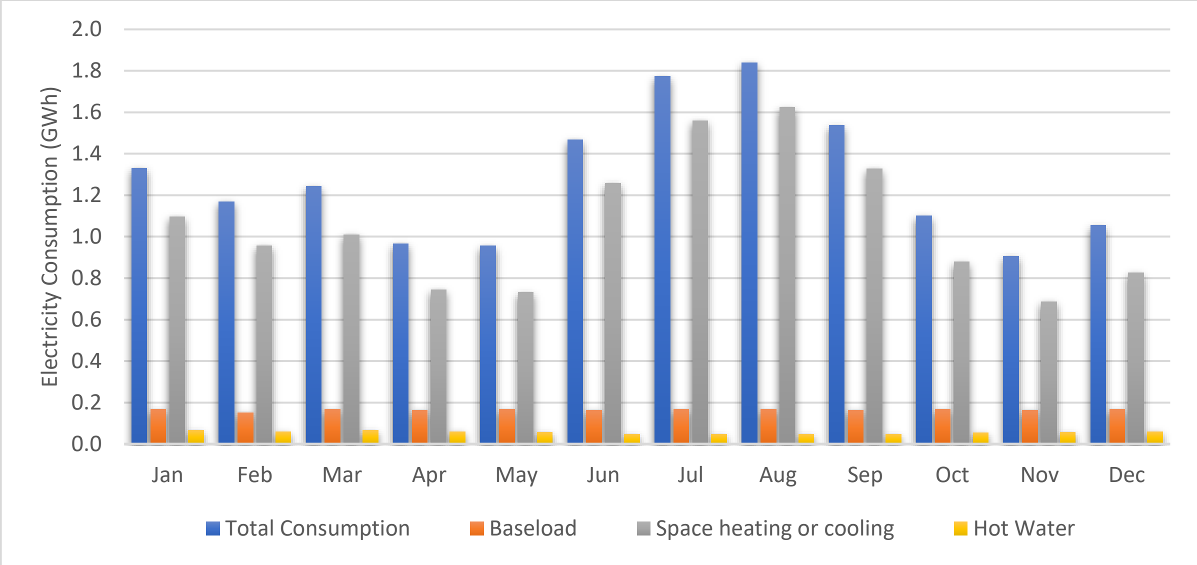

Figure 77 - Monthly total electricity consumption, hot water and baseload in the residential care sub-sector for the year 2022

Table 48 - Monthly electrical consumption distribution for baseload, hot water, space heating and space cooling in the residential care sub-sector during 2022

Month (2022)	Total Electrical Consumption (GWh)	Electrical Consumption for Baseload (GWh)	Final Electrical Consumption for Hot Water (GWh)	Final Electrical Consumption for Space Heating (GWh)	Final Electrical Consumption for Space Cooling (GWh)
January	1.331	0.168	0.066	1.096	0.000
February	1.169	0.152	0.059	0.958	0.000
March	1.244	0.168	0.066	1.010	0.000
April	0.967	0.163	0.060	0.744	0.000
May	0.956	0.168	0.057	0.000	0.731
June	1.468	0.163	0.047	0.000	1.258
July	1.774	0.168	0.047	0.000	1.559
August	1.838	0.168	0.047	0.000	1.623
September	1.538	0.163	0.048	0.000	1.328
October	1.101	0.168	0.054	0.000	0.879
November	0.906	0.163	0.057	0.687	0.000
December	1.055	0.168	0.061	0.827	0.000
Total	15.349	1.981	0.668	5.322	7.379

The overall final electricity consumption for space heating and cooling during 2022 amounts to 5.3 GWh. From the above calculations, the final energy for space heating and cooling generated by electrical means in the residential care sub-sector is shown in Figure 78.

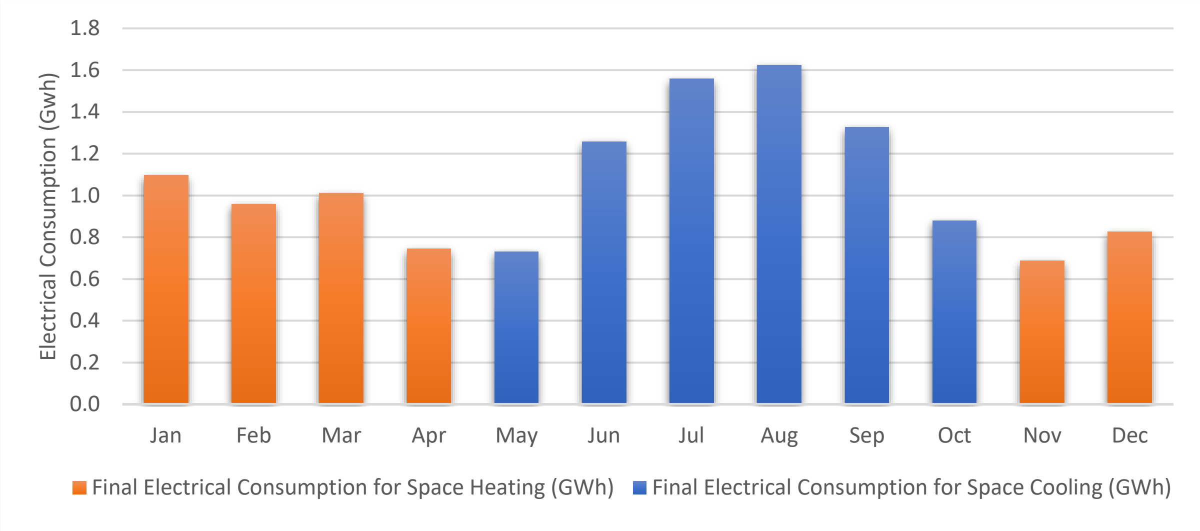

Figure 78 - Final electrical energy consumed for space heating and cooling in 2022 for the residential care sub-sector

Utilizing the average COPs and EERs outlined in the section on the hospitals sector (NACE Q86.1) of the report, the useful energy for space heating, space cooling, and hot water generated via electricity in the residential care sub-sector has been computed. The results of these calculations are displayed in Table 49.

Table 49 - Final and useful electrical energy for the residential care sub-sector in 2022

	End Use	Technology	Final Energy (GWh)	Conversation Factor (Equipment Efficiency)	Useful Energy (GWh)
Electricity (NACE Q87)	Spatial Cooling	Heat Pumps	7.38	3.58	26.42
	Spatial Heating	Heat Pumps	5.32	4.34	23.10
	Water Heating	Electric Boilers	0.67	0.90	0.60
			13.37		50.11

1.5.4.2 Fuel Consumption in the Residential Care Sub-sector

The fossil fuel consumption data for the residential sector was provided by EWA. The yearly fuel consumption in care residences between 2018 and 2022 is shown in Figure 79. A decrease in fuel consumption is significantly visible between 2018 and 2022, where this highlights a change in technology to achieve spatial heating and water heating. This indicates that residential care homes are shifting towards the electrification of certain technologies thus reducing their fossil fuel consumption hence the CO_2 emissions. The fossil fuel consumption during 2022 was further split by fuel type and end use as shown in Table 50.

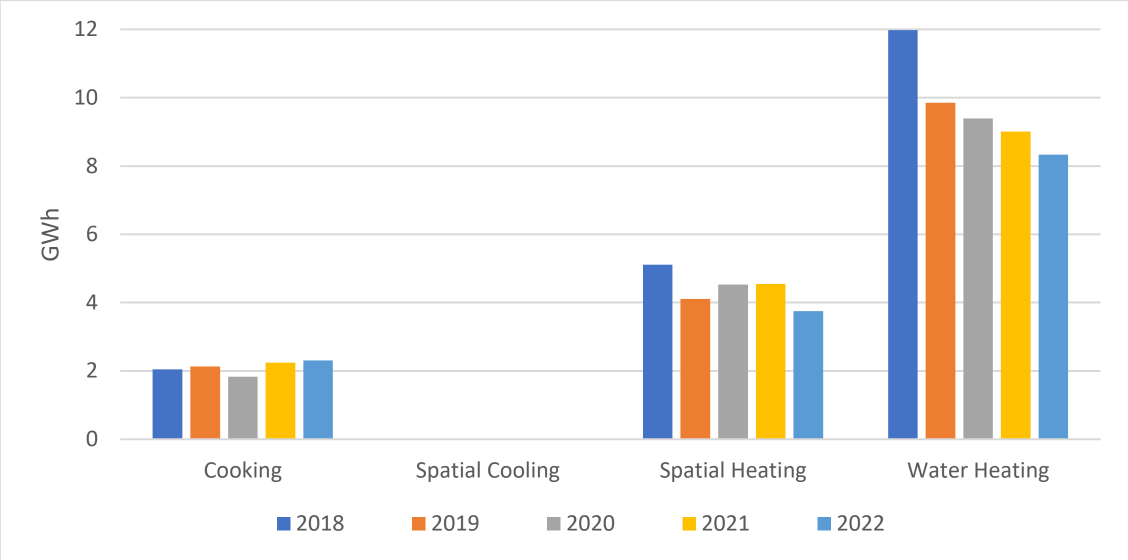

Figure 79 - Fossil fuel consumption in the residential care sub-sector by end use 2018 – 2022 (NACE Q.87)

Table 50 - Fossil Fuel Consumption for residential care for 2022

Fuel Type	Fuel Use	Consumption (Tons)	Conversion Factor (GWh/Ton)	GWh
Diesel	Cooking	0.00	0.01194	0.00
	Spatial Cooling	0.00		0.00
	Spatial Heating	0.00		0.00
	Water Heating	41.36		0.49
Fuel Oil	Cooking	0.00	0.01111	0.00
	Spatial Cooling	0.00		0.00
	Spatial Heating	120.33		1.34
	Water Heating	106.41		1.18
Gasoil	Cooking	0.00	0.01194	0.00
	Spatial Cooling	0.00		0.00
	Spatial Heating	104.27		1.25
	Water Heating	258.88		3.09
LPG	Cooking	180.9	0.01278	2.31
	Spatial Cooling	0.00		0.00
	Spatial Heating	91.36		1.17
	Water Heating	278.81		3.56
Total	Cooking			2.31
	Spatial Cooling			0.00
	Spatial Heating			3.75
	Water Heating			8.33

The percentage distribution between the different types of fuel used in the residential care sub-sector is shown in Figure 80.

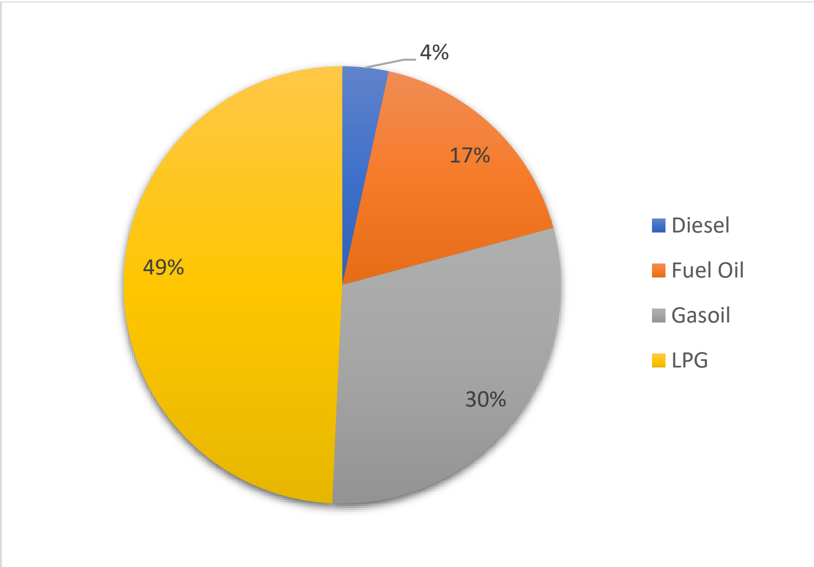

Figure 80 - Fuel consumption distribution for spatial heating, cooling, water heating and cooking in the residential care sub-sector by type in 2022 (NACE Q87)

The data included in Table 50 and Figure 80 shows that, during 2022, LPG was the mostly used fossil fuel in the elderly care sub-sector with the second mostly used fossil fuel being gasoil. The fossil fuel types are mainly used to generate hot water and space heating in the elderly sub-sector, as can be seen in Figure 81.

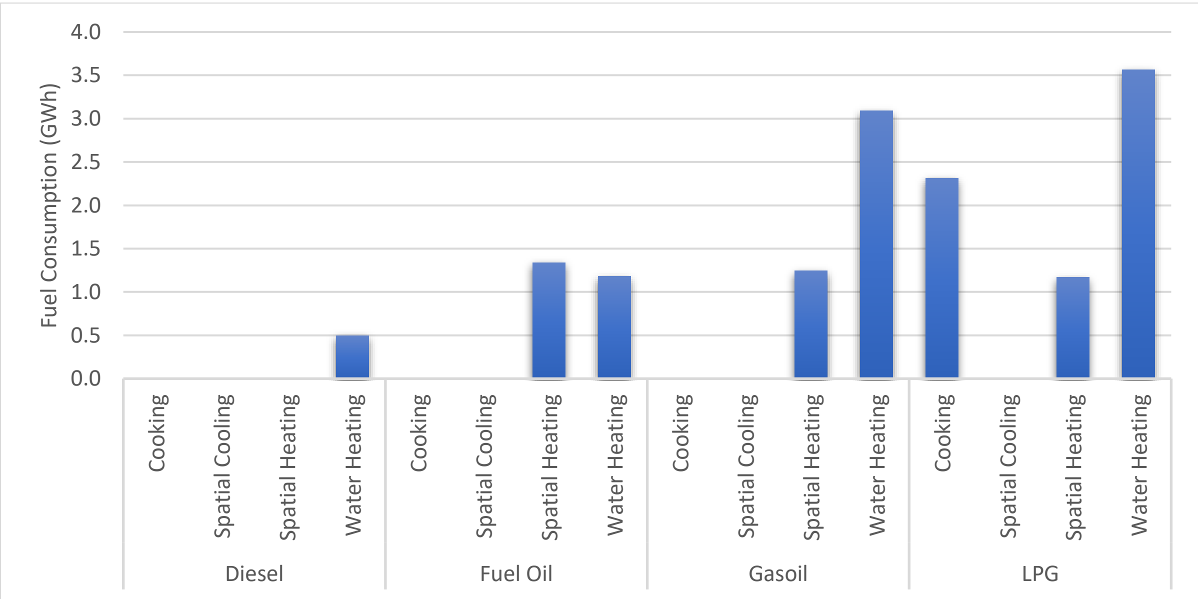

Figure 81 - Fossil Fuel Consumption for the residential care sub-sector for each type of fossil fuel in 2022 (Q87)

On the basis of the data indicated above, Figure 82 shows the percentage distribution of the fossil fuel end uses in the residential care sub-sector, namely space cooling, space heating, cooking and water heating.

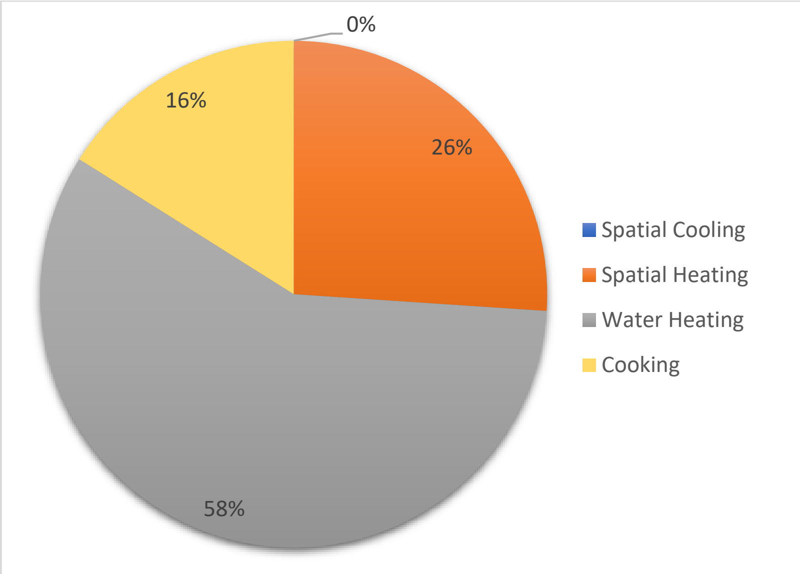

Figure 82 - Percentage Fossil Fuel distribution in the residential care sub-sector for spatial cooling, spatial heating, water heating and cooking in 2022 (NACE Q87)

From the above calculations, the final and useful energy for hot water generation, space heating and cooling generated by fossil fuels in the residential care sub-sector can be seen in Table 51. An efficiency coefficient of 0.92 and 0.85 respectively for fuel-fired boilers was used, based on market research and data available for the technology and the sector.

Table 51 - Final and Useful Energy for fossil fuel use in the residential care sub-sector during 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Fuel (NACE Q87)	Spatial Cooling	Fuel Fired Boilers	0.00	0.92	0.00
	Spatial Heating	Fuel Fired Boilers	3.75	0.92	3.45
	Water Heating	Fuel Fired Boilers	8.33	0.85	7.08
			12.08		10.53

1.5.4.3 Total and Useful Energy for Residential Care Sub-sector

Table 52 depicts the total final and useful energy for the residential care sub-sector, split by different energy source types and by end use. Figure 83 to Figure 86 present a complete overview of the distribution between the final and useful energy consumption for the elderly residential care sub-sector.

Table 52 - Total final and useful energy for the residential care sub-sector in 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Electricity (NACE Q87)	Spatial Cooling	Heat Pumps	7.38	3.58	26.42
	Spatial Heating	Heat Pumps	5.32	4.34	23.10
	Water Heating	Electric Boilers	0.67	0.9	0.60
			13.37		**50.11**
Fuel (NACE Q87)	Spatial Cooling	Fuel Fired Boilers	0.00		0.00
	Spatial Heating	Fuel Fired Boilers	3.75	0.92	3.45
	Water Heating	Fuel Fired Boilers	8.33	0.85	7.08
			12.08		**10.53**
Total	Spatial Cooling		7.38		26.42
	Spatial Heating		9.07		26.55
	Water Heating		9.00		7.68
		Total	**25.45**		**60.65**

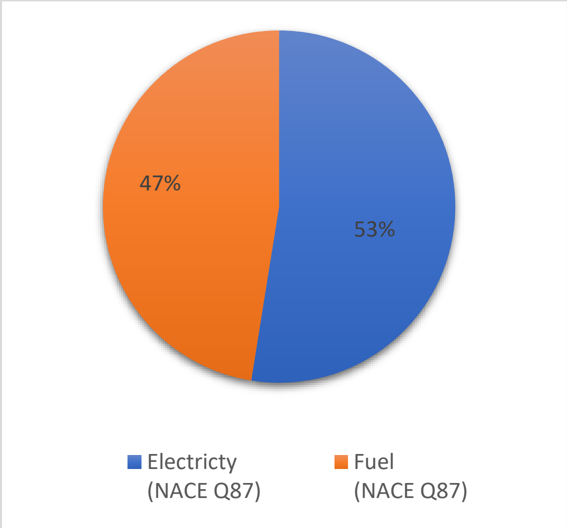

Figure 83 - Final energy consumption for spatial cooling, heating and water heating by end-use

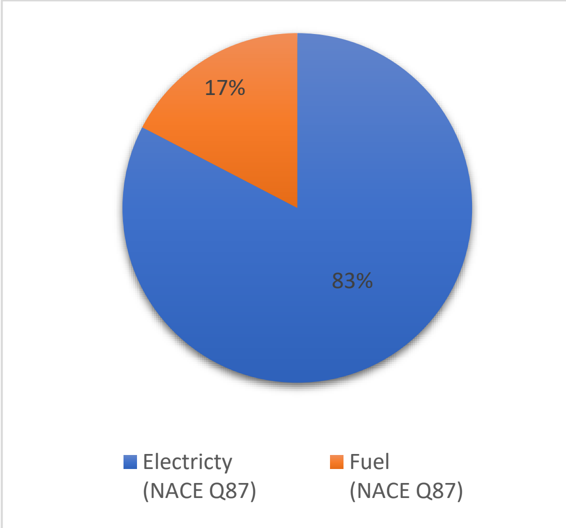

Figure 84 - Useful energy consumption for spatial cooling, heating and water heating by end-use

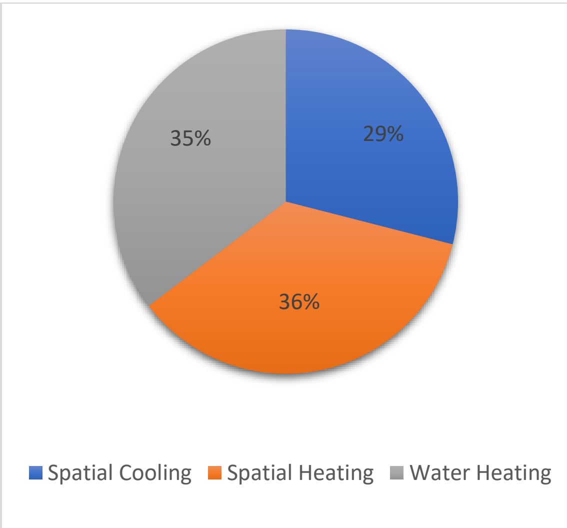

Figure 85 - Final energy consumption by source

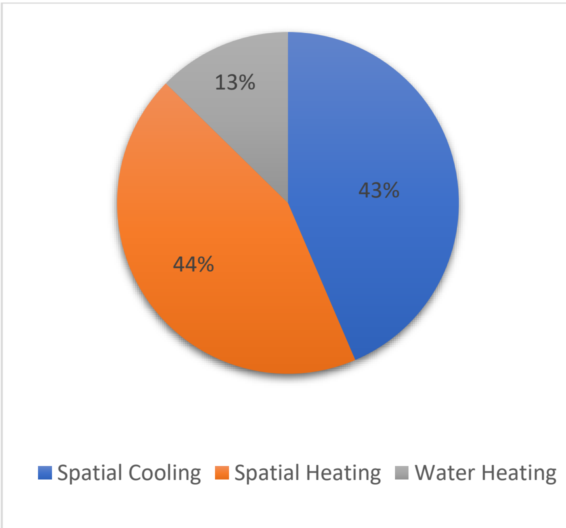

Figure 86 - Useful energy consumption by source

1.5.5 Other Commercial and Services Sub-sectors

This section of the assessment covers the remaining NACE codes within the commercial and services sector not covered under hotels, food and beverages, hospitals and residential care. A summary of the different sub-sectors and the respective NACE codes is presented in Table 53. These NACE codes are being grouped and analysed together, under what is being referred to as ‘commercial and services sub-sector’.

Table 53 - Categories and NACE codes within the commercial and services sub-sector

NACE Code	**Category within the Commercial and Services sub-sector**
E	Water Supply, sewerage, waste management and remediation activities
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
J	Information and communication
K	Financial and insurance activities
L	Real estate activities
M	Professional, scientific and technical activities
N	Administrative and support service activities
P	Education
Q_Other	Medical and dental practice activities (Q86.2) &Social work activities without accommodation (Q88)
R	Arts, entertainment and recreation
S	Other services activities
U	Activities of extraterritorial organisations and bodies

1.5.5.1 Electrical Consumption in the Commercial and Services Sub-sector

The calculations for the electrical consumption have been based on hourly electrical consumption profiles for a sample of buildings under the different NACE codes within the commercial sub-sector, as provided by EWA. The hourly data provided was studied and extrapolated to reach the total consumption for the commercial sector provided by NSO.

Table 54 - Commercial services sub-sector monthly electricity consumption in 2022

Month	Total Consumption (GWh)
January	45.67
February	43.26
March	47.30
April	46.19
May	53.82
June	66.81
July	75.82
August	77.14
September	68.50
October	59.62
November	50.01
December	47.21
Grand Total	**681.34**

The total electricity consumption during 2022 for the commercial sub-sector amounted to 681.3 GWh. The monthly electricity consumption is depicted in Figure 87. Notably, there was a surge in electricity demand over the summer months, with August experiencing the highest consumption.

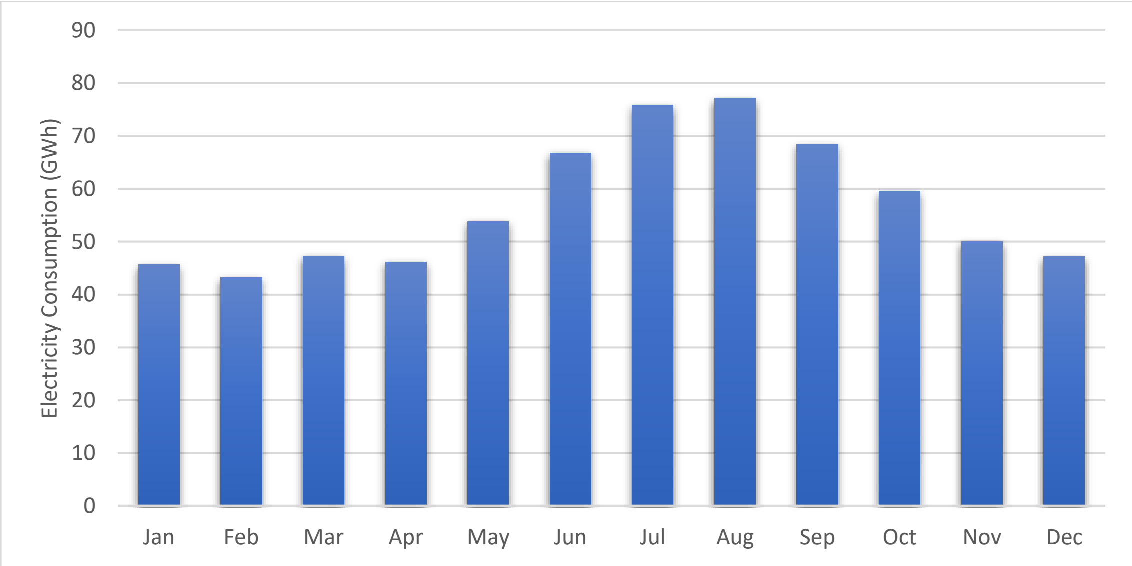

Figure 87 - Monthly Electricity Consumption in 2022 for the other commercial and services sub-sectors

For these sub-sectors, the daily thermal demand for water heating was calculated based on the following: the difference in average monthly temperatures and water outlet temperature, the hot water demand indicated above and the total number of employees. It has been assumed that this sub-sector uses electrical water heaters for water heating generation together with the assumption that no solar water heating is being generated from the services sector.

The number of full-time equivalent employees in 2022 in the other commercial and services sector was obtained from NSO and is shown in

Table 55 below. For the purpose of this assessment the full-time equivalent employees have been considered.

Table 55 - Employees in the commercial sub-sector in 2022[60]

NACE Code	Full time equivalent employees
E	1,800
G	30,864
J	9,449
K	13,568
L	2,591
M	18,743
N	25,819
P	19,198
R	13,167
S	5,713
U	256
Total	141,168

A total of 5.21GWh of electrical energy has been estimated to be required to cover the hot water demand in 2022. The monthly demand for hot water has been determined based on daily calculations, the details of which are outlined below.

Table 56 - DHW calculation

Parameter for DHW Calculation	**Value**
Flow rate per hand washing per min (litres)	8[61]
Avg. time per hand wash per person (minutes)	1[62]
Initial water Temperature (°C)	Average Daily Air Temperature
Water Heater Temperature (°Celsius)	60[63]
Litres of hot water per basin	8
Average employment in 2022	141,168
Electric Water heater efficiency	0.9[64]

[60] NSO, Registered Employment: August 2022: NR083/2023 https://nso.gov.mt/registered-employment-august-2022-2/

[61] Development of European Ecolabel and Green Public Procurement Criteria for Sanitary Tapware – Taps and Showerheads – https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/contentype/product_group_documents/1581682812/1st%20draft_Technical_background_report_Criteria_for_taps_and_showerheads.pdf

[62] Hand washing - https://www.nhs.uk/live-well/best-way-to-wash-your-hands/

[63] Schedule 3 of L.N. 5 of 2006 – Public Health Act, 2003 (ACT NO. XIII of 2003)

[64] B2.3.3.2 – Hot Water Storage -SBEM Technical Manual - https://www.uk-ncm.org.uk/filelibrary/SBEM-Technical-Manual_v5.2.g_20Nov15.pdf

Studies issued by European Union Member States[65],[66],[67] show that 40% of the total electricity consumption in commercial and services buildings is allocated to spatial heating and cooling. Hence, 40% is being applied on the total electricity consumption to factor the spatial heating and cooling load. The daily consumption profile for the electricity used for the baseload in the commercial and services sub-sector has been determined using the formula below:

Total Daily Consumption for Baseload = Total Daily Consumption – Space heating and cooling – Hot water

Figure 88 shows the total electrical consumption of the commercial and services sub-sector in Malta together with the applicable baseload, space heating and cooling and hot water, on a monthly basis.

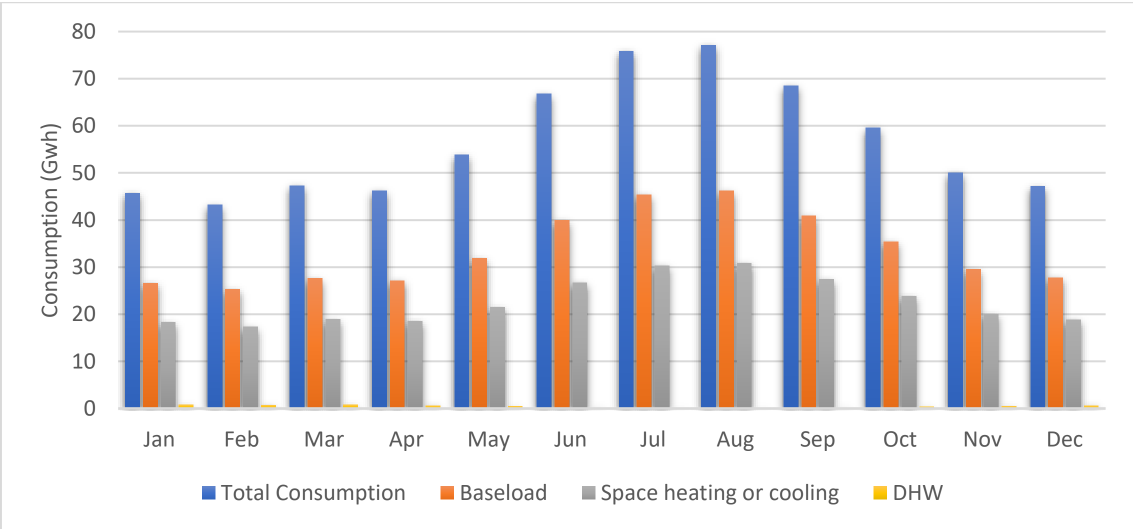

Figure 88 - Monthly total electricity consumption, hot water, baseload and space heating and cooling in the other commercial and services sub-sectors for the year 2022

The monthly electricity consumption figures for the baseload, hot water, space heating and space cooling are presented in Table 57.

[65] Analysis of the space heating and cooling market in Europe – Simon Pezzuto, Wolfram Sparber, Roberto Fedrizzi https://www.researchgate.net/publication/273134023_Analysis_of_the_space_heating_and_cooling_market_in_Europe

[66] Use of energy Explained - https://www.eia.gov/energyexplained/use-of-energy/commercial-buildings.php

[67] Power to heat and cooling: Status - https://www.irena.org/Innovation-landscape-for-smart-electrification/Power-to-heat-and-cooling/Status

Table 57 - Monthly electrical consumption distribution for baseload, hot water, space heating and space cooling in the other commercial and services sub-sectors during 2022

Month (2022)	Total Electricity Consumption (GWh)	Electrical Consumption for Baseload (GWh)	Final Electricity Consumption for Domestic Hot Water (GWh)	Final Electricity Consumption for Space Heating (GWh)	Final Electricity Consumption for Space Cooling (GWh)
January	45.674	26.627	0.777	18.269	0.000
February	43.261	25.273	0.684	17.304	0.000
March	47.297	27.611	0.768	18.919	0.000
April	46.192	27.100	0.615	18.477	0.000
May	53.817	31.851	0.439	0.000	21.527
June	66.807	39.925	0.159	0.000	26.723
July	75.816	45.399	0.090	0.000	30.326
August	77.135	46.186	0.095	0.000	30.854
September	68.502	40.934	0.167	0.000	27.401
October	59.620	35.427	0.345	0.000	23.848
November	50.010	29.515	0.491	20.004	0.000
December	47.207	27.744	0.580	18.883	0.000
Total	**681.338**	**403.593**	**5.210**	**111.856**	**160.679**

The overall final electricity consumption for space heating and cooling during 2022 amounts to 272.54 GWh. From the above calculations, the final energy for space heating and cooling generated by electrical means in the commercial and services sub-sector is shown in Figure 89.

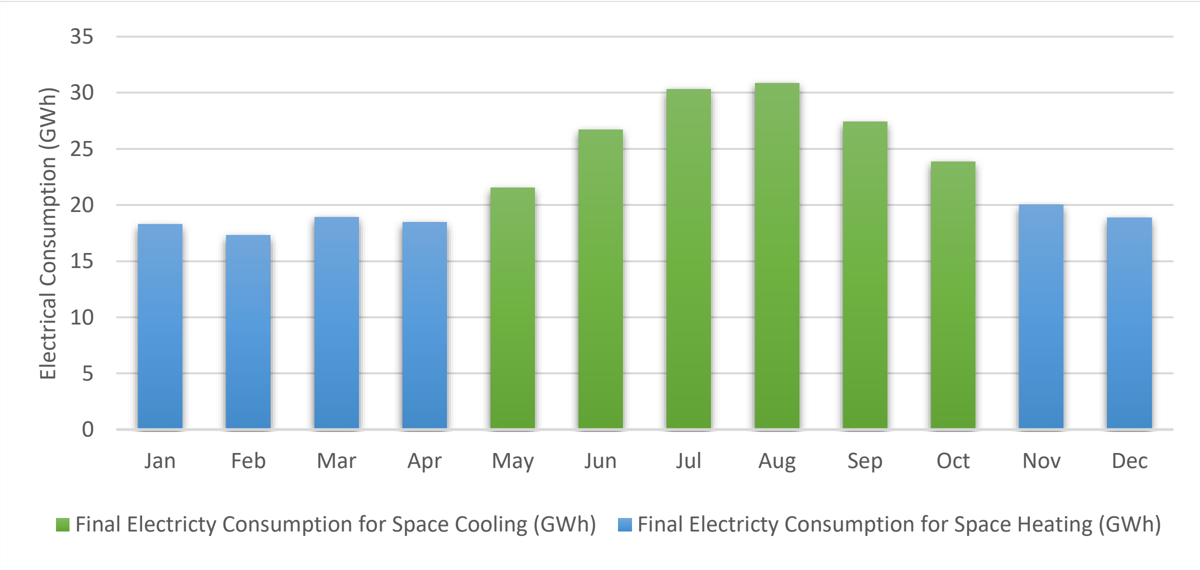

Figure 89 - Final electrical energy consumed for space heating and cooling in 2022 for the other commercial and services sub-sector

The COPs and EER have been based on market research where it shows that a number of buildings make use of split and VRV air-conditioning units. The useful energy for space heating and space cooling and hot water generated by electricity in the commercial sub-sector has been calculated and is shown in Table 58.

Table 58 - Final and useful electrical energy for the other commercial and services sub-sector in 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Electricity (NACE Commercial)	Spatial Cooling	Heat Pumps	160.68	3.08	494.89
	Spatial Heating	Heat Pumps	111.86	3.84	429.53
	Water Heating	Electric Boilers	5.21	0.9	4.69
			277.33		929.11

1.5.5.2 Fuel Consumption in the Other Commercial and Services Sub-sector

The fossil fuel consumption data for the commercial sub-sector was provided by EWA. The yearly fuel consumption in commercial buildings between 2018 and 2022 is shown in Figure 90. The fossil fuel consumption during 2022 was further split by fuel type and end use as shown in Table 59.

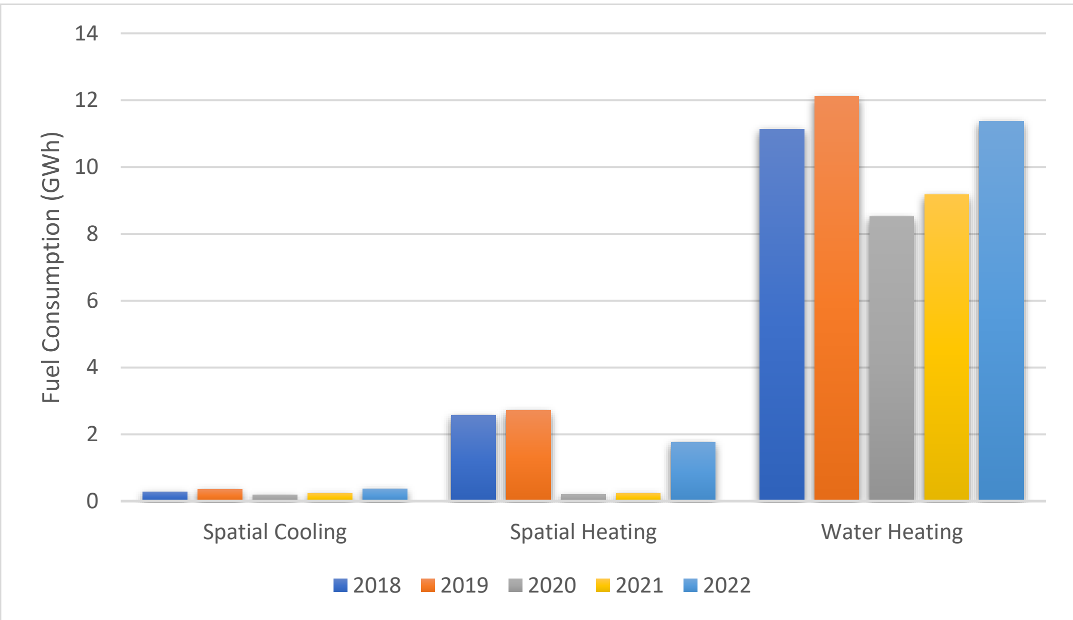

Figure 90 - Fossil fuel consumption in the commercial sub-sector by end use 2018 - 2022

Table 59 - Fossil Fuel Consumption for other commercial and services sub-sector for 2022

Fuel Type	Fuel Use	Consumption (tons)	Conversion Factor (GWh/ton)	GWh
Diesel	Spatial Cooling	14.87	0.01194	0.18
	Spatial Heating	0.00		0.00
	Water Heating	0.00		0.00
Fuel Oil	Spatial Cooling	0.00	0.01111	0.00
	Spatial Heating	6.39		0.07
	Water Heating	776.77		8.63
Gasoil	Spatial Cooling	4.91	0.01194	0.06
	Spatial Heating	1.68		0.02
	Water Heating	47.86		0.57
LPG	Spatial Cooling	9.68	0.01278	0.12
	Spatial Heating	127.83		1.63
	Water Heating	170.32		2.18
Total	Spatial Cooling			0.36
	Spatial Heating			1.73
	Water Heating			12.81

The percentage distribution between the different types of fuel used in the commercial sub-sector is shown in Figure 91. During 2022, fuel oil was the mostly used fossil fuel in the commercial sub-sector. Data provided shows that the majority of the fuel oil is used specifically in NACE S96.01 which represent the washing and (dry) leaning of textile and fur products. The second mostly used fossil fuel is LPG, which is also used mostly by companies within NACE S96.01. These fossil fuels are mainly used to generate hot water and space heating.

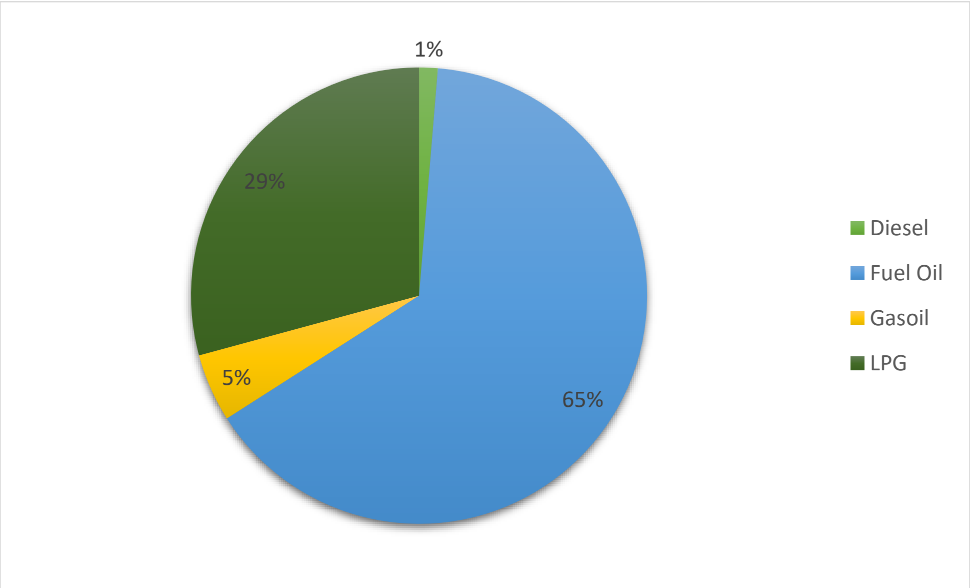

Figure 91 - Fuel consumption distribution in the other commercial and services sub-sectors by type in 2022

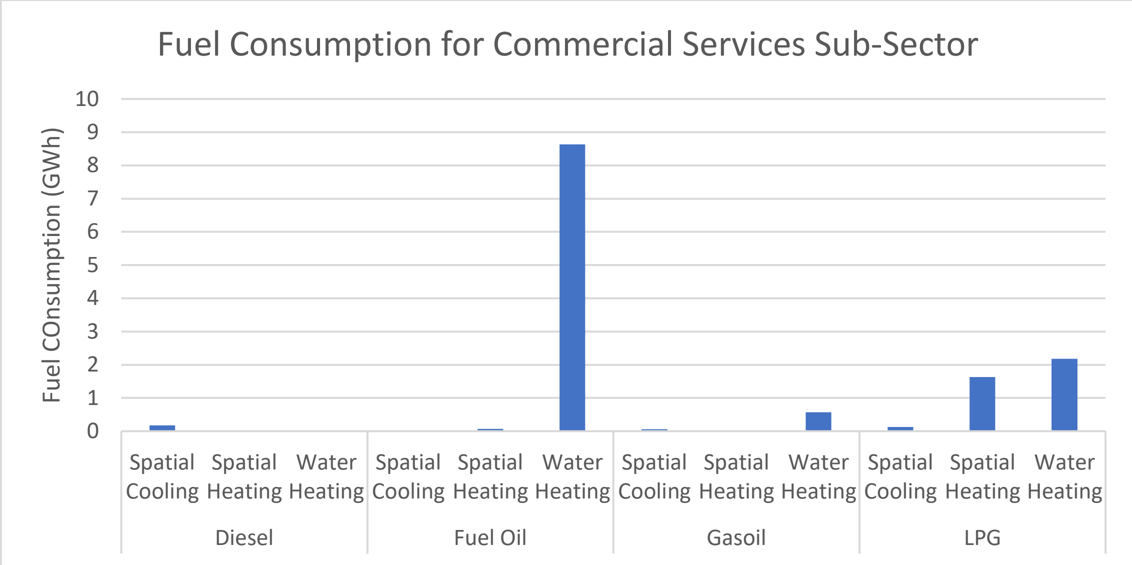

Figure 92 - Fossil Fuel Consumption for the other commercial and services sub-sectors for each type of fossil fuel in 2022

On the basis of the data indicated above, Figure 93 shows the distribution of the fossil fuel by end use in the other commercial and services sub-sectors, namely space cooling, space heating and water heating. The final and useful energy for hot water generation, space heating and cooling generated by fossil fuels in the commercial sub-sector can be seen in Table 60. An efficiency coefficient of 0.87 for fuel-fired boilers was used, based on market research and data available for the technology.

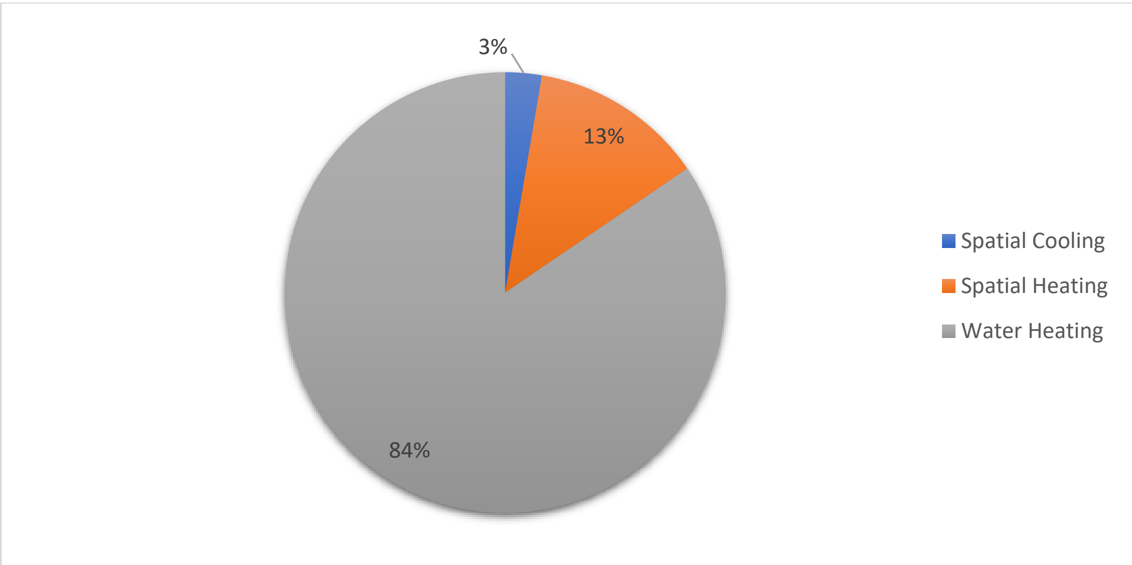

Figure 93 - Percentage Fossil Fuel distribution in the other commercial and services sub-sectors in 2022

Table 60 - Final and Useful Energy for fossil fuel use in the other commercial and services sub-sectors during 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Fuel (NACE Commercial)	Spatial Cooling	Fuel Fired Boilers	0.36	0.87	0.31
	Spatial Heating	Fuel Fired Boilers	1.72	0.87	1.50
	Water Heating	Fuel Fired Boilers	11.38	0.87	9.90
			13.46		11.71

1.5.5.3 Total and Useful Energy Consumption in Other Commercial and Services Sub-sectors

Table 61 depicts the total final and useful energy for the commercial and services sub-sector, split by different energy source types and by end use. Figure 94 to Figure 97 present a complete overview of the distribution between the final and useful energy consumption for the other commercial and services sub-sectors.

Table 61 - Total final and useful energy for the other commercial and services sub-sector in 2022

	End Use	Technology	Final Energy (GWh)	Conversion Factor (Equipment Efficiency)	Useful Energy (GWh)
Electricity (NACE Commercial)	Spatial Cooling	Heat Pumps	160.68	3.08	494.89
	Spatial Heating	Heat Pumps	111.86	3.84	429.53
	Water Heating	Electric Boilers	5.21	0.90	4.69
			277.75		**929.11**
Fuel (NACE Commercial)	Spatial Cooling	Fuel Fired Boilers	0.36	0.87	0.31
	Spatial Heating	Fuel Fired Boilers	1.72	0.87	1.50
	Water Heating	Fuel Fired Boilers	11.38	0.87	9.90
			13.46		**11.71**
Total	Spatial Cooling		161.04		495.20
	Spatial Heating		113.59		431.03
	Water Heating		18.02		15.84
		Total	**291.21**		**940.82**

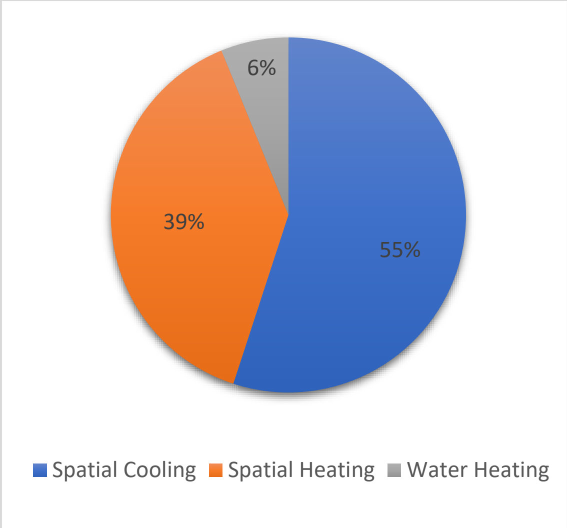

Figure 94 - Final Energy Consumption by end use

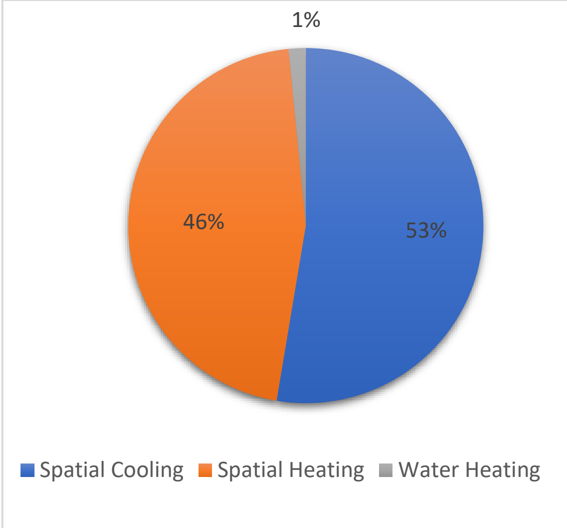

Figure 95 - Useful Energy Consumption by end use

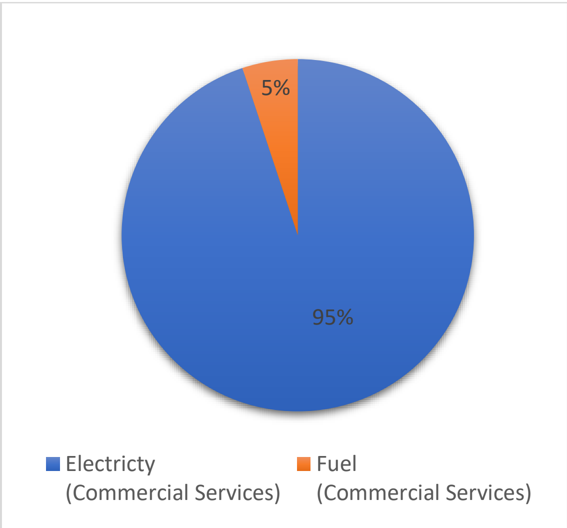

Figure 96 - Final Energy Consumption by source

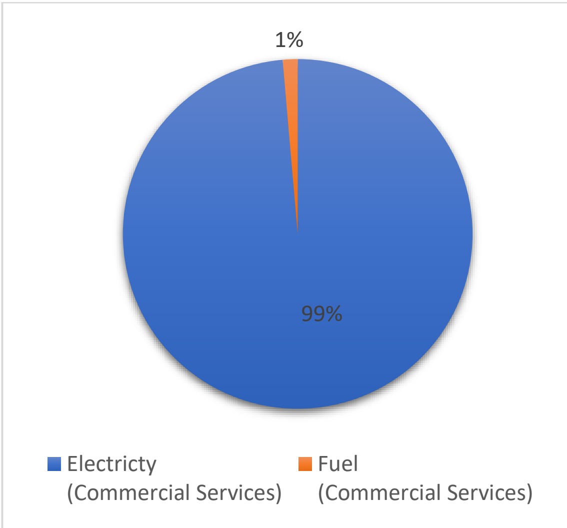

Figure 97 - Useful Energy Consumption by source

1.5.6 Aggregated Results for the Commercial and Services Sector

The total Final Energy and Useful Energy in 2022 including the electricity and fuel consumption attributed to space cooling, space heating and water heating for the entire services sector (sub-divided into different sub-sectors) can be analysed in Table 62. These aggregated results reflect the methodologies and calculations described earlier in this chapter.

Table 62- Total final and useful energy for the commercial and services sector in 2022

Sector	Sub-Sector	Type of Use	Total Final Energy in GWh	Total Useful Energy in GWh
Services	I55	Spatial Cooling	42.68	182.58
		Spatial Heating	40.63	121.76
		Water Heating	50.76	44.17
	I56	Spatial Cooling	19.60	60.34
		Spatial Heating	13.24	46.07
		Water Heating	1.34	1.21
	Q86.1	Spatial Cooling	12.44	44.54
		Spatial Heating	12.50	38.19
		Water Heating	8.07	7.39
	Q87	Spatial Cooling	7.38	26.42
		Spatial Heating	9.07	26.55
		Water Heating	9.00	7.68
	Other NACE Categories	Spatial Cooling	161.04	495.20
		Spatial Heating	113.58	431.03
		Water Heating	16.59	14.59
	Total	**Spatial Cooling**	**243.13**	**809.08**
		Spatial Heating	**189.03**	**663.61**
		Water Heating	**87.19**	**76.29**

The table above reveals that the commercial sub-sector is the most energy-intensive, with space cooling being the primary energy consumer. This outcome is anticipated given that the commercial sub-sector encompasses a wide array of establishments such as offices, public buildings, educational institutions and sports facilities. Following closely is the hotel sector, which also exhibits a substantial demand for space cooling. A comprehensive overview of the final and useful energy consumption within the services sector is depicted in Figure 98.

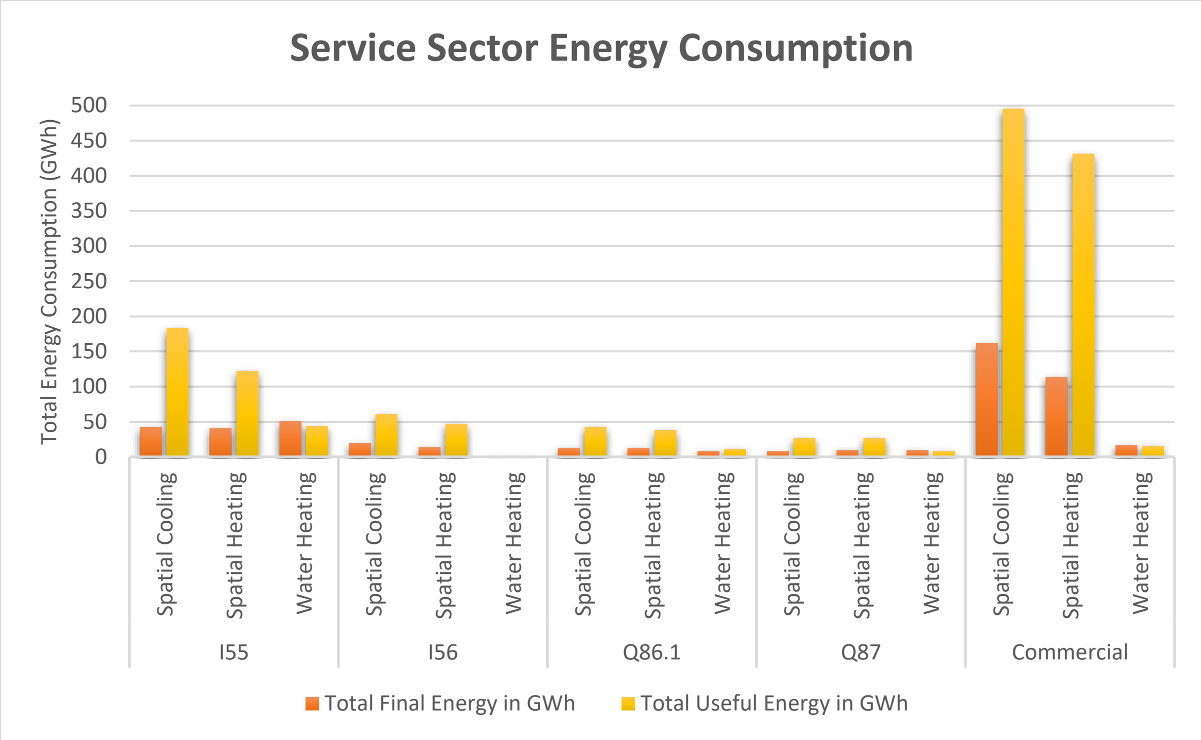

Figure 98 - Service Sector Final and Useful Energy Consumption Summary in 2022

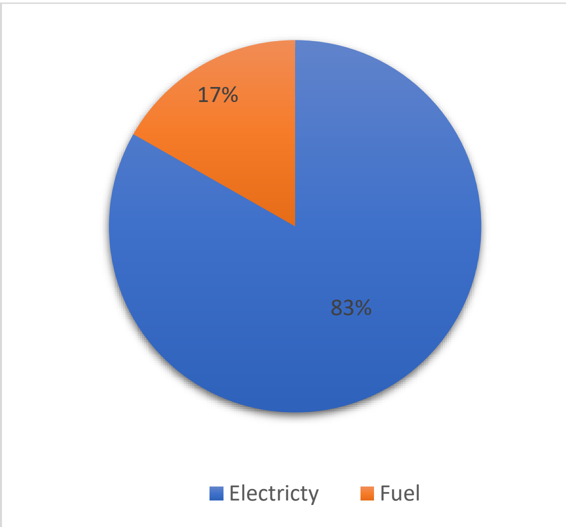

Figure 99 - Final Energy consumption by type for the service sector

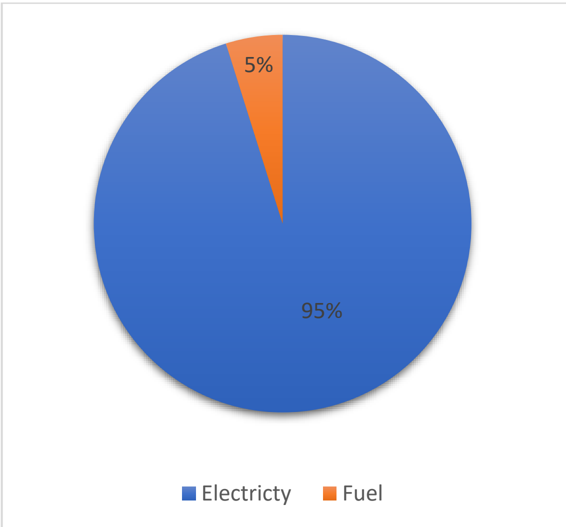

Figure 100 - Useful Energy consumption by type for the service sector

The figures above show the distribution of the final and useful energy consumption for the service sector. As seen from the figures the predominant type of energy used in the service sector is electricity.

1.5.6.1 Electrical Consumption for the Services Sector

Electricity consumption in the service sector is very high and it is mostly used for space cooling with the use of heat pumps to convert electrical energy to space cooling. Table 63 depicts the final and useful electrical energy, divided into three main different energy uses.

Table 63 - Final and Useful Electrical Energy in the service sector

	End Use	Technology	Final Energy (GWh)	Useful Energy (GWh)
Electricity	Spatial Cooling	Heat Pumps	242.49	806.55
	Spatial Heating	Heat Pumps	160.52	638.42
	Water Heating	Electric Boilers	29.29	30.31
			432.31	**1,475.28**

Figure 101 below shows the electrical final energy for the different uses within the services sector, with 56% of the electricity being consumed for space cooling, 36% for space heating, and 8% for water heating. When it comes to useful energy, space cooling covers 55% whilst space heating and water heating consume 43% and 2% respectively (Figure 102 and Figure 101).

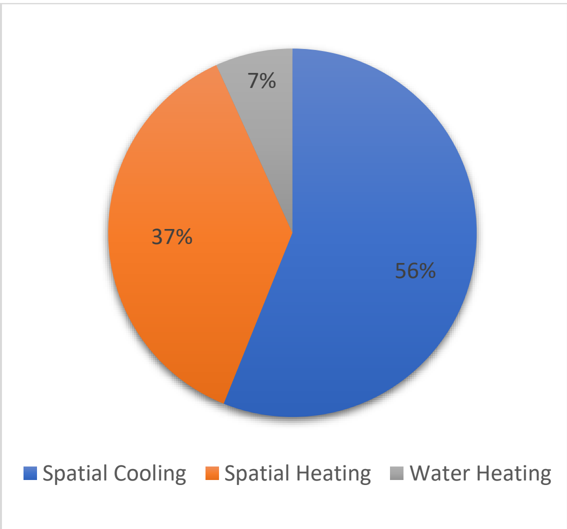

Figure 101 - Electrical Final Energy by end-use

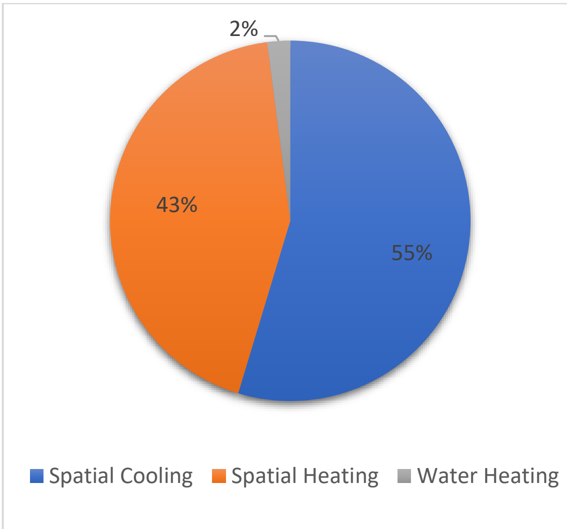

Figure 102 - Electrical Useful Energy by end-use

1.5.6.2 Fuel Consumption for the Services Sector

Fossil fuels in the services sector are mostly used for water heating followed by spatial heating through fuel-fire boilers. Table 64 depicts the final and useful fuel energy divided into the indicated three main energy use categories.

Table 64 - Final and Useful Fuel Energy in the Commercial and services sector

	End Use	Technology	Final Energy (GWh)	Useful Energy (GWh)
Fuel	Spatial Cooling	Fuel Fired Boilers	0.64	0.55
	Spatial Heating	Fuel Fired Boilers	28.50	24.86
	Water Heating	Fuel Fired Boilers	56.46	48.68
			85.60	**74.08**

Figure 103 depicts the final and useful energy demand share for fuels, with 66% use for water heating and 33% for space heating. Only 1% is used for space cooling.

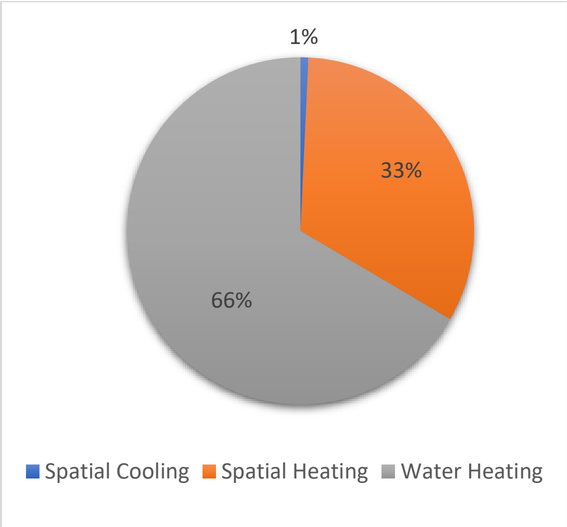

Figure 103 - Fuel final energy consumption by end use

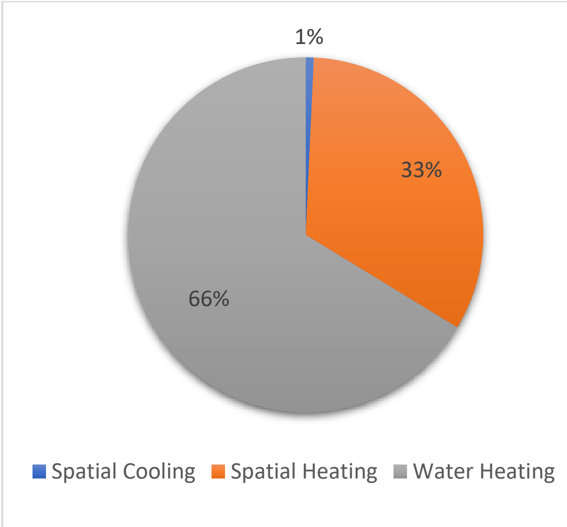

Figure 104 - Fuel useful energy consumption by end use

1.6 Summary of Heating and Cooling Demand

After conducting a thorough examination of the Final Energy Consumption and Useful Energy Consumption across various sectors, the table below depicts the findings for each sector. This synthesis encompasses the analysis of three distinct usage categories: space cooling, space heating, and water heating, as outlined throughout this section of the report. The table provided illustrates the Final Energy Consumption for these sectors and the corresponding totals for the base year 2022.

Table 65 - Final Energy Consumption for all three sectors in 2022

Sector	Space Cooling	Space Heating	Water Heating	Total
	GWh	GWh	GWh	GWh
Residential	207.15	123.32	287.06	617.54
Services	243.13	189.02	85.76	517.91
Industry	59.07	5.70	4.46	69.23
Total	**509.35**	**318.05**	**377.28**	**1,206.12**

Following the analysis conducted across various sectors, the following representation serves as a consolidated overview of the Final Energy Consumption in GWh for space cooling, space heating, and water heating. Additionally, charts are provided to illustrate the Final Energy Consumption usage within each sector.

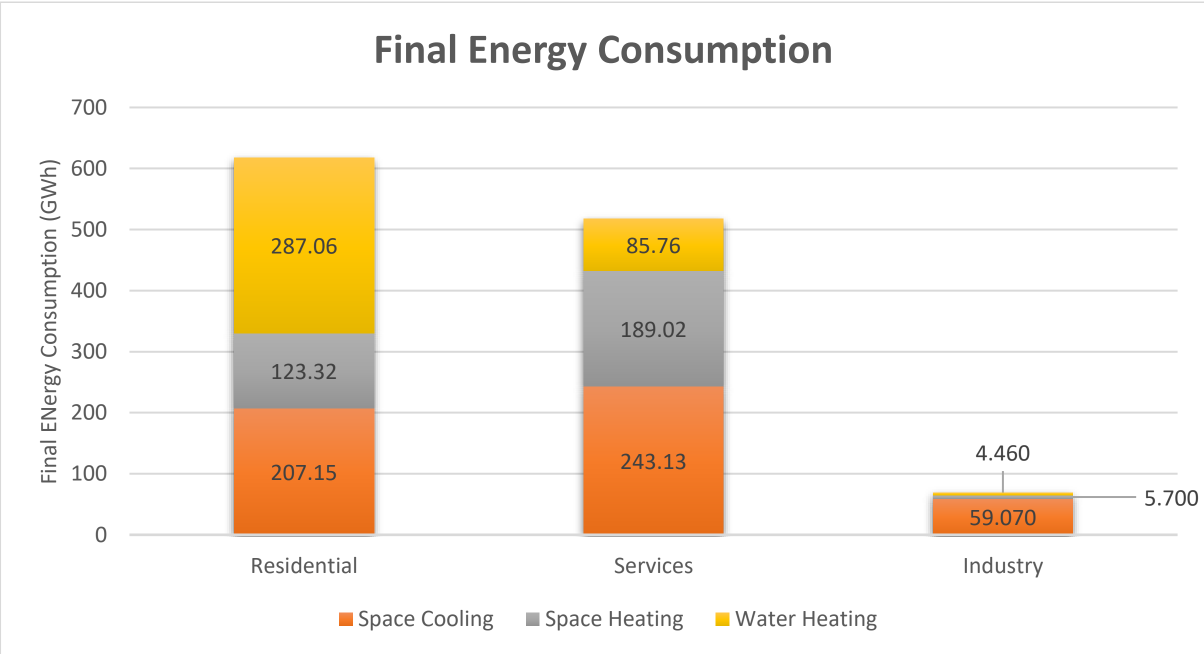

Figure 105 - Final Energy Consumption Distribution for the three different uses covering the residential, services and industry sectors

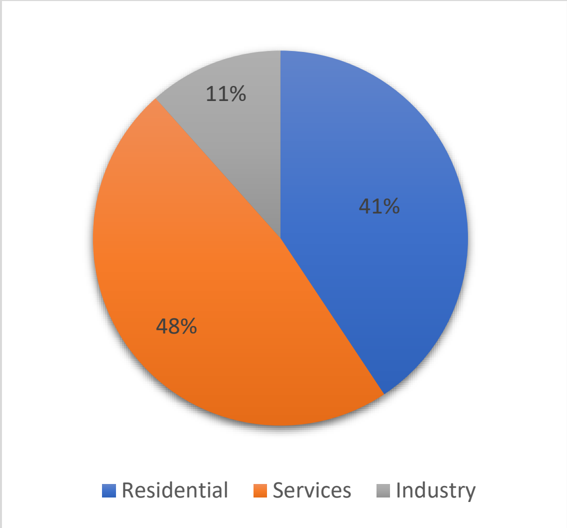

Figure 106 - Final Energy Consumption for Space Cooling distributed between the three sectors

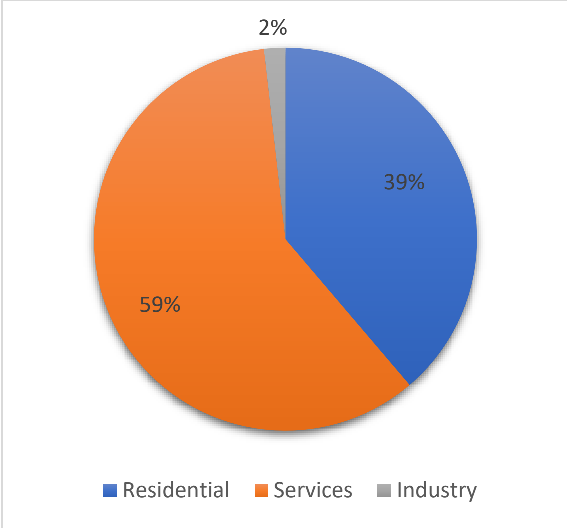

Figure 107 - Final Energy Consumption for Space Heating distributed between the three sectors

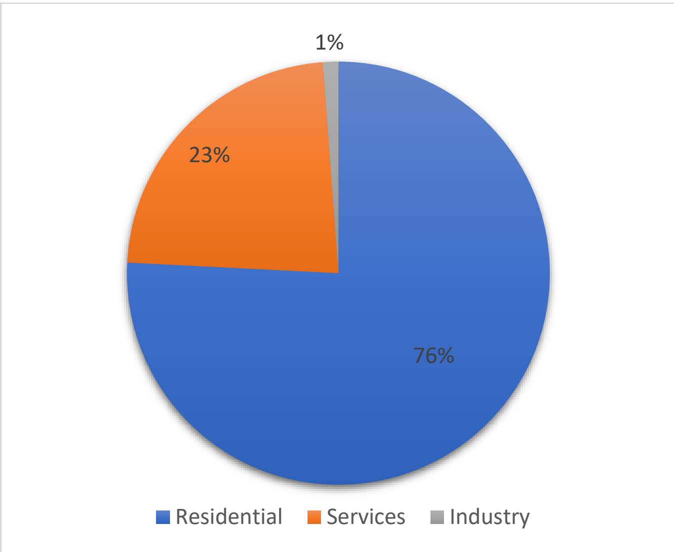

Figure 108 - Final Energy Consumption for Water Heating distributed between the three sectors

Below is a table presenting the Useful Energy Demand for the three sectors examined in this report, along with the corresponding totals for the base year 2022. Following the analysis conducted across various sectors, Figure 109 below offers a consolidated overview of the Useful Energy Consumption in GWh for space cooling, spatial heating, and water heating. Subsequently, figures are provided to depict the Useful Energy Consumption per usage within each sector.

Table 66 - Useful Energy Consumption for all three sectors in 2022

Sector	Space Cooling	Space Heating	Water Heating	Total
	GWh	GWh	GWh	GWh
Residential	638.04	340.96	258.36	1,237.35
Commercial and Services	807.10	663.27	78.99	1,549.36
Industry	244.18	20.25	4.00	394.35
Total	**1,689.31**	**1024.48**	**341.35**	**3,181.06**

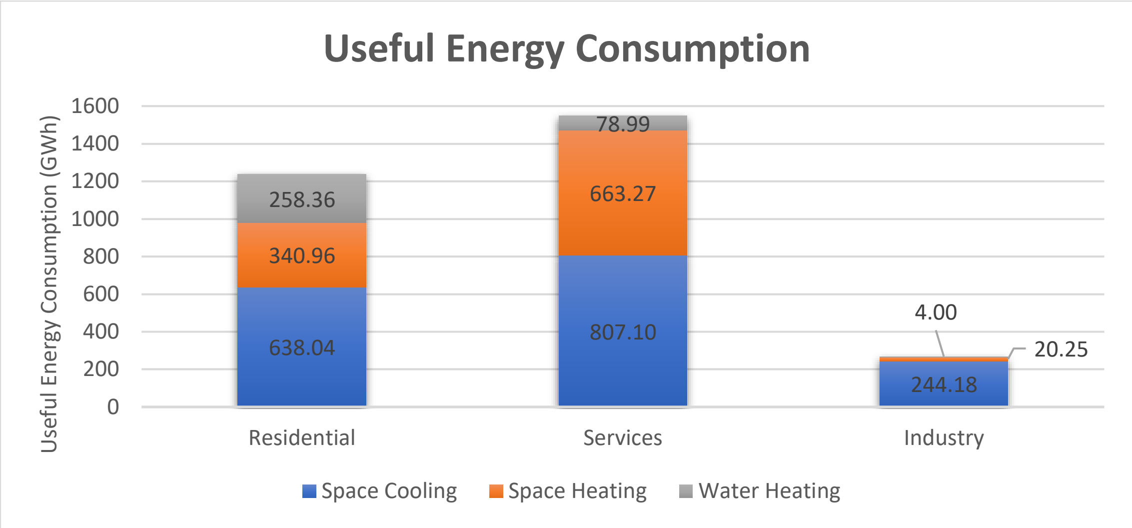

Figure 109 - Useful Energy Consumption Distribution for the three different uses covering the residential, services and industry sectors

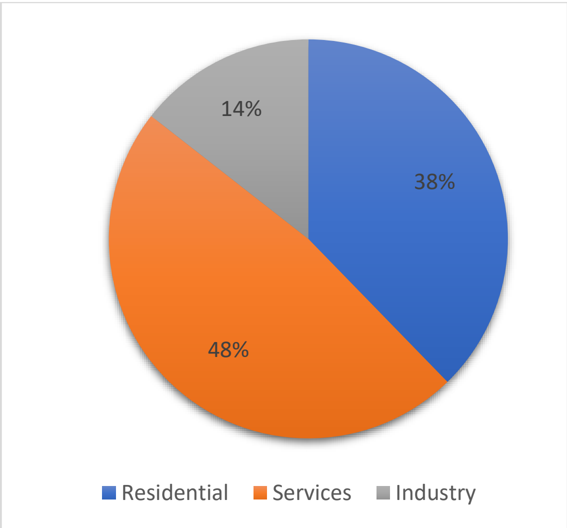

Figure 110 - Useful Energy Consumption for Space Cooling distributed between the three sectors

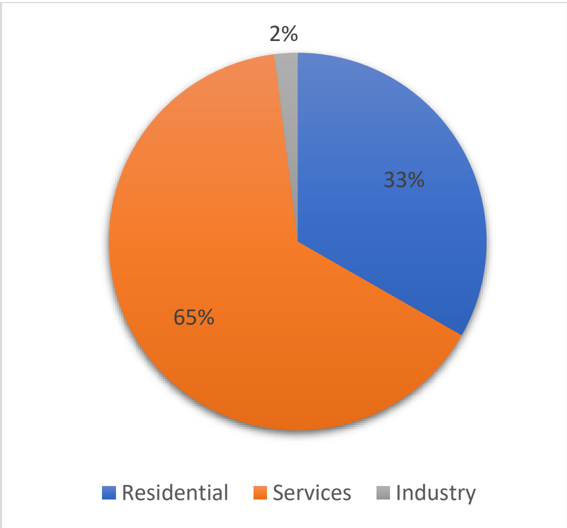

Figure 111 - Useful Energy Consumption for Space Heating distributed between the three sectors

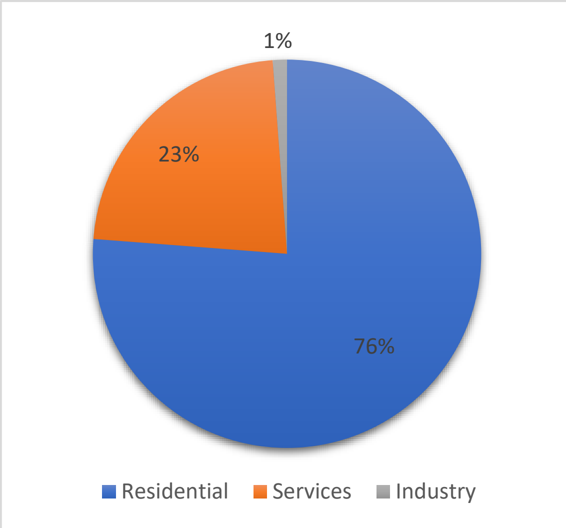

Figure 112 - Useful Energy Consumption for Water Heating distributed between the three sectors

1.7 Technology Analysis for Heating and Cooling Demand

As Malta aims to balance its energy needs with sustainability and efficiency, it's crucial to understand the various technologies driving on-site and off-site energy production. This analysis explores these technologies by sector, emphasizing their relevance to Malta's unique circumstances.

1.7.1 Supply by Technology

1.7.1.1 Residential Sector

The residential sector in Malta relies on a mix of fossil fuels, electricity and renewable energy sources for heating and cooling. Recent initiatives and policies focus on increasing energy efficiency and renewable energy technologies whilst reducing carbon emissions. An overview of the key technologies in use is presented hereunder.

Water Heating

(i) Electric Water Heaters: In Malta's residential sector, electric water heaters are a prevalent choice due to their efficiency, ease of installation, and reliability. Given the island's dense urban areas and limited space, compact electric heaters are favoured for their ability to provide a continuous supply of hot water without the need for extensive infrastructure. The warmer climate also reduces the energy demand, making electric water heaters a cost-effective solution for many households. Additionally, integrating electric water heaters with solar power systems can become a more sustainable option for this technology.

(ii) Solar Water Heaters: Malta has abundant sunshine, making solar thermal systems an option for residential water heating worth considering. Although not as widespread as rooftop solar photovoltaic systems, solar water heaters offer a sustainable source of hot water all year round. Solar water heaters typically have a backup heating element, usually electric, to ensure hot water availability during extended periods of low sunshine.

(iii) Heat Pump Water Heaters: Air source heat pumps (ASHPs) efficiently transfer heat from the outside air to provide hot water, often achieving a high COP. Ground source heat pumps (GSHPs) are less common due to the high installation costs and limited space in residential areas. Heat pump water heaters have recently been introduced in the local market, and uptake has, to date, been relatively low, despite available government incentives.

(iv) LPG Water Heaters: LPG water heaters are less common in Malta due to the lack of extensive natural gas infrastructure. The popularity of LPG water heaters in Malta is due to the good efficiency and supply on demand.

(v) Heat-Only Boilers: While these are less common in Malta due to the relatively warm climate, they are still found in larger residential buildings. Conventional boilers such as the conventional electric heaters generate heat for hot water but lack efficiency due to heat loss in storage tanks.

(vi) Instantaneous Water Heaters: Instantaneous water heaters, also known as tankless water heaters, are another choice in Malta due to their efficiency and space-saving design. Unlike traditional storage water heaters, they heat water on demand, offering a continuous supply of hot water without the need for large tanks. This makes them ideal for Malta's compact living spaces and varying water usage patterns. Their efficiency and ability to save energy by heating water only when needed contribute to their growing popularity in Malta.

Space Heating

(i) Heat Pumps (Air-to-Air): Air-to-air heat pumps are an efficient solution for space heating in residential homes in Malta, leveraging the ambient air to provide warmth during cooler periods. These systems work by extracting heat from the outside air and transferring it indoors, offering an energy-efficient alternative to traditional heating methods. In Malta's relatively mild climate, air-to-air heat pumps can effectively maintain a comfortable indoor temperature without the need for extensive fuel or electric consumption. Air-to-air heat pumps are becoming increasingly popular in Malta for meeting both heating and cooling demand.

(ii) LPG Heaters: LPG heaters are a practical option for space heating in residential homes in Malta. These heaters operate by burning LPG to generate warmth, effectively heating living spaces. Given Malta's mild winters, LPG heaters can quickly and efficiently warm rooms without the need for extensive installations. These heaters offer a flexible and cost-effective solution for space heating in Maltese homes, providing warmth when and where it's needed, with portability within the households and thus use of the same heater to heat up different spaces at different times.

(iii) Biomass heaters: Biomass heating offers a renewable option for space heating in residential homes in Malta, using organic materials such as wood pellets, chips, or logs to generate heat. Biomass heating systems in Malta is limited to small systems such as wood-burning stoves which can offer an eco-friendly alternative for residential space heating.

(iv) Electric Heaters: Electric heaters are a convenient option to achieve space heating in Maltese residential homes. These heaters use electrical energy to generate heat, providing quick warmth without the need for gas or fuel storage. Their simplicity, affordability, and availability make electric heaters a popular choice for homeowners in Malta seeking reliable space heating without complex installations.

(v) Underfloor heating: Underfloor heating is gaining popularity in Malta's residential sector due to its efficient and unobtrusive method of providing warmth. Given the island's relatively mild winters, underfloor heating systems offer a consistent and comfortable temperature. With advancements in technology, the installation of these systems has become more feasible, contributing to their increasing adoption in Maltese residences. These systems can be powered by electricity or fuel (such as LPG or gasoil).

(vi) Heat Only-Boilers: Heat-only boilers, designed exclusively for space heating, are used in some buildings to provide warmth during winter months. Unlike combination boilers, heat-only boilers don't produce domestic hot water for taps or showers; instead, they focus solely on heating radiators or underfloor systems. This makes them suitable for larger properties or settings with separate hot water systems. Heat-only boilers often include a separate hot water cylinder or tank, allowing for a consistent supply of hot water through other means, like electric water heaters or solar systems. In Malta, where space is a key consideration, these boilers are quite limited when it comes to their use for central heating.

Space Cooling

(i) Heat Pumps (Air-to-Air): Heat pumps (air-to-air) are commonly used for space cooling in the residential sector in Malta. These systems work in reverse heat pump mode by transferring heat from inside the home to the outside, effectively cooling indoor spaces during Malta's warm and humid summers. Air-to-air heat pumps offer an energy-efficient alternative to traditional air conditioning units, where such systems used to provide spatial cooling and not able to provide space heating in colder days. Heat-Pumps can also reverse the process to provide heating during cooler months, making them a versatile year-round solution. Their ability to serve both cooling and heating needs makes air-to-air heat pumps a popular choice among homeowners in Malta seeking cost-effective and energy-efficient solutions.

1.7.1.2 Services Sector

Malta's services sector, which includes hotels, restaurants, offices, retail, education, hospitals, elderly residential care and other public buildings, has a varied and complex energy profile. Key technologies used in this sector are outlined below.

Water Heating

(i) Heat-Only Boilers: Heat-only boilers play a significant role in providing hot water in Malta's services sector, especially in commercial settings like hotels and restaurants. In Malta's temperate climate, heat-only boilers can efficiently support the hot water demands of the services sector, allowing businesses to run smoothly and meet health and safety standards. Overall, heat-only boilers offer an effective solution for businesses in Malta that require a dedicated hot water source without the complexity of combined heating systems. These are typically found in older services sector buildings and are being phased out in favour of more efficient technologies.

(ii) Heat Pump Water Heaters: Heat pump water heaters are an increasingly popular choice for water heating in Malta's services sector, providing an energy-efficient solution for businesses such as hotels, restaurants, and fitness centres. Unlike traditional water heaters, heat pumps extract heat from the surrounding air and transfer it to water, offering a more sustainable and cost-effective method for meeting hot water demands. Heat pumps for water heating can significantly reduce energy costs and carbon emissions, aligning with environmental goals while supporting business operations. Water source heat pumps are also used in some hotels and larger commercial buildings with access to a suitable water source.

(iii) High Efficiency Heat and Power Co-Generation (HECHP or CHP): Combined Heat and Power (CHP) systems are used in some facilities to generate electricity and heat simultaneously, providing an efficient energy solution. Malta has a small number of licensed CHP plants. Several challenges affect the adoption of a CHP system, such as the seasonality, where heat is not really a requirement in summer given Malta’s warmer climate, and thus the heat generated through CHP would not be required in certain enterprises. In turn, the return on investment (ROI) is long. There are also specific licensing challenges, particularly because gas-fired engines cannot be stored underground according to Maltese legislation, thus making their installation and operation more difficult.

(iv) Solar Water Heating Systems: Solar water heaters may be installed to generate water heating whilst providing a more efficient energy solution, however the installation of such systems may not always be possible due to limitations of roof access or space.

(v) Waste Heat Recovery (WHR) Systems: WHR systems for water heating are used in Malta's service sector. These systems capture and repurpose excess heat from various operations within the enterprise, such as HVAC systems or commercial kitchens, converting it into useful energy for heating water within the same enterprise. By utilizing this heat, businesses in Malta can significantly reduce energy costs and improve overall efficiency, contributing to sustainability goals and reducing carbon emissions.

Space Heating

(i) Heat Pumps (Air-to-Air): Heat Pumps are used in the services sector in Malta, especially in businesses seeking energy-efficient climate control. These systems work by transferring heat between indoor and outdoor environments, providing heating during cooler periods. These makes them ideal for hotels, restaurants, and office spaces, amongst others. Overall, air-to-air heat pumps represent a practical and eco-friendly solution.

(ii) Heat Only-Boilers: Heat-only boilers are used for space heating in the service sector in Malta, particularly in businesses that require consistent and reliable heating during winter months. These boilers generate heat for radiators or underfloor heating systems, providing warmth to spaces like hotels, offices, and restaurants. Heat-only boilers used in this sector usually also provide water heating production. They are valued for their simplicity and efficiency, offering a straightforward solution to maintain comfortable indoor temperatures.

(iii) High Efficiency Heat and Power Co-Generation: CHP systems are used in Malta's services sector for water heating, providing a highly efficient approach to energy use. CHPs generate electricity and heat simultaneously from a single energy source, typically through the combustion of gasoil/diesel, natural gas, biomass, or other fuels. This dual production process makes CHPs especially attractive in the services sector where both electricity and hot water are needed for various processes. In Malta, CHP systems can help enterprises reduce energy costs and improve overall efficiency by capturing and utilizing heat that would otherwise be wasted. While CHPs require a significant initial investment and careful installation, their long-term benefits in terms of energy efficiency and cost savings make them a valuable addition to Malta's business sector.

Space Cooling

(i) Air-to-Air Heat Pumps: Air-to-air heat pumps are valued for their versatility and energy efficiency. They can be installed as split systems or centralised systems, with a unit indoors (or multiple units in the case of centralised systems) and a compressor outdoors, allowing for flexibility in installation and efficient space cooling. Additionally, many air-to-air heat pumps can reverse their operation to provide heating during cooler months, offering year-round climate control. This dual-function capability is especially useful in Malta's service sector, where buildings often require both cooling and heating at different times of the year.

(ii) Heat Pump Water Heaters: Heat pump water heaters are used in the service sector for spatial cooling in Malta, although they are less common compared to air-to-air systems. They work by extracting heat from the air and transferring it to a water-based system, which can then circulate the cooled water through fan coil units, chilled beams, or other distribution methods to cool indoor spaces. This approach is typically used in larger buildings, hotels or commercial complexes where there is an existing infrastructure for water-based heating and cooling. These systems are beneficial because they can provide both heating and cooling, offering flexibility for businesses that require year-round climate control. Heat pump water heaters are generally more efficient for central cooling in larger spaces, and they align with Malta's sustainability goals by using renewable energy sources.

(iii) Thermal Treatment Plants: Malta has a Thermal Treatment Facility (TTF) that uses biomass from animal tissue waste to generate energy. This contributes to a reduction in fossil fuel use in the services sector.

1.7.1.3 Industry Sector

The industry sector in Malta has traditionally relied on fossil fuels for energy needs for heating and cooling, but there is a growing shift toward renewable energy sources and electricity-based energy-efficient technologies. A summary of key technologies is provided below.

Water Heating

(i) Heat Only-Boilers (Water heating): Heat-only boilers are used in Malta's industrial sector for water heating, serving as a reliable source of hot water for various industrial processes. These boilers focus solely on heating water without providing space heating, making them ideal for industrial applications that require consistent hot water for cleaning, sanitation, or manufacturing processes. In Malta, industries such as food processing, pharmaceuticals, and manufacturing utilize heat-only boilers to maintain the hot water supply essential for their operations. These boilers can be powered by different energy sources, including LPG, oil, or electricity, depending on the specific needs and infrastructure of the facility. Overall, heat-only boilers are a practical and efficient solution for water heating in Malta's industrial sector.

(ii) Heat Pump Water Heaters: are used in Malta's industry sector for water heating, providing an energy-efficient and sustainable solution for various industrial processes. These systems work by extracting heat from the surrounding air and transferring it to water, offering a renewable alternative to conventional boilers. Industries that require hot water for manufacturing, food processing, or cleaning can benefit from the energy efficiency and versatility of heat pumps. They can be designed to meet the specific needs of different industrial applications, and some heat pumps can also reverse their operation for space cooling, providing additional flexibility. Overall, heat pumps offer a cost-effective and environmentally friendly solution for water heating in Malta's industry sector.

(iii) Waste Heat Recovery Systems: WHR systems are used in Malta's industry sector for water heating, offering a sustainable and energy-efficient solution to repurpose excess heat from industrial processes. These systems capture heat from sources like manufacturing machinery, exhaust gases, or other high-temperature operations and convert it into useful energy for water heating or other applications. In Malta's industrial sector, WHR systems are particularly valuable because they help reduce energy costs, improve operational efficiency, and lower carbon emissions.

Spatial Heating

(i) Heat only-boilers: Heat-only boilers are a common choice, providing a reliable source of heat for spaces without contributing to water heating. In industrial environments, they are valued for their simplicity and cost-effectiveness.

(ii) Heat Pumps: Heat pumps, especially air-to-air models, offer a versatile solution by transferring heat from the outside air to indoor spaces, providing an energy-efficient method for maintaining comfortable temperatures.

Spatial Cooling

(i) Air-to-Air Heat Pumps: In the industry sector in Malta, air-to-air heat pumps are more commonly used for spatial cooling compared to heat pump water heaters. Air-to-air systems are designed specifically for cooling applications, making them ideal for instance in offices within industrial environments, where maintaining a comfortable temperature is crucial for worker comfort.

1.7.2 On- and Off- Site Energy Production

On-site and off-site energy generation represent contrasting approaches to meeting energy needs. On-site energy generation, occurring directly at or near the point of consumption, offers increased control, flexibility, and resilience for end-users. It enables customization of energy systems to suit specific needs, provides backup power during grid outages, and potentially yields long-term cost savings, as well as a reduction in transfer losses.

Conversely, off-site energy generation, conducted at centralised facilities separate from consumers, benefits from economies of scale, enabling more efficient and cost-effective energy production. While off-site generation can facilitate the integration of renewable resources and support grid stability, it relies heavily on transmission and distribution networks, making it susceptible to disruptions.

1.7.2.1 Combined Heat and Power Plants

In Malta there are only four co-generation or CHP plants, licensed by the REWS.[68] These plants are as follows:

- Malta North Mechanical Biological Treatment CHP, consisting of a reciprocating engine for a total of 1.523 Mwe. The plant is owned by Malta's national waste management company.

- Ta' Barkat Sewage Treatment Plant, consisting of 3 reciprocating engines with a total capacity 1.11MWe. The plant is owned by Malta's national water utility.

- Maghtab CHP, which has a reciprocating engine of 190 kWe. The plant is owned by Malta's national waste management company.

- A CHP with a reciprocating engine of 49kWe within a private swimming pool facility.

1.7.2.2 Thermal power generators

Delimara Power Station's D3 plant, with a total capacity of 139 MWe (excluding the Steam Turbine Generator) is equipped with a heat recovery system which makes use of heat generated by the internal combustion engines to produce fresh water, and thus it is being considered as a cogeneration process.

1.7.2.3 Waste incinerator plants

Malta has only one waste incineration plant which is the TTF located in Marsa. This consists of an autoclave plant that treats animal tissue waste prior to the incineration process. The process has a by-product of tallow (animal fat) which is used in the incinerator as fuel. This in turn results in fuel savings in the operation of the incinerator.

[68] REWS - 2021 Annual Report - https://www.parlament.mt/media/117155/00129.pdf

Malta has plans for a waste-to-energy TTF, set to be commissioned before 2030. This facility is expected to process 192,000 tonnes of non-recyclable waste per year.

1.7.2.4 Summary of energy production

Malta does not have an existing heating and cooling distribution network. Thus, there are no cases of off-site thermal energy production. This is especially true in the larger scale generation. The values being indicated in the table below for energy provided on-site have been obtained through the analysis carried out in the earlier sections of Part I.

Table 67 - Energy provided on site for the three different sectors under study by means of fossil fuel sources and renewable energy sources for 2022

Energy Provided On-Site			Unit	Value
Residential Sector	Fossil Fuel Sources	Heat Only Boilers	GWh	331.41
		Other Technologies	GWh	286.13
		HECHP	GWh	0
	Renewable Energy Sources	Heat Only Boilers	GWh	0
		Other Technologies	GWh	50.54
		Heat Pumps	GWh	331.64
		HECHP	GWh	0
Service Sector	Fossil Fuel Sources	Heat Only Boilers	GWh	89.54
		Other Technologies	GWh	387.49
		HECHP	GWh	0
	Renewable Energy Sources	Heat Only Boilers	GWh	0
		Other Technologies	GWh	0
		Heat Pumps	GWh	175.74
		HECHP	GWh	0
Industrial Sector	Fossil Fuel Sources	Heat Only Boilers	GWh	5.87
		Other Technologies	GWh	63.36
		HECHP	GWh	0
	Renewable Energy Sources	Heat Only Boilers	GWh	0
		Other Technologies	GWh	0
		Heat Pumps	GWh	25.79
		HECHP	GWh	0

1.7.3 Installations generating waste heat or cold

Annex X of Directive (EU) 2023/1791 requires the identification of installations that generate waste heat or cold and their potential heating or cooling supply for the below systems:

- Thermal power generation installations that can supply or can be retrofitted to supply waste heat with a total thermal input exceeding 50 MW;

- Heat and power cogeneration installations (using technologies referred to in Part II of Annex I of the Directive) with a total thermal input exceeding 20 MW;

- Waste incineration plants;

- Renewable energy installations with a total thermal input exceeding 20 MW; and

- Industrial installations with a total thermal input exceeding 20 MW which can provide waste heat.

As already outlined, Malta does not have any district heating and cooling network, thus there is no potential for generating waste heat or cold.

1.7.4 Share of Energy from Renewable Sources and Waste Heat or Cold in the Heating and Cooling Sector

In earlier sections of Part I of this report, where the energy use for heating and cooling purposes was assessed for residential, services and industry sectors, reference was made to renewables. The generation of renewable energy through solar water heating, biomass and heat pumps is produced in the table below.

Table 68 - Renewable energy (in GWh) generated in heating and cooling sector in 2022

Sector	Total	Spatial Cooling[69]	Spatial Heating[70]	Water Heating
Residential	382.18	199.80	145.05	37.33
Services	175.74	93.39	82.35	0.00
Industry	25.79	23.48	2.31	0.00
Total	**583.71**	**316.67**	**229.71**	**37.33**

In accordance with Article 23 1b of the amending Directive (EU) 2023/2413, Member States are tasked with assessing their potential for renewable energy, alongside the use of waste heat and cold in the heating and cooling sector. This assessment is to include an analysis of areas suitable for deployment at low ecological risk and the potential for small-scale household projects. It must also take into account the available and economically feasible technology for both industrial and domestic applications. The ultimate aim is to establish milestones and measures that will increase the use of renewable energy in heating and cooling, and where fitting, the use of waste heat and cold through district heating and cooling.

[69] Eurostat - Renewable cooling – ambient energy by technology – nrg_ind_rcaebt https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_rcaebt__custom_12121930/default/table?lang=en&page=time:2021

[70] Eurostat – Heat Pumps – ambient heat captured by technology and climate – nrg_ind_ahbtc https://ec.europa.eu/eurostat/databrowser/view/nrg_ind_ahbtc__custom_12122177/default/table?lang=en

This assessment identifies that Malta, due to its lack of heating and cooling networks, does not have the potential for utilizing waste heat and cold. However, the potential for renewable sources in heating and cooling is a significant part of the assessment. Part I shows that technologies such as heat pump water heaters and solar water heaters are found within the residential sector and used for water heating, while biomass is used for space heating, and air-to-air heat pumps cater to both cooling and heating needs. The services and industry sectors employ similar technologies such as centralized and individual air conditioning systems and industrial-sized heat pump water heaters.

As the most densely populated and urbanised Member State within the EU, Malta faces distinct constraints in the deployment of renewable energy technologies. The island's dense urban landscape leaves little room for large-scale installations. This limitation necessitates an integrated approach to renewable energy solutions, focusing on technologies that can be embedded within the existing urban infrastructure. The warmer climate skews the demand towards cooling rather than heating needs within both residential and non-residential buildings. Heating demand is extremely low, thus making renewable energy solutions for spatial heating mostly irrelevant in the local scenario.

Despite these constraints, the renewable energy technologies currently in use within buildings offer a solution to Malta's urban landscape and climate. The government has implemented financial incentives that support renewable energy investments in both households and enterprises. Part II of the report delves into the existing renewable energy interventions and proposes new ones in Part III, with a view to assess their financial and economic feasibility. These interventions are tailored to fit within urban environment and are generally considered to be of low ecological risk. They are also suitable for both single and multi-family homes, enhancing their potential for widespread adoption.

1.8 Maps covering Heating and Cooling Demand in the National Territory

This section presents maps covering the entire national territory, identifying heating and cooling demand areas based on the preceding analysis of residential, service, and industrial sectors. More detailed sectoral maps can be found in Annex I of this report. Currently, in Malta electricity consumption by locality is metered by residential/non-residential account. On the other hand, there is no fuel distribution network, and therefore it was not possible to identify fuel consumption by locality for the economic sector, whereas fuel consumption for the residential sector was estimated based on the number of households in each locality.

1.8.1 Residential Sector

Figure 113 depicts the energy consumption in the residential sector at locality level, with values assigned to each area according to the Local Administrative Unit (LAU) based on the electricity consumption of each specific locality. The figure represents the final energy consumption in GWh, adjusted to reflect the 2022 households in relation to the respective locality. The final energy consumption includes solar thermal energy, biomass and electricity used for heating, cooling, space heating and water heating. Notably, San Pawl il-Baħar stands out as a significant contributor to overall energy consumption, which can be linked to its larger population size, housing nearly 16,000 residences. Birkirkara follows closely, with approximately 11,000 primary dwellings.

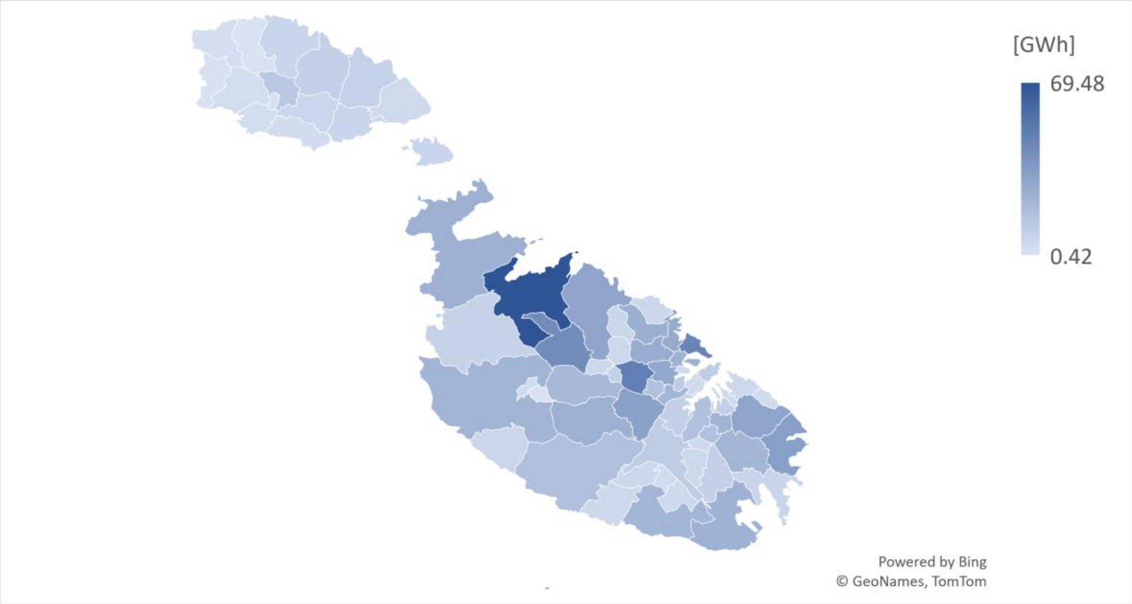

Figure 113 - Residential Total Final Electricity consumption in GWh

1.8.2 Industry Sector

The maps being presented for the industrial sector represent data at the territorial level obtained in the previous analysis.

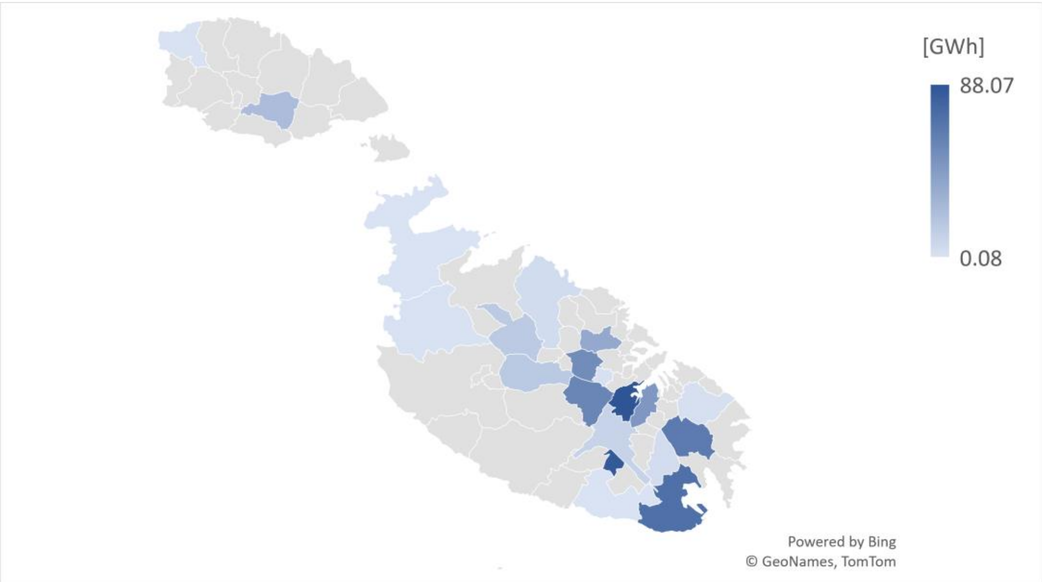

Figure 114 - Industrial Final total electricity consumption in GWh

For the industry sector, the energy consumption values for each LAU were derived from the electricity usage in each corresponding area.[71] The figure presented above displays the total energy consumption measured in GWh for each locality. The map distinctly indicates that Marsa and Kirkop are the predominant consumers of energy, with consumption figures at 88 GWh and 85 GWh, respectively. The energy consumption values assigned to each LAU were calculated based on the electricity usage and the geographical extent of each industrial zone within the Maltese Islands. The specific footprints utilized for these calculations are documented in Table 69.

Table 69 - Industrial Area footprint in m^2

Location	**Industrial Area (m^2)**
Attard	57,819
Birkirkara	194,332
Qormi	210,849
Birzebbugia	260,110
Gharb	1,906
Xewkija	87,654
Il-Marsa	321,701
Zejtun	234,638
Paola	171,729
Zabbar	6,644
Mosta	55,974
Naxxar	15,653
Luqa	36,467
Kirkop	30,888
Ghaxaq	13,634
Zurrieq	536
Mgarr	3,195
Mellieha	305
San Gwann	130,574
Santa Venera	5,091

[71] Electricity Consumption by LAU - Enemalta

1.8.3 Commercial and Services Sector

For the services sector, the values attributed to each LAU were obtained from the electricity consumption in each respective area. Figure 115 depicts the final energy consumption in GWh for each locality. The data illustrates that St. Julian's is the predominant consumer of final energy, with a consumption of 92.05 GWh, while Msida ranks second with an estimated final energy use of 81.21GWh.

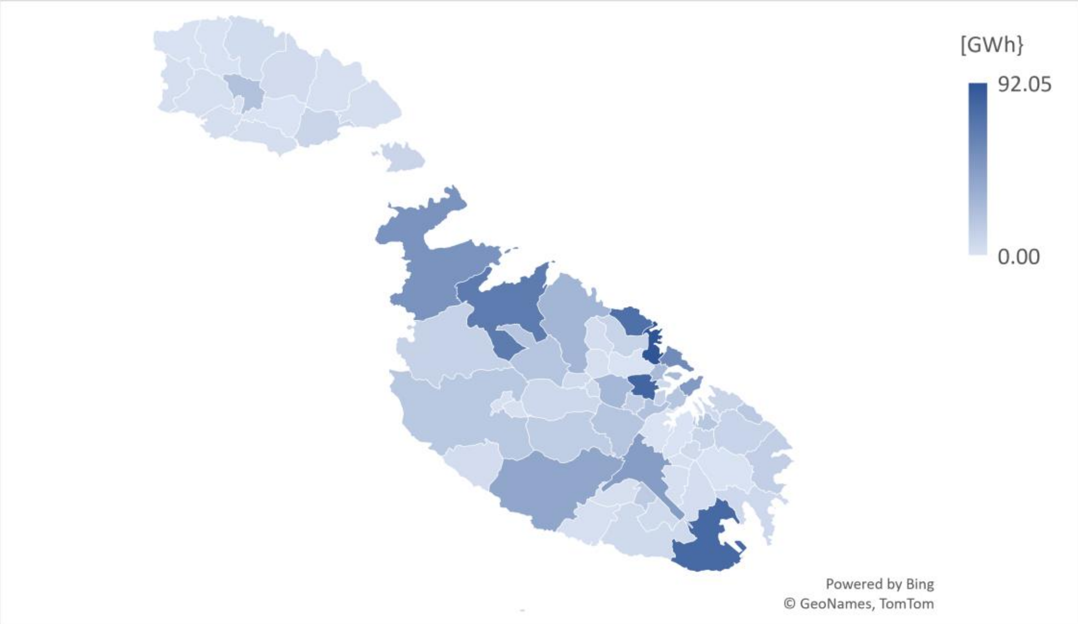

Figure 115 – Commercial and Services Sector Final total electricity consumption in GWh

1.9 Forecast of Trends for Heating and Cooling Demands for the next 30 years

The forecast presented in this section considers the influence of national energy efficiency policies and strategies, as well as heating and cooling demands, across residential, industry and services sectors in Malta. The projection spans over the next three decades, reaching up to the year 2053. Projections for total final electricity and fuel consumption by sector until 2040 were provided by EWA. These are based on the latest demographic and macroeconomic indicators. Based on this data, growth rates were estimated and used to extrapolate consumption to 2053. The ratios obtained for electricity and fuel consumption by end-use in Part 1 were applied on the total forecasted electricity and fuel consumption to obtain a forecasted energy consumption by end-use.

1.9.1 Residential Sector

The forecast for the residential sector is shown in Figure 116. It is based on the outcome of a specifically developed modelling tool for evaluating policies, measures, and their effects on future demand scenarios. These scenarios rely on certain assumptions about framework conditions such as demographic changes, economic activities, technological advancements, energy costs/prices, and other significant variables. For this analysis, Malta has tailored its own methodology and assumptions to predict key macroeconomic indicators, including population numbers, GDP, sectoral Gross Value Added (GVA), household size, number of households, and disposable income.

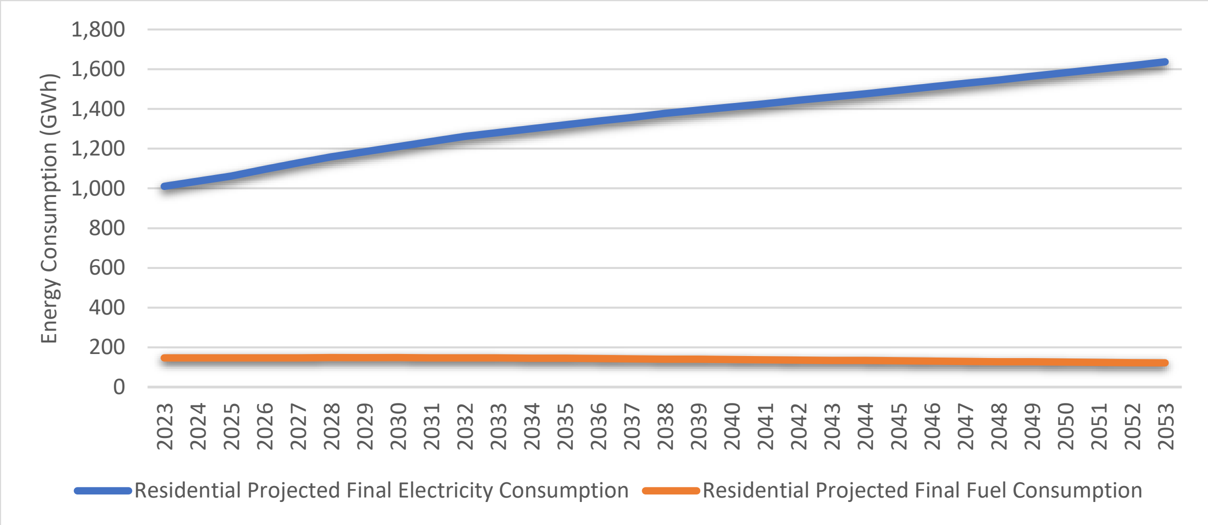

Figure 116 - Final Projected Energy Consumption for the Residential sector

Moreover, the policies and measures, whether already in place or planned for future implementation, are incorporated into the models as normalised variables. The data derived from EWA primarily reflects total electricity and fuel consumption. Adjustments to these values were made to reflect the heating and cooling demand and the anticipated rise in heat pump installations within the residential sector.

For projections extending to 2053, the annual percentage increase in the total electricity consumption in the residential sector household from 2023 to 2040 was calculated and then applied to the period leading up to 2053, taking into account the expected annual increase in the number of households.

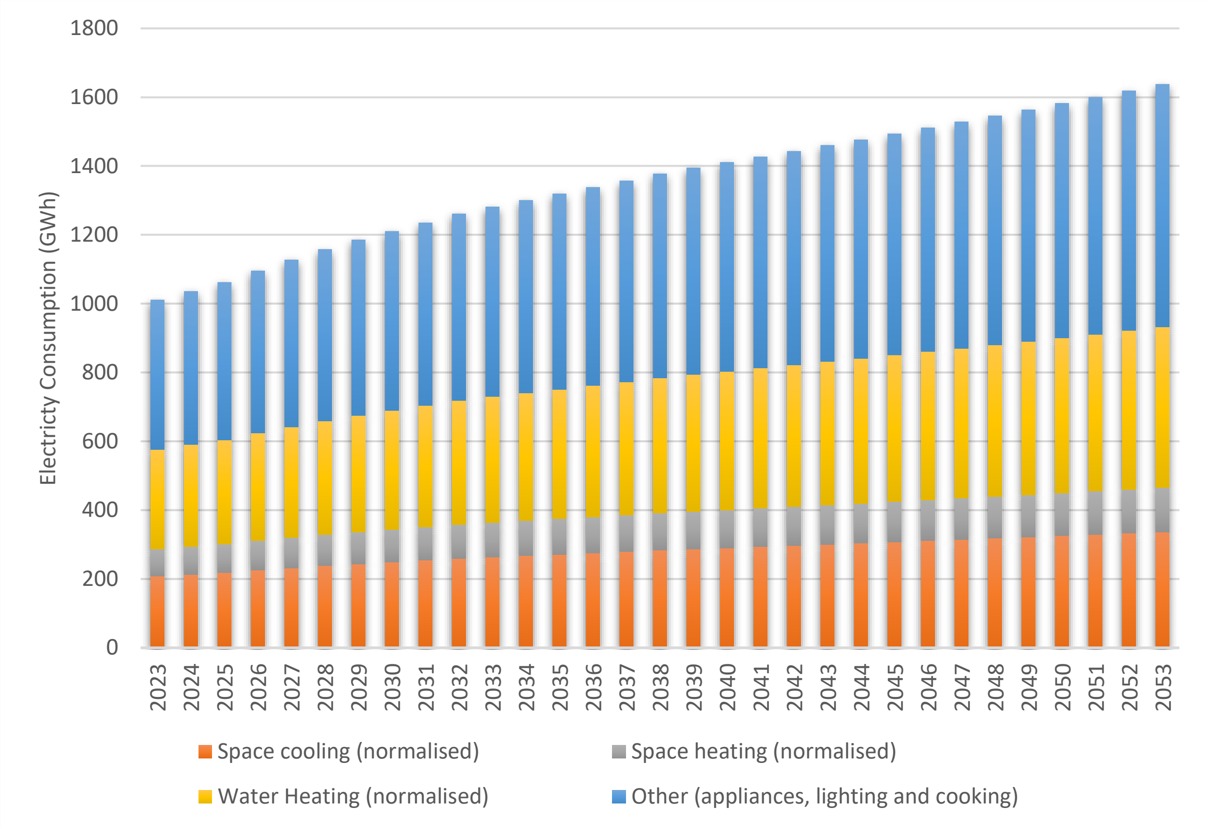

Figure 117 - Projected electricity consumption distribution for the residential sector from 2023 to 2053

Table 70, presented below, details the annual projected electricity demand for heating and cooling in the residential sector, covering the years 2023 to 2028. The complete projected dataset between 2023 and 2053 is available in Annex II of this report.

Table 70 - Projected electricity consumption distribution for the residential sector from 2023 till 2028

Electricity consumption	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
Total Electricity consumption (Projected)	**1,010.51**	**1,036.26**	**1,061.31**	**1,094.93**	**1,127.51**	**1,157.82**
of which						
Spatial cooling (normalised)	207.98	213.28	218.43	225.36	232.06	238.30
Spatial heating (normalised)	79.29	81.31	83.27	85.91	88.47	90.85
Water heating	288.20	295.55	302.69	312.28	321.58	330.22
Other (appliances, lighting and cooking)	435.03	446.12	456.90	471.38	485.41	498.45

Figure 118 displays the demand for heating and cooling derived from fuel sources such as LPG, solar water heaters, and biomass. Table 71 outlines a year-by-year projection of the heating and cooling demand met by fuel in the residential sector from 2023 to 2028. The complete set of forecasted data spanning from 2023 to 2053 can be found in Annex II of this report. It is observed that fuel consumption is expected to decrease, which is attributed to the anticipated rise in the number of households utilizing heat pumps.

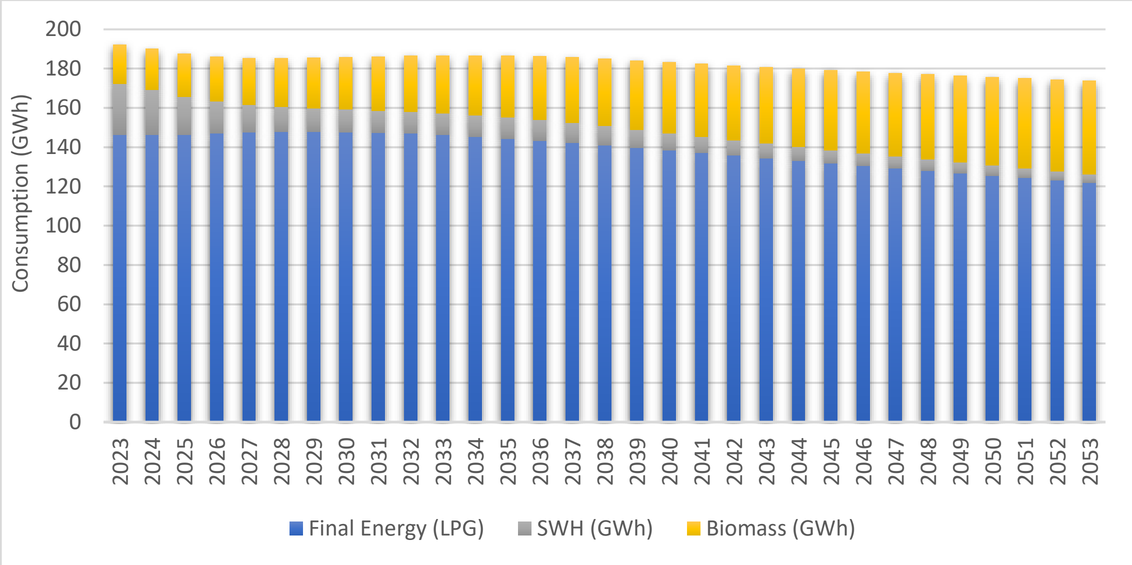

Figure 118 - Projected fuel consumption and solar thermal generation for the residential sector

Table 71 - Projected fuel consumption and solar thermal generation for the residential sector from 2023 - 2028

Year	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
Fossil Fuel (LPG)	146.3	146.3	146.2	147.0	147.5	147.9
Solar Water Heaters (SWH)	26.1	22.9	19.5	16.5	14.2	12.8
Biomass	19.9	20.8	21.8	22.7	23.7	24.6

1.9.2 Industry Sector

The forecast of total final energy consumption in the industrial sector until 2040 is based on EWA estimates. From 2041 to 2053, the annual growth rate for total final energy consumption in this sector follows the average growth rate estimated between 2022 and 2040.

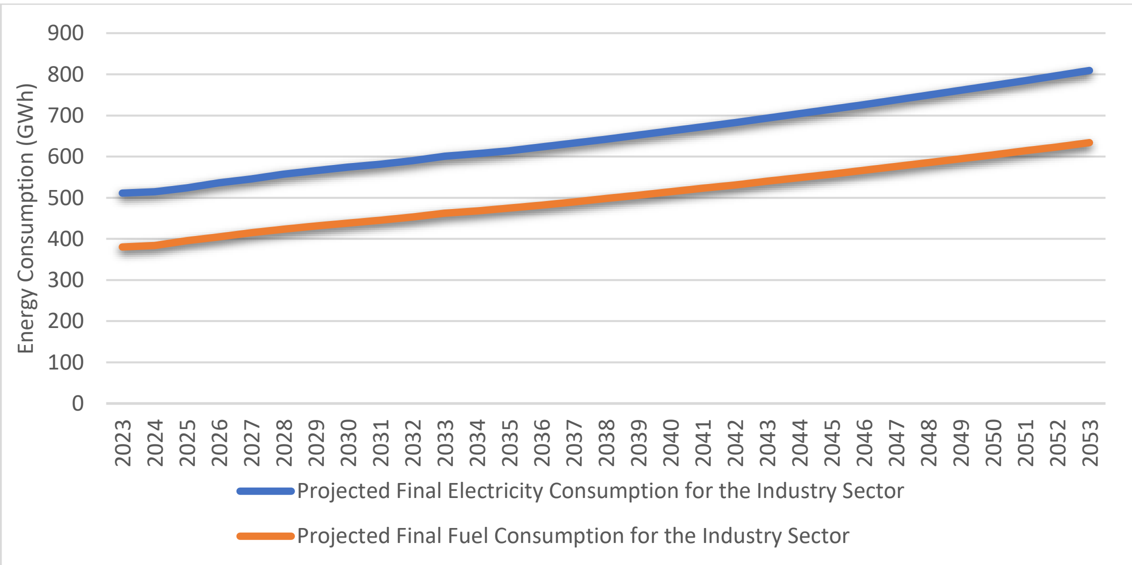

Figure 119 - Final projected energy consumption for the industry sector

To determine the percentage shares for heating and cooling, 2022 data was utilized as a starting point. It is then anticipated that the demand for heating and cooling will grow at an annual rate of 1.53% from the year 2041 through to 2053.

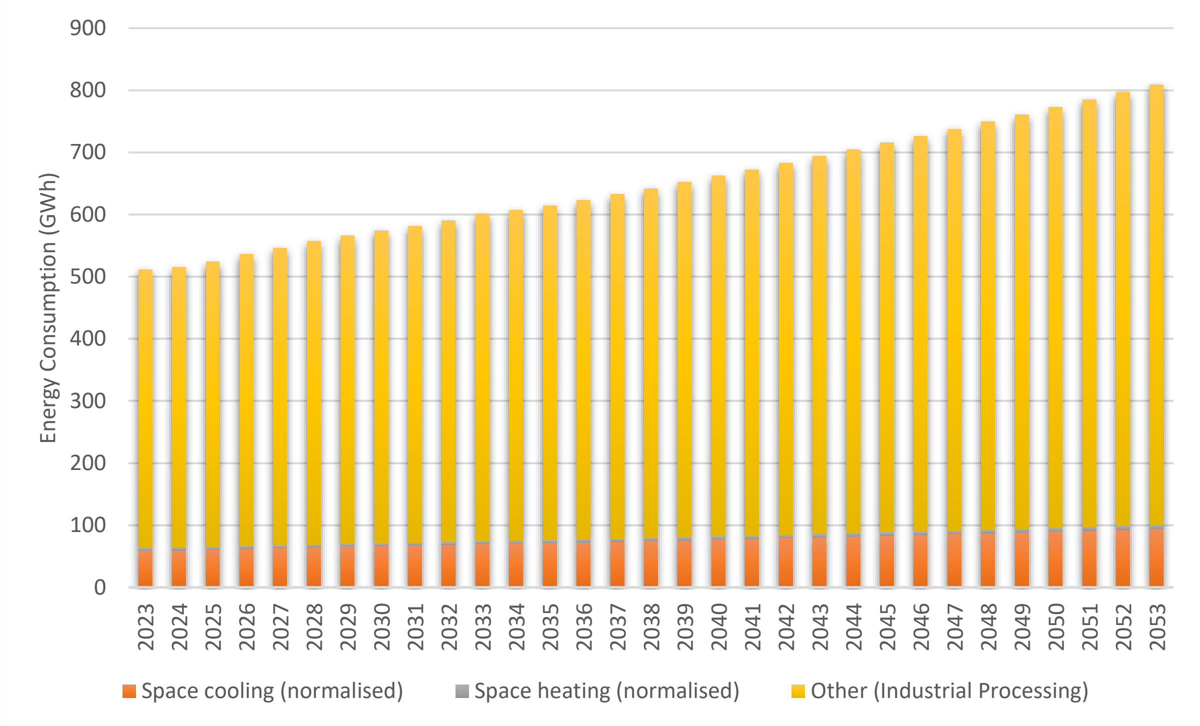

Figure 120 - Projected electricity consumption distribution for the industry sector

Table 72, presented below, outlines the annual projected electrical heating and cooling demand for the industry sector from 2023 to 2028. The full forecasted dataset until 2053 is available in Annex II of this report.

Table 72 - Projected electricity consumption distribution for the industry sector from 2023 till 2028

Year	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
Total Electricity consumption (Projected)	**511.3**	**514.9**	**524.0**	**536.3**	**545.9**	**557.1**
of which						
Spatial cooling (normalised)	59.63	60.04	61.11	62.54	63.66	64.97
Spatial heating (normalised)	4.35	4.38	4.46	4.57	4.65	4.74
Water heating	n/a	n/a	n/a	n/a	n/a	n/a
Other (Industrial Processing)	447.31	450.45	458.42	469.15	477.61	487.43

Table 75 outlines a year-by-year projection of the heating and cooling demand met by fuel in the industrial sector from 2023 to 2028. The complete set of forecasted data spanning from 2023 to 2053 can be found in Annex II of this report.

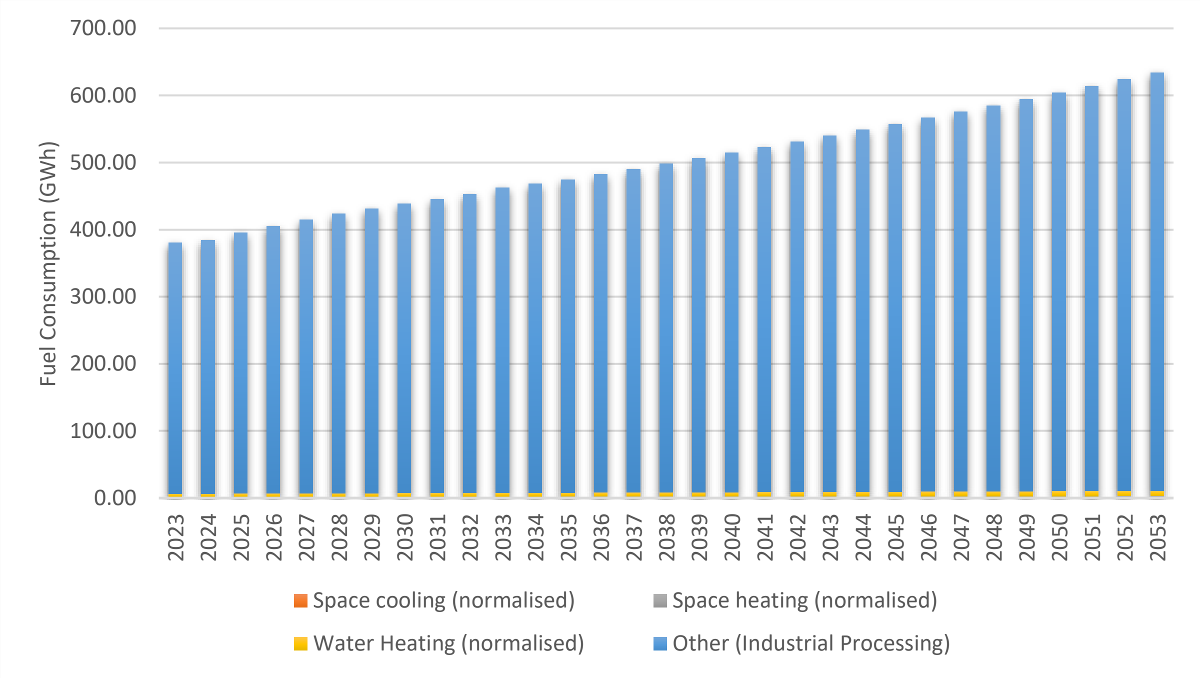

Figure 121 - Projected Fuel distribution for the Industry sector

Table 73 - Projected fuel consumption distribution for the industry sector from 2023 till 2028

Year	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**
Total Fuel consumption (Projected)	**380.3**	**384.1**	**395.7**	**405.1**	**414.6**	**423.7**
of which						
Spatial cooling (normalised)	0.36	0.37	0.38	0.39	0.40	0.40
Spatial heating (normalised)	1.51	1.52	1.57	1.60	1.64	1.68
Water heating	4.75	4.80	4.94	5.06	5.18	5.29
Other (Industrial Processing)	373.72	377.46	388.86	398.05	407.41	416.33

1.9.3 Commercial and Services Sector

For the commercial and services sector, the projected annual growth rate for total final energy consumption from 2041 to 2053 is based on the average annual growth percentage observed from 2022 to 2040. To estimate the share of energy consumption dedicated to space cooling, space heating, and water heating for the years 2041 to 2053, the 2022 energy consumption for these specific functions was used. The growth rates for each category of end-use were extrapolated from EWA's data to project figures up to the year 2040, and these trends were then extended to project values for 2053.

The percentage contributions of heating and cooling demand were estimated starting with the 2023 data, assuming an annual increase in the demand for heating and cooling of 0.33% from 2041 to 2053. This projection is depicted in Figure 122.

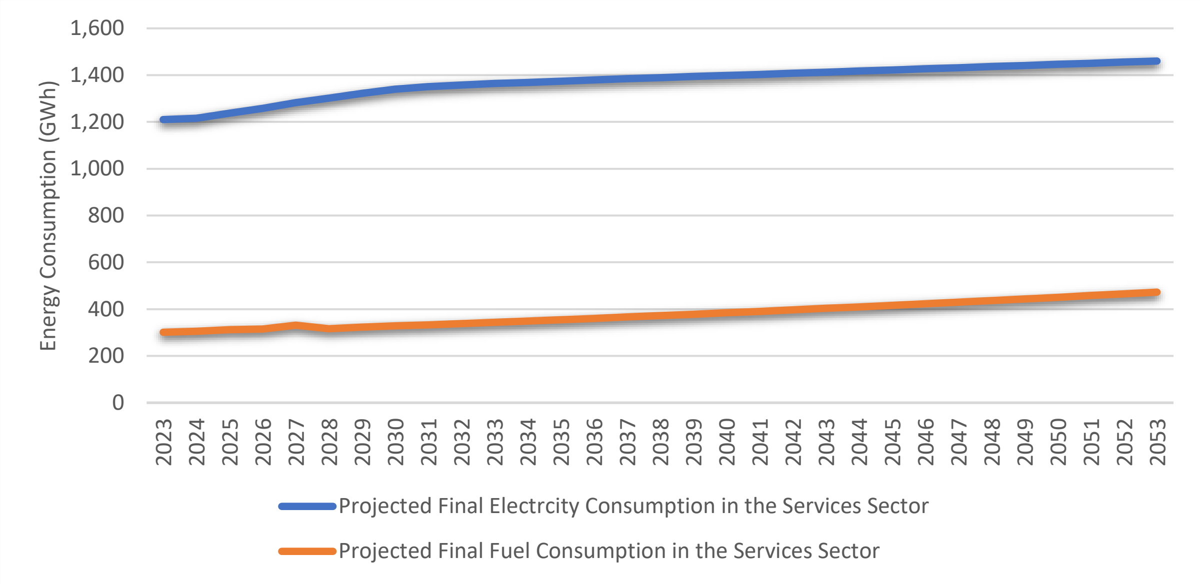

Figure 122 - Final projected energy consumption for the Services sector

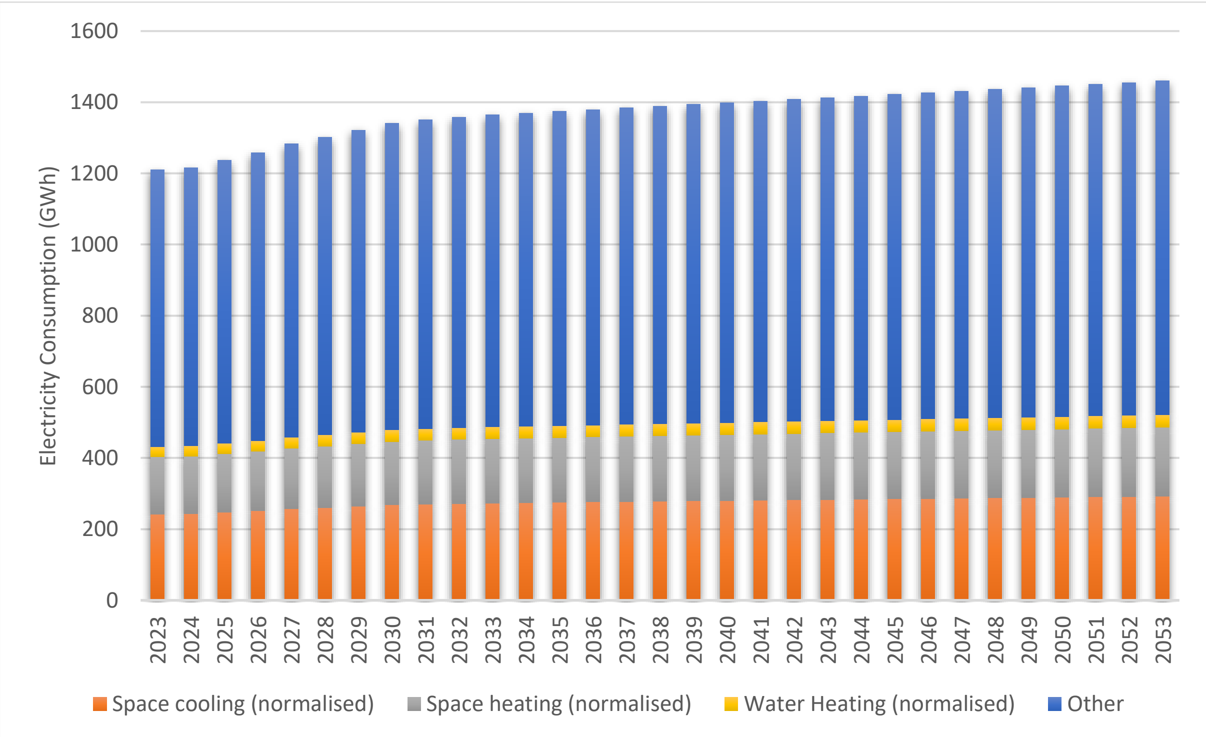

Figure 123 - Projected electricity consumption distribution for the Commercial and Services sector

Table 74, presented below, outlines the annual projected heating and cooling demand for the services sector from 2023 to 2028. The full forecast data set between 2023 and 2053 are available in Annex II of this report.

Table 74 - Projected electricity consumption distribution for the services sector from 2023 till 2028

Year	2023	2024	2025	2026	2027	2028
Total Projected Electricity consumption	**1,210.2**	**1,215.9**	**1,236.8**	**1,257.5**	**1,282.7**	**1,301.2**
of which						
Spatial cooling (normalised)	291.63	293.01	298.04	303.04	309.10	313.57
Spatial heating (normalised)	192.95	193.86	197.18	200.49	204.50	207.46
Water heating	35.22	35.39	36.00	36.60	37.33	37.87
Other	690.39	693.66	705.55	717.39	731.75	742.33

Table 75 outlines a year-by-year projection of the heating and cooling demand met by fuel in the services sector from 2023 to 2028. The complete set of forecasted data spanning from 2023 to 2053 can be found in Annex II of this report.

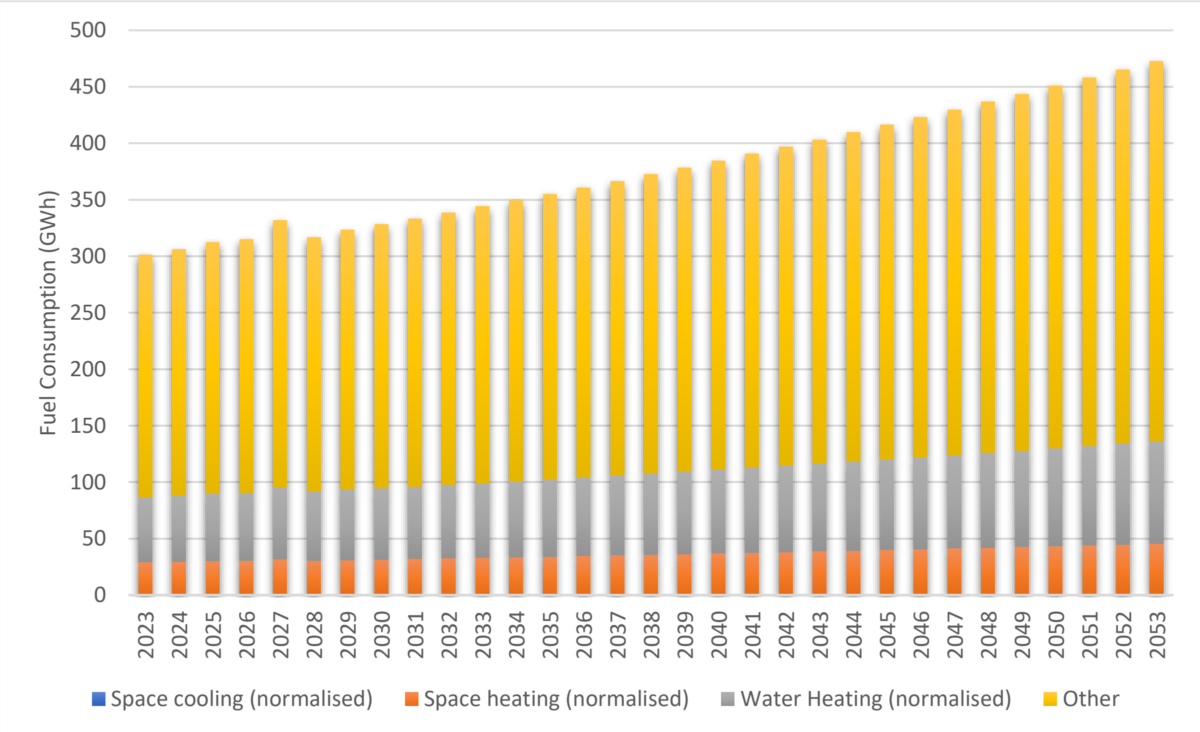

Figure 124 - Projected fuel distribution for the commercial and services sector

Table 75 - Projected fuel consumption distribution for the commercial services sector from 2023 till 2028

Year	2023	2024	2025	2026	2027	2028
Total Projected Fuel consumption	**301.29**	**305.99**	**312.14**	**314.70**	**331.52**	**316.90**
of which						
Space cooling (normalised)	0.56	0.569	0.58	0.59	0.62	0.59
Space heating (normalised)	28.51	28.95	29.54	29.78	31.37	29.99
Water heating	57.90	58.80	59.98	60.48	63.71	60.90
Other	214.32	217.67	222.04	223.86	235.83	225.42

Part II – Objectives, Strategy and Policy Measures

The context within which this part of the study is being carried out is with the aim of providing an overview on the role of efficient heating and cooling in the Maltese islands, in order to eventually achieve greenhouse gas (GHG) emission reductions.

The current policy framework for energy and climate in the Maltese Islands is covered by the following key documents:

- Low Carbon Development Strategy 2050 (LCDS), published in 2021[72]
- Long-Term Renovation Strategy (LTRS) 2050, published in 2021[73]
- Sustainable Development Strategy 2050, published in 2022[74]
- Draft National Strategy for the Environment 2050, published in 2022[75]
- The Draft Update to the National Energy and Climate Plan (NECP), published in September 2023[76]
- The Minimum Energy Performance Requirements in Buildings (Document F)[77]

Annex X of the Energy Efficiency Directive requires that the comprehensive assessment includes an overview of existing policies and measures (PAMs) relevant to the heating and cooling end use as described in the Member State's most recent NECP and any other PAMs not identified in the NECP.

The NECP identifies objectives, targets and measures across the five Energy Union dimensions in line with the Governance Regulation (EU) 2018/1999. These are decarbonisation, energy efficiency, energy security, internal energy market and research, innovation, and

[72] Ministry for the Environment, Climate Change and Planning (2021), "Low Carbon Development Strategy 2050", Malta Low Carbon Development Strategy | UNFCCC
[73] Ministry for the Environment, Climate Change and Planning (2021), "Long Term Renovation Strategy 2050", longTermRenovationStrategy2050.pdf (gov.mt)
[74] Ministry for Environment, Energy and Regeneration of Grand Harbour (2022) "Sustainable Development Strategy for 2050", Malta's Sustainable Development Strategy for 2050.pdf (gov.mt)
[75] Ministry for Environment, Energy and Regeneration of Grand Harbour (2022), "Draft national Strategy for the environment 2050", National-Strategy-for-the-Environment-2050-—-Public-Consultation-Draft.pdf (era.org.mt)
[76] Ministry for Energy and Water Management and Ministry for Environment, Sustainable Development and Climate Change (2023) "Draft National Energy and Climate Plan 2021-2030" National-Energy-and-Climate-Plan-2021-2030.pdf (gov.mt)
[77] Building and Construction Authority, https://bca.org.mt/technical-document-f/

competitiveness. Malta submitted its first NECP in June 2019.[78] Since 2019, the Maltese Government has implemented numerous policies related to energy and climate, committed to fulfilling the EU's collective goal of climate neutrality by 2050, as is outlined in the LCDS, showing the government's commitment to transitioning to a low-carbon economy. However, global events like the COVID-19 pandemic and the EU energy crisis have altered the socio-economic context of these plans, leading to the reorganisation of these policies and measures. The most recent and detailed document from the list of key policy documents indicated above is Malta's draft NECP**,** published in September 2023, which incorporates initiatives from all the said key documents. The draft NECP update sets out Malta's national objectives and contributions for 2030 under the five Energy Union dimensions, which are being summarised below:

Decarbonisation: Malta's strategy under this dimension strives to promote the transition to a low carbon economy primarily through the pursuit of national GHG emission reduction commitments and by continuing to deploy all viable indigenous renewable energy sources and strengthening efforts towards sustainable and active mobility. In the area of renewable energy, Malta will continue its efforts to increase its renewable energy share primarily by extending its current support framework for renewable energy sources to the period until 2030. Malta has also developed an ad-hoc policy for offshore renewables and is actively promoting offshore wind within Malta's maritime exclusive economic zone (EEZ) area and exploring the option for near shore development of floating solar.

Energy efficiency: Malta's efforts in energy efficiency post-2020 seek to achieve cost efficient energy savings in the relative end-use sectors whilst taking into account the effective potential. The Government will also strive to continue decreasing the overall energy intensity of its economy and uphold its obligations under the Energy Efficiency Directive. Temperate climatic conditions and lack of energy-intensive industries mean that Malta has the second lowest final energy consumption per capita across all EU Member States.

As part of Malta's commitment to increase efficiency and decarbonize the building stock by 2050, the Government will continue exploring the possibility to support investments in improving the energy performance of buildings possibly to also address the challenges due to potential longer payback periods of the capital investment. Nevertheless, Government already supports improvements in energy efficiency through several schemes and incentives, particularly those related to roof insulation, higher efficiency glazing, heat pump water heaters and solar water heaters.

In addition to these initiatives, there is a mandatory requirement for the renovation of buildings owned by public bodies to comply with the Energy Efficiency Directive (EED). This is part of a broader effort to sustain energy efficiency measures and retrofitting activities to reach Nearly Zero Energy Building (NZEB) and Zero Energy Building (ZEB) standards. Furthermore, for

[78] Ministry for Energy and Water Management and Ministry for Environment, Sustainable Development and Climate Change (2019), mt_final_necp_main_en_0.pdf (europa.eu)

new constructions, the Government is set to enforce improved energy efficiency standards that will elevate the energy performance of buildings. This will be achieved through the introduction of new building codes and guidelines, coming into force in July 2024, which will be supported by complementary measures to ensure effective implementation and compliance.
Energy security: Malta will continue to emphasize the commitment to achieve greater security of supply through diversification of energy sources and suppliers and reducing energy import dependency primarily through the deployment of indigenous renewable energy sources. The Government will also ensure that periodic contingency planning in the electricity, gas and oil sectors is undertaken. Energy security will also be considered within the context of the long-term objective of decarbonisation of the energy system.

Internal energy market: Malta's electricity grid is linked to the European grid via a 200MW interconnector. The Government intends to invest in a second interconnector to improve energy efficiency and energy storage capacity in the country. The Government also aims to ensure that the legal and regulatory frameworks result in affordable energy pricing, whilst encouraging competition within the limits imposed by the market size and structure. Social measures are also in place to support and protect energy poor and vulnerable consumers.

Research, innovation, and competitiveness: Malta is boosting its research, innovation and competitiveness specifically in the area of energy and low-carbon technologies through the development of the National Strategy for Research and Innovation in Energy and Water for 2021-2030, the main aim of which is to contribute to Malta's transition to a low-impact and decarbonised economy and increase the level of domestic support for Research and Innovation (R&I) in Malta.

The draft NECP update sets the basis for a strategic planning framework that will guide Malta's contribution to achieve the Energy Union's 2030 objectives and targets whilst identifying those objectives and measures necessary for their achievement during the period until 2030, with an outlook to 2040.

2.1 Targets and objectives

For the purposes of this report, this section will primarily focus on the Decarbonisation and Energy Efficiency dimensions, since they are ones which directly relate to the heating and cooling demand. The decarbonisation dimension is sub-divided into GHG emissions and removals and Renewable Energy.

As indicated in Malta's Draft NECP Update, with regards to the objectives and targets related to GHG emissions and removals, Malta has, through the ratification of the Paris Agreement, re-affirmed its commitment to address climate issues and to contribute towards the European Union's increased collective target of 55% reduction of its GHG emissions by 2030 compared to 1990 levels. By 2030, Malta is bound to reduce its GHG emissions by 19% below its 2005 emissions pursuant to the Effort Sharing Regulation.

As regards renewable energy, Malta's contribution to the 2030 Union target in terms of the share of energy from renewable energy in gross final consumption was not updated in the Draft NECP Update of 2023. In 2019, Malta committed to a renewable energy share of 11.5% by 2030. Such a contribution was exclusive of ambient cooling captured by air-to-air heat pumps, as the Commission had not yet established a methodology for calculating renewable energy for cooling. The final NECP update is expected to include a significantly more ambitious commitment for Malta's renewable energy share by 2030.

The revised Energy Efficiency Directive raises the EU's ambition on energy efficiency, making it binding for the EU to collectively achieve an 11.7% reduction in energy consumption by 2030. Thus, overall EU energy consumption by 2030 should not exceed 992.5 million tonnes of oil equivalent (Mtoe) for primary energy and 763 Mtoe for final energy. Each Member State (MS) is expected to contribute towards this target a percentage share which is linked with specific macro-economic indicators, and takes the Reference Scenario 2020 as baseline. The Reference Scenario 2020 projections for Malta diverge significantly from national projections and therefore achieving the calculated contribution from Malta is expected to be challenging.

Article 7(1)(b) of the Energy Efficiency Directive requires Malta to introduce specific obligations/ measures to achieve annual energy savings. Malta's unique circumstances, including its small energy market and reliance on a solitary electricity distributor, are significant factors in this context. Additionally, the absence of a natural gas network in Malta is a critical consideration. Furthermore, the small pool of fuel suppliers, due to their limited number and scale, restricts the variety of actions that Malta can implement to fulfil its energy savings commitments. These circumstances are reflected in the derogation granted to Malta, where it is required to achieve new savings as follows:

- each year from 1 January 2021 to 31 December 2023, equivalent to 0.24% of annual final energy consumption, averaged over the most recent three-year period prior to January 2019.

- From the years 1 January 2024 to 31st December 2030, Malta is required to achieve new savings equal to 0.45% of annual final energy consumption, averaged over the most recent three-year period preceding 1 January 2019.

As regards the milestones of the long-term strategy for the renovation of the national stock of residential and non-residential private and public buildings, in accordance with Article 2a of Directive 2010/31/EU, the LTRS was developed on evidence-based estimates of expected energy savings, taking into account energy performance data collected from a large representative sample of the building stock in Malta. Targets for 2030, 2040 and 2050 have been established.

Under the revised Energy Performance of Buildings Directive (EPBD), MS will set their own national trajectories to reduce the average primary energy use of residential buildings by 16%

by 2030 and 20-22% by 2035, prioritizing the renovation of the worst-performing buildings. For non-residential buildings, Minimum Energy Performance Standards will be introduced to renovate the 16% worst-performing buildings by 2030 and 26% by 2033. Financial support will be crucial, with over €100 billion estimated to be available from EU financing to support renovations between 2023 and 2030. The new standard for all new buildings, both residential and non-residential, is zero emissions from fossil fuels, with implementation deadlines of 2028 for publicly owned buildings and 2030 for all other new buildings. The revised EPBD also allows for exemptions for certain categories of buildings, including historical buildings, while ensuring that renovations are in line with the goal of achieving a decarbonized building stock by 2050.

2.2 Overview of existing policies and measures and planned contribution to national objectives and targets

Table 76 summarizes the main existing policies and measures relating to energy efficiency and decarbonisation of heating and cooling. The majority of the measures are sourced from the Draft NECP Update of 2023; however there are some measures that were adopted post the submission of the NECP.

The planned contribution of the measures/schemes to the energy efficiency dimension, more particularly, Article 8 of the Energy Efficiency Directive, is also included in the table, where this has been quantified. Where this has not been quantified, it is still expected that the measure will contribute to the overall efficiency and decarbonization of the respective sector.

Table 76 - Current policies and measures relating to energy efficiency and decarbonisation of heating and cooling

Policies and Measures	Sector/s	Relevant Energy Union Dimension/s	Description
2024 Renewable Energy Sources Scheme	Residential	Decarbonisation; Energy Efficiency	A financial incentive aimed at promoting the adoption of renewable energy systems in homes, offering various levels of support for the installation of photovoltaic systems and battery storage solutions.[79] This scheme is expected to reach an installed capacity of 300 MW by 2030.
2021 Solar Water Heater Scheme	Residential	Decarbonisation; Energy Efficiency	A financial incentive designed to encourage the installation of solar water heaters in homes, providing substantial cost reimbursements and a dedicated maintenance subsidy after five years.[80] This scheme, together with the heat pump water heater scheme, is expected to contribute 48.4 GWh of cumulative energy savings by 2030.
2021 Heat Pump Water Heater Scheme	Residential	Decarbonisation; Energy Efficiency	A financial incentive program extended through the end of 2024, aimed at promoting the adoption of heat pump water heaters in residential settings by offering partial cost refunds.[81]
Smart and Sustainable Investment Grant	Services	Decarbonisation; Energy Efficiency	A business funding programme extended through 2024, designed to incentivise investments in sustainable processes that enhance enterprise competitiveness by optimising resource use. Eligible investments can receive a cash grant and an additional tax credit if certain guidelines are met, both aimed at fostering sustainability in machinery and equipment.[82] This scheme is expected to contribute 31.11 GWh of cumulative energy savings by 2030.

[79] https://www.gov.mt/en/Government/DOI/Government%20Gazette/Government%20Notices/Pages/2024/02/GovNotices2702.aspx

[80] https://www.rews.org.mt/#/en/sdgr/465-2021-solar-water-heater-scheme-active

[81] https://www.rews.org.mt/#/en/sdgr/466-2021-heat-pump-water-heater-scheme-active

[82]https://maltaenterprise.com/sustainable https://www.gov.mt/en/Government/DOI/Press%20Releases/Pages/2023/12/15/pr231988en.aspx

Policies and Measures	Sector/s	Relevant Energy Union Dimension/s	Description
Investment Aid for Energy Efficiency Projects	Services	Energy Efficiency	A support programme that aims to encourage investments in technology that improves energy efficiency and reduces energy consumption. The assistance is provided as either a cash grant, a tax credit, or a combination of both.[83] This scheme is expected to contribute 23.2GWh in energy savings by 2030.
Vulnerable Household Scheme (LEAP Scheme)	Residential	Energy Efficiency	The EWA, in partnership with the Financial Services for Social Welfare, is overseeing a customised scheme aimed at supporting vulnerable households. This initiative includes home visits to offer guidance on reducing energy and water usage, as well as the free replacement of outdated appliances with new, energy-efficient models. This scheme is expected to contribute 2.4 GWh in energy savings by 2030.
Energy & Water Awareness in Micro SMEs	Services	Decarbonisation; Energy Efficiency	A programme, providing free advisory services to micro-SMEs (small and medium-sized enterprises) on efficient energy and water use within their businesses. Offering guidance on how to improve energy and water efficiency and inform them about additional grants and schemes for which they may qualify.
Promotion of Energy Audits in Small and Medium Sized Enterprises	Services	Energy Efficiency	The EWA is responsible for promoting energy audits and providing support to small and medium-sized enterprises (SMEs) through the 'Promotion of Energy Audits in Small and Medium Sized Enterprises Scheme'. This scheme allows enterprises to apply for an energy audit conducted by a certified auditor in accordance with current regulations.

[83] https://www.maltaenterprise.com/support/energy-efficiency-projects

Policies and Measures	Sector/s	Relevant Energy Union Dimension/s	Description
			After approval by the EWA, these enterprises are eligible to receive funding for the cost of the energy audit.
ECOHIVE investment project; waste-to-energy facility	Residential, Services, Industry	Decarbonisation; Energy Efficiency; Energy Security	An investment in waste treatment infrastructure includes the creation of a waste-to-energy facility to process waste that cannot be easily recycled. Utilising moving grate technology, this investment project will treat non-recyclable waste generated in Malta, diverting it from landfill disposal. In the process, energy in the form of electricity and heat will also be generated.
ECOHIVE investment project; Organic Processing Plant	Residential, Services, Industry	Decarbonisation; Energy efficiency; Energy Security	This investment includes the development of facilities and initiatives to manage organic waste and reduce emissions by diverting waste from landfills. It includes the establishment of a new organic processing plant which will convert organic waste into compost and biogas. Additionally, Malta plans to enhance biogas generation from closed landfills by increasing extraction points and installing a new gas system.
Rising-block tariff and Eco-reduction mechanisms	Residential, Services, Industry	Decarbonisation; Energy Efficiency	The current electricity tariffs incorporate a built-in mechanism to promote end-use electrical energy savings. These include a "rising block tariff" and an eco-reduction mechanism, which incentivize end users to reduce consumption below an established threshold and deter high consumption by applying higher tariffs as consumption increases. This measure is expected to contribute 57.67 GWh in energy savings by 2030.
Energy and Water Efficiency Scheme for Voluntary Organisations[84]	NGOs	Decarbonisation; Energy Efficiency	Supporting voluntary organisations in reducing their overall energy and water consumption through an increase in energy efficiency, and/or reduction in water use, and/or augmentation of water supply.

[84] https://energywateragency.gov.mt/voluntary-organisations-scheme/#:~:text=The%20main%20objective%20of%20this,or%20augmentation%20of%20water%20supply.

Policies and Measures	Sector/s	Relevant Energy Union Dimension/s	Description
Renovation of Public Buildings	Services	Decarbonisation; Energy Efficiency	A decarbonization initiative involves upgrading public sector buildings to enhance energy efficiency and promote environmental sustainability. This includes retrofitting existing structures and implementing new projects in public schools and hospitals to create greener, more energy-conscious facilities. The overall goal is to significantly reduce energy consumption and carbon emissions across government-owned properties. The renovations from this initiative, which are funded through the Recovery and Resilience Funds, are expected to contribute approximately 8.82GWh of cumulative energy savings by 2030.
Renovation of Private Buildings Grant Scheme	Services	Decarbonisation; Energy Efficiency	The objective of the scheme is to improve energy efficiency, reduce energy demand, lower carbon emissions and limit energy waste through the retrofitting of private sector buildings. This initiative funded through the Recovery and Resilience Fund is expected to contribute 18.34GWh in energy savings by 2030.
Technical Guide F	Residential, Services, Industry	Decarbonisation; Energy Efficiency	The Technical Guide F sets new minimum energy performance requirements for new and renovated buildings. The requirements are divided into three parts: Part 1 and Part 2 relate to dwellings and non-dwellings respectively. These set the overall energy performance for new buildings and those undergoing major renovation and set requirements for building elements and the integration of renewable energy sources. Part 3 set requirements for technical systems within buildings, including overall energy efficiency of cooling, heating, domestic hot water and lighting systems among others.

Part III - Analysis of the Economic Potential for Efficiency in Heating and Cooling

3.1 Introduction and Methodology

The third section of this report builds on the previous analysis of Malta's heating and cooling energy requirements and aligns with the country's strategies, goals and contributions across the five dimensions of the Energy Union, in its commitment towards decarbonisation through efficient heating and cooling practices, by examining the economic viability of potential technologies that could be implemented in the Maltese territory. This is in line with the revised Energy Efficiency Directive (EED) 2023/1791/EU, Article 25(3) which requires Member States to *"carry out a cost-benefit analysis covering their territory on the basis of climate conditions, economic feasibility and technical suitability. The cost-benefit analysis shall be capable of facilitating the identification of the most resource- and cost-efficient solutions to meeting heating and cooling needs, taking into account the energy efficiency first principle"*.

With due consideration of the technologies listed in Part III to Annex X of the revised Directive, the following list of intervention measures were identified as a potential group of projects to be pursued in the context of the heating and cooling characteristics of Malta.

Table 77 - List of possible intervention measures

Sector	Intervention Reference	Description of Intervention	Cooling/ Heating Target
Residential	R1 A	Replacing electrical water heaters with heat pumps (Decentralised approach)	Water heating
Residential	R1 B	Replacing electrical water heaters with heat pumps (Centralised approach)	Water heating
Residential	R2 A	Replacing electrical water heaters with solar water heaters (Decentralised approach)	Water heating
Residential	R2 B	Replacing electrical water heaters with solar water heaters (Centralised approach)	Water heating
Residential	R3	Replacing electrical water heaters with combination of PV panels and electric water heaters	Water heating

Sector	Intervention Reference	Description of Intervention	Cooling/ Heating Target
Residential	R4	Complete elimination of LPG use from households (in cooking and heating) by • Replacing gas hobs + ovens with electric hobs + ovens, AND • Using existing air-to-air heat pumps instead of LPG heaters	Space heating
Hotels	H1	Replacing low-efficiency boilers with hot water heat pumps	Water heating
Hotels	H2	Replacing low-efficiency boilers with high-efficiency condensing boilers (powered by biofuels)	Water heating
Hotels	H3	Replacing air-cooled chillers with air-cooled chillers with heat recovery	Space cooling
Hotels	H4	Replacing water-cooled chillers with water-cooled chillers with heat recovery	Space cooling
Hotels	H5A	Replacing ageing heat pumps with new, higher efficiency heat pumps (decentralized to decentralized)	Spatial heating/cooling
Hotels	H5B	Replacing ageing heat pumps with new, higher efficiency heat pumps (decentralized to centralized)	Spatial heating/cooling

Sector	Intervention Reference	Description of Intervention	Cooling/ Heating Target
Restaurants	RST1	Replacing ageing heat pumps with new, higher efficiency heat pumps	Spatial heating/cooling

The intervention measures under consideration tackle the residential and commercial sectors, wherein hotels and restaurants were considered individually for the latter. As concluded in Part I of this assessment, these sectors represent the majority of Malta's energy demands for the purposes of heating and cooling, and are thus where the economic benefits of intervention are expected to be strongest. Moreover, a number of ageing or low efficient technologies are utilized in these sectors, making them well-suited for interventions targeting increased efficiency. Other entities falling under the commercial sector, namely hospitals and care homes for the elderly are either considered to be low consumers, or already employ technologies of relatively high efficiency such as heat pumps. In addition, a number of these institutions are already scheduled for major renovations or will be closing down in the near future.[85] [86] In other cases, such as for offices and retail outlets, data relating to the number and size distribution of establishments was unavailable, and thus prohibited meaningful interventional analysis. For these reasons, intervention measures specific to such entities were not considered, although measures applied for other commercial establishment may be reasonably adapted if necessary.

Industrial operations in Malta have a minimal impact on the overall demand for heating and cooling, representing approximately 6% of the total final energy demand. This is largely due to the fact that the majority of energy demand within the manufacturing sector is attributed to industrial processes, which are considered outside the scope of this heating and cooling assessment. To put this into perspective, nearly 97% of the energy used in manufacturing is dedicated to these industrial processes. When considering strategies to address heating and cooling in these industrial sectors, such as the implementation of cogeneration and trigeneration systems, it is essential to gather detailed information about the current technologies in use at each company and their specific applications. Additionally, it should be noted, as mentioned elsewhere in this report, that Malta does not have any district heating and cooling networks. However, intervention measures like replacing boilers and heat pumps, which have been examined for various service sector entities, could potentially be modified for use in the industrial sector.

Each intervention is subject to a financial feasibility analysis from the point of view of the investor, followed by a financial and economic analysis from the point of view of society, assessing the effects of policy from the wider societal point of view.

[85] Times of Malta, 2023, Cospicua home for the elderly to close for 'extensive' works (timesofmalta.com)
[86] Times of Malta, 2024, Plans to close Mount Carmel Hospital and move acute mental health to Mater Dei (timesofmalta.com)

Meanwhile, the methodology utilised to conduct this Cost-Benefit Analysis (CBA) is based on the various guidelines issued by the European Commission and other European institutions on the preparation of such CBAs, namely:

- European Commission (DG Regio), Guide to Cost-benefit Analysis of Investment Projects: Economic appraisal tool for Cohesion Policy 2014-2020, published in December 2014[87]

- European Commission (DG Regio), Guide to Cost Benefit Analysis of Investment Projects: Structural Funds, Cohesion Fund and Instrument for Pre-Accession, from 2008[88]

- European Commission, Economic Appraisal Vademecum 2021-2027: General Principles and Sector Applications, released in 2021[89]

- European Investment Bank (EIB), The Economic Appraisal of Investment Projects at the EIB, published in 2013[90]

- Directive (EU) 2023/1791 of the European Parliament and of the Council on Energy Efficiency, specifically Part III to Annex X & Annex XI, issued in September 2023[91]

- Commission Delegated Regulation (EU) 480/2014 laying down common and general provisions on the European Regional Development Fund, the European Social Fund, the Cohesion Fund, the European Agricultural Fund for Rural Development and the European Maritime and Fisheries Fund, effective as of March 2014[92]

In line with the requirements set out in Part III (10) of Annex X of the updated Directive 2023/1791, the CBA is mandated to incorporate a financial feasibility analysis performed to assess intervention measures from the investors' point of view, and a financial and economic analysis from the point of view of society, to assess the broader effects of policy from a societal point of view. The subsequent sections will provide a more detailed breakdown of the components that make up each aspect of the analysis.

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87 DG REGIO CBA Guide for 2014 – 2020
https://jaspers.eib.org/knowledge/publications/dg-regio-cba-guide-for-2014-2020

88 Though superseded by the Guide referred to in the previous point, this older version still contains sector-specific case studies that remain relevant.

89 Economic Appraisal Vademecum 2021-2027
https://jaspers.eib.org/knowledge/publications/economic-appraisal-vademecum-2021-2027-general-principles-and-sector-applications

90 European Investment Bank, The Economic Appraisal of Investment Projects at the EIB
https://www.eib.org/attachments/thematic/economic_appraisal_of_investment_projects_en.pdf

91 Updated Energy Efficiency Directive (EED) 2023/1791/EU
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ%3AJOL_2023_231_R_0001&qid=1695186598766

92 Commission Delegated Regulation (EU) 480/2014
https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32014R0480

3.1.1 Methodology for the Financial Analyses (investor point of view)

The financial analysis measures key performance metrics for the various intervention technologies to assess their profitability and financial sustainability from the standpoint of the individual investors. This analysis considers three distinct investor groups – homeowners, hotel operators and restaurants. Additionally, the analysis for hotel owners is differentiated, with a separate examination for owners of 5-star and 4-star hotels, and another for those with 3-star and 2-star establishments.

In line with CBA methodologies and as specified in Annex X of the EED both the financial and economic analyses will utilize the net present value (NPV) as the primary metric for evaluation. This follows the Discounted Cash Flow (DCF) method mandated in section III (method for calculating the discounted net revenue of operations generating net revenue) of the Commission Delegated Regulation (EU) No 480/2014. This implies the following assumptions:

(i) Only cash inflows and outflows ae considered. Depreciation, reserves, price and technical contingencies and other accounting items which do not correspond to actual flows are disregarded.

(ii) Cash flows are considered in the year in which they occur and over the project reference period.

(iii) The calculation of the present value of future cash flows is based on a financial discount rate (FDR). The FDR reflects the opportunity cost of capital and is defined as "*the expected return forgone by bypassing other potential investment activities for a given capital*".[93] There are many theoretical methods of estimating this rate, but for the programming period 2014-2020, the EC recommended that a 4% real rate is considered as the reference parameter for the opportunity cost of capital in the long term.[94] In the more recent EC Economic Appraisal Vademecum 2021-2027 general principles, *"Member States are free to assess their own country- and/or sector specific financial discount rate(s)."*[95] Likewise Annex X of the EED leaves it up to the Member States to assess their own FDR. To this end, and for the purposes of this CBA, the 4% benchmark real discount rate was used in the financial analysis.

It is also worth noting that although the EC makes reference to this 4% discount rate, additional research shows that higher and more subjective FDRs have been

[93] European Commission (2008). Guidance on the Methodology for Carrying out Cost-Benefit Analysis, pg. 8

[94] European Commission (DG Regio), Guide to Cost-benefit Analysis of Investment Projects: Economic appraisal tool for Cohesion Policy 2014-2020, December 2014

[95] European Commission, Economic Appraisal Vademecum 2021-2027: General Principles and Sector Applications, 2021, pg. 13

adopted for small firms and households. These discount rates reflect either business practices, various risk factors or even the perceived cost of lending, while for households, the individual discount rate also reflects an element of risk aversion. For instance, for households, the PRIMES energy modelling framework adopted an individual FDR of 13.5% without the provision of schemes and 9.5%, when considering the provision of schemes[96]. The below analysis is based on the 4% discount rate; additionally, the same analysis is shown after applying a 13.5% discount rate in Section 4 of this report.

(iv) On the time horizon (or reference period), the EIB's publication, The Economic appraisal of Investment Projects at the EIB[97], states that it "depends on the type of the project and can vary from less than 15 years for many energy efficiency investments up to 25 years for some investments concerning the building envelope". Additionally, Annex XI of the EED states that "Member States shall set guiding principles for the methodology, assumptions and time horizon for the economic analysis". To ensure consistency and completeness across the different intervention measures, the financial and economic analyses are carried out over a 25-year reference period. The technical lifespan of the principal technology installed is determined in line with the respective technical lifespan specified in the 2019 National Energy and Climate Plan (NECP, pg. 118), supplemented by additional expert advice.

(v) The financial analysis for potential intervention measures carried out by hotel operators and commercial entities is conducted net of VAT for both expenses and income, as this tax can be reclaimed by the project promoter. However, this does not apply to homeowners, so VAT has been factored into their respective pricing.

(vi) This CBA uses constant (real) prices, meaning prices are pegged to a specific base-year and does not account for potential variations in consumer price indices (CPI) over time. Technology prices are based on those outlined in the NECP and other publicly available sources, with no adjustments for the base year Y1. Reinvestment costs, for the replacement of technology at the end of its technical lifespan but still within the reference period (2025-2050), are assumed to remain unchanged. This is based on the expectation that the price of the same technology will decrease due to technological advancements and market competition. To maintain a conservative stance, costs are kept at present-day values. Costs related to structural alterations are applicable only in the base year of 2025, hence no CPI adjustments are necessary.

As recommended by the European Commission in its Guide to Cost-benefit Analysis of Investment Projects (2014), the CBA follows an incremental approach, where the alternative

[96] U Reference Scenario 2020 Energy, transport and GHG emissions – Trends to 2050
[97] European Investment Bank (2013). The Economic Appraisal of Investment Projects at the EIB.

solutions are compared to the baseline (or business-as-usual) scenario. This technique considers the differences (additions, deductions or savings) in the costs and benefits if a particular course of action is taken compared to those that would have been obtained if that course of action had not been taken.

In the context of Malta's heating and cooling requirements, the baseline scenario is established based on the current state as detailed in Part I of this assessment. It takes into account the existing demand for heating and cooling across various sectors, including residential, services, and industry, and forecasts demand shifts over the projected period, which spans the next 25 years. These forecasts account for demand fluctuations in buildings, industry sectors, and the effects of policies and strategies on managing demand. Additionally, Part I's assessment of the current heating and cooling supply lays the groundwork for understanding the technologies in place for the baseline scenario. This information is the basis for projecting operational, replacement, and maintenance costs, as well as revenues throughout the financial and economic analysis time frame.

All technically feasible options shortlisted above are assessed on their respective profitability after taking into consideration:

a. Initial Investment costs – these include the initial capital expenditures for all fixed assets, such as equipment and machinery, and any necessary structural modifications for the adoption of the technology. These expenses are anticipated to be borne by the household or investor in the initial year of the reference period (Year 1). The distribution of costs over subsequent years aligns with the actual service life (technical lifetime) of the assets and the scheduled timeline for deployment. Estimates of these costs were obtained from the 2019 NECP (pg. 118) and primary market data sought by technical experts from the open market.

b. Replacement costs – these include costs occurring during the reference period to replace the already existing capital equipment once its useful life is surpassed. This is based on the technical life of the individual assets. Such costs are included under the 'initial investment costs' for presentation purposes.

c. Residual value - this represents the discounted value of any net future revenues that will be generated after the project time horizon as a result of the remaining service potential of fixed assets whose remaining useful life is not yet exhausted. Residuals based on market values cannot be computed for this CBA, as the market value of capital as at the end of the CBA time horizon is not available. In this regard, the residual value of initial capital at the end of the project is calculated on the remaining estimated useful life of the underlying technology.

d. Operating and maintenance (O&M) costs – These are the costs associated with the operation and maintenance of the technology to maintain appropriate quality levels.

These expenses can be either fixed or variable and cover a range of outlays, including maintenance and repair charges, fuel expenditures, and electricity costs.

To estimate the electricity costs, the financial analysis will apply the regulated electricity rates that came into effect on 31st March 2014, for both residential and non-residential users.[98] Considering the variation in electricity tariff bands, a weighted average rate has been determined based on the typical electricity usage patterns of the average residential and non-residential consumer. In the same way, to estimate the cost of LPG used by households, the financial analysis will use the regulated retail prices that have been in place since 1st April 2020.[99] A weighted average price has been determined in line with residential LPG usage trends observed in Part I of this assessment.

Part I of this assessment outlines that businesses, like hoteliers, utilize a variety of fuels to operate their boilers and chillers for heating water and cooling spaces. These fuels include Diesel, Fuel oil, Gasoil (Heating oil), LPG, and Biodiesel. The pricing information for these fuels is mainly obtained from the European Commission's oil bulletin, which offers weekly consumer prices for petroleum products across EU countries.[100] The analysis calculates a weighted average price for all the fuels used by a specific technology, taking into account the different fuel consumption patterns of various entities within the same industry.

e. Revenues – these are defined cash inflows directly paid by users for the goods and services provided by the operation, such as charges borne directly by users for the use of infrastructure, sale and rent of land or buildings, or payments for services. For the purposes of the financial analysis in this study, inflows for the investor are only in the form of government grants (subsidies) received, in partial reimbursement of the incremental cost between the baseline and the alternative technology. As stated in the EC Guide,[101] *"transfers or subsidies (e.g. transfers from state budgets) shall not be included within the operating revenues for the calculations of financial profitability because they are not directly attributable to the project operations. On the contrary, they shall be computed for the financial sustainability verification"*.

   To this end, the financial analysis will assess the alternative technology against the baseline, focusing on the incremental investment and technical efficiency only, and gauge the financial returns of the investment in terms of the energy savings it would

98 REWS, 2024, available at https://www.rews.org.mt/#/en/a/13-regulated-electricity-tariffs

99 REWS, 2024, available at https://www.rews.org.mt/#/en/a/97-historical-lpg-and-propane-regulated-retail-prices

100 Energy, Climate and Environment (EC). Weekly Oil Bulletin. Accessed on 31st May 2024. Available at: https://energy.ec.europa.eu/data-and-analysis/weekly-oil-bulletin_en

101 European Commission (2014), Guide to Cost-benefit Analysis of Investment Projects: Economic appraisal tool for Cohesion Policy 2014-2020.

generate. While subsidies and national financial assistance play a crucial role in influencing consumer behaviour towards purchasing energy-efficient equipment, the financial evaluation should be conducted without these incentives to correctly appraise the investment. However, the presence of existing subsidies and financial programs, summarised in Part II of this assessment, that encourage the adoption of more efficient heating and cooling solutions cannot be ignored. Where applicable, these incentives will also be considered in the sensitivity analysis to establish the financial impact these could have on the respective technology take-up. Ultimately, these measures will be re-evaluated in Part IV of the assessment, which aims to propose strategies for encouraging the adoption of solutions that could lead to more efficient heating and cooling usage.

3.1.2 Methodology for the Economic Analyses (societal point of view)

The economic analysis examines the societal costs and benefits associated with private investors – households, hotel operators and other commercial entities mentioned in Section 3.1 of this assessment – adopting more efficient heating and cooling technologies. This involves adjusting market prices to shadow prices to accurately represent the social value of the proposed intervention measures. The following assumptions and adjustments apply:

(i) Geographic boundaries: the economic assessment encompasses the entire territory of the Maltese Islands.

(ii) Fiscal corrections on inputs and outputs: since taxes and subsidies are merely a transfer payment within society, the input prices are adjusted to exclude any direct or indirect taxes. Adjustments primarily involve removing VAT for households[102], excise duties for fuels like LPG, Diesel, and gasoil in the baseline or alternative investment scenarios, and any government subsidies. As there are no outputs in the scenarios, no tariffs or subsidies are considered.

(iii) Conversion to shadow prices: For inputs such as electricity tariffs and fuel, established methods for determining shadow prices are employed, consistent with the EC's *Guide to Cost-Benefit Analysis of Investment Projects*. When assessing the cost savings in energy between the baseline and the proposed investment scenario, the economic analysis adopts the proxy market price of electricity incurred by the distribution system operator. This price reflects the average variable cost per kWh incurred by the distribution system operator to meet the demand forecast for a given year from locally generated conventional and imported electricity. The proxy for the market price for electricity for a particular year is approved by the Regulator for Energy and Water Services (REWS). The rate determined to be the proxy for the market price in 2022, and which will be used in this economic analysis, was determined at €0.0885 per

[102] For hotel operators and other commercial entities VAT can be reclaimed by the project promoter and would therefore have already been excluded from the financial analysis.

kWh.[103] Additionally, the economic analysis calculates the shadow prices for various fuels utilized in both the baseline and alternative scenarios across residential and commercial sectors. This involves starting with the consumer price and subtracting VAT and excise duties to determine the wholesale price. An assumed importer's mark-up is then subtracted to estimate the marginal cost which will be applied to estimate the energy savings in monetary terms between the baseline and alternative scenarios.

(iv) Homogeneity of output: The assumption of homogeneity of output implies that the energy generated by both the baseline and alternative technologies is considered to be of equal value in terms of its usefulness. In other words, it is presumed that consumers regard the energy output from these technologies as equivalent in value, regardless of whether it comes from the baseline or the alternative scenarios, because the useful energy provided is the same. One might argue that consumers value the acquisition of a more environmentally friendly output. Nevertheless, this additional value, or consumer surplus, is deemed negligible compared to the other costs and benefits, and therefore, it is not included in the calculation of the economic net present value.

(v) Evaluation of non-market impacts and corrections for externalities: The analysis takes into account the external costs and benefits of the proposed technologies, particularly in terms of GHG emissions, predominantly CO_2. The assessment of environmental value is based on data available for environmental damage factors per unit of energy consumed. Conversion emission factors from EWA, other local sources and general literature are used to estimate how environmental value changes with the introduction of alternative technologies compared to the baseline scenario.

Additionally, the valuation of GHG emissions and their impact on climate change employs a damage-cost approach, assigning higher values per ton of emissions. These shadow values of CO_2 emissions are tabulated further down in this section of the report. The comparison is made against the baseline scenario, focusing on reductions in greenhouse gas emissions and primary energy savings, measured in GWh per year. On the other hand, the proposed measures are not expected to significantly alter the proportion of renewable energy in the national energy mix and as such, no valuation for this aspect was considered necessary.

For clarity, the CBA mainly accounts for CO_2 emissions. Other greenhouse gases and pollutants are acknowledged but considered minor in comparison to CO_2, and thus are not highlighted in the analysis. Similarly, the analysis does not consider potential cost savings from transportation-related emissions that could be mitigated by specific measures, such as those that would eliminate the need for road transport distribution like the delivery of LPG cylinders, because their overall effect is considered negligible.

[103] Subsidiary legislation 545.34, Electricity Regulation (2021), available at:
LEĠIŻLAZZJONI MALTA (legislation.mt)

(vi) Social discount rate: like the financial analysis before it, economic costs and benefits occurring at different time intervals will need to be discounted in order to take into account the time value of money. The discount rate in the economic analysis of investment projects is the social discount rate (SDR) and reflects the social view on how future benefits and costs should be valued against present ones. In this case, it differs from the FDR on the assumption that the capital market is inefficient, that is, projects having a public good element would not be implemented (in full) by the private sector. Based on the above EC guidelines, an SDR of 5% will be applied to estimate the economic performance indicators for this CBA.

(vii) Economic performance metrics: the project's economic performance is measured using the following metrics:

a. Economic Net Present Value (ENPV): for the investment to be economically acceptable, the ENPV needs to be positive (i.e. the present value of economic benefits outweighs the present value of economic costs, thus increasing social welfare).

b. Economic Rate of Return (ERR): a project with an ERR lower than the SDR should be rejected. Occasionally, the ERR can pose challenges in interpretation since it might be undefined. For this reason, the ENPV is the most important and reliable social CBA indicator and is used as the main reference economic performance signal for project appraisal.

c. Benefit-to-Cost Ratio (B/C): this gives the ratio between the discounted economic benefits and costs. For a project to be deemed desirable from the socio-economic point of view, this ratio should be greater than one.

This study evaluates the economic impact of the proposed alternative solutions by considering the typical benefits and valuation techniques for energy efficiency projects as outlined in the EC Guide to CBA of Investment Projects (2014)[104], namely:

Table 78 - Typical benefits and valuation methods of energy-efficient consumption projects

Economic benefit	Valuation method	Counterfactual
Increase of efficiency for consumption	Variation in economic costs of the energy source/fuel	Business as usual
Increase of comfort	Variation in economic costs of the energy source/fuel	Economic energy cost sustained to maintain a 'thermal comfort' temperature through the without-the-project technology/system of energy production

[104] Guide to Cost-Benefit Analysis of Investment Projects, 2014, pg. 226

Reduction of GHG emissions	Shadow price of GHG emissions	Business as usual
Reduction of air pollutant emissions	Shadow price of air pollutants	Business as usual

Whereas increase of efficiency for consumption and reductions in GHG and air pollutant emissions are directly related to the alternative scenarios considered, there is no increase in thermal comfort from the alternative technologies proposed. The levels of space or water cooling and heating provided by the proposed technologies are equivalent to those in the baseline scenario, and as such, no additional calculations for thermal comfort are conducted. Furthermore, while the reduction of air pollutant emissions does contribute to societal welfare, its economic value is considered less significant compared to the value of CO_2 emission reductions. Therefore, the focus of the calculations is primarily on the latter.

It is important to note that the Government of Malta has a significant ownership stake in Enemalta plc, the sole energy operator and distributor in Malta. The profitability of this entity is of interest to the Government, both as an investor and in terms of ensuring a secure energy supply for the Maltese community. However, this study views these aspects as cost savings for one segment of society (i.e., energy generation and distribution) that are then reinvested by citizens into other sectors (i.e., energy-efficient technologies). Consequently, these displaced impacts are not considered in the economic analysis.

In summary, the main external benefits from the adoption of energy efficient technologies are based on:

i. CO_2 emissions avoided

ii. Primary energy cost savings.

CO_2 emissions are calculated through conversion factors applied to the energy consumed in the baseline and alternative scenarios. For electricity, this depends on the projected mix of fuels used in electricity generation in Malta, taking into consideration three possible scenarios of decarbonization by 2050. These and the factors for the other fuels used in this study are the following:

Table 79 - CO_2 emission factors

Fuel	Emission factor
Electricity - Scenario 1	A shift in the energy mix from 2025 to 2030, which leads to a reduction in the emission factor from 0.3709 kg/kWh in 2025 to 0.1249 kg/kWh in 2030[105], remaining steady thereafter until 2050.
Electricity – Scenario 2	A shift in the energy mix from 2025 to 2030, which leads to a reduction in the emission factor from 0.3709 kg/kWh in 2025 to 0.1249 kg/kWh in 2030, decreasing linearly thereafter up to a 50% reduction in emissions by 2050.
Electricity – Scenario 3	A shift in the energy mix from 2025 to 2030, which leads to a reduction in the emission factor from 0.3709 kg/kWh in 2025 to 0.1249 kg/kWh in 2030, decreasing linearly thereafter up to a 100% reduction (i.e. reaching 0 kg/kWh by 2050.
LPG	0.227160 kg/kWh [106]
Diesel / Gasoil	0.266760 kg/kWh
Biodiesel	0.254880 kg/kWh

In line with the EC technical guidelines on the climate proofing of infrastructure 2021 – 2027, it is recommended that project evaluators use the shadow price of carbon recently established by the EIB *"as the best available evidence on the cost of meeting the temperature goal of the Paris agreement (i.e. the 1.5°C target)"*.[107] [108] For ease of reference, the recommended shadow cost of carbon for 2020 – 2050, which have also been applied by this assessment to estimate the monetary value of GHG emission reductions, are reproduced in the table below.

[105] Source: EWA

[106] IPCC Guidelines for National Greenhouse Gas Inventories (2006). Default emission factors for stationary combustion in the energy industries (pgs16 – 17). Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

[107] European Commission (2021), COMMISSION NOTICE Technical guidance on the climate proofing of infrastructure in the period 2021-2027, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52021XC0916(03)&from=EN)

[108] In 2020, the EIB was engaged in a review of the latest evidence on the cost of carbon, in particular drawing from modelling results that formed the basis of the Intergovernmental Panel on Climate Change Special Report on global Warning of 1.5°C. In light of the Paris Agreement, the review of the EIB's carbon pricing approach focused on the full cost of the marginal measure required to drive the economy to meet the global temperature target (abatement cost approach; see https://www.eib.org/en/publications/the-eib-group-climate-bank-roadmap).

Table 80 - Recommended shadow cost of carbon for 2020 – 2050

Year	Eur/t CO_2e	Year	Eur/t CO_2e	Year	Eur/t CO_2e	Year	Eur/t CO_2e
2020	*80*	**2028**	*216*	**2036**	*417*	**2044**	*633*
2021	*97*	**2029**	*233*	**2037**	*444*	**2045**	*660*
2022	*114*	**2030**	*250*	**2038**	*471*	**2046**	*688*
2023	*131*	**2031**	*278*	**2039**	*498*	**2047**	*716*
2024	*148*	**2032**	*306*	**2040**	*525*	**2048**	*744*
2025	*165*	**2033**	*334*	**2041**	*552*	**2049**	*772*
2026	*182*	**2034**	*362*	**2042**	*579*	**2050**	*800*
2027	*199*	**2035**	*390*	**2043**	*606*		

Whilst there are other concepts to estimate the damage associated with the emission of a tonne of carbon (social cost of carbon), or price signals derived from market-based instruments (e.g. carbon taxes, cap-and-trade schemes such as EU ETS), the shadow price concept applied by EIB establishes the cost of carbon required to drive the economy to meet the 1.5˚C global temperature target of the Paris agreement. Given Malta is a committed signatory of the agreement, as well as the use of these EIB values being recommended in the EC technical guidance on future-proofing infrastructure, these values were applied as they reflect both the national ambition as well as fitting the nature of a energy infrastructure project benefitting society at large. This input is clearly a material variable in the economic model and any applied changes could have an impact on the final outcome. In the sensitivity analysis, presented as part of the CBA of each potential intervention measure, this component is shocked separately to gauge changes to the end result following a 1% change in this variable.

3.2 Financial and Economic Analyses of the Alternative Scenarios

This section analyses the financial and economic potential of different technologies for heating and cooling installed in three key areas identified in the previous parts of this study – residential, hotels, and other commercial entities such as restaurants.

For each solution proposed, an individual cost benefit analysis is conducted to determine:

i. The financial performance from the investor's point of view, and

ii. The consolidated economic impact of adopting the alternative technology by multiple stakeholders in society.

3.2.1 Residential Sector

3.2.1.1 Residential Measure R1A - Replacing electrical water heaters with heat pumps (Decentralised approach)

This measure considers the replacement of individual electric water heaters within private households with heat pump water heaters. Since electric water heaters are presently the most common technology in use to meet residential hot water demand, this intervention is applicable to almost all households in Malta (~233,977) except those that already use heat pumps or have solar water heaters installed (~15,000). The key parameters for the intervention are summarized in Table 81.

Table 81 - Key parameters for measure R1A

	Baseline	**Alternative**
Data	**Electric Water Heaters**	**Heat Pump Water Heaters**
Units per household	1	1
Efficiency losses p.a.	0.015	0.008
Technical Life (years)	10	15
Price per unit inc. VAT (€)	220	2,155
Structural alterations in Y1 inc. VAT (€)	0	113
Annual useful energy demand for water heating per household (kWh, 2022)	1,231	1,231
Coefficient of Performance (CoP)	0.9	3.37
Annual electricity consumption for water heating per household (kWh, 2022)	1,368	365
Weighted electricity tariff – Residential inc. VAT (€/kWh)	0.1186	0.1186
Repairs and Maintenance Cost (% of Investment)	10	10
Repairs and Maintenance Cost Interval (in Years)	5	8

From the perspective of the individual household, the main investment cost is incurred in Y1 (2025), where the current electric water heater installed has reached the end of its technical life and is due for replacement with either the baseline or alternative technology. A one-time cost for structural changes to the household is also included in Y1 for the alternative scenario, and covers ancillary material (such as piping) and any labour costs associated with installation. Within the reference period of this scenario, it is assumed that equipment is replaced with identical technology when it reaches the end of its technical lifetime, and that the equipment experiences an annual drop in efficiency due to ageing. The equipment is also subject to periodic maintenance throughout its technical lifetime, for which the cost is calculated as a percentage of the initial investment.

Operating costs for both electric water heaters and heat pump water heaters are based on their electrical consumption and the weighted tariff shown in Table 81.

Results from financial analysis

Table 82 summarises the results of the financial analysis from the perspective of the homeowner, which is strongly affected by significant incremental investment and reinvestment costs in Y1 and Y15 respectively. These costs are partially offset by the residual value. However, the savings in operational costs achieved by transitioning from an electric water heater to a heat pump do not compensate for the investment costs over the analysed period. Consequently, without any form of subsidies or government incentives, it would not be financially appealing for a private household to adopt this alternative technology. As a result, the recommended action (R1A) leads to a negative financial net present value (FNPV) of €946 and a negative financial rate of return (FRR) of 1.2%. Given the negative FNPV, the payback period is not relevant to the consideration of this measure.

Table 82 - Measure R1A – Financial NPV (25 years, 2025-50)

2025-2050 - NPV (EUR)	Electric Water Heater	Heat Pump	Incremental
Investment Costs	(470)	(3,445)	(2,975)
Residual Value	32	211	179
Operating & Maintenance costs	(2,838)	(988)	1,850
Revenues	-	-	-
Net Cash Flows	(3,276)	(4,222)	(946)
FRR (C)			-1.2%

Results from the Economic Analysis (Benchmark Scenario)

To assess the wider socio-economic impact of the proposed measure, the economic analysis evaluates the change in welfare stemming from the introduction of the alternative technology under three demand scenarios. These scenarios account for diverse degrees of technology adoption within households. Table 83 provides the underlying data on population and households spanning from 2025 to 2050.

Table 83 - Population and household data

	2025	2030	2035	2040	2045	2050
Population of Malta and Gozo	564,212	610,244	643,551	670,787	701,413	727,834
Total number of households	237,840	264,037	282,992	298,492	310,932	320,054

The first scenario assumes a steady rate of 2,000 annual conversions, over and above the 15,000 households which already have a solar water heater or a heat pump installed, resulting in a 27% adoption rate across all households by the year 2050. In contrast, the second and third demand scenarios are more ambitious, projecting 50% and 100% uptake rates by 2050, respectively. Table 84 breaks down the cumulative number of households that would have adopted the alternative technology at ten-year intervals under each of the three scenarios.

Table 84 - Demand for Heat Pumps for water heating in households: three scenarios 2025-2050

Demand Scenario	**Description**	**by 2030**	**by 2040**	**by 2050**	**% by 2050**
R1A-SCN1	2,000 households annually till 2050	27,000	47,000	67,000	21%
R1A-SCN2	50% of all households by 2050	27,000	93,510	160,027	50%
R1A-SCN3	100% of all households by 2050	27,000	173,520	320,054	100%

The Benchmark Scenario (BM) assumes the demand scenario R1A-SCN1. The remaining two scenarios will be explored in the subsequent Sensitivity Analysis. Another factor in the economic assessment is the amount of CO_2 emissions, which is evaluated based on three energy decarbonization scenarios related to electricity generation in Malta. These are reproduced below for ease of reference.

Table 85 - Electricity CO_2 emissions – three scenarios

Fuel	**Emission factor**
Electricity - Scenario 1	A shift in the energy mix from 2025 to 2030, which leads to a reduction in the emission factor from 0.3709 kg/kWh in 2025 to 0.1249 kg/kWh in 2030[109], remaining steady thereafter until 2050.
Electricity – Scenario 2	A shift in the energy mix from 2025 to 2030, which leads to a reduction in the emission factor from 0.3709 kg/kWh in 2025 to 0.1249 kg/kWh in 2030, decreasing linearly thereafter up to a 50% reduction in emissions by 2050.
Electricity – Scenario 3	A shift in the energy mix from 2025 to 2030, which leads to a reduction in the emission factor from 0.3709 kg/kWh in 2025 to 0.1249 kg/kWh in 2030, decreasing linearly thereafter up to a 100% reduction (i.e. reaching 0 kg/kWh by 2050).

[109] Source: EWA

The Benchmark Scenario considers carbon emission factors based on a 2025-2030 forecast for the energy mix for electricity (Source: Electricity Supply Study Update – EWA), that then remains constant post-2030 (Electricity – Scenario 1). The economic performance is summarized below.

Table 86 - Measure R1A – Economic NPV (25 years, 2025-50)

2025-2050 – ENPV, EUR	**Incremental Costs and Benefits (EUR)**
Investment, Repairs and Residual Value (inc. VAT)	(79,432,264)
Fiscal Correction: VAT	9,637,991
Fiscal Correction: Subsidies	-
Residual Value	16,249,879
Net Capex	(53,544,394)
CO2 Emissions avoided	22,452,846
Primary Energy Savings	45,648,723
ENPV: Net (COSTS) / BENEFITS	14,557,174
ERR	9.2%
B/C RATIO	1.27

The estimated ENPV of approximately €14.6 million over the 25-year period indicates that the proposed intervention is likely to enhance social welfare, primarily due to the conservation of primary energy and notable reductions in CO_2 emissions. Furthermore, the intervention yields an ERR of 9.2%, which surpasses the SDR of 5.0% applied in this CBA, indicating that social returns for the measure justify the use of resources being proposed. Additionally, the calculated B/C ratio of 1.27 suggests that the project is economically viable, as a ratio above one indicates that the benefits exceed the costs. Consequently, considering the broader societal benefits, government incentives to close the financial gap for households, thereby encouraging adoption, would be warranted.

Part II of this assessment outlines an existing incentive program administered by REWS for heat pump water heaters, providing residential applicants with a rebate that covers up to 50% of the cost of the heat pump water heater, including VAT, up to a maximum limit of €1,000.[110] The results presented in the accompanying table suggests that this incentive is effective in promoting the adoption of heat pump technology for water heating, as the FNPV becomes positive when the subsidy is factored in.

[110] REWS Heat Pump Water Heater Scheme (Active). Available at: Regulator for Energy and Water Services > en/sdgr/466-2021-heat-pump-water-heater-scheme-active (rews.org.mt)

Table 87 - Measure R1A – Financial NPV with the inclusion of current subsidy scheme (25 years, 2025-50)

2025-2050 - NPV (EUR)	Electric Water Heater	Heat Pump	Incremental
Investment Costs	(470)	(3,445)	(2,975)
Residual Value	32	211	179
Operating & Maintenance costs	(2,838)	(988)	1,850
Revenues	-	981	981
Net Cash Flows	(3,276)	(3,241)	34
FRR (C)			4.4%

Sensitivity Analysis

Sensitivity Analysis (Part 1) – Combination of demand levels and electricity decarbonization scenarios

The ENPVs for each combination of demand and emissions scenario considered in the CBA are summarized in Table 88. The respective effects on the primary energy savings and carbon emissions are presented in Figure 125.

Table 88 - Measure R1A – Sensitivity of ENPV to demand and CO_2 (25 years, 2025-50)

Incremental ENPV (€), 2025-50	Demand 1 [2,000 till 2050]	Demand 2 [50% till 2050]	Demand 3 [100% till 2050]
CO_2 - Scenario 1 (constant 2030 onwards)	14,557,174 (BM)	34,922,383	69,956,146
CO_2 - Scenario 2 (grad-50%)	1,671,413	2,206,441	3,126,835
CO_2 - Scenario 3 (grad-100%)	(7,721,056)	(22,196,316)	(47,097,748)

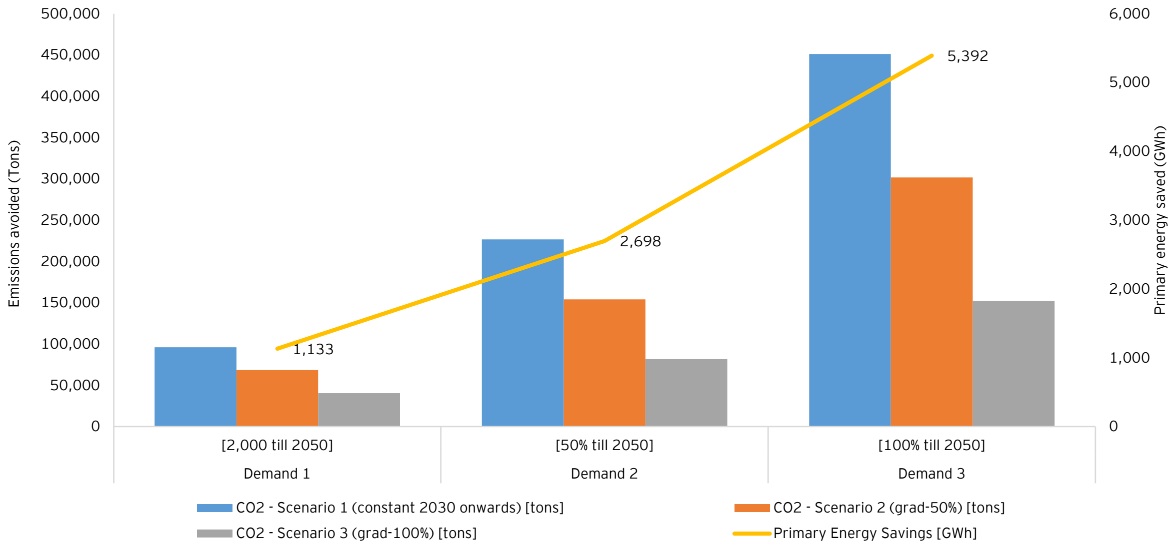

Figure 125 - Measure R1A – CO_2 emissions avoided (tons) and Primary energy savings (GWh)

These results are best described by referring to S below which depicts the path of CO_2 emission reductions for each of the three demand scenarios as determined by the progression of emission factors within three potential pathways for decarbonizing electricity from 2025 to 2050. Under demand scenario 1, the emission factor decreases between 2025 and 2030 and then stabilizes at a constant value of 0.1249 kg/kWh beyond 2030. In contrast, under demand scenarios 2 and 3, the emission factor continues to decrease steadily, reaching 0.0625 kg/kWh (a 50% reduction) and 0 kg/kWh (a 100% reduction) by 2050, respectively. As a result, the emissions savings per kWh of electricity consumed decrease steadily under CO_2 scenario 2 and at twice the rate under CO_2 scenario 3. This progression leads to the stepped decline in emissions reductions observed in Figure 125 under each demand scenario. Additionally, this trend plays a significant role in the decreasing ENPVs shown in Table 88, as emission reductions are pivotal in the calculation of economic benefits, particularly when multiplied by the increased shadow prices of carbon recently set by the EIB.[111] In other words, as the energy grid becomes greener under CO_2 scenarios 2 and 3, there is reduced potential for economic gains from investing in alternative technologies due to emission reductions occurring at the point of energy production. This means that the economic benefits for such investments diminish as emissions are already being cut at the source.

[111] The shadow price component is shocked separately in the next part of the sensitivity analysis, to gauge changes to the end result following a 1% change in this variable.

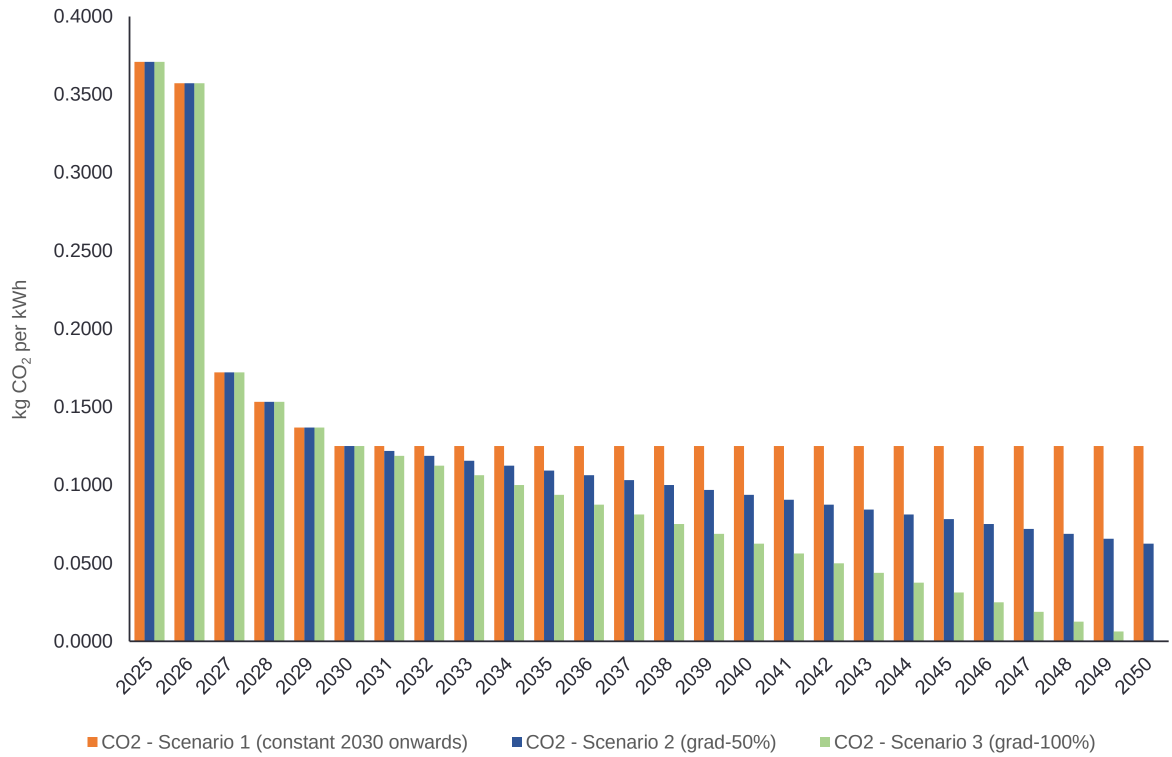

Figure 126 - Levels of decarbonisation – CO_2 emission factor progression under the 3 decarbonisation scenarios

Sensitivity Analysis (Part 2) – Sensitivity to changes in major variables

This part of the analysis examines the reaction of the financial and economic results determined in the economic analysis above, to a positive or negative change in a key variable. The analysis below is carried out by changing one variable at a time and determining the effect of that change on the NPV. As a general rule, in accordance with the CBA Guide (EU CION, 2014), 'critical' variables are those for which a variation of ±1% of the value adopted in the base case (i.e. the benchmark scenario[112]) gives rise to a variation of more than ±1% in the value of the NPV. Three key variables are analysed, namely:

i. Primary energy prices and electricity tariffs

ii. Investment cost of the alternative technology

iii. Shadow prices of carbon

The independent variables are isolated and measures to remove deterministic interdependencies (e.g. splitting a variable in its independent components) are taken. The

[112] The benchmark scenario BM = an uptake of the alternative technology by 2,000 households annually until 2050 and the retention of the 2030 projected electricity mix (Source: Electricity Supply Study Update – EWA) through 2050.

following table summarizes the critical elements for measure R1A in red, those which are not critical are in green.

Table 89 - Measure R1A – Sensitivity Analysis: Critical and non-critical variables

Variable	Variation of the FNPV due to a ± 1 % variation	Criticality judgement	Variation of the ENPV due to a ± 1 % variation	Criticality judgement
Primary energy prices & Electricity tariffs	2.2%	Critical	3.1%	Critical
Alternative technology investment cost	3.6%	Critical	4.0%	Critical
EU ETS Carbon Price	N/A	N/A	1.5%	Critical

The FNPV is sensitive to changes in the main cost drivers – investment costs and the electricity costs. The appeal of measure R1A is based on the potential to improve energy efficiency and consequently reduce energy costs. However, this benefit is offset by the substantial upfront investment and subsequent reinvestment costs. As a result, government subsidies play a crucial role in making the investment viable for investors.

Similarly, economic welfare is closely linked to the level of primary energy and electricity prices, and the price of the alternative technology. As a matter of fact, when higher levels of demand coincide with a completely decarbonized supply of energy, the ENPV turns significantly negative (see Table 90) mainly due to the financial costs invested by a larger population in the alternative technology not being offset by the resulting energy savings and reduction in emissions. The shadow price of carbon, which is applied to the emissions averted to calculate the monetary economic benefit derived from the alternative technology, which has recently been revised upwards by the EIB to align with commitments to GHG emission reductions and removal goals is also found to be a critical input to the analysis.

Table 90 - Measure R1A – Sensitivity Analysis: Comparison Benchmark vs Worst-performing Scenario

2025-2050 – ENPV, EUR	CO_2 - Scenario 3 (grad-100%) & Demand 3 [100% till 2050]	Benchmark scenario
Investment, Repairs and Residual Value (inc. VAT)	(379,155,747)	(79,432,264)
Fiscal Correction: VAT	42,317,568	9,637,991
Fiscal Correction: Subsidies	-	-
Residual Value	101,740,580	16,249,879
Net Capex	(235,097,599)	(53,544,394)
CO2 Emissions avoided	35,970,113	22,452,846
Primary Energy Savings	152,029,738	45,648,723
ENPV: Net (COSTS) / BENEFITS	(47,097,748)	14,557,174

To understand the impact of different estimations of opportunity cost, a separate assessment examines the responsiveness of the key indicators to an increase and decrease in the FDR and the SDR by 1 point over the benchmark rates of 4% and 5% respectively. The results are shown hereunder.

Table 91 - Measure R1A – Sensitivity Analysis: Effect of different FDR and SDR

Financial Discount Rate	FNPV	Social Discount Rate	ENPV
3%	(€848)	4%	€20,893,295
4% - BM	(€946)	5% - BM	€14,557,174
5%	(€1,023)	6%	€9,603,616

As a final assessment of sensitivity, all three key variables were separately tested to identify the minimum change allowed before the FNPV or the ENPV turn negative. Switching values of an absolute value less than 100% are considered critical, with a higher risk of changing the financial or economic feasibility of the scenario. Put it differently, variables with critical switching values will require less than a ±100% change to bring FNPV/ENPV to zero (breakeven point). The below confirms the high sensitivity of both NPVs to changes in the energy prices, investment costs and the shadow price of carbon.

Table 92 - Measure R1A – Sensitivity Analysis: Switching Values

	FNPV - BM	ENPV - BM
	(€946)	€13,067,692
	Percentage change for **FNPV** to become zero	Percentage change for **ENPV** to become zero
Primary energy prices & Electricity tariffs	46%	-32%
Alternative technology investment cost	-28%	25%
EU ETS Carbon Price	N/A	-65%

The relatively low switching value of primary energy prices and electricity in relation to ENPV, indicating sensitivity, can be put down to one key aspect. The benefits of the alternative solution in the context of the Benchmark Scenario (demand scenario at 2,000 households per annum and CO_2 emissions held constant after 2030 until 2050) are mainly driven by its ability to generate savings in primary energy. A change in the unit price of energy has a significant effect on its economic performance – lower energy tariffs reduce the incentive to invest in alternative technologies aimed at energy efficiency, and thus savings.

Scenario Analysis – Increasing maintenance costs for electric water heaters

After consulting with EWA, it was determined that the initial estimate for maintenance costs of electric water heaters was too low. Consequently, the cost analysis was revised to reflect a maintenance expense of €50 every four years, totalling €100 over the lifespan of an electric water heater. This is in contrast to the original estimate, which was based on a maintenance cost of 10% of the investment cost, amounting to €22 throughout the heater's operational period. The updated results are summarised below. Despite these adjustments, the revised assessment does not significantly alter the conclusions drawn from the initial results.

Table 93 - Measure R1A – Sensitivity Analysis: Increasing maintenance costs for electric water heaters

Individual			**Society**		
FNPV	**FRR**	**Payback Period**	**ENPV**	**ERR**	**B/C ratio**
(830)	-0.6%	N/A	16,487,464	9.7%	1.32

3.2.1.2 Residential Measure R1B - Replacing electrical water heaters with heat pumps (Centralised approach)

This measure considers newly constructed apartment blocks made up of 5 separate households which are purposely built to accommodate either:

- Individual electric water heaters per household (the baseline), or
- A centralized heat pump hot water system for the entire block (the alternative).

Retrofitting of existing apartment blocks is not considered in this analysis due to the significant structural expenses required for installation. Additionally, potential alterations to the legislative framework that might be necessary for a centralized system of this kind to be introduced to Malta, as well as the condominium space required for such a system's installation, have not been factored into the assessment. Moreover, the financial implications of how billing would be divided among all residential units utilizing the system have not been considered. Therefore, the evaluation of this measure is strictly from a financial perspective of the system itself, without accounting for these aspects. The key parameters are summarized in Table 94.

Table 94 - Key parameters for measure R1B

	Baseline	Alternative
Data	**Electric Water Heaters**	**Heat Pump Water Heaters**
Units per household	1	0.2
Efficiency losses p.a.	0.015	0.008
Technical Life (years)	10	15
Price per unit inc. VAT (€)	220	10,300
Price per household inc. VAT (€)	220	2,060
Structural alterations in Y1 inc. VAT (€)	0	0
Annual useful energy demand for water heating per household (kWh, 2022)	1,231	1,231
Coefficient of Performance (CoP)	0.9	3.37
Annual electricity consumption for water heating per household (kWh, 2022)	1,368	365
Weighted electricity tariff – Residential inc. VAT (€/kWh)	0.1186	0.1186
Repairs and Maintenance Cost (% of Investment)	10	10
Repairs and Maintenance Cost Interval (in Years)	5	8

The main investment cost from the perspective of the individual household is incurred in Y1 (2025), and only covers the cost of the equipment itself. Since this measure only targets new builds, no costs associated with structural alternations are included in the model. Within the reference period of this measure, it is assumed that equipment is replaced with identical technology when it reaches the end of its technical lifetime, and that the equipment experiences an annual drop in efficiency due to ageing. The equipment is also subject to periodic maintenance throughout its technical lifetime, for which the cost is calculated as a percentage of the initial investment. Operating costs for both electric water heaters and heat pump water heaters are based on their electrical consumption and the weighted tariff shown in Table 94.

Results from financial analysis

Table 95 presents the financial analysis from the viewpoint of a homeowner who, along with four other homeowners in the same apartment block, invests in a centralized system. Comparable to the findings from the decentralized approach (R1A), the centralized method results in a negative FNPV of €687 and a marginally negative FRR of 0.2%. This outcome stems from the substantial initial investment required for the entire system, which nonetheless delivers improved financial outcomes on a per-unit basis relative to the decentralized setup, thanks to the economies of scale behind centralisation. Given the negative FNPV, the payback period is not relevant to the consideration of this measure.

Table 95 - Measure R1B – Financial NPV (25 years, 2025-50)

2025-2050 - NPV (EUR)	**Electric Water Heater**	**Heat Pump**	**Incremental**
Investment Costs	(470)	(3,187)	(2,717)
Residual Value	32	202	170
Operating & Maintenance costs	(2,838)	(977)	1,861
Revenues	-	-	-
Net Cash Flows	(3,276)	(3,962)	(687)
FRR (C)			-0.2%

Results from the Economic Analysis (Benchmark Scenario)

The economic analysis examines the broader socio-economic effects of the proposed initiative by measuring the shift in welfare due to the adoption of a new technology under three different demand scenarios. These scenarios reflect varying levels of technology uptake, specifically in the context of new apartment blocks. Table 96 presents the foundational data on the housing inventory projections from 2025 to 2050. Drawing from the existing building stock in Malta, the assumption is made that approximately 74% of the new construction will be apartment buildings, making them suitable candidates for the centralized approach. Additionally, it is estimated that, on average, an apartment block will consist of 5 residential units.

Table 96 - Underlying household data and projected number of new apartment units[113]

	2025	**2030**	**2035**	**2040**	**2045**	**2050**
Total number of households	237,840	264,037	282,992	298,492	310,932	320,054

	2025	**2026**	**2027**	**2028**	**2029**	**2030**
Number of new apartment units each year	4,042	6,117	5,902	5,611	5,067	4,716
	2031	**2032**	**2033**	**2034**	**2035**	**2036**
	3,472	3,494	2,640	2,604	2,613	2,560
	2037	**2038**	**2039**	**2040**	**2041**	**2042**
	2,487	2,418	2,345	2,312	2,101	2,120
	2043	**2044**	**2045**	**2046**	**2047**	**2048**
	1,901	1,916	1,690	1,702	1,469	1,478
	2049	**2050**				
	1,239	1,245				

113 Source: NECP and EWA; Author's estimates

The initial scenario envisions a consistent annual adoption rate of 10% for new apartments through to the year 2050. On the other hand, the second and third scenarios are more optimistic, forecasting adoption rates increasing linearly towards 50% and 100% by 2050, respectively. Table 97 details the total number of new apartments that will have installed centralized heat pump water heaters, with the data segmented into ten-year periods for each scenario.

Table 97 - Demand for Heat Pumps for water heating in households: three scenarios 2025-2050

Demand Scenario	Cumulative take-up by 2050	by 2030	by 2040	by 2050
R1B-SCN1	10% annual uptake by 2050	3,135	5,805	7,470
R1B-SCN2	50% of all new apartments by 2050	3,135	8,565	15,275
R1B-SCN3	100% of all new apartments by 2050	3,135	12,020	25,055

The Benchmark Scenario (BM) assumes the demand scenario R1B-SCN1. The remaining two scenarios will be explored in the subsequent Sensitivity Analysis. Another factor in the economic assessment is the amount of CO_2 emissions, which is evaluated based on three energy decarbonization scenarios related to electricity generation in Malta, already described when assessing R1A. The Benchmark Scenario considers carbon emission factors based on a 2025-2030 forecast for the energy mix for electricity (Source: Electricity Supply Study Update – EWA), that then remains constant post-2030 (Electricity – Scenario 1). The economic performance is summarized below.

Table 98 - Measure R1B – Economic NPV (25 years, 2025-50)

2025-2050 – ENPV, EUR	Incremental Costs and Benefits (EUR)
Investment, Repairs and Residual Value (inc. VAT)	(12,883,289)
Fiscal Correction: VAT	1,652,006
Fiscal Correction: Subsidies	-
Residual Value	2,053,472
Net Capex	(9,177,811)
CO2 Emissions avoided	4,030,708
Primary Energy Savings	8,724,293
ENPV: Net (COSTS) / BENEFITS	3,577,191
ERR	10.9%
B/C RATIO	1.39

Similar to the decentralized model, the centralized heat pump water heater system's ENPV is positive, at around €3.6 million over a 25-year span. This figure is less than the €14.6 million observed for R1A, primarily because the centralized system targets new apartments, which represent a smaller potential market compared to all households. Despite this, the centralized option generates better financial results due to economies of scale, resulting in a higher ERR of 10.9%, compared to R1A's 9.2%. The B/C ratio for the centralized system is also marginally better at 1.39, surpassing R1A's ratio. Regardless, these figures indicate the project's economic soundness, as a B/C ratio over one signifies that the benefits outweigh the costs. Therefore, to maximize societal gains, it would be prudent for the government to incentivize market participation by bridging the financial gap for landlords/households, thereby promoting wider adoption. This could involve extending the existing financial incentives referenced with regards to R1A to also cover the centralized approach.

Sensitivity Analysis

Sensitivity Analysis (Part 1) – Combination of demand levels and electricity decarbonization scenarios

The ENPVs for each combination of demand and emissions scenario considered in the CBA are summarized in Table 99. The respective effects on the primary energy savings and carbon emissions are presented in Figure 127.

Table 99 - Measure R1B – Sensitivity of ENPV to demand and CO_2 (25 years, 2025-50)

Incremental ENPV (€), 2025-50	**Demand 1 [10% till 2050]**	**Demand 2 [50% till 2050]**	**Demand 3 [100% till 2050]**
CO_2 - Scenario 1 (constant 2030 onwards)	3,577,191 (BM)	5,458,366	7,814,686
CO_2 - Scenario 2 (grad-50%)	1,389,569	1,866,788	2,464,303
CO_2 - Scenario 3 (grad-100%)	(160,856)	(777,680)	(1,550,814)

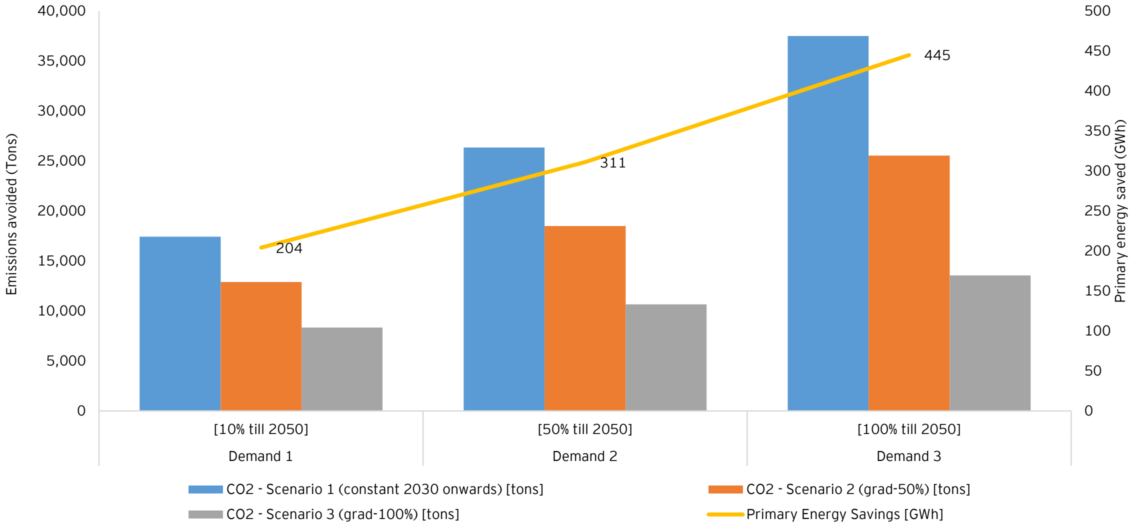

Figure 127 - Measure R1B – CO_2 emissions avoided (tons) and Primary energy savings (GWh)

Comparable to the findings for the earlier residential measure (R1A), the emissions savings for each kWh of electricity used consistently diminish under CO_2 scenario 2 and do so at double the pace under CO_2 scenario 3, due to more rapid decarbonization of electricity post-2030. This trend results in the reduction in emissions savings across different demand scenarios observed in Figure 127, which is a key factor in the declining ENPVs presented in Table 99. The forecasted emission factors associated with each CO_2 scenario remain an essential variable for determining the economic benefits associated with this measure.

Sensitivity Analysis (Part 2) – Sensitivity to changes in major variables

The critical variables are in red below.

Table 100 - Measure R1B – Sensitivity Analysis: Critical and non-critical variables

Variable	**Variation of the FNPV due to a ± 1 % variation**	**Criticality judgement**	**Variation of the ENPV due to a ± 1 % variation**	**Criticality judgement**
Primary energy prices & Electricity tariffs	3.0%	Critical	2.4%	Critical
Alternative technology investment cost	4.7%	Critical	3.0%	Critical
EU ETS Carbon Price	N/A	N/A	1.1%	Critical

In conclusion, with regards to the above, the same points discussed previously for measure R1A are applicable to R1B. Meanwhile, the impact of varying FDR and SDR is shown below.

Table 101 - Measure R1B – Sensitivity Analysis: Effect of different FDR and SDR

Financial Discount Rate	**FNPV**	**Social Discount Rate**	**ENPV**
3%	(€581)	4%	€4,793,153
4% - BM	(€687)	5% - BM	€3,577,191
5%	(€771)	6%	€2,606,131

Finally, the switching values under this measure are the following.

Table 102 - Measure R1B – Sensitivity Analysis: Switching Values

	FNPV - BM	**ENPV - BM**
	(€687)	€3,287,771
	Percentage change for **FNPV** to become zero	Percentage change for **ENPV** to become zero
Primary energy prices & Electricity tariffs	33%	-41%
Alternative technology investment cost	-21%	33%
EU ETS Carbon Price	N/A	-89%

Scenario Analysis – Increasing maintenance costs for electric water heaters

Same as measure R1A, it was determined that the initial estimate for maintenance costs of electric water heaters was too low. Consequently, the cost analysis was revised to reflect a maintenance expense of €50 every four years, totalling €100 over the lifespan of an electric water heater. This is in contrast to the original estimate, which was based on a maintenance cost of 10% of the investment cost, amounting to €22 throughout the heater's operational period. The updated results are summarised below. Despite these adjustments, the revised assessment does not significantly alter the conclusions drawn from the initial results.

Table 103 - Measure R1B – Sensitivity Analysis: Increasing maintenance costs for electric water heaters

Individual			Society		
FNPV	**FRR**	**Payback Period**	**ENPV**	**ERR**	**B/C ratio**
(571)	0.5%	N/A	3,949,144	11.5%	1.45

3.2.1.3 Residential Measure R2A - Replacing electrical water heaters with solar water heaters (Decentralised approach)

This measure considers the replacement of individual electric water heaters within private households with solar water heaters. Since electric water heaters are presently the most common technology in use to meet residential hot water demand, this intervention is theoretically applicable to almost all households in Malta (~233,977) except those that already have solar water heaters installed or use heat pumps (~15,000). However, the physical limitations of many existing builds (namely, the lack of adequate flat space exposed to sunlight for those living in apartments) will decrease the number of households that can practically adopt this measure. Still, this assessment will account for the maximum possible adoption rate. The key parameters for the intervention are summarized in Table 104.

Table 104 - Key parameters for measure R2A

	Baseline	**Alternative**
Data	**Electric Water Heaters**	**Solar Water Heaters**
Units per household	1	1
Efficiency losses p.a.	0.015	0.0075
Technical Life (years)	10	15
Price per unit inc. VAT (€)	220	2,126
Structural alterations in Y1 inc. VAT (€)	0	226
Annual useful energy demand for water heating per household (kWh, 2022)	1,231	1,231
Coefficient of Performance (CoP)	0.9	0.58
Annual electricity consumption for water heating per household (kWh, 2022)	1,368	0
Electricity tariff – Residential inc. VAT (€/kWh)	0.1186	N/A
Repairs and Maintenance Cost (% of Investment)	10	10
Repairs and Maintenance Cost Interval (in Years)	5	8

From the perspective of the individual household, the main investment cost is incurred in Y1 (2025), where the current electric water heater installed has reached the end of its technical life and is due for replacement with either the baseline or alternative technology. A one-time cost for structural changes to the household is also included in Y1 for the alternative scenario, and covers ancillary material (such as piping) and any labour costs associated with installation. Within the reference period of this scenario, it is assumed that equipment is replaced with identical technology when it reaches the end of its technical lifetime, and that the equipment experiences an annual drop in efficiency due to ageing. The equipment is also subject to periodic maintenance throughout its technical lifetime, for which the cost is calculated as a percentage of the initial investment.

Operating costs for electric water heaters are based on their electrical consumption and the weighted tariff shown in Table 104. Since solar water heaters do not withdraw electricity from the grid, the annual electricity consumption for water heating is assumed to be 0 kWh in the alternative scenario, and thus the weighted electricity tariff does not apply. It is to be noted however, that in practice, during successive days of no sunshine, the need might arise to use the back-up filament heater of the Solar water heater.

Results from financial analysis

Table 105 summarises the results of the financial analysis from the perspective of the homeowner, which is strongly affected by significant incremental investment and reinvestment costs in Y1 and Y15 respectively. These costs are partially offset by the residual value. However, the savings in operational costs achieved by transitioning from an electric water heater to a solar water heater do not compensate for the investment costs over the analysed period. Consequently, without any form of subsidies or government incentives, it would not be financially appealing for a private household to adopt this alternative technology. As a result, the recommended action (R2A) leads to a negative FNPV of €273. Despite being unfavourable, the FNPV of this action is less adverse than that of R1A (-€946), due to the increased incremental benefits stemming from solar water heaters entirely removing the cost of electricity. The FRR of 2.6%, although positive, falls below the FDR of 4%. Given the negative FNPV, the payback period is not relevant to the consideration of this measure.

Table 105 - Measure R2A – Financial NPV (25 years, 2025-50)

2025-2050 - NPV (EUR)	**Electric Water Heater**	**Solar Water Heater**	**Incremental**
Investment Costs	(470)	(3,511)	(3,041)
Residual Value	32	209	176
Operating & Maintenance costs	(2,838)	(246)	2,592
Revenues	-	-	-
Net Cash Flows	(3,276)	(3,549)	(273)
FRR (C)			2.6%

Results from the Economic Analysis (Benchmark Scenario)

The economic analysis examines the broader socio-economic effects of the proposed initiative by measuring the shift in welfare due to the adoption of a new technology under three different demand scenarios. These scenarios reflect varying levels of technology uptake. Table 106 provides the underlying data on households spanning from 2025 to 2050.

The uptake scenarios for measure R2A are identical to those described under R1A. The cumulative number of households that have adopted the alternative technology at ten-year intervals for each of the three scenarios is summarised by the table below.

Table 106 - Demand for Solar Water Heaters in households: three scenarios 2025-2050

Demand Scenario	Description	by 2030	by 2040	by 2050	% by 2050
R2A-SCN1	2,000 households annually till 2050	27,000	47,000	67,000	21%
R2A-SCN2	50% of all households by 2050	27,000	93,510	160,027	50%
R2A-SCN3	100% of all households by 2050	27,000	173,520	320,054	100%

The Benchmark Scenario (BM) assumes the demand scenario R2A-SCN1. The remaining two scenarios will be explored in the subsequent Sensitivity Analysis. Another factor in the economic assessment is the amount of CO_2 emissions, which is evaluated based on three energy decarbonization scenarios related to electricity generation in Malta, already described when assessing R1A. The Benchmark Scenario considers carbon emission factors based on a 2025-2030 forecast for the energy mix for electricity, that then remains constant post-2030 (Electricity – Scenario 1). The economic performance is summarized below.

Table 107 - Measure R2A – Economic NPV (25 years, 2025-50)

2025-2050 – ENPV, EUR	Incremental Costs and Benefits (EUR)
Investment, Repairs and Residual Value (inc. VAT)	(81,583,273)
Fiscal Correction: VAT	10,003,348
Fiscal Correction: Subsidies	-
Residual Value	16,005,770
Net Capex	(55,574,155)
CO2 Emissions avoided	30,467,182
Primary Energy Savings	61,933,558
ENPV: Net (COSTS) / BENEFITS	36,826,585
ERR	14.8%
B/C RATIO	1.66

The estimated ENPV of approximately €36.8 million over the 25-year period indicates that the proposed intervention is likely to enhance social welfare, primarily due to the conservation of primary energy alongside notable reductions in CO_2 emissions. Furthermore, the intervention yields an ERR of 14.8%, which surpasses the SDR of 5.0% applied in this CBA, indicating that social returns for the project justify the use of resources being proposed. Additionally, the calculated B/C ratio of 1.66 suggests that the project is economically viable. Consequently, considering the broader societal benefits, government intervention in the market through incentives to close the financial gap for potential investors and encourage adoption would be warranted.

Part II of this assessment outlines an existing incentive program administered by REWS for solar water heaters, providing residential applicants with a rebate that covers up to 75% of the cost of the solar water heater, including VAT, up to a maximum limit of €1,400. The program also includes a grant of €500 after 5 years to cover the maintenance costs.[114] The results presented in the accompanying table suggest that this incentive is effective in promoting the adoption of solar water heater technology, as the FNPV becomes positive when the subsidy is factored in.

Table 108 - Measure R2A – Financial NPV with the inclusion of current subsidy scheme (25 years, 2025-50)

2025-2050 - NPV (EUR)	Electric Water Heater	Solar Water Heater	Incremental
Investment Costs	(470)	(3,511)	(3,041)
Residual Value	32	209	176
Operating & Maintenance costs	(2,838)	(246)	2,592
Revenues	-	1,792	1,792
Net Cash Flows	(3,276)	(1,756)	1,519
FRR (C)			37.1%

Sensitivity Analysis

Sensitivity Analysis (Part 1) – Combination of demand levels and electricity decarbonization scenarios

The ENPVs for each combination of demand and emissions scenario considered in the CBA are summarized in Table 109. The respective effects on the primary energy savings and carbon emissions are presented in Figure 128.

[114] REWS Solar Water Heater Scheme (Active). Available at: [Regulator for Energy and Water Services > en/sdgr/465-2021-solar-water-heater-scheme-active (rews.org.mt))]

Table 109 - Measure R2A – Sensitivity of ENPV to demand and CO_2 (25 years, 2025-50)

Incremental ENPV (€), 2025-50	**Demand 1 [2,000 till 2050]**	**Demand 2 [50% by 2050]**	**Demand 3 [100% by 2050]**
CO_2 - Scenario 1 (constant 2030 onwards)	36,826,585 (BM)	85,006,263	167,898,927
CO_2 - Scenario 2 (grad-50%)	19,342,003	40,610,195	77,201,910
CO_2 - Scenario 3 (grad-100%)	6,596,013	7,492,265	9,034,257

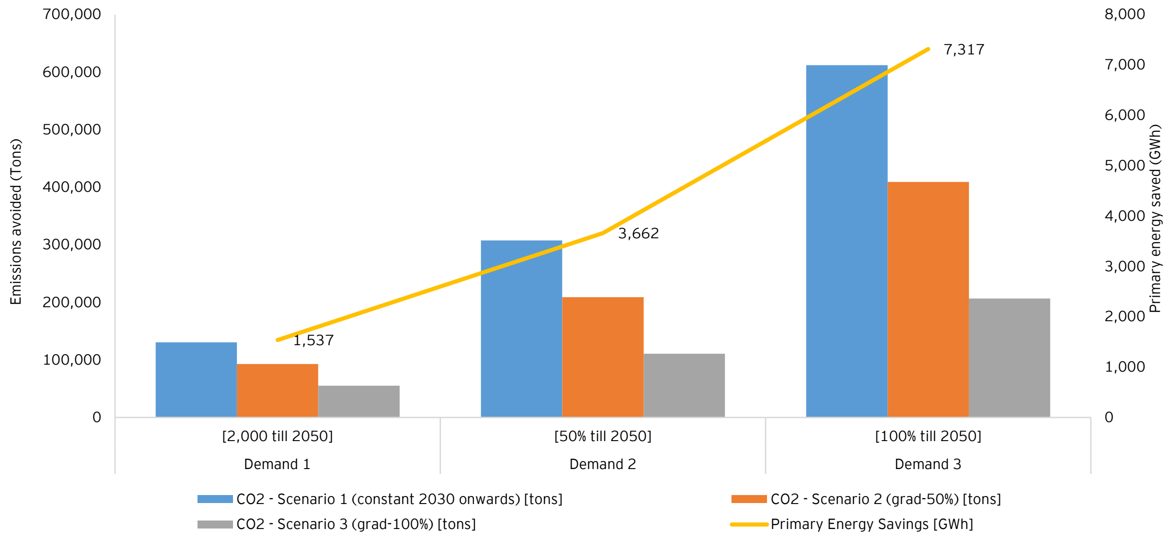

Figure 128 - Measure R2A – CO_2 emissions avoided (tons) and Primary energy savings (GWh)

As observed in the R1 measures, the emissions savings for each kWh of electricity used consistently diminish under CO_2 scenario 2 and do so at double the pace under CO_2 scenario 3 due to more rapid decarbonization of electricity post-2030. This trend results in the reduction of emissions savings across different demand scenarios observed in Figure 128, which is a key reason behind the declining ENPVs presented in Table 109. The forecasted emission factors associated with each CO_2 scenario remain an essential variable for determining the economic benefits associated with this measure.

Sensitivity Analysis (Part 2) – Sensitivity to changes in major variables

Table 110 - Measure R2A – Sensitivity Analysis: Critical and non-critical variables

Variable	**Variation of the FNPV due to a ± 1 % variation**	**Criticality judgement**	**Variation of the ENPV due to a ± 1 % variation**	**Criticality judgement**
Primary energy prices & Electricity tariffs	10.2%	Critical	1.7%	Critical
Alternative technology investment cost	12.2%	Critical	1.6%	Critical
EU ETS Carbon Price	N/A	N/A	0.8%	Not Critical

The FNPV is highly sensitive to changes in the main cost drivers – investment costs and the electricity costs. The appeal of measure R2A is based on the potential to eliminate electricity consumption related to water heating by harnessing solar energy, but the alternative technology is burdened by relatively high initial investment costs and reinvestment costs. Government subsidies are therefore important to ensure feasibility for the investor.

Similarly, economic welfare is closely linked to the level of primary energy and electricity prices and the price of the alternative technology. However, unlike the R1 measures, when higher levels of demand coincide with a completely decarbonized supply of energy, the ENPV remains positive. This is because households continue to reap substantial savings on their energy bills, thanks to the adoption of renewable technology. The shadow price of carbon, which is applied to the emissions averted to calculate the monetary economic benefit derived from the alternative technology, is in this case not a critical input to the analysis. This is primarily because, in this scenario, the ENPV is largely influenced by the savings on energy costs, especially since solar water heaters completely negate the need for electricity. This evidenced in Table 107, where the savings from primary energy are twice as much as the benefits from avoided CO_2 emissions.

The impact of varying FDR and SDR is shown below.

Table 111 - Measure R2A – Sensitivity Analysis: Effect of different FDR and SDR

Financial Discount Rate	**FNPV**	**Social Discount Rate**	**ENPV**
3%	(€89)	4%	€46,951,294
4% - BM	(€273)	5% - BM	€36,826,585
5%	(€423)	6%	€28,731,737

Finally, the switching values under this measure are the following.

Table 112 - Measure R2A – Sensitivity Analysis: Switching Values

	FNPV - BM	**ENPV - BM**
	(€273)	€36,826,585
	Percentage change for **FNPV** to become zero	Percentage change for **ENPV** to become zero
Primary energy prices & Electricity tariffs	10%	-59%
Alternative technology investment cost	-8%	63%
EU ETS Carbon Price	N/A	-121%

3.2.1.4 Residential Measure R2B - Replacing electrical water heaters with solar water heaters (Centralised approach)

This measure considers newly constructed apartment blocks made up of 5 separate households which are purposely built to accommodate either:

- Individual electric water heaters per household (the baseline), or
- A centralized solar water heating system for the entire block (the alternative).

Similar to the centralised heat pump system (R1B) explored earlier, retrofitting of existing apartment blocks is not considered in this analysis as this would also involve significant structural expenses required for installation. Unlike intervention measure R2A, a centralized solar water heating system may benefit from the economies of scale, and may thus be less affected by the issue of limited space when compared to 5 individual solar water heating set-ups. This being said, with a centralised system, there may still be legislative factors to consider within the local Maltese context, particularly in cases where private airspace rights are implicated.

The key parameters for the intervention are summarized in Table 113.

Table 113 - Key parameters for measure R2B

	Baseline	Alternative
Data	**Electric Water Heaters**	**Solar Water Heaters**
Units per household	1	0.2
Efficiency losses p.a.	0.015	0.0075
Technical Life (years)	10	15
Price per unit inc. VAT (€)	220	6,495
Price per unit inc. VAT (€)	220	1,299
Structural alterations in Y1 inc. VAT (€)	0	0
Annual useful energy demand for water heating per household (kWh, 2022)	1,231	1,231
Coefficient of Performance (CoP)	0.9	0.58
Annual electricity consumption for water heating per household (kWh, 2022)	1,368	0
Weighted electricity tariff – Residential inc. VAT (€/kWh)	0.1186	N/A
Repairs and Maintenance Cost (% of Investment)	10	10
Repairs and Maintenance Cost Interval (in Years)	5	8

The main investment cost from the perspective of the individual household is incurred in Y1 (2025), and only covers the cost of the equipment itself. Since this measure only targets new builds, no costs associated with structural alternations are included in the model. Within the reference period of this measure, it is assumed that equipment is replaced with identical technology when it reaches the end of its technical lifetime, and that the equipment experiences an annual drop in efficiency due to ageing. The equipment is also subject to periodic maintenance throughout its technical lifetime, for which the cost is calculated as a percentage of the initial investment.

Operating costs for electric water heaters are based on their electrical consumption and the weighted tariff shown in Table 113. Since solar water heaters do not withdraw electricity from the grid, the annual electricity consumption for water heating is assumed to be 0 kWh in the alternative scenario, and thus residential electricity tariffs do not apply. It is to be noted however, that in practice, during successive days of no sunshine, the need might arise to use the back-up filament heater of the Solar water heater.

Results from financial analysis

Table 114 presents the financial analysis from the viewpoint of a homeowner who, along with four other homeowners in the same apartment block, invests in a centralized system. Unlike the previous measures discussed (R1A, R1B, R2A) which exhibited negative FNPVs, the findings from the centralized R2B measure results in a positive FNPV of €1,242 and a positive FRR of 16.2%. This outcome stems from the substantially reduced initial investment per household required for the entire system, which delivers improved financial outcomes on a per-household basis relative to the decentralized setup, as a result of the economies of scale behind centralisation. In line with CBA Guides, in this case, a government subsidy would not be warranted, as there is no market failure present, and the technology itself proves to be a sound investment independently. Measure R2B, in fact, has a payback period of 7 years.

Table 114 - Measure R2B – Financial NPV (25 years, 2025-50)

2025-2050 - NPV (EUR)	Electric Water Heater	Solar Water Heater	Incremental
Investment Costs	(470)	(2,010)	(1,540)
Residual Value	32	127	95
Operating & Maintenance costs	(2,838)	(151)	2,688
Revenues	-	-	-
Net Cash Flows	(3,276)	(2,033)	1,242
FRR (C)			16.2%

Results from the Economic Analysis (Benchmark Scenario)

In this instance, the economic analysis is somewhat less important for the assessment, given that the financial benefits alone would provide a strong incentive for individuals to invest in the technology. However, assessing the wider socio-economic impacts of the proposed initiative by examining the change in welfare resulting from the adoption of new technology across three varied demand scenarios will further strengthen the case. These scenarios reflect varying levels of technology uptake, specifically in the context of new apartment blocks. Table 115 presents the foundational data on the housing inventory projections from 2025 to 2050. Drawing from the existing building stock in Malta, the assumption is made that approximately 74% of the new construction will be apartment buildings, making them suitable candidates for the centralized approach. Additionally, it is estimated that, on average, an apartment block will consist of 5 residential units.

Table 115 - Underlying household data and projected number of new apartment units[115]

	2025	2030	2035	2040	2045	2050
Total number of households	237,840	264,037	282,992	298,492	310,932	320,054

	2025	2026	2027	2028	2029	2030
Number of new apartment units each year	4,042	6,117	5,902	5,611	5,067	4,716
	2031	**2032**	**2033**	**2034**	**2035**	**2036**
	3,472	3,494	2,640	2,604	2,613	2,560
	2037	**2038**	**2039**	**2040**	**2041**	**2042**
	2,487	2,418	2,345	2,312	2,101	2,120
	2043	**2044**	**2045**	**2046**	**2047**	**2048**
	1,901	1,916	1,690	1,702	1,469	1,478
	2049	**2050**				
	1,239	1,245				

The initial scenario envisions a consistent annual adoption rate of 10% for new apartments through to the year 2050. On the other hand, the second and third scenarios are more optimistic, forecasting adoption rates increasing linearly towards 50% and 100% by 2050, respectively. Table 116 details the total number of new apartments that will have installed centralized solar water heaters, with the data segmented into ten-year periods for each scenario.

Table 116 - Demand for Solar Water Heating in households: three scenarios 2025-2050

Demand Scenario	Cumulative take-up by 2050	by 2030	by 2040	by 2050
R2B-SCN1	10% annual uptake by 2050	3,135	5,805	7,470
R2B-SCN2	50% of all new apartments by 2050	3,135	8,565	15,275
R2B-SCN3	100% of all new apartments by 2050	3,135	12,020	25,055

The Benchmark Scenario (BM) assumes the demand scenario R2B-SCN1. The remaining two scenarios will be explored in the subsequent Sensitivity Analysis. Another factor in the economic assessment is the amount of CO_2 emissions, which is evaluated based on three energy

[115] Source: NECP and EWA; Author’s estimates

decarbonization scenarios related to electricity generation in Malta, already described when assessing R1A. The Benchmark Scenario considers carbon emission factors based on a 2025-2030 forecast for the energy mix for electricity, that then remains constant post-2030 (Electricity – Scenario 1). The economic performance is summarized below.

Table 117 - Measure R2B – Economic NPV (25 years, 2025-50)

2025-2050 – ENPV, EUR	Incremental Costs and Benefits (EUR)
Investment, Repairs and Residual Value (inc. VAT)	(7,346,826)
Fiscal Correction: VAT	938,702
Fiscal Correction: Subsidies	-
Residual Value	1,193,116
Net Capex	(5,215,008)
CO2 Emissions avoided	5,469,398
Primary Energy Savings	11,836,484
ENPV: Net (COSTS) / BENEFITS	12,090,874
ERR	40.0%
B/C RATIO	3.32

Similar to the decentralized model, the centralized solar water heater system's ENPV is positive, at around €12.1 million over a 25-year span. This figure is less than the €36.8 million observed for R2A, primarily because the centralized system targets new apartments, which represent a smaller potential market compared to all households. Despite this, the centralized option generates better financial results due to scale economies, resulting in a higher ERR of 40.0%, compared to R2A's 14.8%. The B/C ratio for the centralized system is also marginally better at 3.32, surpassing R2A's ratio of 1.66.

Sensitivity Analysis

Sensitivity Analysis (Part 1) – Combination of demand levels and electricity decarbonization scenarios

The ENPVs for each combination of demand and emissions scenario considered in the CBA are summarized in Table 118. The respective effects on the primary energy savings and carbon emissions are presented in Figure 129.

Table 118 - Measure R2B – Sensitivity of ENPV to demand and CO_2 (25 years, 2025-50)

Incremental ENPV (€), 2025-50	**Demand 1 [10% till 2050]**	**Demand 2 [50% till 2050]**	**Demand 3 [100% till 2050]**
CO_2 - Scenario 1 (constant 2030 onwards)	12,090,874 (BM)	17,672,723	24,664,243
CO_2 - Scenario 2 (grad-50%)	9,122,766	12,799,857	17,405,192
CO_2 - Scenario 3 (grad-100%)	7,018,906	9,211,624	11,957,289

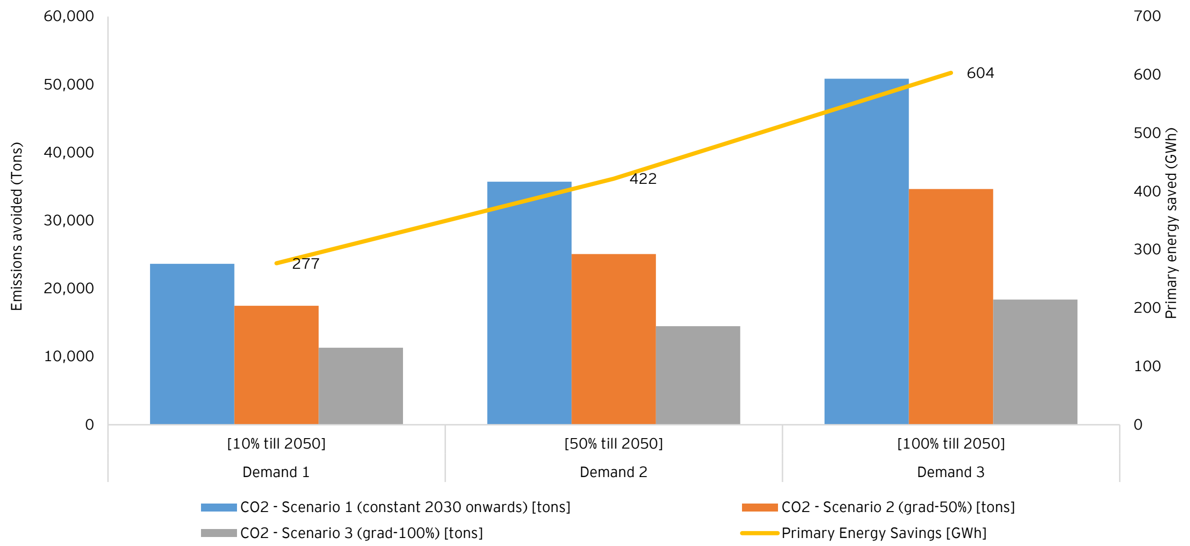

Figure 129 - Measure R2B – CO_2 emissions avoided (tons) and Primary energy savings (GWh)

Comparable to the findings for the earlier residential measure (R2A), the emissions savings for each kWh of electricity used consistently diminish under CO_2 scenario 2 and do so at double the pace under CO_2 scenario 3 due to more rapid decarbonization of electricity post-2030. This trend results in the reduction in emissions savings across different demand scenarios observed in Figure 129, which is a key factor in the declining ENPVs presented in Table 118.

Sensitivity Analysis (Part 2) – Sensitivity to changes in major variables

The critical variables are in red below.

Table 119 - Measure R2B – Sensitivity Analysis: Critical and non-critical variables

Variable	Variation of the FNPV due to a ± 1 % variation	Criticality judgement	Variation of the ENPV due to a ± 1 % variation	Criticality judgement
Primary energy prices & Electricity tariffs	2.3%	Critical	1.0%	Not Critical
Alternative technology investment cost	1.6%	Critical	0.6%	Not Critical
EU ETS Carbon Price	N/A	N/A	0.5%	Not Critical

Interestingly, none of the key variables are critical to the ENPV, as the primary motivation for the measure stems from its positive financial outcomes. Other economic factors merely enhance the attractiveness of the proposed initiative. Meanwhile, the impact of varying FDR and SDR is shown below.

Table 120 - Measure R2B – Sensitivity Analysis: Effect of different FDR and SDR

Financial Discount Rate	FNPV	Social Discount Rate	ENPV
3%	€1,492	4%	€14,319,917
4% - BM	€1,242	5% - BM	€12,090,874
5%	€1,034	6%	€10,252,967

Finally, the switching values under this measure are the following.

Table 121 - Measure R2B – Sensitivity Analysis: Switching Values

	FNPV - BM	ENPV - BM
	€1,242	€12,090,874
	Percentage change for **FNPV** to become zero	Percentage change for **ENPV** to become zero
Primary energy prices & Electricity tariffs	-44%	-102%
Alternative technology investment cost	61%	179%
EU ETS Carbon Price	N/A	-221%

3.2.1.5 Residential Measure R3 - Replacing electrical water heaters with a combination of PV panels and electric water heaters

This measure considers the replacement of individual electric water heaters within private households with a combination of photovoltaic (PV) panels and electric water heaters. The system (illustration shown in Figure 130) relies on a smart controller that autonomously determines whether electricity from the grid, or solar energy generated by the connected PV panels, is used to power the electric heater. Although the system preferentially runs on renewable energy (i.e., in DC mode), this autonomous switching function allows households to generate hot water irrespective of the weather conditions.

Unlike traditional solar water heating systems, this technology may be adopted by households with spatial limitations, as the set-up does not require a large, flat space for installation, provided the structure receives sufficient amounts of sunlight. In fact, to meet the energy requirements of this measure only a set of three PV panels will need to be installed. Moreover, the technology is cheaper when compared to other decentralised methods of water heating (i.e., the heat pump water heater [R1A] and the solar water heater [R2A]), thus increasing accessibility of green and high-efficiency technology to low-income households in line with just transition principles.

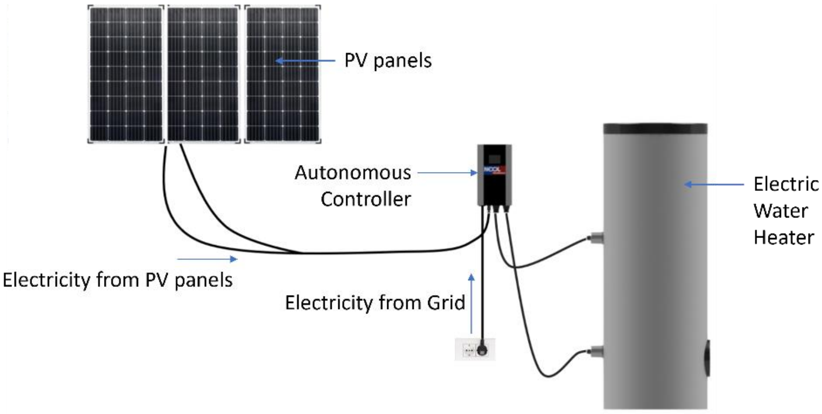

Figure 130 - Schematic of system described for residential measure R3. Adapted from [[116]].

The key parameters of this potential measure are summarized in Table 122.

Table 122 - Key parameters for measure R3

	Baseline	Alternative
Data	**Electric Water Heaters**	**Combination of PV panels & Electric water heaters**
Units per household	1	1
Efficiency losses p.a. of Electric Water Heater	0.015	0.015
Efficiency losses p.a. of PV panels	N/A	0.0075
Technical Life (years) of Electric Water Heater	10	10
Technical Life (years) of PV panels	N/A	25
Price per Electrical Water Heater inc. VAT (€)	220	220
Price per PV Panel system inc. VAT (€)	N/A	1,556
Structural alterations in Y1 inc. VAT (€)	0	150
Annual useful energy demand for water heating per household (kWh, 2022)	1,231	1,231
Coefficient of Performance (CoP)	0.9	0.9
Annual electricity consumption for water heating per household (kWh, 2022)	1,368	1,368
% of final electrical demand from grid	100	17
Annual electricity consumption for water heating per household from the Grid (kWh, 2022)	1368	233

[116] PV Magazine, 2022, 'New PV water heater from Germany', https://www.pv-magazine.com/2022/04/29/new-pv-water-heater-from-germany/

	Baseline	Alternative
Data	**Electric Water Heaters**	**Combination of PV panels & Electric water heaters**
Annual electricity consumption for water heating per household from PV panels (kWh, 2022)	0	1,135
Weighted electricity tariff – Residential inc. VAT (€/kWh)	0.1186	0.1186
Repairs and Maintenance Cost (% of Investment)	10	10
Repairs and Maintenance Cost Interval (in Years) for Electric Water Heater	5	5
Repairs and Maintenance Cost Interval (in Years) for PV Panels	N/A	13

The main investment cost from the perspective of the individual household is incurred in Y1 (2025), where the current electric water heater installed has reached the end of its technical life and is due for replacement with either the baseline or alternative technology. A one-time cost for structural changes to the household is also included in Y1 for the alternative scenario, and covers ancillary material (such as piping) and any labour costs associated with installation. Within the reference period of this scenario, it is assumed that equipment is replaced with identical technology when it reaches the end of its technical lifetime, and that the equipment experiences an annual drop in efficiency due to ageing. The equipment is also subject to periodic maintenance throughout its technical lifetime, for which the cost is calculated as a percentage of the initial investment.

Operating costs for electric water heaters are based on their electrical consumption and the weighted tariff shown in Table 122. Due to the autonomous switching feature of the alternative technology, the electricity demand is assumed to originate predominantly from photovoltaic energy (~83%), and partly from the grid (~17%), representing an estimated yearly total of 300 days of sunshine and 65 days of bad weather, respectively. Since PV panels do not withdraw electricity from the grid, the annual electricity consumption for water heating originating from photovoltaic energy is assumed to be 0 kWh, and thus residential electricity tariffs based on €/kWh do not apply.

Results from financial analysis

Table 123 summarises the results of the financial analysis from the perspective of the homeowner, which is strongly affected by significant incremental investment and reinvestment costs in Y1 and Y25 respectively. These costs are partially offset by the residual value. The savings in operational costs achieved by transitioning from an electric water heater to a combination of an electric water heater with a PV panel compensate for the investment costs over the analysed period. Therefore, it would be financially appealing for a private household to adopt this alternative technology, as indicated by the recommended action's (R3) positive FNPV of €502, and FRR of 6.9%, which exceeds the 4% FDR. Measure R3 has a payback period of 12 years.

Table 123 - Measure R3 – Financial NPV (25 years, 2025-50)

2025-2050 - NPV (EUR)	Electric Water Heater	PV & Electric Water Heater	Incremental
Investment Costs	(470)	(2,738)	(2,269)
Residual Value	32	582	550
Operating & Maintenance costs	(2,838)	(617)	2,221
Revenues	-	-	-
Net Cash Flows	(3,276)	(2,773)	502
FRR (C)			6.9%

Results from the Economic Analysis (Benchmark Scenario)

The economic analysis examines the broader socio-economic effects of the proposed initiative by measuring the shift in welfare due to the adoption of a new technology under three different demand scenarios. These scenarios reflect varying levels of technology uptake. Table 124 provides the underlying data on households spanning from 2025 to 2050.

The uptake scenarios for measure R3 are identical to those described under previously discussed decentralised measures (R1A, R2A). The cumulative number of households that have adopted the alternative technology at ten-year intervals for each of the three scenarios is summarised by the table below.

Table 124 - Demand for Solar Water Heaters in households: three scenarios 2025-2050

Demand Scenario	Description	by 2030	by 2040	by 2050	% by 2050
R3-SCN1	2,000 households annually till 2050	27,000	47,000	67,000	21%
R3-SCN2	50% of all households by 2050	27,000	93,510	160,027	50%
R3-SCN3	100% of all households by 2050	27,000	173,520	320,054	100%

The Benchmark Scenario (BM) assumes the demand scenario R3-SCN1. The remaining two scenarios will be explored in the subsequent Sensitivity Analysis. Another factor in the economic assessment is the amount of CO_2 emissions, which is evaluated based on three energy decarbonization scenarios related to electricity generation in Malta, already described when assessing previously discussed measures. The Benchmark Scenario considers carbon emission factors based on a 2025-2030 forecast for the energy mix for electricity, that then remains constant post-2030 (Electricity – Scenario 1). The economic performance is summarized below.

Table 125 - Measure R3 – Economic NPV (25 years, 2025-50)

2025-2050 – ENPV, EUR	Incremental Costs and Benefits (EUR)
Investment, Repairs and Residual Value (inc. VAT)	(53,871,591)
Fiscal Correction: VAT	6,307,330
Fiscal Correction: Subsidies	-
Residual Value	12,523,540
Net Capex	(35,040,721)
CO2 Emissions avoided	25,261,657
Primary Energy Savings	51,414,687
ENPV: Net (COSTS) / BENEFITS	41,635,623
ERR	17.6%
B/C RATIO	2.19

In this instance as well, the economic analysis is of secondary importance for the evaluation, as the financial advantages alone offer a compelling reason for individuals to invest in the technology. Nonetheless, a comprehensive assessment of the broader socio-economic effects through an examination of the welfare changes brought about by the adoption of new technology will further solidify the argument. The estimated ENPV showing a strong return of €41.6 million over a 25-year span suggests that the proposed action is expected to improve social welfare. Moreover, the initiative presents an ERR of 17.6%, which is significantly higher than the SDR of 5.0% used in this CBA, indicating that social returns for the project justify the use of resources being proposed. In addition, the B/C ratio of 2.19 indicates that the project is economically sound.

Sensitivity Analysis

Sensitivity Analysis (Part 1) – Combination of demand levels and electricity decarbonization scenarios

The ENPVs for each combination of demand and emissions scenario considered in the CBA are summarized in Table 126. The respective effects on the primary energy savings and carbon emissions are presented in Figure 131.

Table 126 - Measure R3 – Sensitivity of ENPV to demand and CO_2 (25 years, 2025-50)

Incremental ENPV (€), 2025-50	**Demand 1 [2,000 till 2050]**	**Demand 2 [50% by 2050]**	**Demand 3 [100% by 2050]**
CO_2 - Scenario 1 (constant 2030 onwards)	41,635,623 (BM)	94,670,895	185,917,563
CO_2 - Scenario 2 (grad-50%)	27,152,502	57,816,291	110,573,041
CO_2 - Scenario 3 (grad-100%)	16,602,014	30,334,752	53,961,794

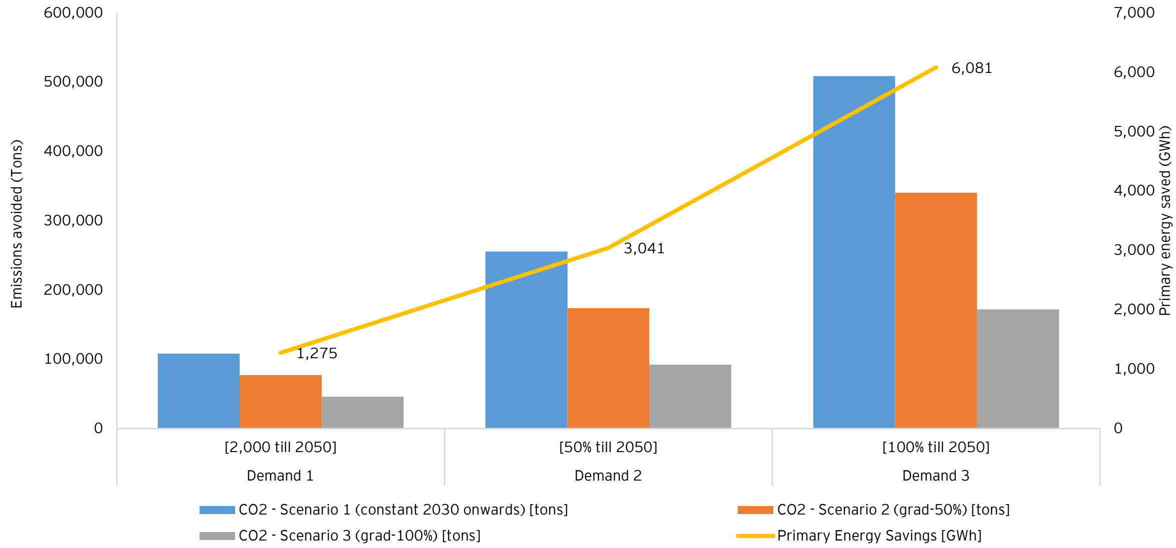

Figure 131 - Measure R3 – CO_2 emissions avoided (tons) and Primary energy savings (GWh)

As observed in the R1 and R2 measures, the emissions savings for each kWh of electricity used consistently diminish under CO_2 scenario 2 and do so at double the pace under CO_2 scenario 3 due to more rapid decarbonization of electricity from post-2030. This trend results in the reduction in emissions savings across different demand scenarios observed in Figure 131, which is a key factor in the declining ENPVs presented in Table 126.

Sensitivity Analysis (Part 2) – Sensitivity to changes in major variables

Table 127 - Measure R3 – Sensitivity Analysis: Critical and non-critical variables

Variable	Variation of the FNPV due to a ± 1 % variation	Criticality judgement	Variation of the ENPV due to a ± 1 % variation	Criticality judgement
Primary energy prices & Electricity tariffs	4.6%	Critical	1.2%	Critical
Alternative technology investment cost	3.3%	Critical	0.8%	Not Critical
EU ETS Carbon Price	N/A	N/A	0.6%	Not Critical

The FNPV is highly sensitive to changes in the main cost drivers – investment costs and the electricity costs. The appeal of measure R3 is based on the potential to eliminate the majority of electricity consumption related to water heating by harnessing solar energy, but the alternative technology is burdened by relatively higher initial investment costs and reinvestment costs.

For the same reasons, economic welfare is closely linked to the level of primary energy and electricity prices. However, the alternative technology investment cost does not have a critical impact to the ENPV. The shadow price of carbon, which is applied to the emissions averted to calculate the monetary economic benefit derived are also determined to have no critical input to the analysis of measure R3.

The impact of varying FDR and SDR is shown below.

Table 128 - Measure R3 – Sensitivity Analysis: Effect of different FDR and SDR

Financial Discount Rate	FNPV	Social Discount Rate	ENPV
3%	€738	4%	€51,972,370
4% - BM	€502	5% - BM	€41,635,623
5%	€303	6%	€33,303,308

Finally, the switching values under this measure are the following.

Table 129 - Measure R3 – Sensitivity Analysis: Switching Values

	FNPV - BM	**ENPV - BM**
	(€273)	€36,826,585
	Percentage change for **FNPV** to become zero	Percentage change for **ENPV** to become zero
Primary energy prices & Electricity tariffs	-22%	-81%
Alternative technology investment cost	30%	133%
EU ETS Carbon Price	N/A	-165%

3.2.1.6 Residential Measure R4 - Complete elimination of LPG use from households (in cooking and heating)

This measure considers the complete elimination of LPG use within private households for the purposes of spatial heating and cooking. The intervention operates on the following assumptions:

- That the majority of households using LPG heaters for space heating (~70,349 households[117]) already use an air-to-air heat pump to meet their space cooling needs in the warmer months. The same equipment can thus be used to meet space heating needs in the colder months.
- That the majority of households using LPG heaters for space heating also use gas-fired appliances for cooking.
- That the majority of households using gas ovens (~96,739 households[118]) also use gas hobs (~168,535 households[119]), but not vice versa.
- That households are more likely to transition away from using LPG heaters if they did not also purchase LPG for cooking.

[117] Numbers provided by EWA.
[118] Ibid.
[119] Ibid.

As such, this intervention measure will explore the electrification of cooking appliances as an incentive for the elimination of LPG use in space heating.[120] The key parameters are summarized in Table 130.

Table 130 - Key parameters for measure R4

	Baseline	**Alternative**
Data	**LPG Heaters and LPG Hobs + Ovens**	**Air-to-Air Heat Pumps and Electric Hobs + Ovens**
Price per unit of space heating equipment inc. VAT (€)	102	0
Structural alterations in Y1 inc. VAT (€) associated with space heating equipment	0	0
Technical Life (years) of space heating equipment	20	17
Efficiency losses p.a. of space heating equipment	0.01	0.008
Annual useful energy demand for space heating per household (kWh, 2022)	536	536
Coefficient of Performance (CoP) of space heating equipment	0.85	3.84
Annual final energy consumption for space heating per household (kWh, 2022)	630	140
Price per unit of cooking equipment inc. VAT (€)	322	435
Structural alterations in Y1 inc. VAT (€) associated with cooking equipment	0	1,000
Technical Life (years) of cooking equipment	20	20
Efficiency losses p.a. of cooking equipment	0.010	0.015
Annual useful energy demand for cooking per household (kWh, 2022)	244	244
Energy efficiency of cooking equipment	0.42	0.79
Annual final energy consumption for cooking per household (kWh, 2022)	581	309
Weighted price of LPG (residential) inc. VAT (€/kWh)	1.25	N/A

[120] The effective implementation of this measure, which involves a substantial transition from LPG to electric power for heating and cooking purposes, is expected to greatly impact the electricity grid, necessitating substantial investment for its upgrades. The investment cost for upgrading the grid has not been included in this analysis.

Weighted electricity tariff – Residential inc. VAT (€/kWh)	N/A	0.1186
Repairs and Maintenance Cost Interval (in Years) for Heating Equipment	10	N/A
Repairs and Maintenance Cost Interval (in Years) for cooking equipment	10	10
Repairs and Maintenance Cost (% of Investment)	10	10

The main investment cost from the perspective of the individual household is incurred in Y1 (2025), where the current gas oven and/or hob installed have reached the end of their technical life and are due for replacement with either the baseline or alternative technology. At the same time, it is assumed that LPG heaters meeting space heating needs have also reached the end of their technical lifetime. However, no investment cost associated with the purchase of an alternative technology (i.e., the air-to-air heat pump) is incurred by the household within the boundaries of this intervention, as it is assumed that heating requirements will be satisfied by the investment that would have made regardless for space cooling purposes. A one-time cost for structural changes to the household is included in Y1 for the alternative scenario (for the installation of electric cooking equipment specifically), and covers costs incurred for ancillary material (such as wiring) and any labour costs associated with installation. Within the reference period of this scenario, it is assumed that equipment is replaced with identical technology when it reaches the end of its technical lifetime, and that the equipment experiences an annual drop in efficiency due to ageing. The equipment is also subject to periodic maintenance throughout its technical lifetime, for which the cost is calculated as a percentage of the initial investment. Operating costs for electric cooking equipment, and gas-fired heating and cooking equipment are based on their electrical consumption and the weighted tariff, and LGP consumption and the weighted LPG prices, respectively as shown in Table 130.

Results from financial analysis

Table 131 summarises the results of the financial analysis from the perspective of the homeowner, assuming a switch from gas to electricity for both hobs and space heating. The sub-tables that follow isolate the first and second order financial results. The first order effect arises from replacing gas hobs with electric ones, while the second order effects stem from the switch from gas heaters to air-to-air heat pumps.

The results are strongly affected by significant incremental investment costs, which are mainly driven by the initial structural alteration costs involved of €1,000, to make the transition to electric cooking equipment. The incremental residual value and savings in operational costs achieved by transitioning a hob and heater from gas to electric does not compensate for the investment costs incurred over the analysed period. Consequently, without any form of subsidies or government incentives, it would not be financially appealing for a private household to adopt this alternative technology. As a result, the recommended action (R4) leads to a negative FNPV of €297. The FRR of 0.7%, although positive, falls below the FDR of 4%.

The segregated results indicate that the second-order effect of this measure is financially feasible in isolation, as it incurs no investment cost for the alternative because it would utilize the air-air heat pump previously installed for summer cooling needs, alongside gains arising from operating and maintenance savings. Nevertheless, when combined, the financial impracticality of the primary effect overshadows this viability. Given the negative FNPV, the payback period is not relevant to the consideration of this measure.

Table 131 - Measure R4 – Financial NPV (25 years, 2025-50)

Combined: Hob and Heater Replacement			
2025-2050 - NPV (EUR)	**Gas Hob & Heater**	**Electric Hob & Heater**	**Incremental**
Investment Costs	(613)	(1,610)	(997)
Residual Value	109	112	3
Operating & Maintenance costs	(2,106)	(1,408)	697
Revenues	-	-	-
Net Cash Flows	(2,609)	(2,906)	(297)
FRR (C)			0.7%

First order effects: Hob replacement			
2025-2050 - NPV (EUR)	**Gas Hob**	**Electric Hob**	**Incremental**
Investment Costs	(465)	(1,610)	(1,145)
Residual Value	83	112	29
Operating & Maintenance costs	(1,023)	(1,056)	(32)
Revenues	-	-	-
Net Cash Flows	(1,406)	(2,553)	(1,148)
FRR (C)			-14.3%

Second order effects: Heater replacement			
2025-2050 - NPV (EUR)	**Gas Space Heater**	**Electric Space Heater**	**Incremental**
Investment Costs	(148)	-	148
Residual Value	26	-	(26)
Operating & Maintenance costs	(1,082)	(353)	729
Revenues	-	-	-
Net Cash Flows	(1,204)	(353)	851
FRR (C)			N/A

Results from the Economic Analysis (Benchmark Scenario)

The economic analysis examines the broader socio-economic effects of the proposed initiative by measuring the shift in welfare from the switch to electric appliances for both cooking and heating, which would completely phase out LPG usage in homes. This assessment is based on three different demand scenarios that represent various degrees of technology adoption. Table 132 provides the underlying data on households spanning from 2025 to 2050.

The uptake scenarios for the R4 measure are identically formulated to those described under the previously decentralised measures (R1A, R2A, R3). However, the cumulative adoption rates for R4 differ from those initiatives due to R4's unique initial adoption levels (households with electric hobs versus those with heat pump water heaters or solar water heaters). The adoption timeline for transitioning to both electric hobs and electric heating systems is identical. The table below summarizes the total number of households that have switched to these alternatives at ten-year intervals for each scenario.

Table 132 - Demand for Electric Hobs/Heaters in households: three scenarios 2025-2050

Demand Scenario	**Description**	**by 2030**	**by 2040**	**by 2050**	**% by 2050**
R4-SCN1	2,000 households annually till 2050	77,442	97,442	117,442	37%
R4-SCN2	50% of all households by 2050	77,442	118,732	160,027	50%
R4-SCN3	100% of all households by 2050	77,442	198,742	320,054	100%

The Benchmark Scenario (BM) assumes the demand scenario R4-SCN1. The remaining two scenarios will be explored in the subsequent Sensitivity Analysis. Another factor in the economic assessment is the amount of CO_2 emissions. In the case of gas-powered baseline technologies, emission factors were assumed to remain constant throughout the forecast horizon, at 0.227160 kg of CO_2 emissions per kWh. On the other hand, with regards to the electricity usage of the alternative solutions, this is evaluated based on three energy decarbonization scenarios related to electricity generation in Malta, already described when assessing the previous measures. The Benchmark Scenario considers carbon emission factors based on a 2025-2030 forecast for the energy mix for electricity, that then remains constant post-2030 (Electricity – Scenario 1).

Similar to the financial analysis section, our combined economic results have been segregated into the first order and second order effects of this measure. The economic performance is summarized below.

Table 133 - Measure R4 – Economic NPV (25 years, 2025-50)

Combined: Hob and Heater Replacement	
2025-2050 – ENPV, EUR	**Incremental Costs and Benefits (EUR)**
Investment, Repairs and Residual Value (inc. VAT)	(30,872,732)
Fiscal Correction: VAT	4,693,795
Fiscal Correction: Subsidies	-
Residual Value	102,296
Net Capex	(26,076,640)
CO2 Emissions avoided	34,697,200
Primary Energy Savings	15,216,367
ENPV: Net (COSTS) / BENEFITS	23,836,926
ERR	15.8%
B/C RATIO	1.91

First order effects: Hob replacement	
2025-2050 – ENPV, EUR	Incremental Costs and Benefits (EUR)
Investment, Repairs and Residual Value (inc. VAT)	(33,515,198)
Fiscal Correction: VAT	4,958,287
Fiscal Correction: Subsidies	-
Residual Value	1,010,871
Net Capex	(27,546,040)
CO2 Emissions avoided	12,227,191
Primary Energy Savings	2,197,777
ENPV: Net (COSTS) / BENEFITS	(13,121,071)
ERR	-5.4%
B/C RATIO	0.52

Second order effects: Heater replacement	
2025-2050 – ENPV, EUR	Incremental Costs and Benefits (EUR)
Investment, Repairs and Residual Value (inc. VAT)	2,642,466
Fiscal Correction: VAT	(264,492)
Fiscal Correction: Subsidies	-
Residual Value	(908,575)
Net Capex	1,469,399
CO2 Emissions avoided	22,470,008
Primary Energy Savings	13,018,589
ENPV: Net (COSTS) / BENEFITS	36,957,997
ERR	N/A
B/C RATIO	N/A

The estimated ENPV of approximately €23.8 million over the 25-year period indicates that the proposed intervention is likely to enhance social welfare, primarily due to reductions in CO_2 emissions, alongside the conservation of primary energy. Furthermore, the intervention yields an ERR of 15.8%, which surpasses the SDR of 5.0% applied in this CBA, indicating that social returns for the project justify the use of resources being proposed. Additionally, the calculated B/C ratio of 1.91 suggests that the project is economically viable. Therefore, considering the broader societal benefits, government intervention in the market through incentives to close the financial gap for potential investors and encourage adoption would be warranted. An upfront subsidy of approximately €300 per household is needed to cover the projected FNPV shortfall, making the implementation of the R4 measure financially viable.

Sensitivity Analysis

Sensitivity Analysis (Part 1) – Combination of demand levels and electricity decarbonization scenarios

The ENPVs for each combination of demand and emissions scenario considered in the CBA are summarized in Table 134. The respective effects on the primary energy savings and carbon emissions are presented in Figure 132.

Table 134 - Measure R4 – Sensitivity of ENPV to demand and CO_2 (25 years, 2025-50)

Incremental ENPV (€), 2025-50	**Demand 1 [2,000 till 2050]**	**Demand 2 [50% by 2050]**	**Demand 3 [100% by 2050]**
CO_2 - Scenario 1 (constant 2030 onwards)	23,836,926 (BM)	39,308,252	97,451,077
CO_2 - Scenario 2 (grad-50%)	28,138,786	46,745,425	116,671,077
CO_2 - Scenario 3 (grad-100%)	32,440,646	54,182,598	135,891,077

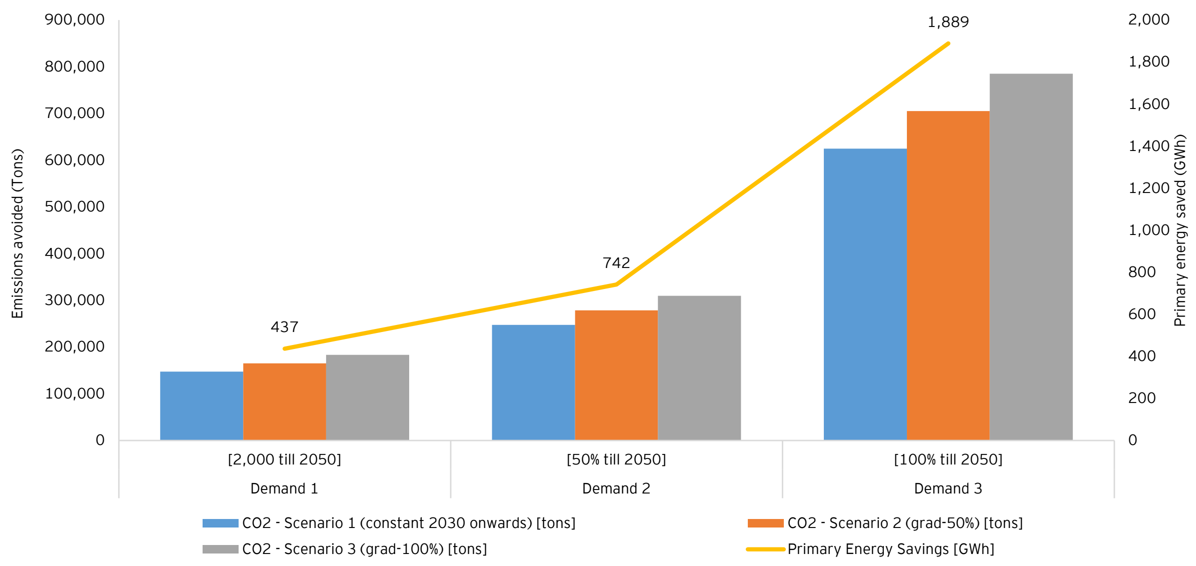

Figure 132 - Measure R4 – CO_2 emissions avoided (tons) and Primary energy savings (GWh)

Unlike the other residential measures discussed, the R4 measure results in increased emissions avoided moving along from CO_2 scenario 1 towards scenario 3. This is because electricity is the energy source for the alternative solution rather than the baseline. In this case, the baseline is LPG, which emits constant 0.227160 kg of CO_2 per kWh. Throughout most of the reference period, this emission factor is higher than that of electricity. Consequently, we see an increase in emissions savings across various demand scenarios as depicted in Figure 132, which is a key contributor to the growing ENPVs presented in Table 134.

Sensitivity Analysis (Part 2) – Sensitivity to changes in major variables

Table 135 - Measure R4 – Sensitivity Analysis: Critical and non-critical variables

Variable	Variation of the FNPV due to a ± 1 % variation	Criticality judgement	Variation of the ENPV due to a ± 1 % variation	Criticality judgement
Primary energy prices & Electricity tariffs	4.4%	Critical	0.6%	Not Critical
Alternative technology investment cost	2.0%	Critical	0.4%	Not Critical
EU ETS Carbon Price	N/A	N/A	1.5%	Critical

The FNPV of measure R4 is particularly sensitive to fluctuations in key cost factors, such as investment and electricity expenses. The attractiveness of measure R4 lies in its ability to eliminate two gas consumption sources with a single intervention. However, the alternative first-order technology, the electric hob, comes with substantial upfront costs, mainly due to the need for structural modifications. Consequently, government subsidies play a crucial role in making the investment financially viable.

While the prices of primary energy, electricity, and the alternative technology are not found to be critical in assessing economic welfare, the potential of measure R4 to completely phase out LPG, which has a higher CO_2 emission factor compared to electric hobs and heating systems like air-to-air heat pumps, is significant. In this context, the shadow price of carbon becomes a critical element. This price is used to assign a monetary value to the emissions reductions achieved by the alternative solution, making it a critical factor in the economic analysis of measure R4.

The impact of varying FDR and SDR is shown below.

Table 136 - Measure R4 – Sensitivity Analysis: Effect of different FDR and SDR

Financial Discount Rate	**FNPV**	**Social Discount Rate**	**ENPV**
3%	(€226)	4%	€29,855,650
4% - BM	(€297)	5% - BM	€23,836,926
5%	(€358)	6%	€18,950,977

Finally, the switching values under this measure are the following.

Table 137 - Measure R4 – Sensitivity Analysis: Switching Values

	FNPV - BM	**ENPV - BM**
	(€297)	€23,836,926
	Percentage change for **FNPV** to become zero	Percentage change for **ENPV** to become zero
Primary energy prices & Electricity tariffs	-23%	-157%
Alternative technology investment cost	-49%	223%
EU ETS Carbon Price	N/A	-69%

3.2.2 Hotels Sub-Sector

3.2.2.1 Hotels Measure H1 - Replacing low-efficiency boilers with heat pumps (for water heating)

This intervention considers the replacement of low-efficiency boilers with heat pump water heaters for the scope of water heating within hotels. It is assumed that the baseline scenario will continue to operate using the current fuel mix (comprising of diesel, fuel oil, gasoil, and LPG), while the alternative scenario runs on grid electricity. The key parameters are summarized in Table 138, where it is assumed that only 4&5-star hotels use fuel-fired boilers to meet their hot water demand.[121] Of these establishments, it is further assumed that circa 70% currently use low-efficiency equipment, and thus a maximum number of 48 hotels can adopt this intervention.

Table 138 - Key parameters for measure H1 – 4&5 Star Hotels

Data	Low-Efficiency Boiler (using current fuel mix)	Heat Pump Water Heater
Power Rating of Boiler (kW)	125	N/A
No. of Boilers Installed	3	N/A
Thermal Power Installed (kW)	375	375
Technical Life (years) of equipment	20	20
Efficiency losses p.a.	0.01	0.008
Total price for Water Heating Equipment (€)	7,500	135,833
Routine repairs and maintenance cost frequency (in years)	1	1
Routine repairs and maintenance cost (% of investment)	5	5
Major repairs and maintenance cost interval (in years)	10	10
Major repairs and maintenance cost (% of investment)	10	10
Weighted electricity tariff (non-residential) exc. VAT (€/kWh)	N/A	0.136
Weighted price of fuel (non-residential) exc. VAT (€/kWh)	0.0785	N/A

[121] Conversely, 2 and 3-star hotels are assumed to use small, electric boilers, where each room has its own water heating equipment.

Useful Energy for Water Heating (per hotel) p.a. (kWh)	434,497	434,497
Coefficient of Performance (CoP)	0.85	4.20
Final Energy for Water Heating (per hotel) p.a. (kWh)	511,173	103,452

The main investment cost from the perspective of the individual hotel is incurred in Y1 (2025), where the current low-efficiency boilers installed have reached the end of their technical life and are due for replacement with either the baseline or alternative technology. Within the reference period of this measure, it is assumed that equipment is replaced with identical technology when it reaches the end of its technical lifetime, and that the equipment experiences an annual drop in efficiency due to ageing. The equipment is also subject to periodic maintenance (both routine and major) throughout its technical lifetime, for which the cost is calculated as a percentage of the initial investment.

Operating costs for the boiler are based on fuel consumption and the cost of weighted fuel prices, whereas those for the heat pump are based on electricity consumption and the weighted (non-residential) electricity tariff. In this case, and for all other hotel measures, operating costs are calculated net of VAT since VAT can be reclaimed by the hotel operator.

Results from financial analysis

Table 139 summarises the results of the financial analysis from the perspective of the hotel owner, which is strongly affected by significant incremental investment and reinvestment costs in Y1 and Y20 respectively. These costs are partially offset by the residual value. However, the savings in operational costs achieved by transitioning from a low-efficiency boiler to an electric heat pump sufficiently compensate for the increased investment costs over the analysed period. This implies that the alternative technology is financially appealing without any form of subsidies or government incentives. As a result, the recommended action (H1) leads to a positive FNPV of circa €208k and a FRR of 18.8%, exceeding the 4% FDR. Measure H1 has a payback period of 7 years.

Table 139 - Measure H1 – Financial NPV (25 years, 2025-50)

2025-2050 - NPV (EUR)	Low-efficiency Boiler	Heat Pump	Incremental
Investment Costs	(10,847)	(189,435)	(178,587)
Residual Value	1,931	43,455	41,524
Operating & Maintenance costs	(708,911)	(363,854)	345,057
Revenues	-	-	-
Net Cash Flows	(717,826)	(509,833)	207,993
FRR (C)			18.8%

Results from the Economic Analysis (Benchmark Scenario)

To assess the wider socio-economic impact of the proposed measure, the economic analysis evaluates the change in welfare stemming from the introduction of the alternative technology under three demand scenarios. These scenarios account for diverse degrees of technology adoption within hotels. Table 140 provides the relevant supply of hotel buildings as of the latest data available (Q1 2024).[122] It is assumed that the supply of hotel buildings is unchanged over the reference period.

Table 140 - Measure H1 – Hotel Building Stock Data

Category	Number of Hotels
4-Star Hotels	50
5-Star Hotels	18
Total	68
Available for uptake: 4&5 Star Hotels with low-efficiency boilers (70%)	48

The first demand scenario assumes a steady rate of 1 annual hotel conversion throughout the reference period, resulting in a 54% adoption rate across all 4&5-star hotels by the year 2050. In contrast, the second and third demand scenarios are more ambitious, projecting post-2030 uptake increasing to 2 and 3 hotels respectively. Demand scenario 2 results in 96% adoption by 2050, whereas scenario 3 achieves 100% adoption by the year 2044. Table 141 breaks down the cumulative number of hotels that would have adopted the measure at ten-year intervals for each of the three scenarios.

Table 141 - Demand for heat pumps for water heating in hotels: three scenarios 2025-2050

Demand Scenario	Description	by 2030	by 2040	by 2050	% by 2050
H1-SCN1	1 hotel annually till 2050	6	16	26	54%
H1-SCN2	1 hotel annually till 2030, then 2 hotels till 2050	6	26	46	96%
H1-SCN3	1 hotel annually till 2030, then 3 hotels till 2050	6	36	48	100%

The Benchmark Scenario (BM) assumes the demand scenario H1-SCN1. The remaining two scenarios will be explored in the subsequent Sensitivity Analysis.

[122] NSO (2024). Collective Accommodation Establishments: Q1/2024. Released 28 May 2024. https://nso.gov.mt/collective-accommodation-establishments-q1-2024/

Another factor in the economic assessment is the amount of CO_2 emissions, which is evaluated based on three energy decarbonization scenarios related to electricity generation in Malta. These are reproduced from previously discussed measures below for reference.

Table 142 - Electricity CO_2 emissions – three scenarios

Fuel	Emission factor
Electricity - Scenario 1	A shift in the energy mix from 2025 to 2030, which leads to a reduction in the emission factor from 0.3709 kg/kWh in 2025 to 0.1249 kg/kWh in 2030[123], remaining steady thereafter until 2050.
Electricity – Scenario 2	A shift in the energy mix from 2025 to 2030, which leads to a reduction in the emission factor from 0.3709 kg/kWh in 2025 to 0.1249 kg/kWh in 2030, decreasing linearly thereafter up to a 50% reduction in emissions by 2050.
Electricity – Scenario 3	A shift in the energy mix from 2025 to 2030, which leads to a reduction in the emission factor from 0.3709 kg/kWh in 2025 to 0.1249 kg/kWh in 2030, decreasing linearly thereafter up to a 100% reduction (i.e. reaching 0 kg/kWh by 2050).

The Benchmark Scenario considers carbon emission factors based on a 2025-2030 forecast for the energy mix for electricity, that then remains constant post-2030 (Electricity – Scenario 1). The economic performance is summarized below.

Table 143 - Measure H1 – Economic NPV (25 years, 2025-50)

2025-2050 – ENPV, EUR	Incremental Costs and Benefits (EUR)
Investment, Repairs and Residual Value (excl. VAT)	(3,129,458)
Fiscal Correction: VAT	-
Fiscal Correction: Subsidies	-
Residual Value	543,735
Net Capex	(2,585,723)
CO2 Emissions avoided	10,110,766
Primary Energy Savings	5,475,783
ENPV: Net (COSTS) / BENEFITS	13,000,826
ERR	64.2%
B/C RATIO	6.03

[123] Source: EWA

The estimated ENPV of approximately €13.0 million over the 25-year period indicates that the proposed intervention is likely to enhance social welfare, primarily due to the conservation of primary energy and notable reductions in CO_2 emissions. Transitioning from fuel-run equipment (such as boilers) to electrically powered technologies (like heat pump water heaters) results in stable or even declining CO_2 emissions from electricity, which are anticipated to be at or below 0.1249 kg per kWh after 2030 (depending on the type of electricity scenario assumed). In contrast, the CO_2 emission factor for fuel-based boilers is predicted to remain unchanged at 0.2472 kg per kWh[124] throughout the entire reference period. Therefore, for the majority of the reference period, the emission factor for fuel is greater than that for electricity, leading to a progressive rise in emissions savings over time.

Furthermore, the intervention yields an ERR of 64.2%, which significantly surpasses the SDR of 5.0% applied in this CBA, indicating that social returns for the measure justify the use of resources being proposed. Additionally, the calculated B/C ratio of 6.03 suggests that the project is economically viable, as a ratio above one indicates that the benefits exceed the costs.

Sensitivity Analysis

Sensitivity Analysis (Part 1) – Combination of demand levels and electricity decarbonization scenarios

The ENPVs for each combination of demand and emissions scenario considered in the CBA are summarized in Table 144. The respective effects on the primary energy savings and carbon emissions are presented in Figure 133.

Table 144 - Measure H1 – Sensitivity of ENPV to demand and CO2 (25 years, 2025-50)

Incremental ENPV (€), 2025-50	**Demand 1 [1 hotel till 2050]**	**Demand 2 [1 hotel till 2030, 2 hotels till 2050]**	**Demand 3 [1 hotel till 2030, 3 hotels till 2050]**
CO_2 - Scenario 1 (constant 2030 onwards)	13,000,826 (BM)	20,552,372	26,065,908
CO_2 - Scenario 2 (grad-50%)	13,339,177	21,140,251	26,814,410
CO_2 - Scenario 3 (grad-100%)	13,677,528	21,728,130	27,562,913

[124] This has been estimated on the weighted average of the different emission factors applicable to the current fuel mix (comprising of diesel, fuel oil, gasoil, and LPG) used in hotels to operate hot water boilers.

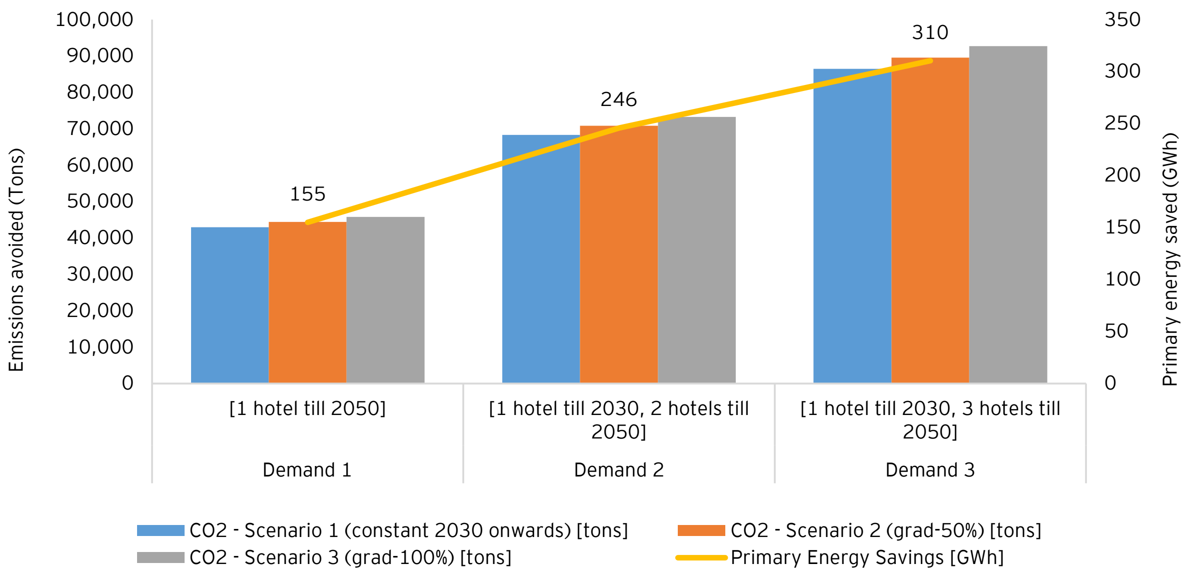

Figure 133 - Measure H1 – CO_2 emissions avoided (tons) and Primary energy savings (GWh)

Sensitivity Analysis (Part 2) – Sensitivity to changes in major variables

This part of the analysis examines the reaction of the financial and economic results determined in the economic analysis above, to a positive or negative change in a key variable. The analysis below is carried out by changing one variable at a time and determining the effect of that change on the NPV. The key variables tested for the hotel initiatives are same to those examined in the residential sector.

The following table summarizes the critical elements for measure H1 in red, those which are not critical are in green.

Table 145 - Measure H1 – Sensitivity Analysis: Critical and non-critical variables

Variable	**Variation of the FNPV due to a ± 1 % variation**	**Criticality judgement**	**Variation of the ENPV due to a ± 1 % variation**	**Criticality judgement**
Primary energy prices & Electricity tariffs	2.2%	Critical	0.4%	Not Critical
Alternative technology investment cost	1.3%	Critical	0.2%	Not Critical
EU ETS Carbon Price	N/A	N/A	0.8%	Not Critical

The FNPV is sensitive to changes in the main cost drivers – investment costs and the electricity costs. The appeal of measure H1 is based on the potential to improve energy efficiency, but it is burdened by relatively heavy initial investment costs and reinvestment costs. This implies that although measure H1 exhibits a positive FNPV, it is still sensitive to cost variations, as a rise in the expense of the alternative technology could significantly affect the financial viability of the entire project. When it comes to the economic analysis none of the key variables are found to have a critical impact on the measure's economic welfare.

To understand the impact of different estimations of opportunity cost, a separate assessment examines the responsiveness of the key indicators to an increase and decrease in the FDR and the SDR by 1 point over the benchmark rates of 4% and 5% respectively. The results are shown hereunder.

Table 146 - Measure H1 – Sensitivity Analysis: Effect of different FDR and SDR

Financial Discount Rate	FNPV	Social Discount Rate	ENPV
3%	€245,406	4%	€15,486,033
4% - BM	€207,993	5% - BM	€13,000,826
5%	€176,373	6%	€10,962,440

As a final assessment of sensitivity, all three variables were separately tested to identify the percentage change allowed before the FNPV or the ENPV turn negative. Switching values of an absolute value less than 100% are considered critical, with a higher risk of changing the financial or economic feasibility of the scenario. Put it differently, variables with critical switching values will require less than a ±100% change to bring FNPV/ENPV to zero (breakeven point). The below confirms the high sensitivity of FNPV to changes in the energy prices and investment costs.

The critical switching values identified below are in line with the critical variables identified in the sensitivity analysis. None of the key variables had a critical switching value for economic welfare since the positive ENPV is propelled by a combination of substantial reductions in final energy consumption and the expanding divergence in emission factors. This divergence is characterized by the decreasing CO_2 emissions associated with the alternative over the reference period, while the emission factor for the baseline remains constant throughout.

Table 147 - Measure H1 – Sensitivity Analysis: Switching Values

	FNPV - BM	ENPV - BM
	€207,993	€13,000,826
	Percentage change for **FNPV** to become zero	Percentage change for **ENPV** to become zero
Primary energy prices & Electricity tariffs	-45%	-237%
Alternative technology investment cost	79%	474%
EU ETS Carbon Price	N/A	-129%

3.2.2.2 Hotels Measure H2 - Replacing low-efficiency boilers with high-efficiency condensing boilers (powered by biofuels) for water heating

This intervention considers the replacement of low-efficiency boilers with high-efficiency, condensing-type boilers for the scope of water heating within hotels. The EU state aid rules have been undergoing changes to align with the EU's climate and environmental objectives, particularly in the context of the European Green Deal and the push towards carbon neutrality. As a result, support for fossil fuels is generally becoming increasingly restricted under EU state aid rules. Aid for investments in equipment, machinery and industrial production facilities using fossil fuels, including those using natural gas, is not exempted from the notification obligation under Article 36 of the General Block Exemption Regulation.[125] Thus, this intervention assumes that the alternative technology will operate exclusively on biofuels, while the baseline scenario will continue to operate using the current fuel mix (comprising of diesel, fuel oil, gasoil, and LPG) where it is assumed that only 4&5-star hotels use fuel-fired boilers[126]. Of these establishments, it is further assumed that circa 70% currently use low-efficiency equipment, and thus a maximum number of 48 hotels can adopt this intervention. The key parameters are summarized in Table 148.

[125] European Commission, General Block Exemption Regulation, General Block Exemption Regulation | EUR-Lex (europa.eu)

[126] Conversely, 2 and 3-star hotels are assumed to use small, electric boilers, where each room has its own water heating equipment.

Table 148 - Key parameters for measure H2 – 4&5 Star Hotels.

Data	Low-Efficiency Boiler (using current fuel mix)	High-Efficiency Condensing Boiler (using bioliquid)
Power Rating of Boiler (kW)	125	
No. of Boilers Installed	3	
Thermal Power Installed (kW)	375	
Technical Life (years) of equipment	20	20
Efficiency losses p.a.	0.01	0.01
Total price for Water Heating Equipment (€)	7,500	21,563
Routine repairs and maintenance cost frequency (in years)	1	1
Routine repairs and maintenance cost (% of investment)	5	5
Major repairs and maintenance cost interval (in years)	10	10
Major repairs and maintenance cost (% of investment)	10	10
Weighted price of fuel (non-residential) exc. VAT (€/kWh)	0.0785	0.1111
Useful Energy for Water Heating (per hotel) p.a. (kWh)	434,497	434,497
Coefficient of Performance (CoP)	0.85	0.998
Final Energy for Water Heating (per hotel) p.a. (kWh)	511,173	435,368

The main investment cost from the perspective of the individual hotel is incurred in Y1 (2025), where the current low-efficiency boilers installed have reached the end of their technical life and are due for replacement with either the baseline or alternative technology. Within the reference period of this measure, it is assumed that equipment is replaced with identical technology when it reaches the end of its technical lifetime, and that the equipment experiences an annual drop in efficiency due to ageing. The equipment is also subject to periodic maintenance (both routine and major) throughout its technical lifetime, for which the cost is calculated as a percentage of the initial investment.

Operating costs for the boilers are based on their fuel consumption, and the cost of weighted fuel prices or the cost of biodiesel for the baseline and alternative scenarios, respectively.

Results from financial analysis

Table 149 summarises the results of the financial analysis from the perspective of the hotel owner, which is affected by significant incremental investment and reinvestment costs in Y1 and Y20 respectively. These costs are partially offset by the residual value. Notably, however, measure H2 does not offer any savings to the hotel owner by way of reductions in operational and maintenance costs. This is primarily driven by a higher cost of biofuels that overpowers the reduction in final energy usage when switching from the baseline fuel mix. Therefore, the resulting FNPV is negative at circa €173k, implying that the government would have to intervene with subsidies or incentives to incline hotel owners to switch to the alternative technology. The financial FRR is undefined for this measure, as a result of a series of incremental financial costs without any subsequent benefit. Given the negative FNPV, the payback period is not relevant to the consideration of this measure.

Table 149 - Measure H2 – Financial NPV (25 years, 2025-50)

2025-2050 - NPV (EUR)	**Low-efficiency boiler**	**Biofuel Boiler**	**Incremental**
Investment Costs	(10,847)	(31,185)	(20,338)
Residual Value	1,931	5,553	3,622
Operating & Maintenance costs	(708,911)	(864,929)	(156,018)
Revenues	-	-	-
Net Cash Flows	(717,826)	(890,561)	(172,735)
FRR (C)			N/A

Results from the Economic Analysis (Benchmark Scenario)

To assess the wider socio-economic impact of the proposed measure, the economic analysis evaluates the change in welfare stemming from the introduction of the alternative technology under three demand scenarios. The demand scenarios applied and the hotels available for uptake (4&5-star hotels with low-efficiency boilers) are identical to measure H1. Table 150 breaks down the cumulative number of hotels that would have adopted the measure at ten-year intervals for each of the three scenarios.

Table 150 - Demand for biofuel boilers in hotels: three scenarios 2025-2050

Demand Scenario	Description	by 2030	by 2040	by 2050	% by 2050
H2-SCN1	1 hotel annually till 2050	6	16	26	54%
H2-SCN2	1 hotel annually till 2030, then 2 hotels till 2050	6	26	46	96%
H2-SCN3	1 hotel annually till 2030, then 3 hotels till 2050	6	36	48	100%

The Benchmark Scenario (BM) assumes the demand scenario H2-SCN1. The remaining two scenarios will be explored in the subsequent Sensitivity Analysis.

Another factor in the economic assessment is the amount of CO_2 emissions, which, for previous measures, was evaluated based on three energy decarbonization scenarios related to electricity generation in Malta. In the case of measure H2, these CO_2 scenarios have no impact since the measure's base and alternative cases do not involve the consumption of electricity. The economic performance is summarized below.

Table 151 - Measure H2 – Economic NPV (25 years, 2025-50)

2025-2050 – ENPV, EUR	Incremental Costs and Benefits (EUR)
Investment, Repairs and Residual Value (excl. VAT)	(357,614)
Fiscal Correction: VAT	-
Fiscal Correction: Subsidies	-
Residual Value	84,901
Net Capex	(272,714)
CO2 Emissions avoided	1,374,705
Primary Energy Savings	1,018,988
ENPV: Net (COSTS) / BENEFITS	2,120,979
ERR	141.5%
B/C RATIO	8.78

The estimated ENPV of approximately €2.1 million over the 25-year period indicates that the proposed intervention is likely to enhance social welfare, primarily due to reductions in CO_2 emissions and the conservation of primary energy. Furthermore, the intervention yields an ERR of 141.5%, which significantly surpasses the SDR of 5.0% applied in this CBA, indicating that social returns for the measure justify the use of resources being proposed. Additionally, the calculated B/C ratio of 8.78 suggests that the project is economically viable, as a ratio above one indicates that the benefits exceed the costs. Consequently, considering the broader societal benefits, government intervention in the market through incentives to close the financial gap for potential investors and encourage adoption would be warranted. An upfront subsidy amounting to circa €170k per hotel would close the FNPV deficit to make this measure financially viable to hotel owners.

Sensitivity Analysis

Sensitivity Analysis (Part 1) – Combination of demand levels

The ENPVs for each combination of demand scenario considered in the CBA are summarized in Table 152. The respective effects on the primary energy savings are presented in Figure 134.

Table 152 - Measure H2 – Sensitivity of ENPV to demand levels (25 years, 2025-50)

	Demand 1 [1 hotel till 2050]	**Demand 2 [1 hotel till 2030, 2 hotels till 2050]**	**Demand 3 [1 hotel till 2030, 3 hotels till 2050]**
Incremental ENPV (€), 2025-50	2,120,979 (BM)	3,344,783	4,231,755

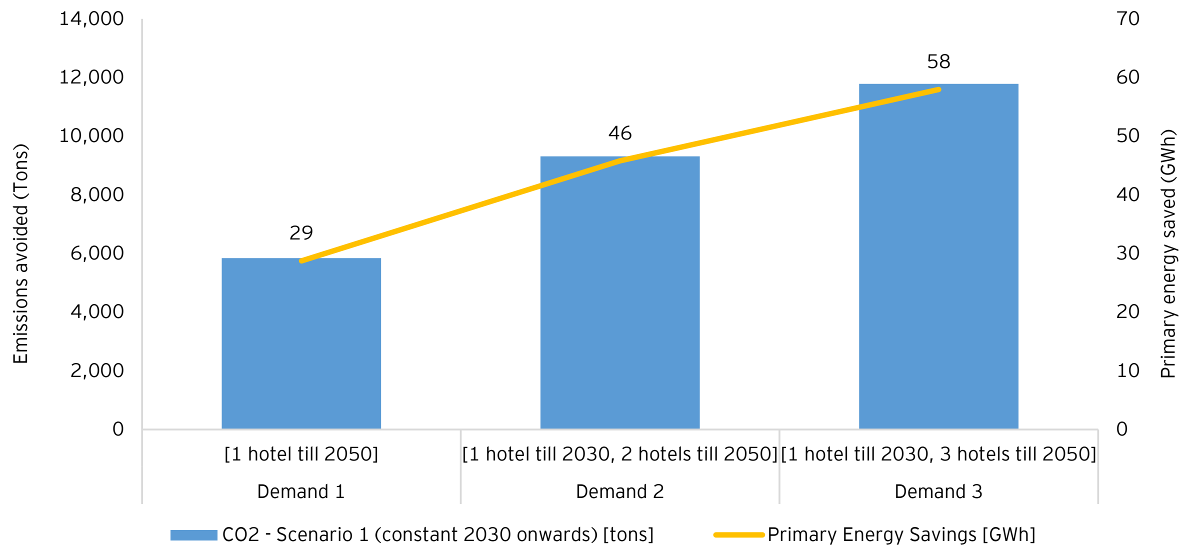

Figure 134 -Measure H2 – CO_2 emissions avoided (tons) and Primary energy savings (GWh)

Sensitivity Analysis (Part 2) – Sensitivity to changes in major variables

Table 153 - Measure H2 – Sensitivity Analysis: Critical and non-critical variables

Variable	Variation of the FNPV due to a ± 1 % variation	Criticality judgement	Variation of the ENPV due to a ± 1 % variation	Criticality judgement
Primary energy prices & Electricity tariffs	0.8%	Not Critical	0.5%	Not Critical
Alternative technology investment cost	0.3%	Not Critical	0.2%	Not Critical
EU ETS Carbon Price	N/A	N/A	0.6%	Not Critical

None of the three key variables assessed were critical to the FNPV or ENPV of measure H2. The impact of varying FDR and SDR is shown below.

Table 154 - Measure H2 – Sensitivity Analysis: Effect of different FDR and SDR

Financial Discount Rate	FNPV	Social Discount Rate	ENPV
3%	(€191,011)	4%	€2,512,203
4% - BM	(€172,735)	5% - BM	€2,120,979
5%	(€157,131)	6%	€1,799,305

Finally, the switching values under this measure are the following.

Table 155 - Measure H2 – Sensitivity Analysis: Switching Values

	FNPV - BM	**ENPV - BM**
	(€172,735)	€2,120,979
	Percentage change for **FNPV** to become zero	Percentage change for **ENPV** to become zero
Primary energy prices & Electricity tariffs	-120%	-208%
Alternative technology investment cost	-391%	469%
EU ETS Carbon Price	N/A	-154%

In line with the sensitivity analysis, none of the variables' switching values were determined to be critical.

3.2.2.3 Hotels Measure H3 - Replacing air-cooled chillers (without heat recovery) with air-cooled chillers with heat recovery

This intervention considers the replacement of regular air-cooled chillers with air-cooled chillers capable of heat recovery within hotels. The chillers are used for the scope of spatial cooling in the summer months, whereas the heat recovered from the alternative measure would be used to meet water heating demands within the same timespan. The key parameters are summarized in Table 156. It is assumed that all 5-star hotels and circa 50% of 4-star hotels currently use chillers[127] to meet their spatial cooling needs, and thus a maximum of 43 establishments can adopt this intervention.[128] It is simultaneously assumed that all of these establishments use fuel-fired boilers (with an average CoP of 0.9) to meet their hot water demand. Therefore, the heat reclaimed from the upgraded chillers would result in reduced energy consumption and savings on the fuel used by the boilers.

[127] The number of establishments that use air-cooled chillers (measure H3) versus water-cooled chillers (measure H4) is unknown. As such, to gauge the impact of the alternative technology, it is assumed that all chillers in operation are either entirely air-cooled or entirely water-cooled for measures H3 and H4, respectively.

[128] Conversely, all of the 2 and 3-star hotels, as well as the remaining half of 4-star hotels are assumed to use air-to-air heat pumps (in a variety of set-ups) to meet their spatial cooling needs.

Table 156 - Key parameters for measure H3.

	Baseline	Alternative
Data	**Air-cooled chiller (without heat recovery)**	**Air-cooled chiller with heat recovery**
Price for Spatial Cooling Equipment (€)	124,615	143,654
Power Rating of Chiller (kW)	150	
No. of Chillers Installed	5	
Cooling Power Installed (kW)	750	
Technical Life (years) of equipment	20	
Efficiency losses p.a.	0.01	
Routine repairs and maintenance cost frequency (in years)	1	
Routine repairs and maintenance cost (% of investment)	5	
Major repairs and maintenance cost interval (in years)	10	
Major repairs and maintenance cost (% of investment)	10	
Weighted price of fuel (non-residential) exc. VAT (€/kWh) for water heating	0.0785	
Weighted electricity tariff (non-residential) exc. VAT (€/kWh) for space cooling	0.136	
Final energy demand for space cooling per hotel p.a. (GWh)	0.54	0.54
Energy Efficiency Ratio (EER)	3.86	5.16
Total useful energy produced per hotel p.a. (Gwh)	2.1	2.81
Useful energy demand for space cooling per hotel p.a. (Gwh)	2.1	2.1
Recovered useful energy per hotel p.a. (Gwh)	N/A	0.71
Recovered final energy per hotel p.a. (Gwh) recovery (assuming hot water produced using a boiler with a CoP of 0.9)	N/A	0.79
Maximum final energy for water heating that can be satisfied by recovered energy (Gwh)	N/A	0.34

The main investment cost from the perspective of the individual hotel is incurred in Y1 (2025), where the current air-cooled chillers installed have reached the end of their technical life and are due for replacement with either the baseline or alternative technology. Within the reference period of this measure, it is assumed that equipment is replaced with identical technology when it reaches the end of its technical lifetime, and that the equipment experiences an annual drop in efficiency due to ageing. The equipment is also subject to periodic maintenance (both routine and major) throughout its technical lifetime, for which the cost is calculated as a percentage of the initial investment.

Operating costs for the chiller are based on electricity consumption and the weighted (non-residential) electricity tariff. Operational savings from the energy recovered in the alternative measure are based on the cost of weighted (non-residential) fuel prices.

Results from financial analysis

Table 157 summarises the results of the financial analysis from the perspective of the hotel owner, which is affected by incremental investment and reinvestment costs in Y1 and Y20 respectively. These costs are partially offset by the residual value. The incremental financial costs of adopting the alternative technology are exceeded by the incremental benefit arising from reduced operating & maintenance costs. As a result, the FNPV is positive at circa €397k, implying that the government would not have to incentivise hotel owners to adopt the measure. The FRR is undefined for this measure, as a result of a series of incremental financial benefits without an initial incremental cost. The payback period of measure H3 is 1 year.

Table 157 - Measure H3 – Financial NPV (25 years, 2025-50)

2025-2050 - NPV (EUR)	Standard Air-Cooled Chiller	Air-Cooled Chiller w/Heat Recovery	Incremental
Investment Costs	(180,229)	(207,764)	(27,535)
Residual Value	32,092	36,995	4,903
Operating & Maintenance costs	(1,283,370)	(864,203)	419,167
Revenues	-	-	-
Net Cash Flows	(1,431,507)	(1,034,972)	396,535
FRR (C)			N/A

Results from the Economic Analysis (Benchmark Scenario)

To assess the wider socio-economic impact of the proposed measure, the economic analysis evaluates the change in welfare stemming from the introduction of the alternative technology under three demand scenarios. Whereas the demand scenarios applied are identical to measure H1, the hotels available for uptake varied.

Table 158 - Number of 4-star & 5-star hotels as at Q1 2024

Category	Number of Hotels*
4-Star Hotels	50
5-Star Hotels	18
Total	68
Available for uptake: 4&5 Star Hotels with Chillers (100% of 5-star & 50% of 4-star)	43

**Data is as of Q1 2024. Assumes that there will be no changes to the hotel building supply.*

Table 159 below breaks down the cumulative number of hotels that have adopted the measure at ten-year intervals for each of the three scenarios.

Table 159 - Demand for heat recovery air-cooled chillers in hotels: three scenarios 2025-2050

Demand Scenario	Description	by 2030	by 2040	by 2050	% by 2050
H3-SCN1	1 hotel annually till 2050	6	16	26	54%
H3-SCN2	1 hotel annually till 2030, then 2 hotels till 2050	6	26	43	100%
H3-SCN3	1 hotel annually till 2030, then 3 hotels till 2050	6	36	43	100%

The Benchmark Scenario (BM) assumes the demand scenario H3-SCN1. The remaining two scenarios will be explored in the subsequent Sensitivity Analysis.

Another factor in the economic assessment is the amount of CO_2 emissions, which, for previous measures (excl. measure H2), was evaluated based on three energy decarbonization scenarios related to electricity generation in Malta. As with H2, these scenarios have no impact on H3 since the measure's incremental costs/benefits do not involve electricity. This is because the baseline and alternative cooling systems both use electricity, and their effects net out with respect to incremental results. The resulting incremental economic benefit for H3 is the useful energy produced via heat recovery in the alternative case, which otherwise would have been produced by a boiler which runs on fuel. The economic performance is summarized below.

Table 160 - Measure H3 – Economic NPV (25 years, 2025-50)

2025-2050 – ENPV, EUR	Incremental Costs and Benefits (EUR)
Investment, Repairs and Residual Value (excl. VAT)	(484,155)
Fiscal Correction: VAT	-
Fiscal Correction: Subsidies	-
Residual Value	84,793
Net Capex	(399,361)
CO2 Emissions avoided	486,414
Primary Energy Savings	393,473
ENPV: Net (COSTS) / BENEFITS	480,526
ERR	N/A
B/C RATIO	2.20

The estimated ENPV of approximately €481k over the 25-year period indicates that the proposed intervention is likely to enhance social welfare, primarily due to reductions in CO_2 emissions and the conservation of primary energy. These savings relate to the energy expenditure that would have taken place to heat water via boilers in the absence of heat recovery. The ERR for this measure is undefined. However, the calculated B/C ratio of 2.20 suggests that the project is economically viable, as a ratio above one indicates that the benefits exceed the costs.

Sensitivity Analysis

Sensitivity Analysis (Part 1) – Combination of demand levels and electricity decarbonization scenarios

The ENPVs for each combination of demand scenario considered in the CBA are summarized in Table 161. The respective effects on the primary energy savings and carbon emissions are presented in Figure 135.

Table 161 - Measure H3 – Sensitivity of ENPV to demand levels (25 years, 2025-50)

	Demand 1 [1 hotel till 2050]	**Demand 2 [1 hotel till 2030, 2 hotels till 2050]**	**Demand 3 [1 hotel till 2030, 3 hotels till 2050]**
Incremental ENPV (€), 2025-50	480,526 (BM)	1,223,603	2,043,171

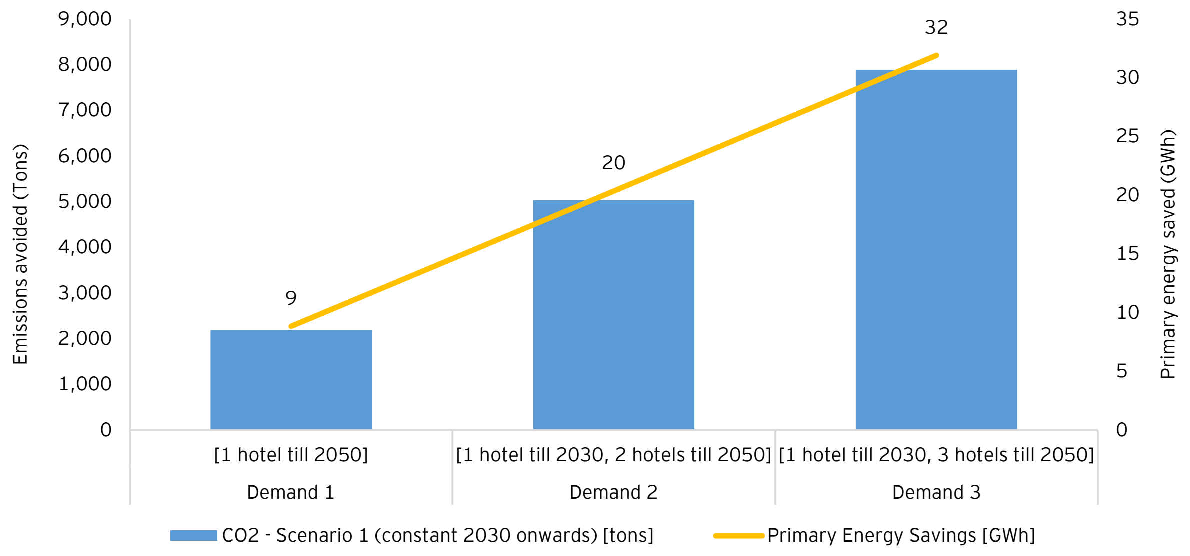

Figure 135 - Measure H3 – CO_2 emissions avoided (tons) and Primary energy savings (GWh)

As mentioned previously, since the savings from this measure are associated with fuel, the CO_2 scenarios based on electricity mix have no impact on the results.

Sensitivity Analysis (Part 2) – Sensitivity to changes in major variables

Table 162 - Measure H3 – Sensitivity Analysis: Critical and non-critical variables

Variable	**Variation of the FNPV due to a ± 1 % variation**	**Criticality judgement**	**Variation of the ENPV due to a ± 1 % variation**	**Criticality judgement**
Primary energy prices & Electricity tariffs	1.1%	Critical	0.8%	Not Critical
Alternative technology investment cost	0.7%	Not Critical	6.3%	Critical
EU ETS Carbon Price	N/A	N/A	1.0%	Not Critical

The FNPV is sensitive to changes in energy costs, however, the sensitivity to alternative technology costs is not critical. The appeal of measure H3 lies in its ability to cut down on the energy needed for water heating through heat recovery. This advantage outweighs the approximately 15% higher cost of the alternative air-cooled chiller unit.

On the other hand, the cost of alternative technology is a critical variable to economic welfare, unlike the impact of primary energy costs and tariffs. The ENPV of measure H3 increases alongside uptake, and as such, the benchmark scenario depicts the least favourable outcome for this measure. Meanwhile, the shadow price of carbon, which is applied to the emissions averted to calculate the monetary economic benefit derived from the alternative technology, is not a critical input to the analysis of this measure.

The impact of varying FDR and SDR is shown below.

Table 163 - Measure H3 – Sensitivity Analysis: Effect of different FDR and SDR

Financial Discount Rate	FNPV	Social Discount Rate	ENPV
3%	€443,366	4%	€549,780
4% - BM	€396,535	5% - BM	€480,526
5%	€356,750	6%	€423,210

Finally, the switching values under this measure are the following.

Table 164 - Measure H3 – Sensitivity Analysis: Switching Values

	FNPV - BM	ENPV - BM
	€396,535	€480,526
	Percentage change for **FNPV** to become zero	Percentage change for **ENPV** to become zero
Primary energy prices & Electricity tariffs	-91%	-122%
Alternative technology investment cost	135%	16%
EU ETS Carbon Price	N/A	-99%

3.2.2.4 Hotels Measure H4 - Replacing water-cooled chillers (without heat recovery) with water-cooled chillers with heat recovery

This intervention considers the replacement of regular water-cooled chillers with water-cooled chillers capable of heat recovery within hotels. The intended result is identical to the H3 measure but the technology in this case is water-cooled chillers. The chillers are used for the scope of spatial cooling in the summer months, whereas the heat recovered from the alternative measure would be used to meet water heating demands within the same timespan. The key parameters are summarized in Table 165. It is assumed that all 5-star hotels and circa 50% of

4-star hotels currently use chillers[129] to meet their spatial cooling needs, and thus a maximum of 43 establishments can adopt this intervention.[130] It is simultaneously assumed that all of these establishments use fuel-fired boilers (with an average CoP of 0.9) to meet their hot water demand. The heat recovered from the chillers in the alternative measure will thus translate to energy savings from fuel consumption.

Table 165 - Key parameters for measure H4.

	Baseline	Alternative
Data	Water-cooled chiller (without heat recovery)	Water-cooled chiller with heat recovery
Price for Spatial Cooling Equipment (€)	141,761	160,563
Power Rating of Chiller (kW)	150	
No. of Chillers Installed	5	
Cooling Power Installed (kW)	750	
Technical Life (years) of equipment	20	
Efficiency losses p.a.	0.01	
Routine repairs and maintenance cost frequency (in years)	1	
Routine repairs and maintenance cost (% of investment)	5	
Major repairs and maintenance cost interval (in years)	10	
Major repairs and maintenance cost (% of investment)	10	
Weighted price of fuel (non-residential) exc. VAT (€/kWh) for water heating	0.0785	
Weighted electricity tariff (non-residential) exc. VAT (€/kWh) for space cooling	0.136	
Final energy demand for space cooling per hotel p.a. (GWh)	0.54	0.54
Energy Efficiency Ratio (EER)	4.18	5.48
Total useful energy produced per hotel p.a. (Gwh)	2.26	2.96

[129] The number of establishments that use air-cooled chillers (measure H3) versus water-cooled chillers (measure H4) is unknown. To gauge the impact of the alternative technology, it is assumed that all chillers in operation are either entirely air-cooled or entirely water-cooled for measures H3 and H4, respectively.
[130] Conversely, all of the 2 and 3-star hotels, as well as the remaining half of 4-star hotels are assumed to use air-to-air heat pumps (in a variety of set-ups) to meet their spatial cooling needs.

	Baseline	Alternative
Data	Water-cooled chiller (without heat recovery)	Water-cooled chiller with heat recovery
Useful energy demand for space cooling per hotel p.a. (Gwh)	2.26	2.26
Recovered useful energy per hotel p.a. (Gwh)	N/A	0.70
Recovered final energy per hotel p.a. (Gwh) recovery (assuming hot water produced using a boiler with a CoP of 0.9)	N/A	0.79
Maximum final energy for water heating that can be satisfied by recovered energy (Gwh)	N/A	0.34

The main investment cost from the perspective of the individual hotel is incurred in Y1 (2025), where the current water-cooled chillers installed have reached the end of their technical life and are due for replacement with either the baseline or alternative technology. Within the reference period of this measure, it is assumed that equipment is replaced with identical technology when it reaches the end of its technical lifetime, and that the equipment experiences an annual drop in efficiency due to ageing. The equipment is also subject to periodic maintenance (both routine and major) throughout its technical lifetime, for which the cost is calculated as a percentage of the initial investment.

Operating costs for the chiller are based on electricity consumption and the weighted (non-residential) electricity tariff. Operational savings from the energy recovered in the alternative measure are based on the cost of weighted (non-residential) fuel prices.

Results from financial analysis

Table 166 summarises the results of the financial analysis from the perspective of the hotel owner, which is affected by incremental investment and reinvestment costs in Y1 and Y20 respectively. These costs are partially offset by the residual value. The incremental financial costs of adopting the alternative technology are exceeded by the incremental benefit arising from reduced operating & maintenance costs. As a result, the FNPV is positive at circa €397k, implying that the government would not have to incentivise hotel owners to adopt the measure. The FRR is undefined for this measure, as a result of a series of incremental financial benefits without an initial incremental cost. The payback period of measure H4 is 1 year.

Table 166 - Measure H4 – Financial NPV (25 years, 2025-50)

2025-2050 - NPV (EUR)	Standard Water-Cooled Chiller	Water-Cooled Chiller w/Heat Recovery	Incremental
Investment Costs	(205,026)	(232,220)	(27,194)
Residual Value	36,508	41,350	4,842
Operating & Maintenance costs	(1,297,936)	(878,569)	419,367
Revenues	-	-	-
Net Cash Flows	(1,466,454)	(1,069,439)	397,016
FRR (C)			N/A

Results from the Economic Analysis (Benchmark Scenario)

To assess the wider socio-economic impact of the proposed measure, the economic analysis evaluates the change in welfare stemming from the introduction of the alternative technology under three demand scenarios. The demand scenarios applied and the hotels available for uptake are identical to those under measure H3, reproduced below.

Table 167 - Demand for heat recovery water-cooled chillers in hotels: three scenarios 2025-2050

Demand Scenario	Description	by 2030	by 2040	by 2050	% by 2050
H4-SCN1	1 hotel annually till 2050	6	16	26	54%
H4-SCN2	1 hotel annually till 2030, then 2 hotels till 2050	6	26	43	100%
H4-SCN3	1 hotel annually till 2030, then 3 hotels till 2050	6	36	43	100%

The Benchmark Scenario (BM) assumes the demand scenario H4-SCN1. The remaining two scenarios will be explored in the subsequent Sensitivity Analysis.

Another factor in the economic assessment is the amount of CO_2 emissions, which, for previous measures (excl. H2, H3), was evaluated based on three energy decarbonization scenarios related to electricity generation in Malta. As with H2 and H3, these scenarios have no impact on H4 since the measure's incremental costs/benefits do not involve electricity. This is because the baseline and alternative cooling systems both use electricity, and their effects net out with respect to incremental results. The resulting incremental economic benefit for H4 is the useful energy produced via heat recovery in the alternative case, which otherwise would have been produced by a boiler which runs on fuel. The economic performance is summarized below.

Table 168 - Measure H4 – Economic NPV (25 years, 2025-50)

2025-2050 – ENPV, EUR	Incremental Costs and Benefits (EUR)
Investment, Repairs and Residual Value (excl. VAT)	(478,162)
Fiscal Correction: VAT	-
Fiscal Correction: Subsidies	-
Residual Value	83,744
Net Capex	(394,418)
CO2 Emissions avoided	486,414
Primary Energy Savings	393,473
ENPV: Net (COSTS) / BENEFITS	485,469
ERR	N/A
B/C RATIO	2.23

The estimated ENPV of approximately €485k over the 25-year period indicates that the proposed intervention is likely to enhance social welfare, primarily due to reductions in CO_2 emissions and the conservation of primary energy. These savings relate to the energy expenditure that would have taken place to heat water via boilers in the absence of heat recovery. The ERR for this measure is undefined, however, the calculated B/C ratio of 2.23 suggests that the project is economically viable, as a ratio above one indicates that the benefits exceed the costs.

Sensitivity Analysis

Sensitivity Analysis (Part 1) – Combination of demand levels and electricity decarbonization scenarios

The ENPVs for each combination of demand scenario considered in the CBA are summarized in Table 169. The respective effects on the primary energy savings and carbon emissions are presented in Figure 136.

Table 169 - Measure H4 – Sensitivity of ENPV to demand and CO_2 (25 years, 2025-50)

	Demand 1 [1 hotel till 2050]	**Demand 2 [1 hotel till 2030, 2 hotels till 2050]**	**Demand 3 [1 hotel till 2030, 3 hotels till 2050]**
Incremental ENPV (€), 2025-50	485,469 (BM)	1,231,164	2,052,404

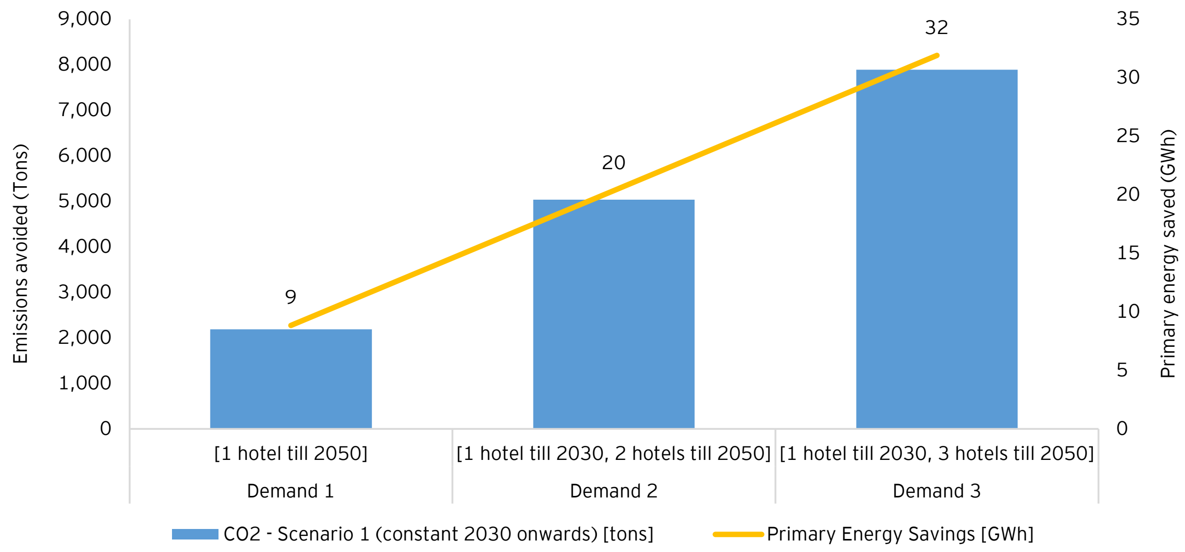

Figure 136 - Measure H4 – CO_2 emissions avoided (tons) and Primary energy savings (GWh)

As mentioned previously, since the savings from this measure are associated with fuel, the CO_2 scenarios based on electricity mix have no impact on the results.

Sensitivity Analysis (Part 2) – Sensitivity to changes in major variables

Table 170 - Measure H4 – Sensitivity Analysis: Critical and non-critical variables

Variable	**Variation of the FNPV due to a ± 1 % variation**	**Criticality judgement**	**Variation of the ENPV due to a ± 1 % variation**	**Criticality judgement**
Primary energy prices & Electricity tariffs	1.1%	Critical	0.8%	Not Critical
Alternative technology investment cost	0.8%	Not Critical	6.9%	Critical
EU ETS Carbon Price	N/A	N/A	1.0%	Not Critical

As with measure H3, the FNPV is sensitive to changes in energy costs, however, the sensitivity to alternative technology costs is not critical. The appeal of measure H4 lies in its ability to cut down on the energy needed for water heating through heat recovery. This advantage outweighs the approximately 13% higher cost of the alternative water-cooled chiller unit.

On the other hand, the cost of alternative technology is a critical variable to economic welfare, unlike the impact of primary energy costs and tariffs. The ENPV of measure H4 increases alongside uptake, and as such, the benchmark scenario depicts the least favourable outcome for this measure. Meanwhile, the shadow price of carbon, which is applied to the emissions averted to calculate the monetary economic benefit derived from the alternative technology, is not a critical input to the analysis of this measure.

The impact of varying FDR and SDR is shown below.

Table 171 - Measure H4 – Sensitivity Analysis: Effect of different FDR and SDR

Financial Discount Rate	FNPV	Social Discount Rate	ENPV
3%	€443,876	4%	€555,246
4% - BM	€397,016	5% - BM	€485,469
5%	€357,205	6%	€427,697

Finally, the switching values under this measure are the following.

Table 172 - Measure H4 – Sensitivity Analysis: Switching Values

	FNPV - BM	ENPV - BM
	€397,016	€485,469
	Percentage change for **FNPV** to become zero	Percentage change for **ENPV** to become zero
Primary energy prices & Electricity tariffs	-91%	-123%
Alternative technology investment cost	121%	14%
EU ETS Carbon Price	N/A	-100%

3.2.2.5 Hotels Measure H5A – Replacing ageing heat pumps with new, higher efficiency heat pumps (decentralised to decentralised)

This intervention considers the replacement of old heat pumps (aged 10+ years) within 2 and 3-star hotels[131] that have not yet reached the end of their technical lifetime, yet operate on reduced efficiencies due to a combination of outdated technology and annual efficiency losses. The key parameters are outlined in Table 173. It is assumed that all existing 2 and 3-star hotels will be eligible for this measure, once their heat pumps are aged a minimum of 10 years.

[131] It is assumed that only 2 and 3-star hotels make use of decentralized climate control models (i.e., each room having its own AC). Useful energy demand per establishment was thus calculated based on the figures obtained from Part I for space heating and cooling within the sub-sector (107.54 and 182.35 GWh, respectively), and proportioned according to the number of bed-nights recorded for a typical 2- and 3- star hotel in 2022 (NSO).

Table 173 - Key parameters for measure H5A.

Data	Baseline Low-efficiency Heat Pumps (aged ~10 years) Decentralised	Alternative High-efficiency Heat Pumps (new) Decentralised
Price for Heat Pumps (€) exc. VAT	42,000	
Technical Life (years) of equipment	17	
Efficiency losses p.a.	0.01	
Routine repairs and maintenance cost frequency (in years)	1	
Routine repairs and maintenance cost (% of investment)	5	
Major repairs and maintenance cost interval (in years)	10	
Major repairs and maintenance cost (% of investment)	10	
Weighted electricity tariff (non-residential) exc. VAT (€/kWh) for space cooling and water heating	0.136	
Final Energy (kWh) for Space Cooling per Establishment p.a.	190,000	160,639
Final Energy (kWh) for Space Heating per Establishment p.a.	248,154	210,417
EER at Y1 (2025)	3.89	4.60
CoP at Y1 (2025)	4.07	4.80
Useful Energy (kWh) for Space Cooling per Establishment p.a.	738,940	738,940
Useful Energy (kWh) for Space Heating per Establishment p.a.	1,010,000	1,010,000

In the baseline scenario, the heat pump is only replaced at the end of its technical lifetime, which is after 17 years. Thus, the main investment cost from the perspective of the individual hotel is incurred in Y7 (2032), based on the assumption that the heat pump will have been in use for 10 years by that time. Conversely, in the alternative scenario, the heat pump is changed in Y1 before the end of its technical lifetime, and thus the main investment cost is incurred in that year (2025). For both scenarios, it is assumed that the equipment is then replaced with identical technology when it reaches the end of its technical lifetime (the full 17 years), and that the equipment experiences an annual drop in efficiency due to ageing (refer to Figure 137). The equipment is also subject to periodic maintenance (both routine and major) throughout its technical lifetime, for which the cost is calculated as a percentage of the initial investment.

Operating costs for the heat pumps are based on electricity consumption and the weighted (non-residential) electricity tariff.

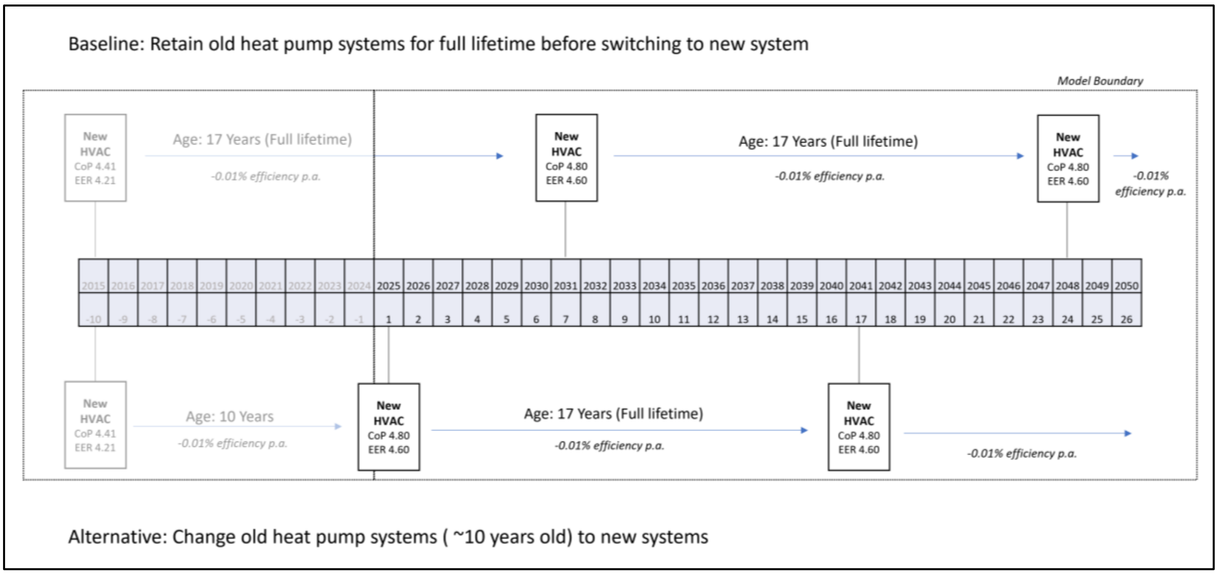

Figure 137 - Graphic summary of measures H5A, H5B, and RST1.

Results from financial analysis

Table 174 summarises the results of the financial analysis from the perspective of the hotel owner, which is affected by incremental investment and reinvestment costs in Y1 and Y17 respectively. An incremental residual cost is also factored in. The incremental financial costs of adopting the alternative technology are offset by the incremental benefit arising from reduced operating & maintenance costs. Consequently, from a financial standpoint, it would be prudent for the hotel operator to invest in the high-efficiency heat pumps now (in the year 2025) instead of delaying the upgrade until the existing heat pumps are no longer serviceable after 7 more years. The positive FNPV of approximately €156k suggests that there is no need for government incentives to persuade hotel owners to adopt this measure – the investment justifies itself. With a FRR of 53.9%, which surpasses the 4% FDR, the proposed measure is financially attractive. The payback period of measure H5A is 4 years.

Table 174 - Measure H5A – Financial NPV (25 years, 2025-50)

2025-2050 - NPV (EUR)	Retaining Old HP until end of tech. life	Replacing Old HP	Incremental
Investment Costs	(49,268)	(63,185)	(13,918)
Residual Value	13,634	7,271	(6,363)
Operating & Maintenance costs	(1,075,955)	(899,431)	176,524
Revenues	-	-	-
Net Cash Flows	(1,111,589)	(955,344)	156,244
FRR (C)			53.9%

Results from the Economic Analysis (Benchmark Scenario)

To assess the wider socio-economic impact of the proposed measure, the economic analysis evaluates the change in welfare stemming from the introduction of the measure under three demand scenarios. The demand scenarios applied were identical to those under previous hotel measures, however, the hotels available for uptake varied since this measure targets 2&3-star hotels with heating/cooling systems older than 10 years.

In consideration of the targeted population of measure H5A, the forecasted number of hotels available for uptake varied with each passing year as the hotel building stock's heating/cooling systems aged.

Table 175 - Hotels available for uptake in 5-year intervals under measure H5A

	2025	**2030**	**2035**	**2040**	**2045**	**2050**
Number of 2&3-star hotels	77	77	77	77	77	77
Average age of 2&3-star hotels' air heating/cooling systems	10	15	20	25	30	35
Percentage of 2&3-star hotels with 10+ year-old air heating/cooling systems	50%	95%	100%	100%	100%	100%
Available for uptake: 2&3-star hotels with 10+ year-old air heating/cooling systems	39	73	77	77	77	77

The above uptake eligible population schedule is based on the following key assumptions:

- No changes in the supply of 2&3-star hotels throughout the reference period.
- All 2&3-star hotels have decentralised air heating/cooling systems.
- The starting average age of the air heating/cooling systems of 2&3-star hotels is 10 years.
- Age of hotel air heating/cooling systems is normally distributed with a standard deviation of 3 years.

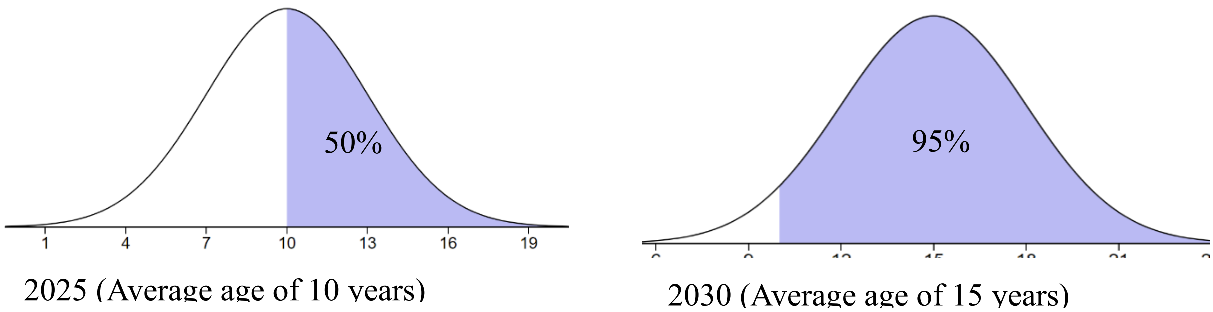

Figure 138 - Measure H5A – Percentage eligible for uptake under a normal distribution

Table 176 - Demand for measure H5A: three scenarios 2025-2050

Demand Scenario	**Description**	**by 2030**	**by 2040**	**by 2050**	**% by 2050**
H5A-SCN1	1 hotel annually till 2050	6	16	26	34%
H5A-SCN2	1 hotel annually till 2030, then 2 hotels till 2050	6	26	46	60%
H5A-SCN3	1 hotel annually till 2030, then 3 hotels till 2050	6	36	66	86%

The Benchmark Scenario (BM) assumes the demand scenario H5A-SCN1. The remaining two scenarios will be explored in the subsequent Sensitivity Analysis.

Another factor in the economic assessment is the amount of CO_2 emissions, which, as described in H1, was evaluated based on three energy decarbonization scenarios related to electricity generation in Malta. The Benchmark Scenario considers carbon emission factors based on a 2025-2030 forecast for the energy mix for electricity, that then remains constant post-2030 (Electricity – Scenario 1). Under the previous two measures discussed (H3 & H4), energy savings were directed towards reducing energy consumption by fuel-powered boilers, with no incremental costs or benefits pertaining to electricity consumption. Although measure H5A also uses electricity under both the baseline and the alternative scenario, in this case electricity consumption does not net off during the incremental analysis since the alternative technology uses less electricity in achieving the same outcome, therefore reducing electricity consumption and carbon emissions. The economic performance is summarized below.

Table 177 - Measure H5A – Economic NPV (25 years, 2025-50)

2025-2050 – ENPV, EUR	Incremental Costs and Benefits (EUR)
Investment, Repairs and Residual Value (excl. VAT)	(378,823)
Fiscal Correction: VAT	-
Fiscal Correction: Subsidies	-
Residual Value	27,776
Net Capex	(351,047)
CO2 Emissions avoided	456,765
Primary Energy Savings	1,103,346
ENPV: Net (COSTS) / BENEFITS	1,209,064
ERR	112.7%
B/C RATIO	4.44

The estimated ENPV of approximately €1.2 million over the 25-year period indicates that the proposed intervention is likely to enhance social welfare. This improvement is largely attributed to the preservation of primary energy resources through the adoption of more energy-efficient technology, which leads to lower energy consumption and a consequent decrease in CO_2 emissions due to reduced energy requirements. The ERR for this proposed measure stands at 112.7%, which is significantly higher than the 5% SDR. With a B/C ratio of 4.44, the project is deemed economically feasible, as a ratio greater than one signifies that the benefits surpass the associated costs.

Sensitivity Analysis

Sensitivity Analysis (Part 1) – Combination of demand levels and electricity decarbonization scenarios

The ENPVs for each combination of demand and emissions scenario considered in the CBA are summarized in Table 178. The respective effects on the primary energy savings and carbon emissions are presented in Figure 139 below.

Table 178 - Measure H5A – Sensitivity of ENPV to demand and CO_2 (25 years, 2025-50)

Incremental ENPV (€), 2025-50	**Demand 1 [1 hotel till 2050]**	**Demand 2 [1 hotel till 2030, 2 hotels till 2050]**	**Demand 3 [1 hotel till 2030, 3 hotels till 2050]**
CO_2 - Scenario 1 (constant 2030 onwards)	1,209,064 (BM)	2,011,814	2,814,564
CO_2 - Scenario 2 (grad-50%)	988,520	1,597,238	2,205,956
CO_2 - Scenario 3 (grad-100%)	840,036	1,312,528	1,785,021

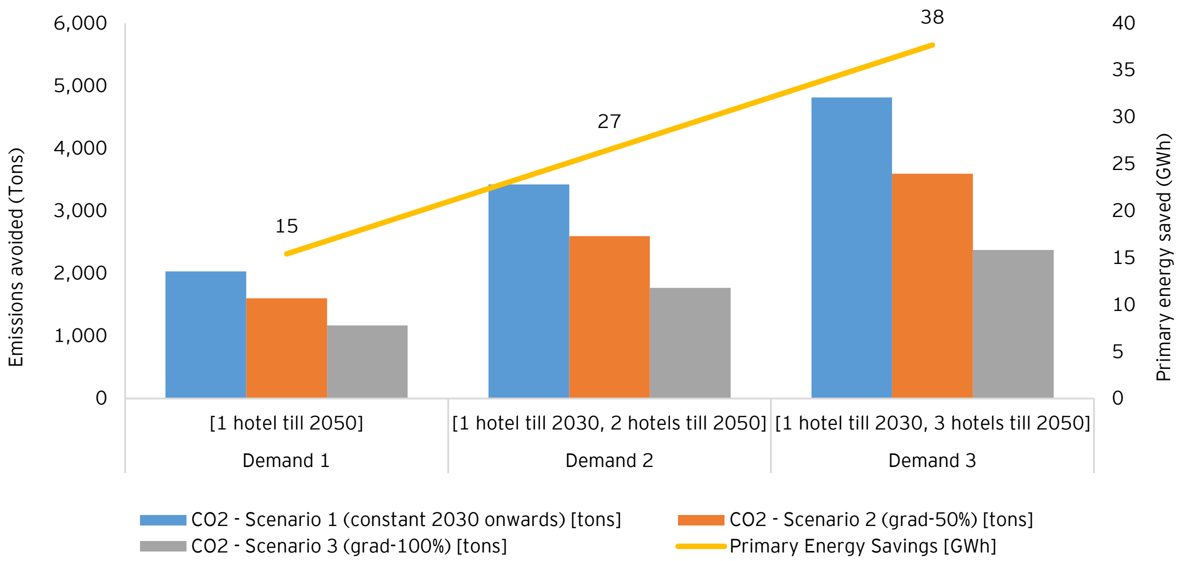

Figure 139 - Measure H5A – CO_2 emissions avoided (tons) and Primary energy savings (GWh)

As observed for most of the residential measures, the emissions savings for each kWh of electricity used consistently diminish under CO_2 scenario 2 and do so at double the pace under CO_2 scenario 3 due to more rapid decarbonization of electricity post-2030. This trend results in the reduction of emissions savings across different demand scenarios observed in Figure 139, which is a key reason behind the declining ENPVs presented in Table 178.

Sensitivity Analysis (Part 2) – Sensitivity to changes in major variables

Table 179 - Measure H5A – Sensitivity Analysis: Critical and non-critical variables

Variable	Variation of the FNPV due to a ± 1 % variation	Criticality judgement	Variation of the ENPV due to a ± 1 % variation	Criticality judgement
Primary energy prices & Electricity tariffs	1.1%	Critical	0.9%	Not Critical
Alternative technology investment cost	0.4%	Not Critical	0.4%	Not Critical
EU ETS Carbon Price	N/A	N/A	0.4%	Not Critical

The FNPV is critically sensitive to changes in energy costs, however, the sensitivity to alternative technology costs is not critical. The appeal of measure H5A is the reduction of energy consumption arising from a more efficient heating/cooling system, the benefits from which exceed the incremental cost of replacing a 10-year-old heat pump prior to the end of its technical life.

With regards to economic welfare, neither energy costs nor alternative technology costs are critical variables. The shadow price of carbon, which is applied to the emissions averted to calculate the monetary economic benefit derived from the alternative technology, is also found to be not a critical input to the analysis of the measure.
The impact of varying FDR and SDR is shown below.

Table 180 - Measure H5A – Sensitivity Analysis: Effect of different FDR and SDR

Financial Discount Rate	FNPV	Social Discount Rate	ENPV
3%	€175,699	4%	€1,377,277
4% - BM	€156,244	5% - BM	€1,209,064
5%	€139,707	6%	€1,066,660

Finally, the switching values under this measure are the following.

Table 181 - Measure H5A – Sensitivity Analysis: Switching Values

	FNPV - BM	ENPV - BM
	€156,244	€1,209,064
	Percentage change for **FNPV** to become zero	Percentage change for **ENPV** to become zero
Primary energy prices & Electricity tariffs	-88%	-110%
Alternative technology investment cost	279%	226%
EU ETS Carbon Price	N/A	-265%

3.2.2.6 Hotels Measure H5B – Replacing ageing heat pumps with new, higher efficiency heat pumps (decentralised to centralised)

Similar to Measure H5A[132], this intervention considers the replacement of old heat pumps (aged 10+ years) within 2 and 3-star hotels that have not yet reached the end of their technical lifetime, yet operate on reduced efficiencies due to a combination of outdated technology and annual efficiency losses. However, this measure presents an alternative scenario that can be adopted by hotels scheduled to undergo major refurbishments, whereby the original decentralised heat pump system may be replaced by a centralised model. It is being assumed that this measure would begin to reap benefits starting in its initial year of implementation (2025). The key parameters are outlined in Table 182. It is also assumed that all existing 2 and 3-star hotels will be eligible for this measure, once they reach a minimum age of 30 years (at which it is assumed that major renovations are likely to be required).

Table 182 - Key parameters for measure H5B.

	Baseline	**Alternative**
Data	**Low-efficiency Heat Pumps (aged ~10 years) Decentralised**	**High-efficiency Heat Pumps (new) *Centralised***
Price for Heat Pumps (€) exc. VAT	42,000	40,000
Technical Life (years) of equipment	17	
Efficiency losses p.a.	0.01	

[132] It is assumed that only 2 and 3-star hotels make use of decentralized climate control models (i.e., each room having its own AC).

Routine repairs and maintenance cost frequency (in years)	1	
Routine repairs and maintenance cost (% of investment)	5	
Major repairs and maintenance cost interval (in years)	10	
Major repairs and maintenance cost (% of investment)	10	
Weighted electricity tariff (non-residential) exc. VAT (€/kWh) for space cooling and water heating	0.136	
Final Energy (kWh) for Space Cooling per Establishment p.a.	190,000	160,639
Final Energy (kWh) for Space Heating per Establishment p.a.	248,154	210,417
EER at Y1 (2025)	3.89	4.60
CoP at Y1 (2025)	4.07	4.80
Useful Energy (kWh) for Space Cooling per Establishment p.a.	738,940	738,940
Useful Energy (kWh) for Space Heating per Establishment p.a.	1,010,000	1,010,000

In the baseline scenario, the heat pump is only replaced at the end of its technical lifetime, which is after 17 years. Thus, the main investment cost from the perspective of the individual hotel is incurred in Y7 (2032), based on the assumption that the heat pump will have been in use for 10 years by that time. Conversely, in the alternative scenario, the heat pump is changed in Y1 before the end of its technical lifetime, and thus the main investment cost is incurred in that year (2025). Since the measure is only applicable to hotels undergoing renovations, no costs associated with structural alterations are considered. For both scenarios, it is assumed that the equipment is then replaced with identical technology when it reaches the end of its technical lifetime (the full 17 years), and that the equipment experiences an annual drop in efficiency due to ageing (refer to Figure 137). The equipment is also subject to periodic maintenance (both routine and major) throughout its technical lifetime, for which the cost is calculated as a percentage of the initial investment.

Operating costs for the heat pumps are based on electricity consumption and the weighted (non-residential) electricity tariff.

Results from financial analysis

Table 183 summarises the results of the financial analysis from the perspective of the hotel owner, which is affected by incremental investment and reinvestment costs in Y1 and Y17 respectively. An incremental residual cost is also factored in. The incremental financial costs of adopting the alternative technology are offset by the incremental benefit arising from reduced operating & maintenance costs. As a result, the FNPV is positive at circa €160k, implying that the government would not have to incentivise hotel owners to adopt the measure. With a FRR of 58.1%, which surpasses the 4% FDR, the proposed measure is financially attractive. The payback period of measure H5B is 3 years.

Table 183 - Measure H5B – Financial NPV (25 years, 2025-50)

2025-2050 - NPV (EUR)	Retaining old HP until end of tech. life	Replacing old HP with centralised HP	Incremental
Investment Costs	(49,268)	(60,402)	(11,134)
Residual Value	13,634	6,951	(6,683)
Operating & Maintenance costs	(1,075,955)	(897,859)	178,096
Revenues	-	-	-
Net Cash Flows	(1,111,589)	(951,310)	160,279
FRR (C)			58.1%

Results from the Economic Analysis (Benchmark Scenario)

To assess the wider socio-economic impact of the proposed measure, the economic analysis evaluates the change in welfare stemming from the introduction of the measure under three demand scenarios. These scenarios are consistent with those used in the previous assessments of hotel-related measures. However, the availability of hotels for this particular measure differs, as it is aimed at 2&3-star hotels that are over 30 years old. Taking into account the specific group of hotels targeted by measure H5B, the forecasted number of hotels available for uptake varied with each passing year as the hotel building stock aged.

Table 184 - Hotels available for uptake in 5-year intervals under measure H5B

	2025	2030	2035	2040	2045	2050
Number of 2-star hotels	15	15	15	15	15	15
Number of 3-star hotels	62	62	62	62	62	62
Average age of 2-star hotels	25	30	35	40	45	50
Average age of 3-star hotels	19	24	29	34	39	44
Percentage of 30+ year-old 2-star hotels	16%	50%	84%	98%	100%	100%
Percentage of 30+ year-old 3-star hotels	1%	11%	41%	78%	96%	100%
Available for uptake: 30+ year-old 2&3-star hotels	3	14	38	63	75	77

The above uptake-eligible population schedule is based on the following key assumptions:

- No changes in the supply of 2&3-star hotels.

- The starting average age of 2-star and 3-star hotels is 25 years and 19 years, respectively. The latter is calculated by adjusting the base assumption of a 25-year average age to account for newly constructed hotels between 2022 and 2024, which reduces the overall average age.

- Hotel age is normally distributed with a standard deviation of 5 years.

Table 185 - Demand for measure H5B: three scenarios 2025-2050

Demand Scenario	**Description**	**by 2030**	**by 2040**	**by 2050**	**% by 2050**
H5B-SCN1	1 hotel annually till 2050	6	16	26	34%
H5B-SCN2	1 hotel annually till 2030, then 2 hotels till 2050	6	26	46	60%
H5B-SCN3	1 hotel annually till 2030, then 3 hotels till 2050	6	36	66	86%

The Benchmark Scenario (BM) assumes the demand scenario H5B-SCN1. The remaining two scenarios will be explored in the subsequent Sensitivity Analysis.

Another factor in the economic assessment is the amount of CO_2 emissions, which, as described in H1, was evaluated based on three energy decarbonization scenarios related to electricity generation in Malta. The Benchmark Scenario considers carbon emission factors based on a 2025-2030 forecast for the energy mix for electricity, that then remains constant post-2030 (Electricity – Scenario 1). As explained under H5A, this measure results in an incremental impact on electricity consumption and its associated CO_2 emissions due to efficiency improvements by investing in the alternative approach. The economic performance is summarized below.

Table 186 - Measure H5B – Economic NPV (25 years, 2025-50)

2025-2050 – ENPV, EUR	Incremental Costs and Benefits (EUR)
Investment, Repairs and Residual Value (excl. VAT)	(329,411)
Fiscal Correction: VAT	-
Fiscal Correction: Subsidies	-
Residual Value	19,588
Net Capex	(309,823)
CO2 Emissions avoided	456,765
Primary Energy Savings	1,103,346
ENPV: Net (COSTS) / BENEFITS	1,250,288
ERR	129.4%
B/C RATIO	5.04

The estimated ENPV of approximately €1.3 million over the 25-year period indicates that the proposed intervention is likely to enhance social welfare, primarily due to the conservation of primary energy, as a result of the more efficient alternative, and the resulting reductions in CO_2 emissions. The ERR for this measure is 129.4%, exceeding the 5% SDR. The calculated B/C ratio of 5.04 suggests that the project is economically viable, as a ratio above one indicates that the benefits exceed the costs.

Sensitivity Analysis

Sensitivity Analysis (Part 1) – Combination of demand levels and electricity decarbonization scenarios

The ENPVs for each combination of demand and emissions scenario considered in the CBA are summarized in Table 187. The respective effects on the primary energy savings and carbon emissions are presented in Figure 140 below.

Table 187 - Measure H5B – Sensitivity of ENPV to demand and CO_2 (25 years, 2025-50)

Incremental ENPV (€), 2025-50	**Demand 1 [1 hotel till 2050]**	**Demand 2 [1 hotel till 2030, 2 hotels till 2050]**	**Demand 3 [1 hotel till 2030, 3 hotels till 2050]**
CO_2 - Scenario 1 (constant 2030 onwards)	1,250,288 (BM)	2,074,988	2,899,688
CO_2 - Scenario 2 (grad-50%)	1,029,744	1,660,412	2,291,080
CO_2 - Scenario 3 (grad-100%)	881,260	1,375,702	1,870,145

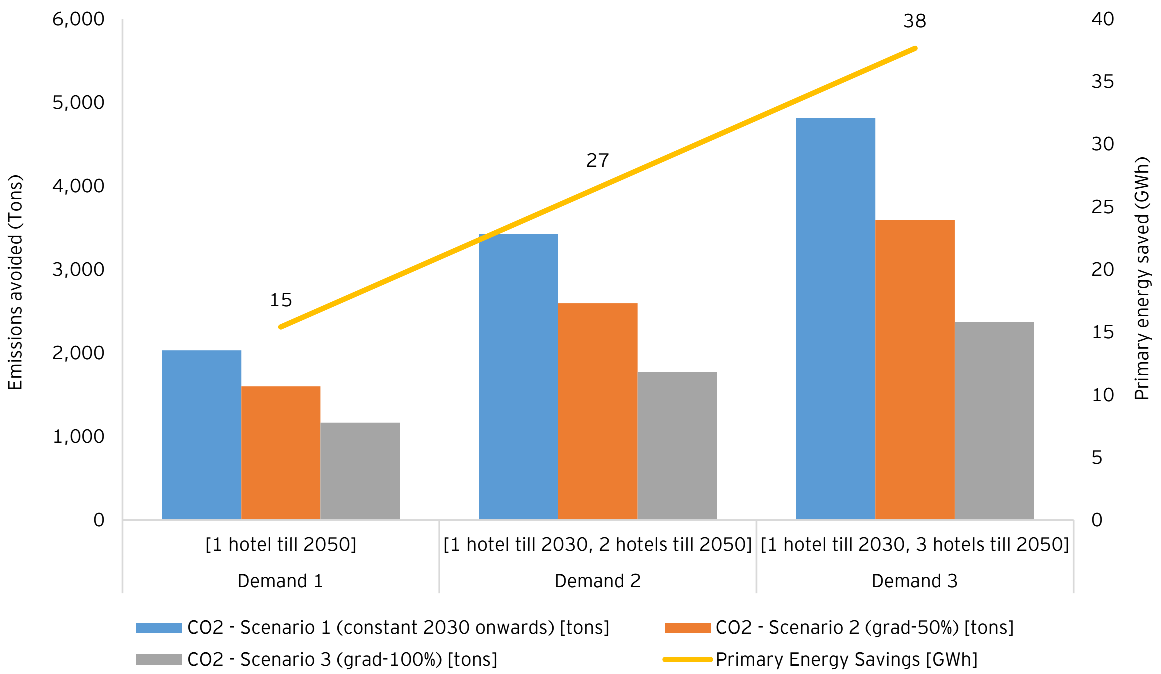

Figure 140 - Measure H5B – CO_2 emissions avoided (tons) and Primary energy savings (GWh)

As observed in measure H5A, the emissions savings for each kWh of electricity used consistently diminish under CO_2 scenario 2 and do so at double the pace under CO_2 scenario 3 due to more rapid decarbonization of electricity post-2030. This trend results in the reduction of emissions savings across different demand scenarios observed in Figure 140 above which is a key reason behind the declining ENPVs presented in Table 187.

Sensitivity Analysis (Part 2) – Sensitivity to changes in major variables

Table 188 - Measure H5B – Sensitivity Analysis: Critical and non-critical variables

Variable	Variation of the FNPV due to a ± 1 % variation	Criticality judgement	Variation of the ENPV due to a ± 1 % variation	Criticality judgement
Primary energy prices & Electricity tariffs	1.1%	Critical	0.9%	Not Critical
Alternative technology investment cost	0.3%	Not Critical	0.4%	Not Critical
EU ETS Carbon Price	N/A	N/A	0.4%	Not Critical

The FNPV is only slightly critically sensitive to primary energy prices and electricity tariffs. The appeal of measure H5B is the reduction of energy consumption arising from a more efficient heating/cooling system, the benefits from which exceed the incremental cost of replacing 10-year-old heat pumps with a centralised system prior to the end of its technical life. Notably, the cost of the hotels' demolition is not included as an incremental cost, since these old hotels are assumed to be demolished under the base case scenario (regardless of the measure's implementation).

With regards to economic welfare, neither energy costs nor alternative technology costs are critical variables. The shadow price of carbon, which is applied to the emissions averted to calculate the monetary economic benefit derived from the alternative technology, is also found to be not a critical input to the analysis of the measure.

The impact of varying FDR and SDR is shown below.

Table 189 - Measure H5B – Sensitivity Analysis: Effect of different FDR and SDR

Financial Discount Rate	FNPV	Social Discount Rate	ENPV
3%	€179,997	4%	€1,423,053
4% - BM	€160,279	5% - BM	€1,250,288
5%	€143,510	6%	€1,103,931

Finally, the switching values under this measure are the following.

Table 190 - Measure H5B – Sensitivity Analysis: Switching Values

	FNPV - BM	ENPV - BM
	€160,279	€1,250,288
	Percentage change for **FNPV** to become zero	Percentage change for **ENPV** to become zero
Primary energy prices & Electricity tariffs	-91%	-113%
Alternative technology investment cost	309%	253%
EU ETS Carbon Price	N/A	-274%

3.2.3 Restaurants Sub-Sector

3.2.3.1 Restaurants Measure RST1 - Replacing ageing heat pumps with new, higher efficiency heat pumps

This intervention considers the replacement of old heat pumps (aged 10+ years) within restaurants that have not yet reached the end of their technical lifetime, yet operate on reduced efficiencies due to a combination of outdated technology and annual efficiency losses. The key parameters are outlined in Table 191. It is assumed that all existing restaurants (873 establishments[133]) will be eligible to consider this measure, once their heat pumps are aged a minimum of 10 years. The type of air-to-air heat pump system (i.e., individual ACs, VRFs, split-units, etc.) is intentionally not specified to account for the different existing set-ups. Calculations are based on the average catering establishment, which is assumed to have circa 72,000 btu (British thermal unit) installed.

[133] Malta Tourism Authority - Licensing. Available: https://www.mta.com.mt/en/licensing Accessed on 4th July 2024.

Table 191 - Key parameters for measure RST1.

	Baseline	Alternative
Data	**Low-efficiency Heat Pumps (aged ~10 years)**	**High-efficiency Heat Pumps (new)**
Price for Heat Pumps (€) excl. VAT	3,900	
Technical Life (years) of equipment	17	
Efficiency losses p.a.	0.01	
Routine repairs and maintenance cost frequency (in years)	1	
Routine repairs and maintenance cost (% of investment)	5	
Major repairs and maintenance cost interval (in years)	10	
Major repairs and maintenance cost (% of investment)	10	
Weighted electricity tariff (non-residential) exc. VAT (€/kWh) for space cooling and water heating	0.136	
Final Energy (kWh) for Space Cooling per Establishment p.a.	14,528	12,283
Final Energy (kWh) for Space Heating per Establishment p.a.	8,637	7,324
EER at Y1 (2025)	3.89	4.6
CoP at Y1 (2025)	4.07	4.8
Useful Energy (kWh) for Space Cooling per Establishment p.a.	56,503	56,503
Useful Energy (kWh) for Space Heating per Establishment p.a.	35,153	35,153

In the baseline scenario, the heat pump is only replaced at the end of its technical lifetime, which is after 17 years. Thus, the main investment cost from the perspective of the individual restaurant operator is incurred in Y7 (2032), based on the assumption that the heat pump will have been in use for 10 years by that time. Conversely, in the alternative scenario, the heat pump is changed in Y1 before the end of its technical lifetime, and thus the main investment cost is incurred in that year (2025). For both scenarios, it is assumed that the equipment is then replaced with identical technology when it reaches the end of its technical lifetime (the full 17 years), and that the equipment experiences an annual drop in efficiency due to ageing. The equipment is also subject to periodic maintenance (both routine and major) throughout its technical lifetime, for which the cost is calculated as a percentage of the initial investment.

Operating costs for the heat pumps are based on electricity consumption and the weighted (non-residential) electricity tariff.

Results from financial analysis

Table 192 summarises the results of the financial analysis from the perspective of the restaurant owner, which is affected by incremental investment and reinvestment costs in Y1 and Y17 respectively. An incremental residual cost is also factored in. The incremental financial costs of adopting the alternative technology are offset by the incremental benefit arising from reduced operating & maintenance costs. Consequently, from a financial standpoint, it would be prudent for the restaurant owner to invest in the high-efficiency heat pumps now (in the year 2025) instead of delaying the upgrade until the existing heat pumps are no longer serviceable after 7 more years. The positive FNPV of approximately €7k suggests that there is no need for government incentives to persuade restaurant owners to adopt this measure – the investment justifies itself. With a FRR of 27.9%, which surpasses the 4% FDR, the proposed measure is financially attractive. The payback period of measure RST1 is 6 years.

Table 192 - Measure RST1 – Financial NPV (25 years, 2025-50)

2025-2050 - NPV (EUR)	Retaining Old HP until end of tech. life	Replacing Old HP	Incremental
Investment Costs	(4,575)	(5,867)	(1,292)
Residual Value	1,266	675	(591)
Operating & Maintenance costs	(58,299)	(48,954)	9,345
Revenues	-	-	-
Net Cash Flows	(61,608)	(54,146)	7,461
FRR (C)			27.9%

Results from the Economic Analysis (Benchmark Scenario)

In consideration of the targeted population of measure RST1, the forecasted number of restaurants available for uptake varied with each passing year as the restaurant building stock's heating/cooling systems aged.

Table 193 – Restaurants available for uptake in 5-year intervals under measure RST1

	2025	2030	2035	2040	2045	2050
Number of restaurants	873	873	873	873	873	873
Average age of restaurants' air heating/cooling systems	5	10	15	20	25	30
Percentage of restaurants with 10+ year-old air heating/cooling systems	1%	50%	95%	100%	100%	100%
Available for uptake: restaurants with 10+ year-old air heating/cooling systems	5	437	831	873	873	873

The above uptake eligible population schedule is based on the following key assumptions:

- No changes in the supply of restaurants throughout the reference period.
- The starting average age of the air heating/cooling systems of restaurants is 5 years.[134]
- Age of restaurant air heating/cooling systems is normally distributed with a standard deviation of 2 years.

To assess the wider socio-economic impact of the proposed measure, the economic analysis evaluates the change in welfare stemming from the introduction of the measure under three demand scenarios. The first demand scenario assumes a steady rate of 10 annual restaurant conversions throughout the reference period, resulting in a 29% adoption rate across all restaurants by the year 2050. In contrast, the second and third demand scenarios are more ambitious, projecting post-2030 uptake increasing to 25 and 35 restaurants respectively. Demand scenario 2 results in 64% adoption by 2050, whereas scenario 3 achieves 86% adoption by the year 2050. Table 194 breaks down the cumulative number of restaurants that would have adopted the measure at ten-year intervals for each of the three scenarios.

[134] Based on data from the Central Bank of Malta – Development Permits for restaurants and bars (which can be found at https://www.centralbankmalta.org/real-economy-indicators), there were 2,110 permits issued for restaurants and bars over the eight-year period from 2016 to 2023. In contrast, only 419 permits were granted in the preceding thirteen years from 2003 to 2015. This indicates a significant increase in the establishment of new dining venues in the more recent years. Furthermore, to remain competitive with these new establishments, many older restaurants have invested in extensive renovations, including updates to their heating and cooling systems. This trend has effectively reduced the average age of the heating/cooling infrastructure in the existing restaurant sector.

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Table 194 - Demand for measure RST1: three scenarios 2025-2050

Demand Scenario	Description	by 2030	by 2040	by 2050	% by 2050
RST1-SCN1	10 restaurants annually till 2050	55	155	255	29%
RST1-SCN2	10 restaurants annually till 2030, then 25 restaurants till 2050	55	305	555	64%
RST1-SCN3	10 restaurants annually till 2030, then 35 restaurants till 2050	55	405	720	86%

(In the years where the uptake assumption exceeded the number of establishments available for uptake, it was assumed that all establishments available for uptake adopted the measure.)
The Benchmark Scenario (BM) assumes the demand scenario RST1-SCN1. The remaining two scenarios will be explored in the subsequent Sensitivity Analysis.

Another factor in the economic assessment is the amount of CO_2 emissions, which, as described in measures R1A and H1, was evaluated based on three energy decarbonization scenarios related to electricity generation in Malta. The Benchmark Scenario considers carbon emission factors based on a 2025-2030 forecast for the energy mix for electricity, that then remains constant post-2030 (Electricity – Scenario 1). The economic performance is summarized below.

Table 195 - Measure RST1 – Economic NPV (25 years, 2025-50)

2025-2050 – ENPV, EUR	Incremental Costs and Benefits (EUR)
Investment, Repairs and Residual Value (excl. VAT)	(338,035)
Fiscal Correction: VAT	-
Fiscal Correction: Subsidies	-
Residual Value	28,106
Net Capex	(309,929)
CO2 Emissions avoided	235,101
Primary Energy Savings	561,261
ENPV: Net (COSTS) / BENEFITS	486,433
ERR	37.1%
B/C RATIO	2.57

The estimated ENPV of approximately €0.5 million over the 25-year period indicates that the proposed intervention is likely to enhance social welfare. This improvement is largely attributed to the preservation of primary energy resources through the adoption of more energy-efficient technology, which leads to lower energy consumption and a consequent decrease in CO_2 emissions due to reduced energy requirements. The ERR for this proposed measure stands at 37.1%, which is significantly higher than the 5% SDR. With a B/C ratio of 2.57, the project is deemed economically feasible, as a ratio greater than one signifies that the benefits surpass the associated costs.

Sensitivity Analysis

Sensitivity Analysis (Part 1) – Combination of demand levels and electricity decarbonization scenarios

The ENPVs for each combination of demand and emissions scenario considered in the CBA are summarized in Table 196. The respective effects on the primary energy savings and carbon emissions are presented in Figure 141 below.

Table 196 - Measure RST1 – Sensitivity of ENPV to demand and CO_2 (25 years, 2025-50)

Incremental ENPV (€), 2025-50	**Demand 1 [10 restaurants till 2050]**	**Demand 2 [10 restaurants till 2030, 25 restaurants till 2050]**	**Demand 3 [10 restaurants till 2030, 35 restaurants till 2050]**
CO_2 - Scenario 1 (constant 2030 onwards)	486,433 (BM)	1,005,020	1,350,744
CO_2 - Scenario 2 (grad-50%)	369,947	734,281	977,171
CO_2 - Scenario 3 (grad-100%)	291,576	547,607	718,294

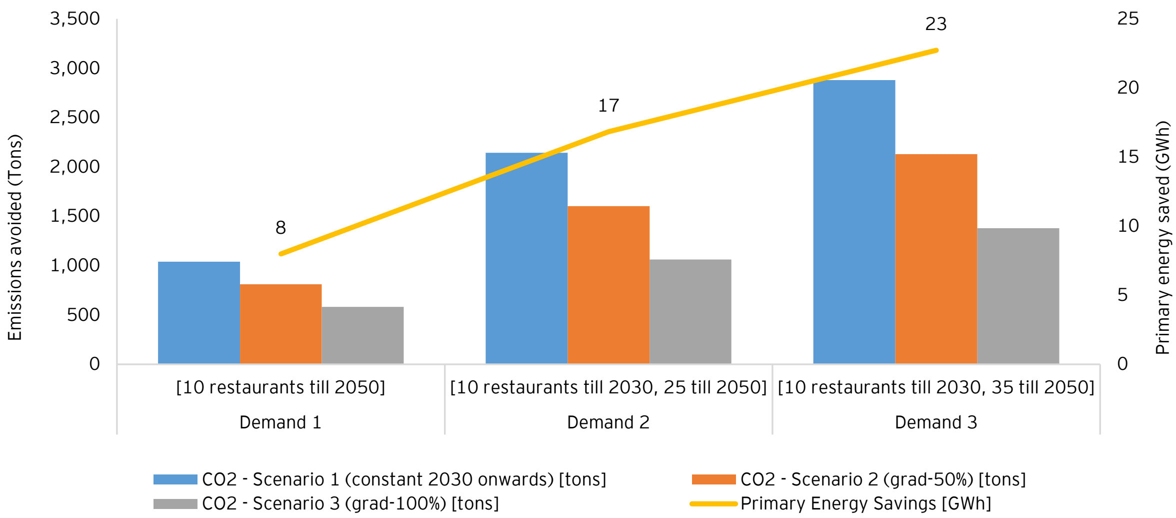


Figure 141 - Measure RST1 – CO_2 emissions avoided (tons) and Primary energy savings (GWh)

As observed for most of the residential measures, the emissions savings for each kWh of electricity used consistently diminish under CO_2 scenario 2 and do so at double the pace under CO_2 scenario 3 due to more rapid decarbonization of electricity post-2030. This trend results in the reduction of emissions savings across different demand scenarios observed in Figure 141, which is a key reason behind the declining ENPVs presented in Table 196.

Sensitivity Analysis (Part 2) – Sensitivity to changes in major variables

Table 197 - Measure RST1 – Sensitivity Analysis: Critical and non-critical variables

Variable	Variation of the FNPV due to a ± 1 % variation	Criticality judgement	Variation of the ENPV due to a ± 1 % variation	Criticality judgement
Primary energy prices & Electricity tariffs	1.3%	Critical	1.2%	Critical
Alternative technology investment cost	0.7%	Not Critical	1.0%	Not Critical
EU ETS Carbon Price	N/A	N/A	0.5%	Not Critical

The FNPV is critically sensitive to changes in energy costs, however, the sensitivity to alternative technology costs is not critical. The appeal of measure RST1 is the reduction of energy consumption arising from a more efficient heating/cooling system, the benefits from which exceed the incremental cost of replacing a 10-year-old heat pump prior to the end of its technical life.

With regards to economic welfare, energy prices represent a critical variable, whereas alternative technology costs are not critical. The shadow price of carbon, which is applied to the emissions averted to calculate the monetary economic benefit derived from the alternative technology, is also determined to be non-critical input to the analysis of this measure.

The impact of varying FDR and SDR is shown below.

Table 198 - Measure RST1 – Sensitivity Analysis: Effect of different FDR and SDR

Financial Discount Rate	FNPV	Social Discount Rate	ENPV
3%	€8,519	4%	€562,814
4% - BM	€7,461	5% - BM	€486,433
5%	€6,561	6%	€421,945

Finally, the switching values under this measure are the following.

Table 199 - Measure RST1 – Sensitivity Analysis: Switching Values

	FNPV - BM	**ENPV - BM**
	€7,461	€486,433
	Percentage change for **FNPV** to become zero	Percentage change for **ENPV** to become zero
Primary energy prices & Electricity tariffs	-80%	-87%
Alternative technology investment cost	144%	103%
EU ETS Carbon Price	N/A	-207%

3.2.4 Applying Intervention Measure RST1 to Offices and Retail Outlets

Though offices and retail outlets typically employ similar technologies to restaurants (i.e., VRF and split-unit systems) to meet their spatial heating and cooling demands, it has been proven challenging to conduct an identical feasibility analysis for these two sub-sectors. This is primarily due to the lack of critical data, namely the total number of offices and retail outlets in Malta, as well as the range of sizes within both categories of establishments. Furthermore, insights into the age profile of these establishments are also missing. This information is essential to determine the proportion of offices and retail outlets that are in a position to implement new heating and cooling measures, and to accurately estimate the potential adoption rate of such measures. Consequently, this gap in data significantly hinders the ability to carry out a comprehensive and reliable feasibility analysis for the office and retail sectors in Malta.

However, results from the economic analysis on restaurants indicate that the individual investor will always benefit from switching out old technology for new, more efficient technology. As evidenced by the resulting B/C ratio of 2.57, the incremental financial costs of adopting the alternative technology are offset by the incremental benefit arising from reduced operating & maintenance costs. From a financial standpoint, it would thus be attractive for the establishment owner, whether it be a restaurant, office, or retail outlet, to invest in the high-efficiency heat pumps now instead of delaying the upgrade until the existing heat pumps are no longer serviceable. However, taking into consideration the different average operating hours per annum for the three types of establishments (refer to Table 200), it is likely that the financial benefit for offices and retail would be slightly less than those observed for restaurants, or materialise over a longer period of time.

Table 200 - Comparison of the average operating hours for a typical restaurant, office, and retail outlet.

Typical Establishment	**Average operating hours per day**	**Average no. of Operating days per week**	**Average no. Of operating hours p.a.**
Restaurant	10	6	3,130
Office	9	5	2,340
Retail Outlet	8	6	2,496

Part IV – Potential new strategies and policy measures

4.1 Introduction

Based on the assessment undertaken in Parts I and III of this report, this section outlines strategies, policies and measures which Malta can consider to adopt in the coming years. The technical, financial and economic assessments of different intervention measures, detailed in Part III and summarized in Table 201 below, along with the heating and cooling demand analysed in Part I, have led to the development of policy recommendations outlined below. These recommendations, together with their assessed impact, have been developed separately from any policies and measures set out in the draft NECP update.

Table 201 - Summary of results: All intervention measures

Results: Benchmark Scenario		Individual				Society		
Measure Name	Measure Description	FNPV (€) (4% FDR)	FRR (%)	Payback Period (Years)	FNPV (€) (13.5% FDR Scenario**)	ENPV (€)	ERR (%)	B/C Ratio
Residential								
Residential 1A	Replacing electrical water heaters with heat pumps (decentralised)	(946)	-1.2%	N/A*	(1,289)	14,557,174	9.2%	1.27
Residential 1B	Replacing electrical water heaters with heat pumps (centralised)	(687)	-0.2%	N/A*	(1,075)	3,577,191	10.9%	1.39
Residential 2A	Replacing electrical water heaters with solar water heaters (decentralised)	(273)	2.6%	N/A*	(1,021)	36,826,585	14.8%	1.66
Residential 2B	Replacing electrical water heaters with solar water heaters (centralised)	1,242	16.2%	7	130	12,090,874	40.0%	3.32
Residential 3	Replacing electrical water	502	6.9%	12	(569)	41,635,623	17.6%	2.19

Results: Benchmark Scenario		Individual				Society		
Measure Name	Measure Description	FNPV (€) (4% FDR)	FRR (%)	Payback Period (Years)	FNPV (€) (13.5% FDR Scenario**)	ENPV (€)	ERR (%)	B/C Ratio
	heaters with PV+EWH (decentralised)							
Residential 4	Replacing gas hobs (and heaters) with electric hobs (and heat pumps) (decentralised)	(297)	0.7%	N/A*	(620)	23,836,926	15.8%	1.91
Hotels								
Hotel 1	Replacing boilers with heat pumps - 4&5 Star Hotels	207,993	18.8%	7	-	13,000,826	64.2%	6.03
Hotel 2	Replacing mixed fuel boilers with biofuel boilers - 4&5 Star Hotels	(172,735)	N/A	N/A*	-	2,120,979	141.5%	8.78
Hotel 3	Replacing air-cooled chillers (without heat recovery) with air-cooled chillers with heat recovery - 4&5 Star Hotels	396,535	N/A	1	-	480,526	N/A	2.20
Hotel 4	Replacing water-cooled chillers (without heat recovery) with water-cooled chillers with heat recovery - 4&5 Star Hotels	397,016	N/A	1	-	485,469	N/A	2.23
Hotel 5A	Replacing old low-efficiency heat pumps with new high-	156,244	53.9%	4	-	1,209,064	112.7%	4.44

Results: Benchmark Scenario		Individual				Society		
Measure Name	Measure Description	FNPV (€) (4% FDR)	FRR (%)	Payback Period (Years)	FNPV (€) (13.5% FDR Scenario**)	ENPV (€)	ERR (%)	B/C Ratio
	efficiency heat pumps (decentralised) - 2&3 Star Hotels							
Hotel 5B	Replacing old low-efficiency heat pumps with centralised heat pump system - 2&3 Star Hotels	160,279	58.1%	3	-	1,250,288	129.4%	5.04
Restaurants								
Restaurants 1	Replacing old low-efficiency heat pumps with new high-efficiency heat pumps (decentralised)	7,461	27.9%	6	-	486,433	37.1%	2.57

*Payback period not applicable for measures with a negative FNPV.
** As previously discussed, additional research shows that higher FDRs have been adopted for small firms and households. The table above presents the same analysis with a 13.5% discount rate.[135]

It is worth noting that, although some of the options analysed above have a positive FNPV, it is envisaged that financial aid from the government may still be required to overcome some of the barriers, such as initial high capital outlay. In fact, if households apply a distinct FDR of 13.5%, the negative FNPV is accentuated, or in certain cases, what was previously a positive FNPV becomes negative, reflecting the risk factors considered by households. Moreover, one shall also note that households are more inclined to make use of simple payback period methods rather than financial analysis when deciding on their choice of technology. The longer the payback period, as is the case with the proposed household measures that return a positive FNPV, the less attractive it becomes for households to invest in these technologies in the absence of government support.

From this summary, it is evident that the proposed interventions for the residential, hotel, and restaurant sectors – which, by extension, could also be relevant to other services sector– yield economically favourable outcomes. The benefits these technologies provide to society at large outweigh the costs associated with their implementation, resulting in enhanced heating and

[135] U Reference Scenario 2020 Energy, transport and GHG emissions – Trends to 2050

cooling efficiency across Malta. As elaborated in Part III, the primary driver of these benefits is the increased energy efficiency for heating and cooling purposes, which in turn lowers operational expenses for both households and businesses through reduced energy bills. Additionally, these technologies contribute to a decrease in GHG emissions, which, when valued in economic terms, further amplify the overall benefits.

A significant number of these interventions, such as the shift towards heat pumps and solar systems in place of conventional energy solutions, also support an increase in the use of renewable energy. This shift is particularly crucial for Malta, which, as discussed earlier in the report, faces unique challenges in deploying renewable energy technologies due to its densely populated urban areas and limited space for large-scale installations. Consequently, an integrated approach to renewable energy that is compatible with the existing urban fabric is essential. The proposed measures provide renewable energy solutions that are well-suited to Malta's urban and climatic context. These solutions are designed to integrate into the urban environment and are generally considered low-risk in terms of ecological impact. They are adaptable for use in both single and multi-family dwellings, as well as various business establishments, regardless of size, enhancing their potential for widespread adoption.

4.2 National Considerations

The feasibility of energy-related interventions is influenced by a variety of factors, both economic and social. The cost-effectiveness of these projects is closely tied to the electricity tariff; higher tariffs mean greater potential savings, while lower tariffs can diminish the financial appeal of such initiatives, though it is recognized that this effect is somewhat artificial. The trajectory of CO_2 prices also plays a crucial role in determining the viability of projects, as changes in carbon pricing can significantly impact the economics of reducing emissions.

However, assessing feasibility is not solely a matter of economic calculation; it is essential to consider the wider social implications, and the specific realities of the country. The following are some of the national considerations that must be taken into account when contemplating the introduction of the proposed intervention measures.

- Initially, the comprehensive assessment must consider the impacts on local communities and the need for a just transition that equitably distributes the benefits and burdens of moving towards a low-carbon economy. One needs to consider vulnerable households and other vulnerable groups, and their more pressing priorities. Any policy measures need to be assessed against social impacts to ensure that inequality is not widened, or the required schemes are in place to help vulnerable categories.

- Another consideration relates to the size of these interventions and their potential benefits/ impact. Especially for households, they might be perceived to be too small and not worth the switching costs (financial and non-financial).

- A key consideration relates to the potential benefit in property value of such improvements in buildings. Currently, the market is not pricing in such changes; one key factor is the lack of link between a building's Energy Performance Certificate rating and its selling price, indicating lack of market and end user appreciation/ awareness of the benefits.

- Additionally, as assessed in different emission scenarios in Part III, as the grid becomes increasingly decarbonized, the standalone measures that once seemed advantageous may see a decline in feasibility, as the baseline for carbon emissions lowers and the relative benefits of individual measures diminish. This evolving context underscores the complexity of determining feasibility in a landscape where environmental objectives and regulatory requirements are in constant flux.

- Meanwhile, many of the recommendations made in this assessment rely on electrification as a simultaneous method for efficiency gains and decarbonization. However, it is worth noting that the large-scale electricity-related, distribution and generation infrastructural investments and their associated costs, were not taken into consideration when conducting the CBA for mass electrification. A nationwide shift from LPG technology (currently used for heating and cooking) towards electricity will require an expanded electrical generation system to meet the increased demand. This may translate into higher energy imports through the interconnector, the investment of new generation / transmission capacity, or the mass installation of renewable energy sources. Moreover, the shift towards decarbonisation will necessitate substantial enhancements to the electricity distribution network. This will entail additional major investments for the excavation of trenches, laying of new cables, and the construction of new substations and distribution centres. These upgrades are critical not only to accommodate the increasing electrification of heating and cooling demand but also in light of the government's commitment to decarbonize road transport, as per government targets set out in the LCDS and NECP. This ambitious goal underscores the need of upgrading Malta's energy infrastructure to support a decarbonised future.

- Another key national consideration relates to funding and pricing. As Malta's GDP per capita increases, the opportunities for EU funding are diminishing.

- Another major challenge is Malta's heavy reliance on imported goods, leading to a persistent trade deficit. Trade disruptions in the Red Sea, coupled with increased transport costs due to higher fuel prices following the Ukraine war, have exacerbated this issue. The inclusion of maritime shipping activities in the EU emissions directive as well as the extension of the renewable energy target for transport to also include the maritime sector within its scope, will likely lead to further price increases for transported goods, adding another layer of complexity to the economic environment. Additionally, there is a critical need for a just transition to ensure that vulnerable social groups are protected and that the distribution of rewards, risks, and responsibilities remains equitable.

4.3 Policy Recommendations

While the economic advantages of the proposed interventions are evident, the initial investment costs for some, particularly in the residential sector, may deter individual investors due to the high upfront costs. Without governmental financial assistance, the uptake of these energy-efficient technologies is likely to be minimal. Below is a list of policy recommendations aimed at promoting the adoption of efficient heating and cooling technologies. It is crucial to note that these proposed interventions are merely policy proposals at this stage and are yet to be discussed within Malta's government and officially approved as part of Malta's strategy to meet its heating and cooling objectives. They also need to be framed within Malta's socio-economic realities as described above.

Maintain and extend current incentive measures

Part II of this report highlighted existing policies and measures related to energy efficiency and the decarbonization of heating and cooling, including financial incentives aimed at promoting the installation of solar water heaters and heat pump water heaters in the residential sector, as well as grants and aid for energy efficiency projects targeting businesses.

Part III evaluated the impact of these incentives on the FNPV of the respective interventions. The analysis revealed that these incentives would lead to a positive FNPV, indicating that the design of these measures is adequate to motivate individual investors to adopt these efficient heating and cooling technologies. Therefore, it is recommended to maintain these incentives and consider their extension to additional interventions. For other measures where the FNPV remains negative and lacks specific financial incentives, Part III suggests an indicative level of aid intensity necessary to achieve financial viability.

Despite the availability of incentives, the current adoption rate of these technologies is relatively low, with only about 15,000 households—or approximately 6.4% of Malta's total household stock—equipped with a heat pump/ solar water heater. More efforts should be directed towards educational campaigns to increase awareness of the existing schemes and the financial benefits of adopting such technologies.

Explore centralized technological systems for new developments

Part III indicates that centralized systems typically yield better financial results compared to decentralized alternatives. This advantage arises from the significantly lower initial investment required per household when implementing a centralized system, which leads to more favourable financial outcomes for each household due to the economies of scale associated with centralization.

Despite the clear economic benefits of implementing centralized heating and cooling systems for multi-unit dwellings, the current lack of legislative framework on the matter presents a significant challenge for mass uptake in the future. With very few exceptions, almost all of Malta's current and future-planned multi-unit apartment blocks operate on a decentralized model, whereby each household manages its own heating and cooling systems independently. Malta's mild climate and lower need for space heating have historically negated the necessity for a centralized heating district network, which is the norm in urban areas in northern/central Europe. Standalone gas or electric heaters, rather than central systems, have been the norm for heating. Similarly, water heating in Malta is predominantly powered by electricity, not by centralized services. Since retrofitting existing buildings to accommodate a centralized system is not economically feasible, a cultural shift that is driven by legislative pressure is likely necessary to stimulate uptake of centralised heating and cooling alternatives.

The recently updated Technical Guide F[136], which will come into force in July 2024, mandates the integration of renewable energy sources such as heat pumps or solar water heating systems, alongside additional requirements for the incorporation of solar photovoltaic systems. This represents a pivotal move towards centralized heating and cooling solutions. However, to ensure a comprehensive and effective transition, new national legislation will be imperative. Such legislation should encompass the standardization of building designs to facilitate uniformity and ease of system integration, the establishment of penalties to enforce compliance, and the implementation of rigorous metering and monitoring protocols to ensure system efficiency and reliability. Additionally, it should address the development of fair billing practices that equitably distribute costs among different units, thereby safeguarding consumer interests and promoting widespread acceptance of these centralized systems.

Consider alternative financial instruments in the face of a shifting economic landscape

Most of the proposed services sector intervention measures return a positive FNPV, indicating that these investments are financially viable without the need for government subsidies to encourage adoption of such technologies. However, the substantial initial capital expenditure required may deter private operators from making these investments. In cases where the intervention involves replacing outdated technology with more efficient alternatives sooner than the end of their useful life, the upfront investment is considerable and will only be recovered over time once the operational savings kick in. Without incentives to promote this shift towards cleaner and more efficient technologies, the transition may be delayed until the existing technology reaches the end of its life. Therefore, it is recommended for the government to explore funding assistance to support this transition – this can range from direct grants to other blended financial instruments, including loan guarantees leading to better-priced lending.

Recognizing these challenges, Malta has already begun to tap into various funding sources to facilitate energy efficiency improvements. Existing heating and cooling efficiency initiatives are currently being supported through a combination of sources. These include the national budget, the European Union's Recovery and Resilience Facility (RRF), and other EU funds

[136] Building & Construction Authority (BCA). Guidance Documents - Technical Guide F. https://bca.org.mt/guidance-documents/

primarily focused on providing grants. In addition, select banks are leveraging funds from the EIB to offer loan guarantees, enabling them to create lending products for specific investments (such as the retrofitting of buildings), at lower interest rates and reduced collateral requirements. The Malta Development Bank (MDB) is playing a significant role in these loan guarantee and lending schemes. Furthermore, the private sector is making contributions by investing in projects that yield a return on investment, such as renovations that increase rental income or the adoption of energy-efficient technologies that reduce operational costs. A notable development in sustainable financing is the issuance of a green bond by a subsidiary of the Water Services Corporation, with proceeds earmarked to fund sustainability projects.

The intervention measures proposed in this assessment will require a substantial financial commitment. While the government is set to introduce policies and allocate funding towards this end, more resources are required to deliver successful outcomes. Additional funding will need to be sourced from the EU, and private sector investment will be crucial to bridge the financial gap. These additional sources of investment are necessary within the context of significant market and sector shifts. Firstly, government funding is being constrained due to recent measures taken to mitigate the impacts of the pandemic and high inflation, which may necessitate greater fiscal consolidation within the EU. Secondly, the government must prioritize meeting the demands of a growing population, which includes enhancing social services and developing infrastructure, particularly in energy generation and distribution. Thirdly, the current high-interest rate scenario is leading to a higher cost of capital, further complicating the financial landscape.

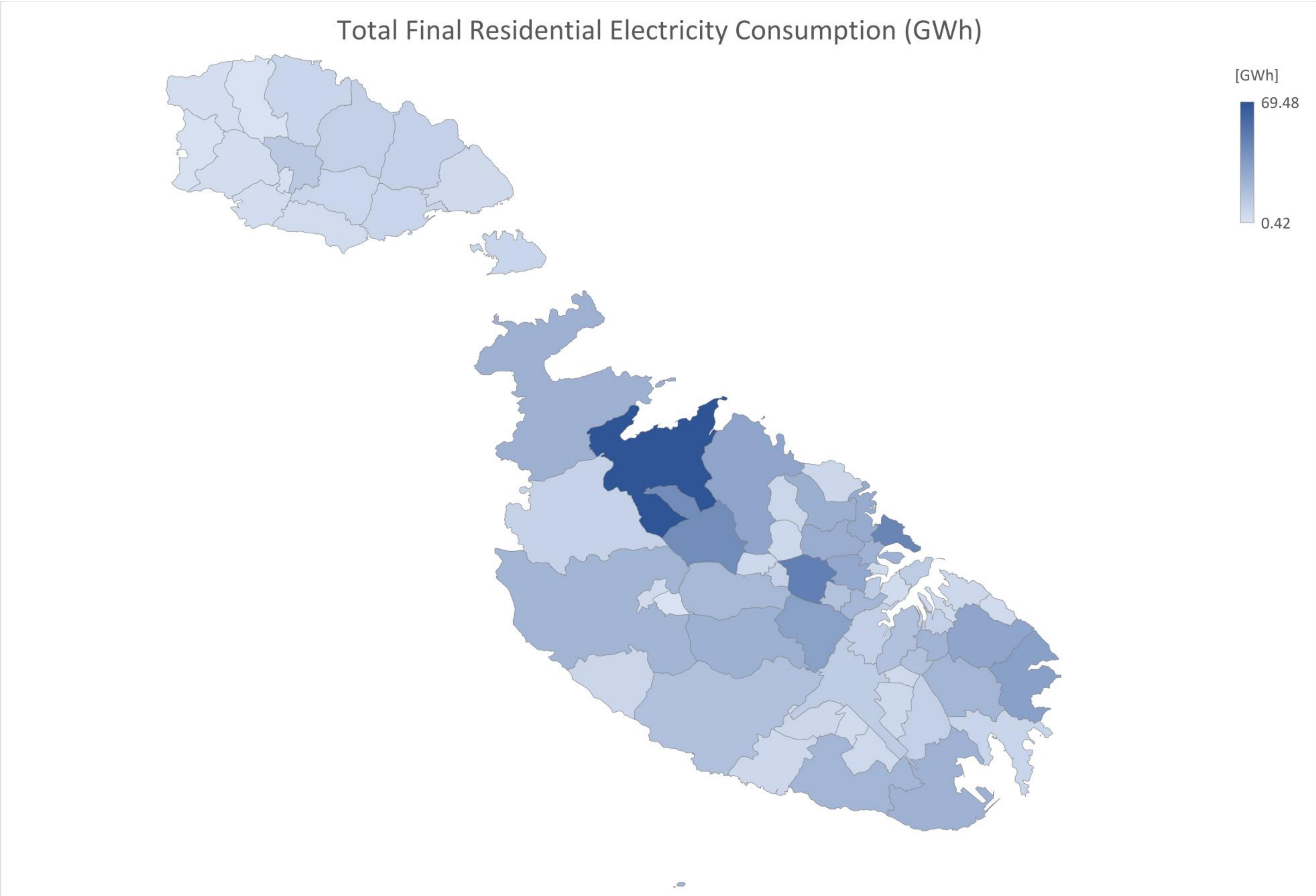
A strategic mix of funding sources is thus envisaged for the successful adoption of these intervention measures. This will include sustained commitments from the national budget in the form of grants, the utilization of existing and forthcoming EU funding, blending of funding sources, and the enhancement of bank lending through loan guarantees to achieve higher leverage ratios. The MDB is expected to take on a more prominent role, while government policies should aim to attract further private sector investment, potentially through incentives like tax credits. Additionally, there is an interest in exploring the use of capital markets, such as the issuance of green bonds by both public and private sector entities, to support environmentally sustainable initiatives.

Overcome data gaps to allow for better decision making in the future

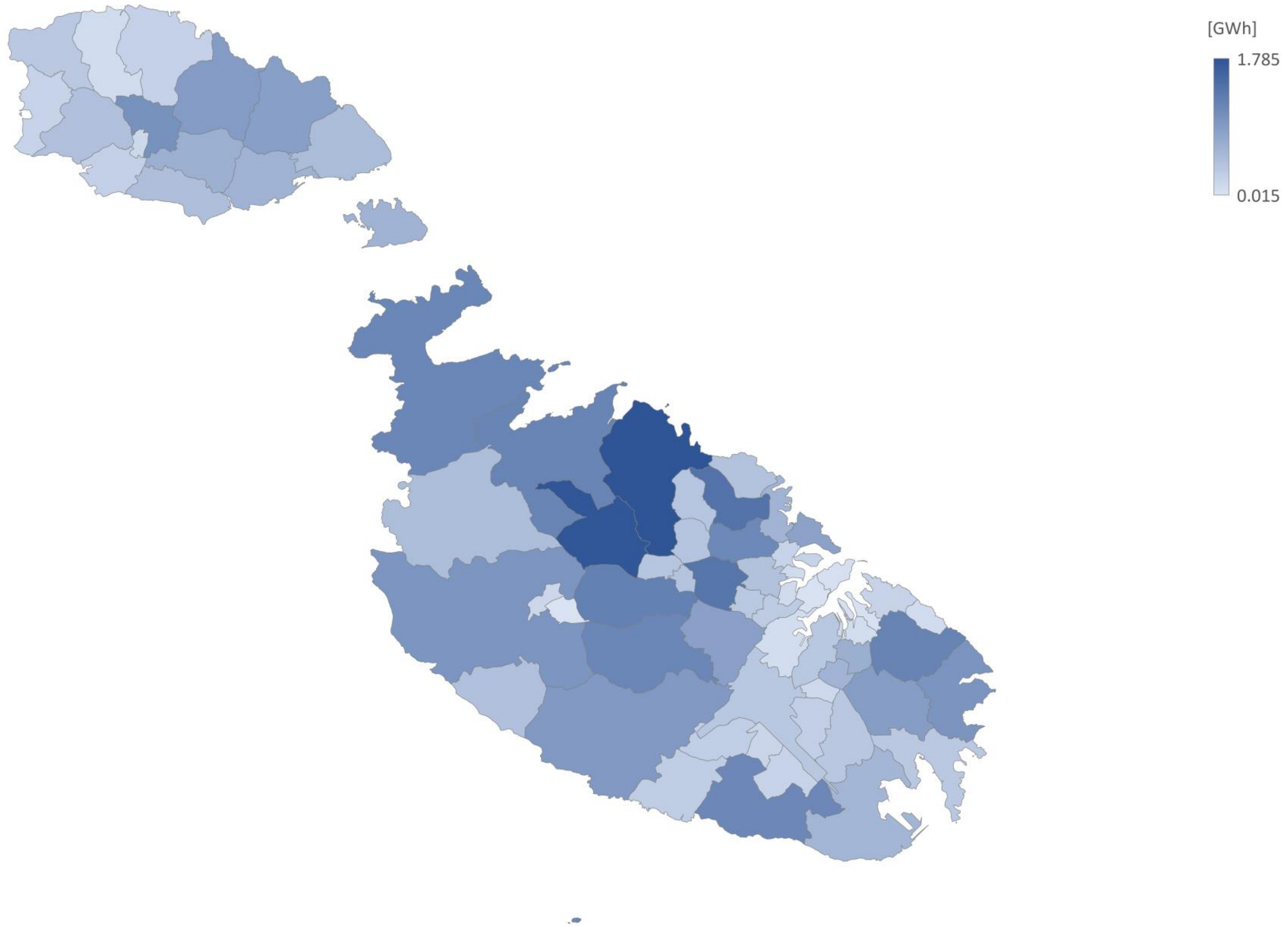
This assessment had to contend with significant data challenges, both in terms of missing data (i.e., information that had not been collected), and inaccessible data (i.e., information that had been collected, but was not available for use during the assessment). Notably, information on existing technology use across the different economic sectors was absent, such as the number of hotels employing water-cooled versus air-cooled chillers, the prevalence of low-efficiency boilers compared to high-efficiency condensing boilers in different establishments, and the extent to which they use outdated, low-efficiency air-to-air heat pumps as opposed to modern, high-efficiency models. Furthermore, the absence of comprehensive data on commercial buildings, such as the total number of shops and offices, including aggregate area of retail/office space, posed another significant obstacle. While proxies and approximations were used to perform the necessary calculations in this assessment, the availability of more precise data in future would substantially enhance the accuracy and usefulness of the results, thus allowing for more informed decision-making going forward.

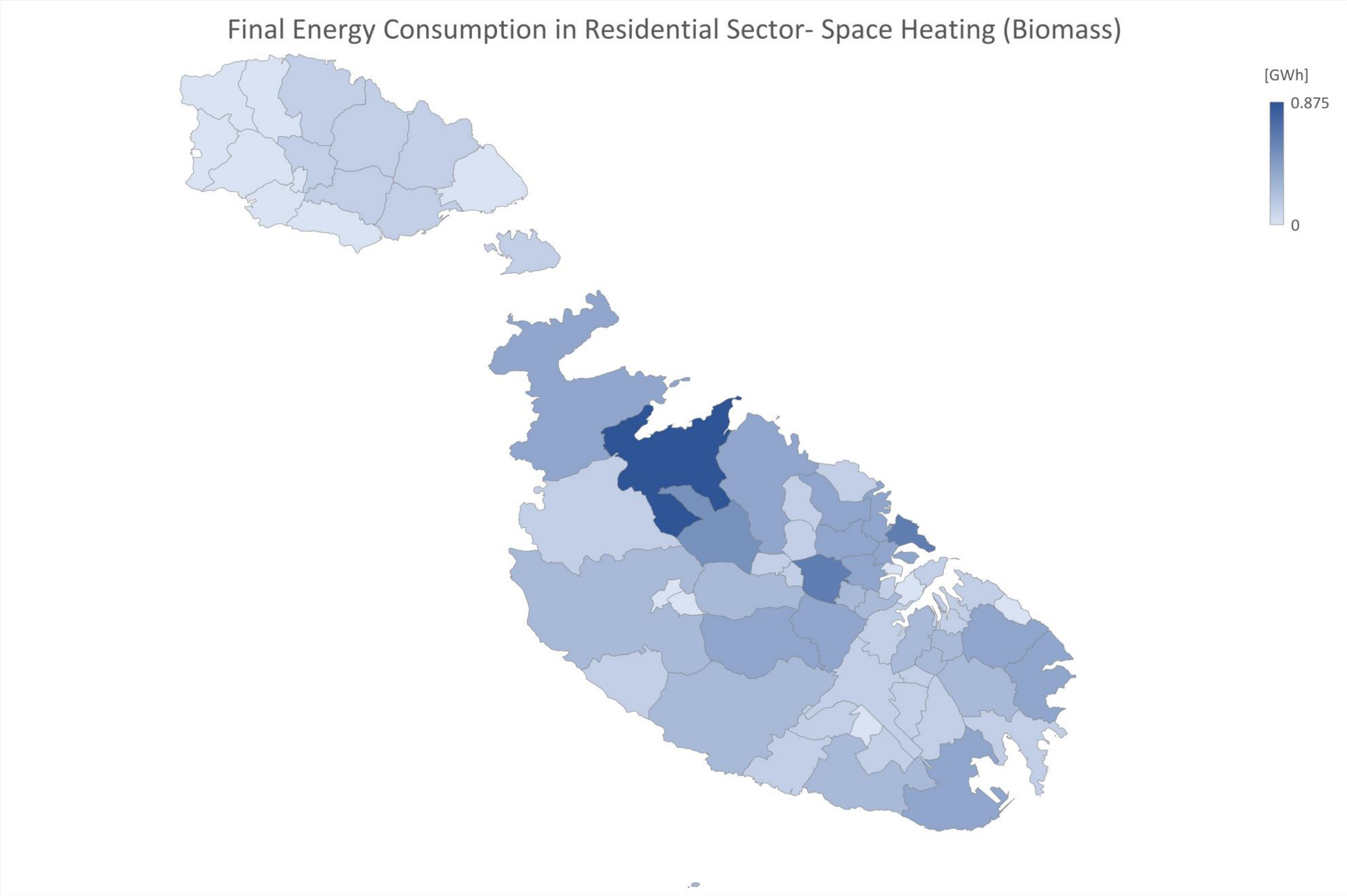
Annex I

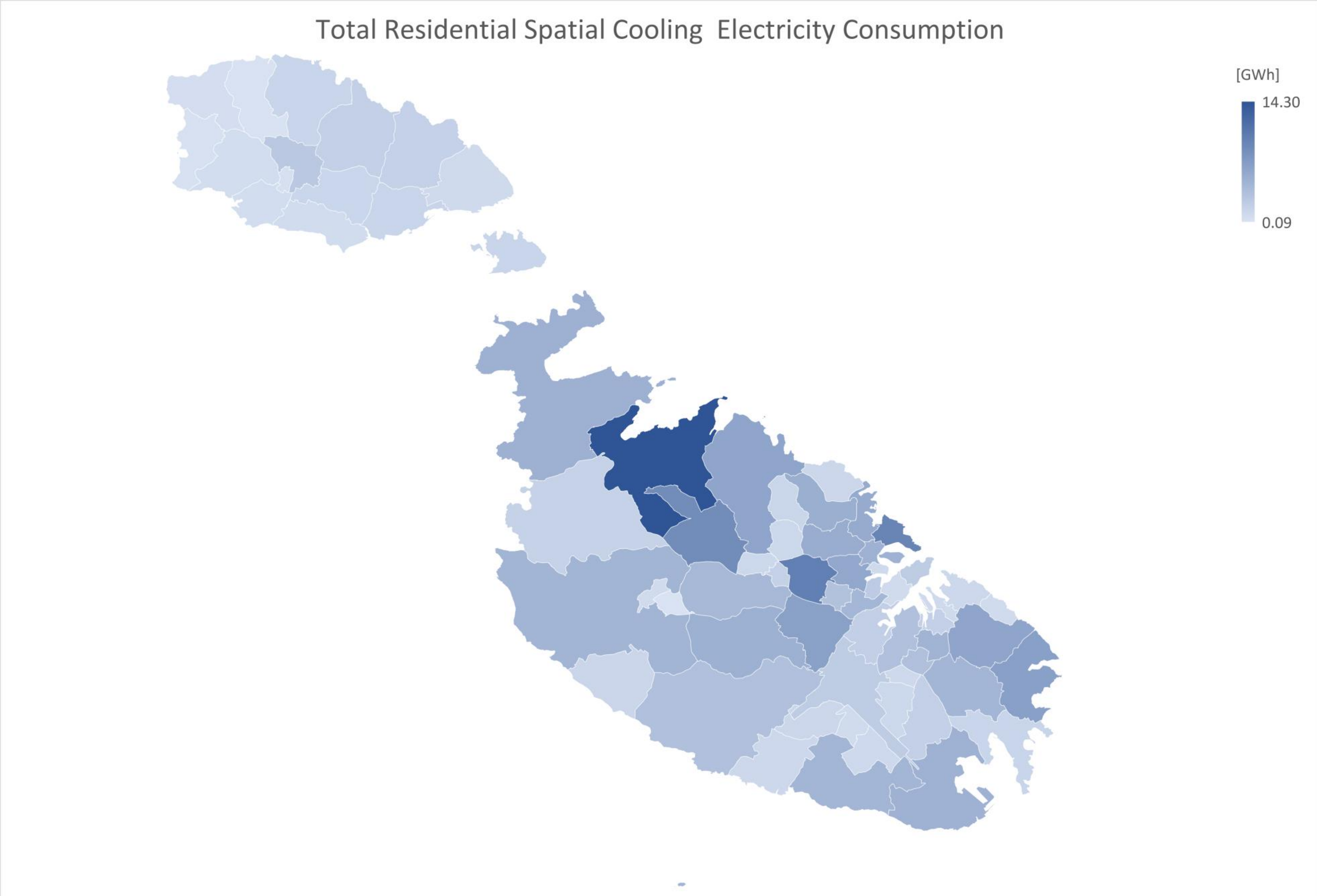
Mapping for Heating and Cooling consumption for the Maltese Islands


Total Final Residential Electricity Consumption (GWh)
[GWh]
69.48
0.42

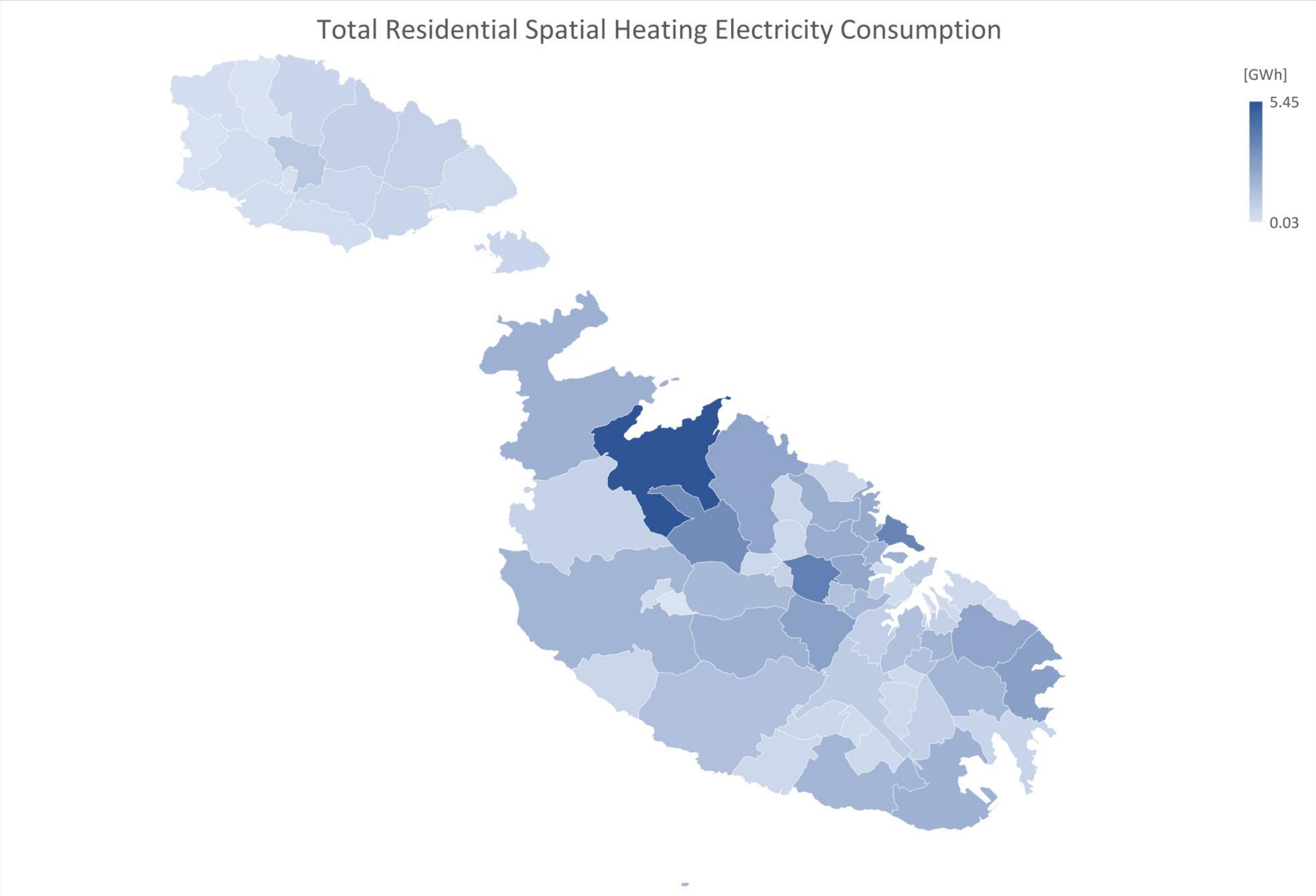
Final Energy Consumption in Residential Sector - Solar Thermal Water Heating

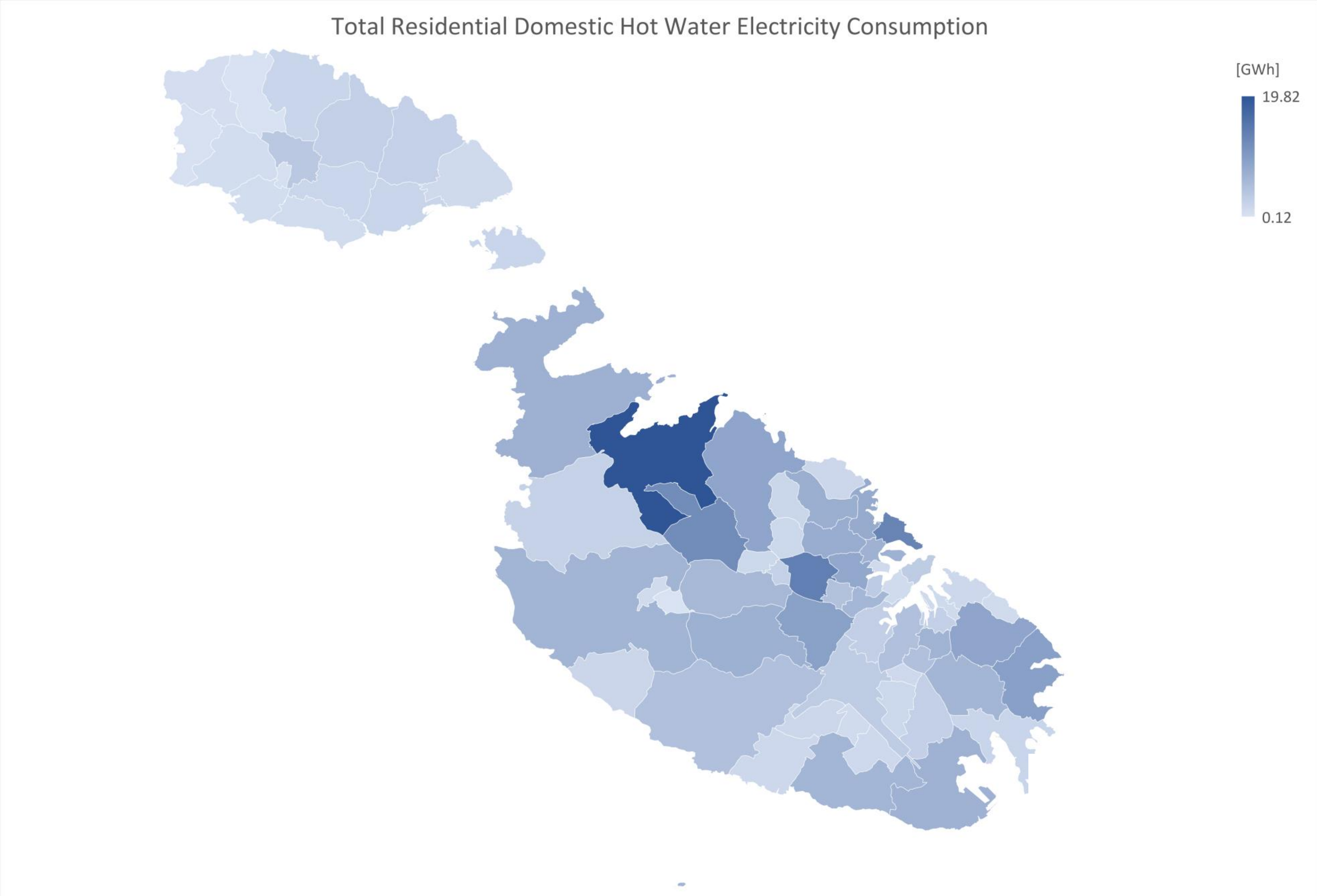


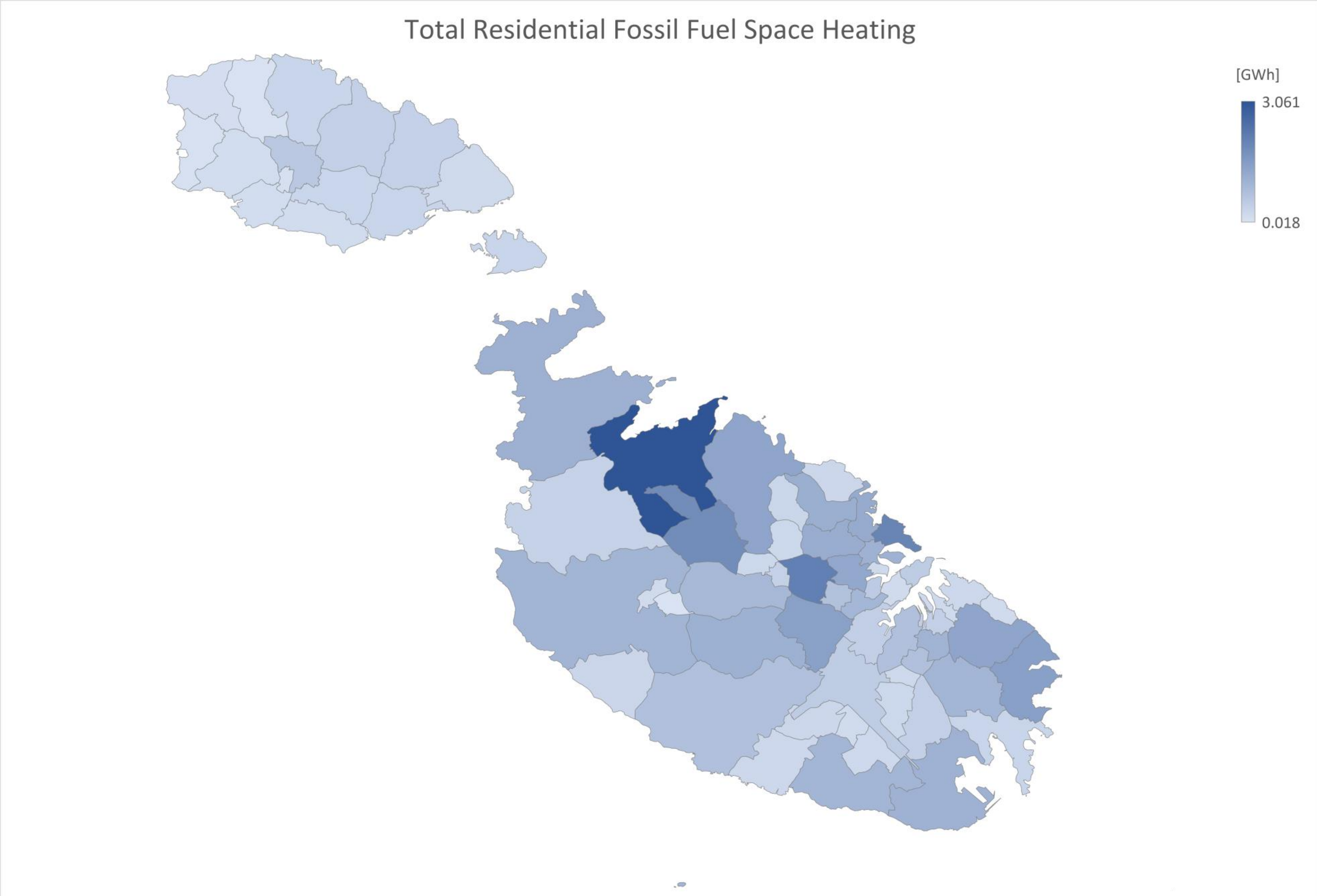

Final Energy Consumption in Residential Sector- Space Heating (Biomass)
[GWh]
0.875
0

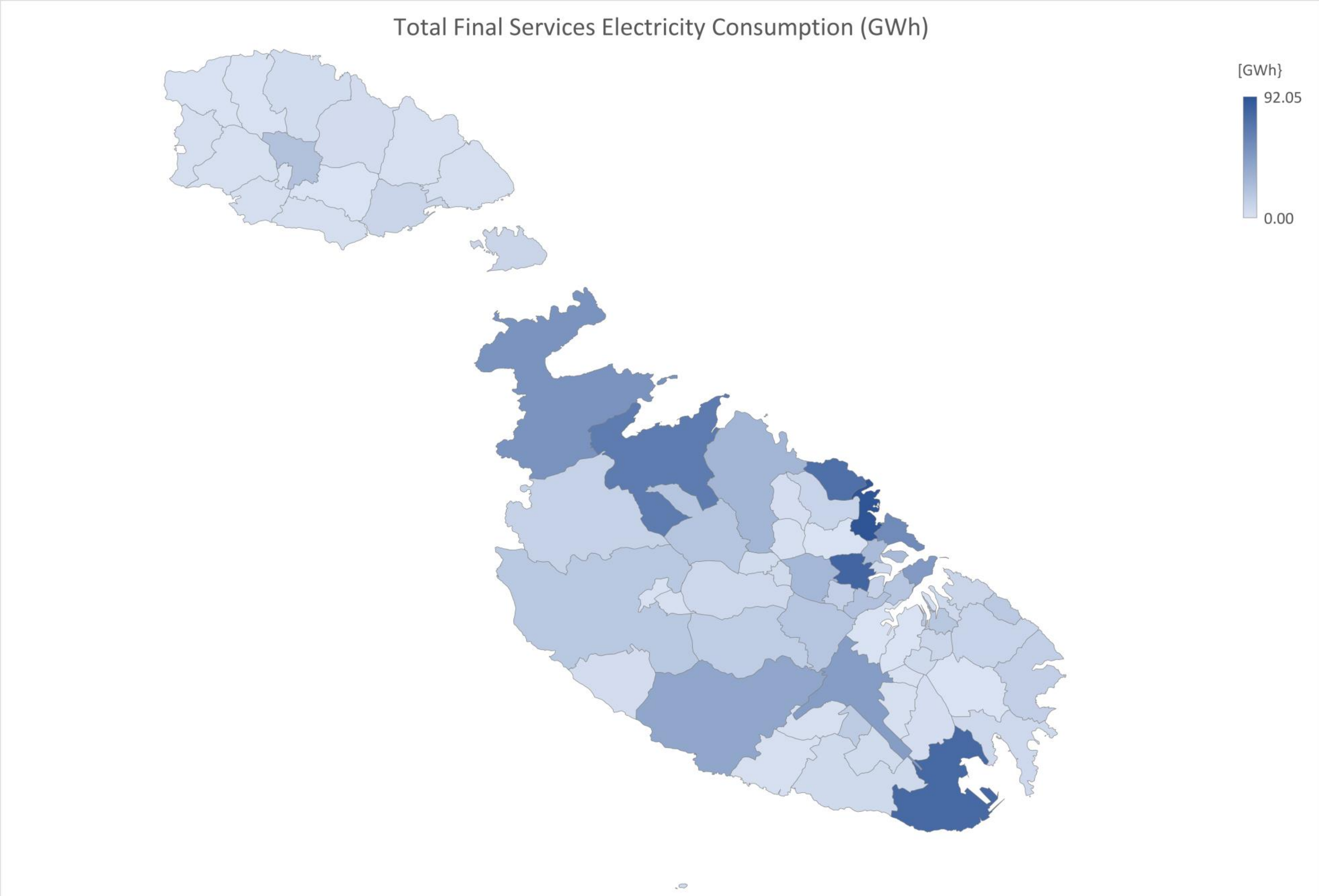


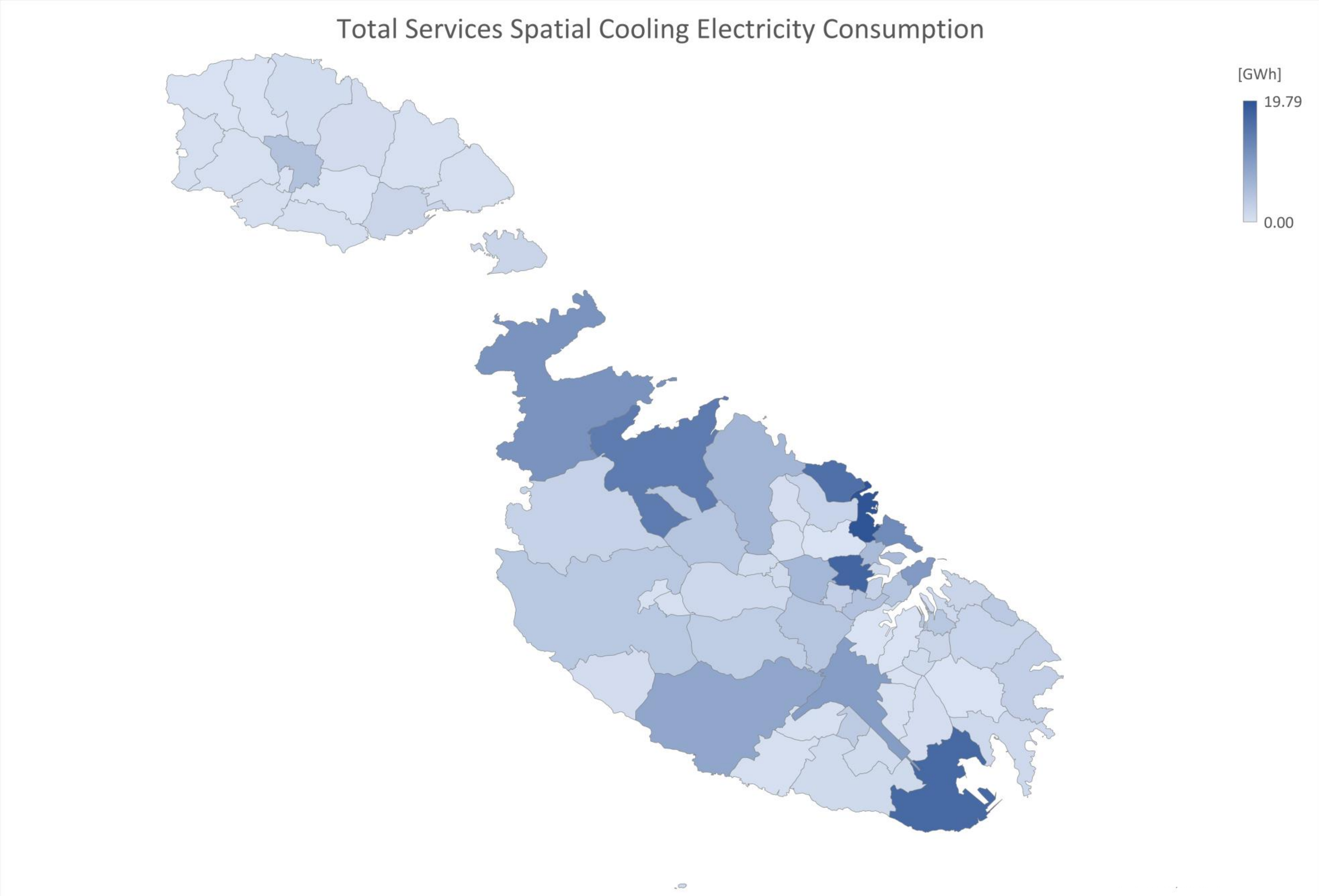
Total Residential Spatial Cooling Electricity Consumption
[GWh]
14.30
0.09

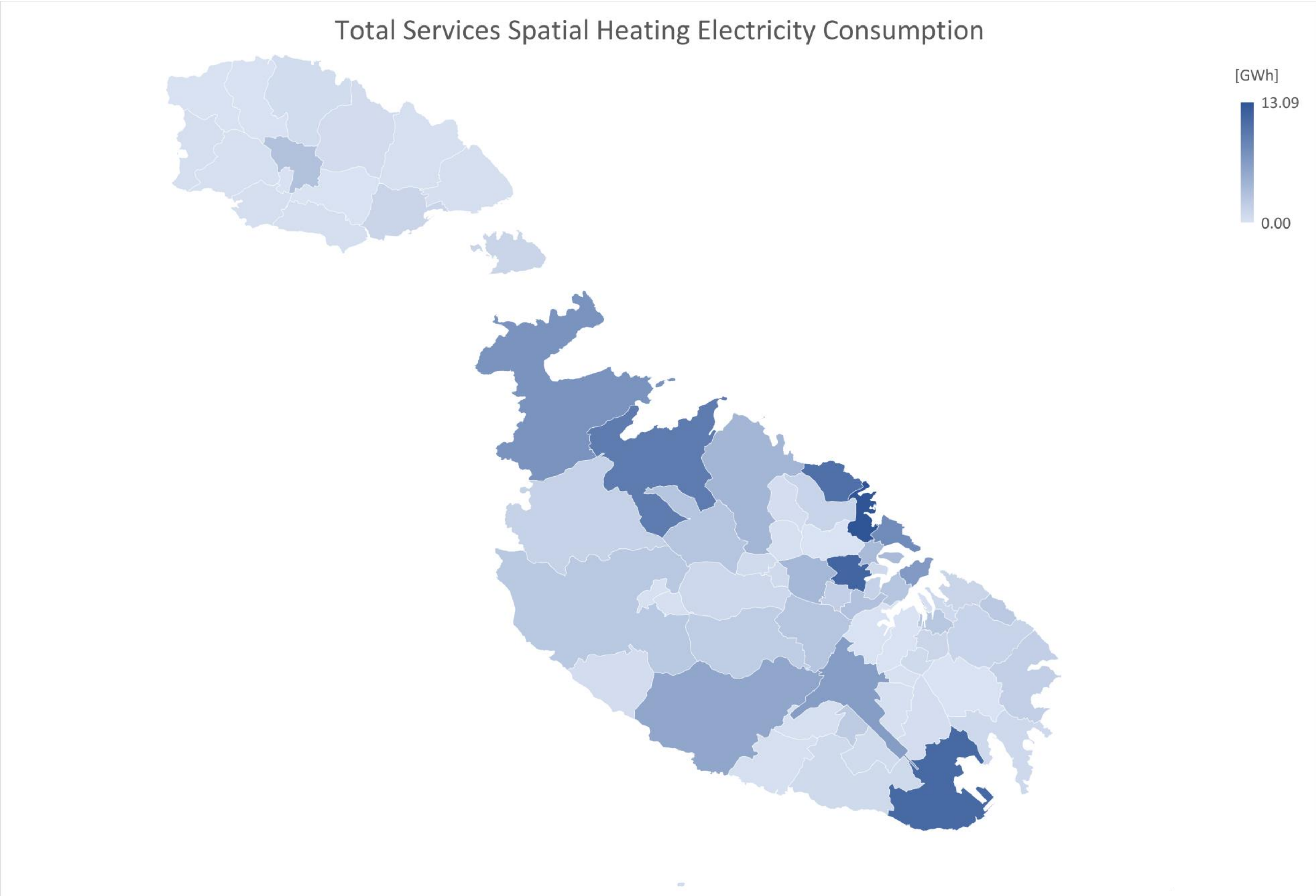

Total Residential Spatial Heating Electricity Consumption
[GWh]
5.45
0.03


Total Residential Domestic Hot Water Electricity Consumption
[GWh]
19.82
0.12

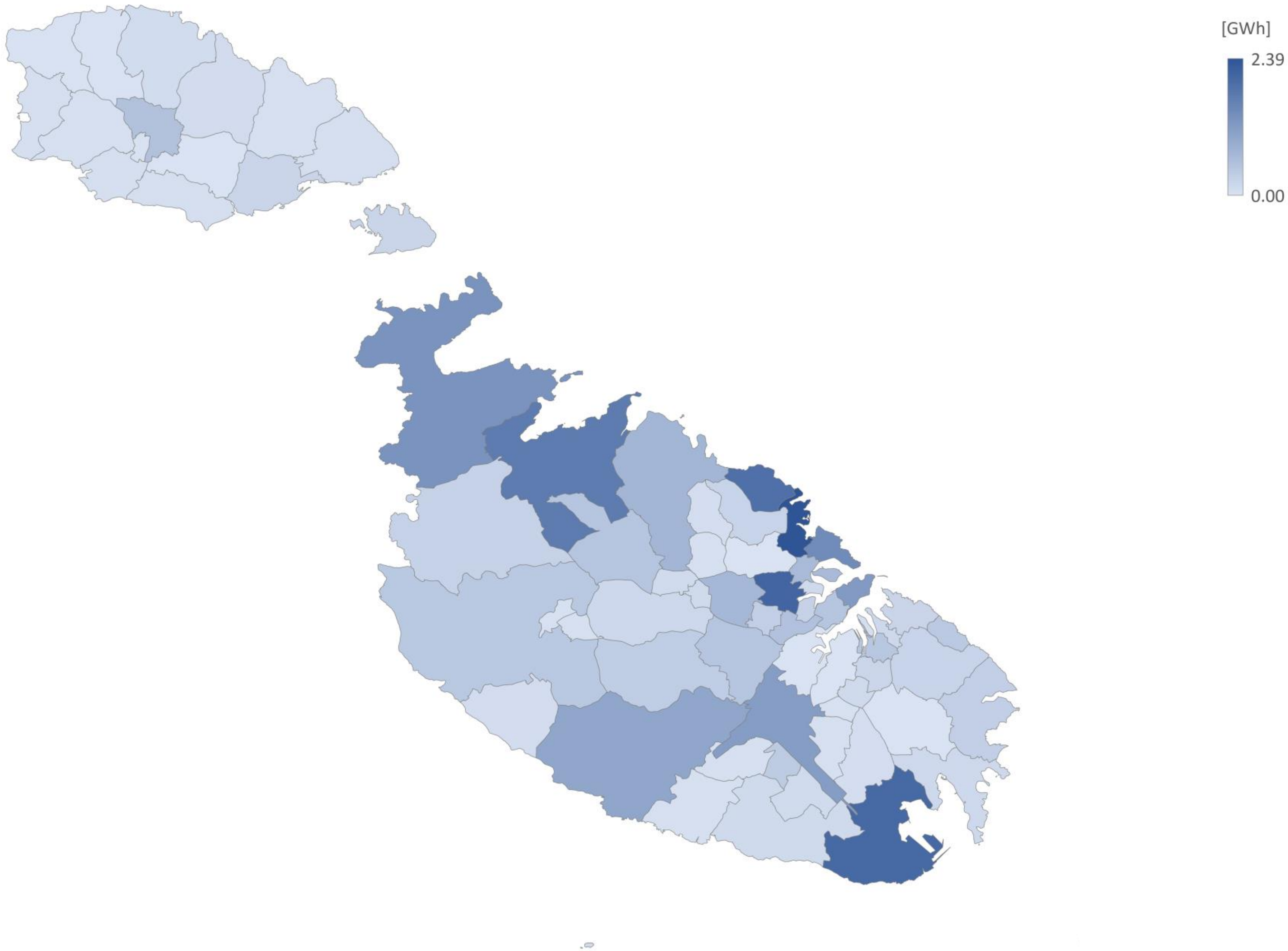

Total Residential Fossil Fuel Space Heating
[GWh]
3.061
0.018


Total Final Services Electricity Consumption (GWh)
[GWh}
92.05
0.00

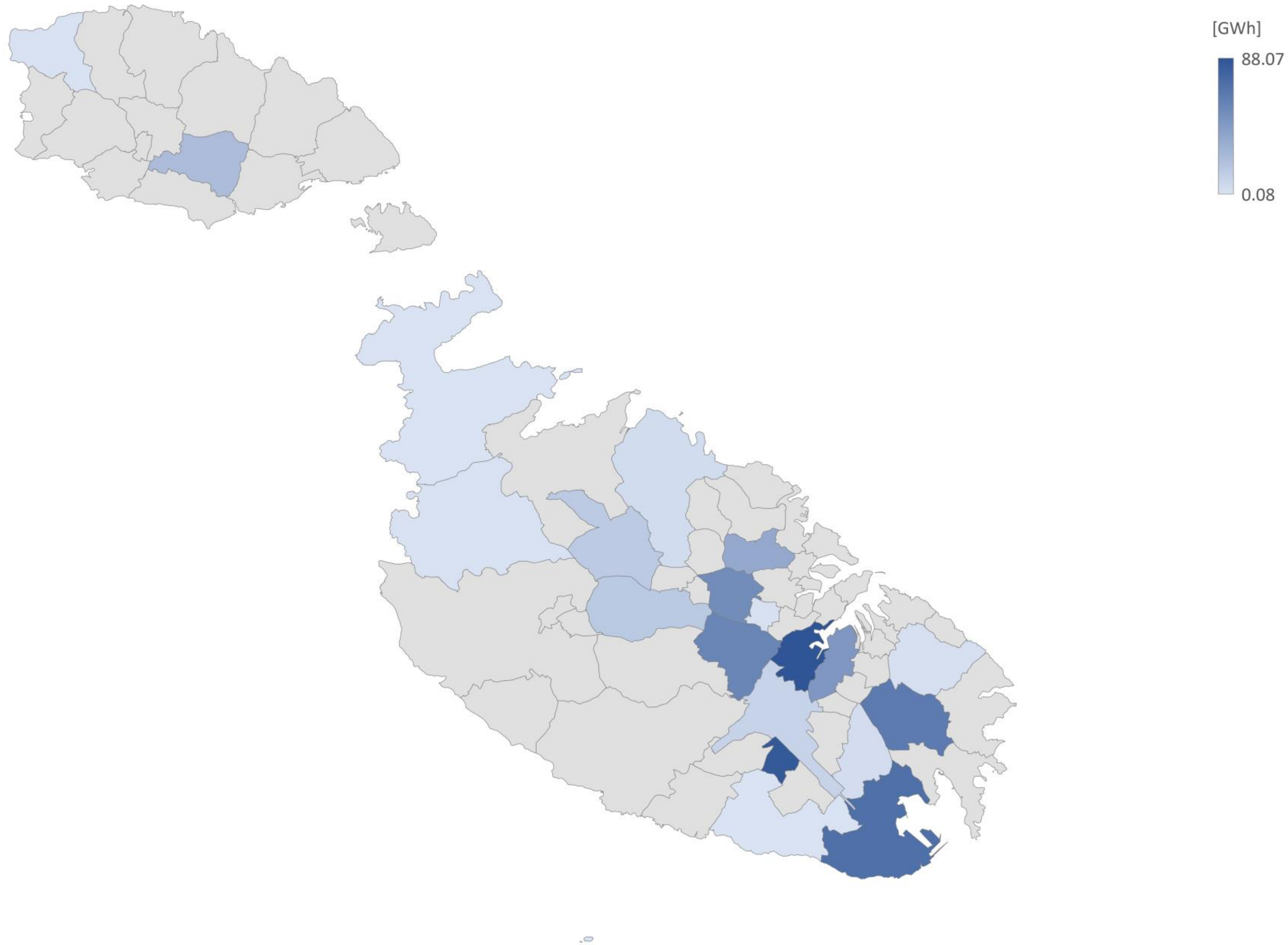

Total Services Spatial Cooling Electricity Consumption
[GWh]
19.79
0.00


Total Services Spatial Heating Electricity Consumption
[GWh]
13.09
0.00

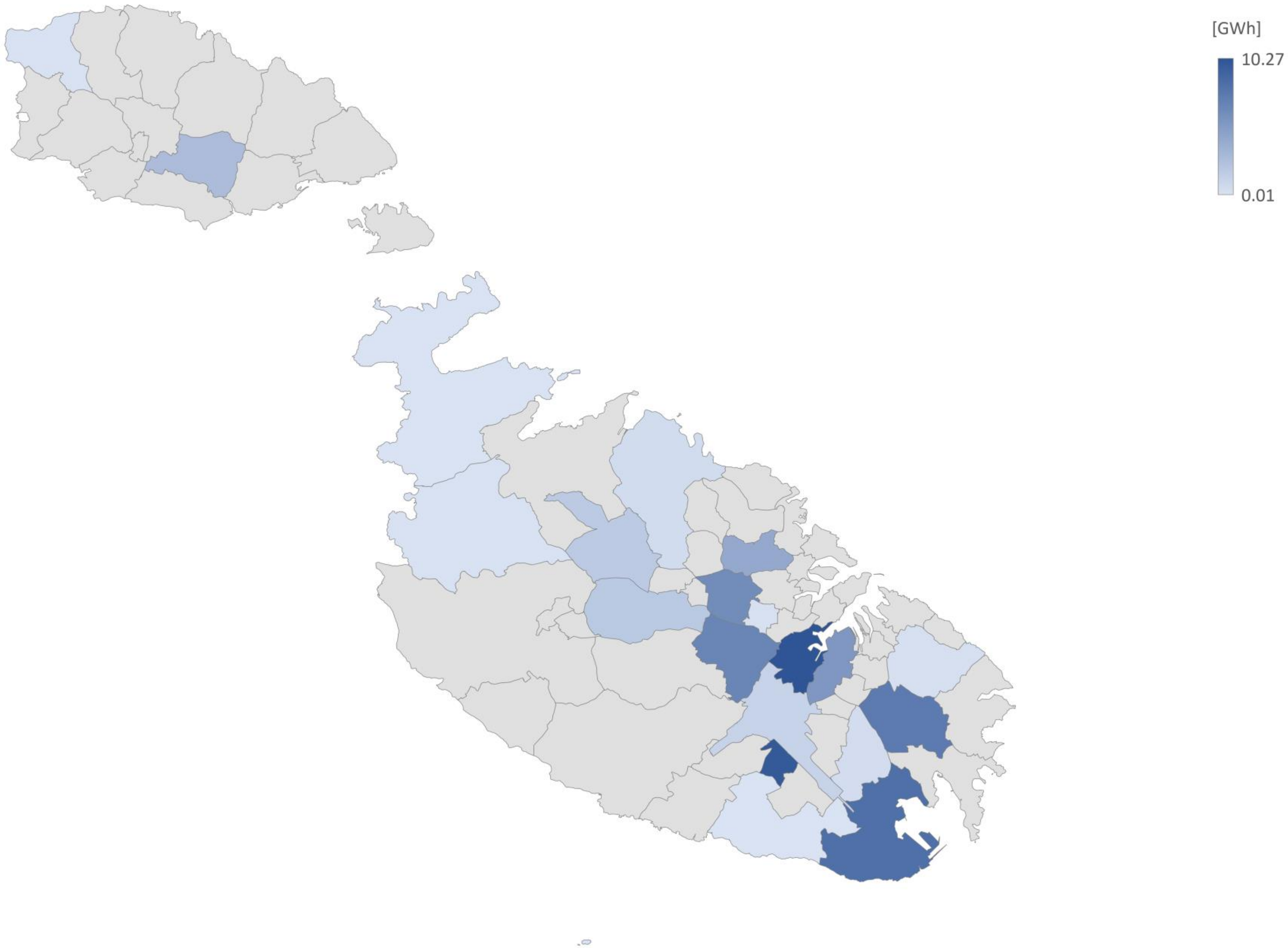
Total Services Domestic Hot Water Electricity Consumption



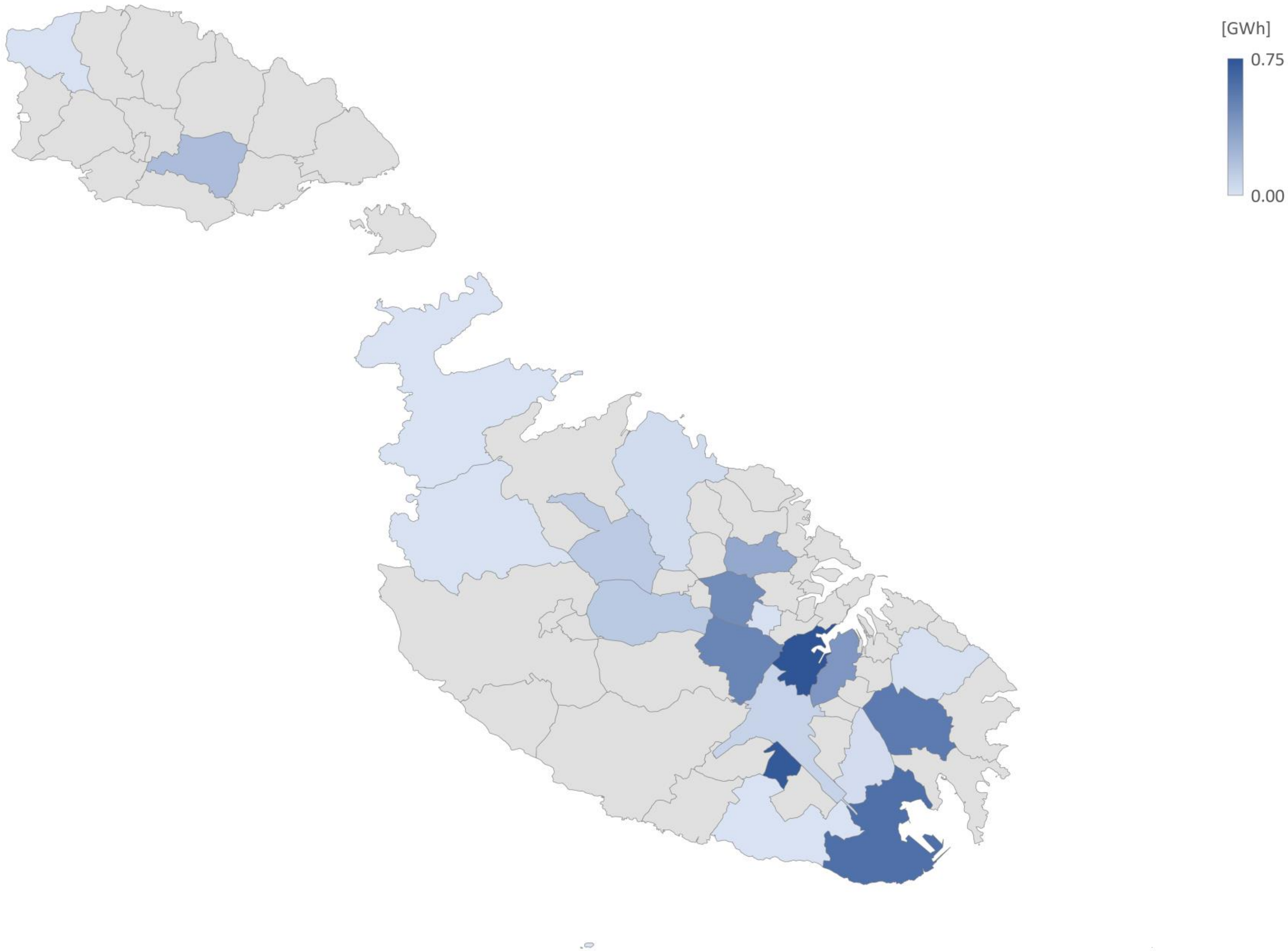
Total Final Electricity Consumption - Industry Sector



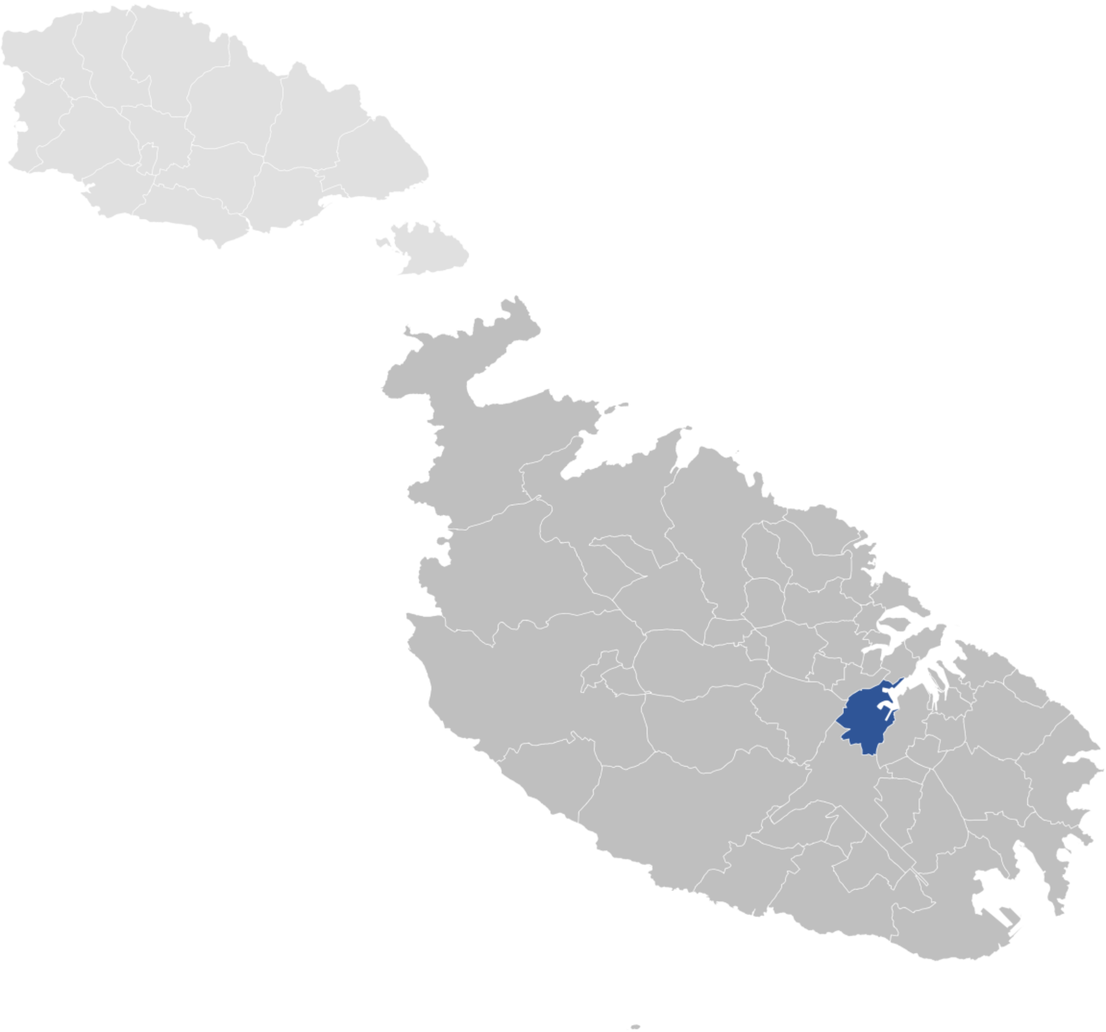
Final Electricity Consumption - Space Cooling - Industry Sector



Final Electricity Consumption - Space Heating - Industry Sector



Existing Heating and Cooling Supply Points Incinerator and Autoclave Plant



Planned Waste to Energy Plant

Annex II

Forecast for Heating and Cooling demand between 2023-2053

Residential Sector

Year	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
Residential Final Electricity Consumption	**1,011**	**1,036**	**1,061**	**1,095**	**1,128**	**1,158**	**1,185**	**1,210**	**1,235**	**1,261**	**1,281**
Spatial Cooling	207.98	213.28	218.43	225.36	232.06	238.30	243.92	249.12	254.27	259.58	263.72
Spatial Heating	79.29	81.31	83.27	85.91	88.47	90.85	92.99	94.97	96.94	98.96	100.54
Water Heating	288.20	295.55	302.69	312.28	321.58	330.22	338.00	345.22	352.36	359.71	365.45

Year	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**
Residential (Fuel, mainly LPG)	146.3	146.3	146.2	147.0	147.5	147.9	147.9	147.7	147.5	147.1	146.3
Solar Water Heating (SWH)	26.1	22.9	19.5	16.5	14.2	12.8	12.0	11.5	11.1	10.9	10.9
Biomass (GWh)	19.9	20.8	21.8	22.7	23.7	24.6	25.6	26.5	27.5	28.5	29.4

Year	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**
Residential Final Electricity Consumption	**1,301**	**1,319**	**1,338**	**1,357**	**1,377**	**1,394**	**1,410**	**1,427**	**1,443**	**1,460**
Spatial Cooling	267.68	271.51	275.43	279.29	283.40	286.93	290.28	293.63	297.02	300.44
Spatial Heating	102.05	103.51	105.00	106.48	108.04	109.39	110.66	111.94	113.23	114.54
Water Heating	370.93	376.24	381.67	387.03	392.72	397.61	402.25	406.90	411.59	416.34

Year	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**
Residential (Fuel, mainly LPG)	145.38	144.42	143.39	142.27	141.06	139.78	138.44	137.09	135.76	134.44
Solar Water Heating (SWH)	10.9	10.8	10.6	10.2	9.7	9.2	8.7	8.3	7.9	7.5
Biomass (GWh)	30.4	31.3	32.3	33.2	34.2	35.1	36.1	37.0	38.0	38.9

Year	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053
Residential Total Final Electricity Consumption	**1,477**	**1,494**	**1,511**	**1,528**	**1,546**	**1,564**	**1,582**	**1,600**	**1,619**	**1,637**
Spatial Cooling	303.91	307.42	310.96	314.55	318.18	321.85	325.56	329.32	333.12	336.96
Spatial Heating	115.86	117.20	118.55	119.92	121.30	122.70	124.12	125.55	127.00	128.46
Water Heating	421.14	426.00	430.91	435.89	440.92	446.00	451.15	456.35	461.62	466.94

Sector	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053
Residential (Fuel, mainly LPG)	133.1	131.8	130.6	129.3	128.0	126.8	125.6	124.3	123.1	121.9
Solar Water Heating (SWH)	7.1	6.7	6.3	6.0	5.7	5.4	5.1	4.9	4.6	4.4
Biomass (GWh)	39.8	40.7	41.6	42.4	43.3	44.1	45.0	45.8	46.6	47.4

Services Sector

Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Services Total Final Electricity Consumption	**1,210.2**	**1,215.9**	**1,236.8**	**1,257.5**	**1,282.7**	**1,301.2**	**1,321.8**	**1,340.4**	**1,350.8**	**1,358.0**	**1,364.3**
Spatial cooling	291.63	293.01	298.04	303.04	309.10	313.57	318.53	323.01	325.51	327.25	328.77
Spatial heating	192.95	193.86	197.18	200.49	204.50	207.46	210.74	213.71	215.36	216.51	217.51
Water Heating	35.22	35.39	36.00	36.60	37.33	37.87	38.47	39.01	39.31	39.52	39.71

Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Services Total Fuel Consumption	**301.29**	**305.99**	**312.14**	**314.70**	**331.52**	**316.90**	**323.21**	**328.10**	**333.15**	**338.53**	**343.95**
Spatial cooling	0.56	0.57	0.58	0.59	0.62	0.59	0.60	0.61	0.62	0.63	0.64
Spatial heating	28.51	28.95	29.54	29.78	31.37	29.99	30.58	31.05	31.52	32.03	32.55
Water Heating	57.90	58.80	59.98	60.48	63.71	60.90	62.11	63.05	64.02	65.06	66.10

Year	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Services Total Final Electricity Consumption	**1,369.0**	**1,374.1**	**1,379.4**	**1,384.4**	**1,389.3**	**1,394.0**	**1,398.6**	**1,403.3**	**1,407.9**	**1,412.6**
Spatial cooling	329.91	331.13	332.40	333.61	334.78	335.92	337.04	338.16	339.28	340.41
Spatial heating	218.27	219.08	219.92	220.72	221.49	222.24	222.99	223.73	224.47	225.22
Water Heating	39.85	39.99	40.15	40.29	40.43	40.57	40.71	40.84	40.98	41.11

Year	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Services Total Fuel Consumption	**349.39**	**354.96**	**360.65**	**366.44**	**372.34**	**378.36**	**384.52**	**390.67**	**396.92**	**403.28**
Spatial cooling	0.65	0.66	0.67	0.68	0.69	0.70	0.71	0.73	0.74	0.75
Spatial heating	33.06	33.59	34.13	34.67	35.23	35.80	36.38	36.97	37.56	38.16
Water Heating	67.14	68.21	69.31	70.42	71.55	72.71	73.89	75.08	76.28	77.50

Year	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053
Services Total Final Electricity Consumption	**1,417.31**	**1,422.03**	**1,426.76**	**1,431.51**	**1,436.27**	**1,441.05**	**1,445.84**	**1,450.65**	**1,455.48**	**1,460.32**
Spatial cooling	341.55	342.68	343.82	344.97	346.11	347.27	348.42	349.58	350.74	351.91
Spatial heating	225.97	226.72	227.47	228.23	228.99	229.75	230.52	231.28	232.05	232.83
Water Heating	41.25	41.39	41.53	41.66	41.80	41.94	42.08	42.22	42.36	42.50

Year	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053
Services Total Fuel Consumption	**409.73**	**416.29**	**422.95**	**429.72**	**436.60**	**443.59**	**450.69**	**457.90**	**465.23**	**472.68**
Spatial cooling	0.76	0.77	0.79	0.80	0.81	0.82	0.84	0.85	0.86	0.88
Spatial heating	38.77	39.39	40.02	40.66	41.31	41.97	42.65	43.33	44.02	44.73
Water Heating	78.74	80.00	81.28	82.58	83.90	85.24	86.61	88.00	89.40	90.84

Industry Sector

Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Industry Total Final Electricity Consumption	**511.3**	**514.9**	**524.0**	**536.3**	**545.9**	**557.1**	**565.7**	**574.3**	**581.1**	**590.0**	**600.9**
Spatial cooling	59.63	60.04	61.11	62.54	63.66	64.97	65.97	66.97	67.77	68.81	70.07
Spatial heating	4.35	4.38	4.46	4.57	4.65	4.74	4.82	4.89	4.95	5.02	5.12
Water Heating	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Year	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Industry Total Fuel Consumption	**380.3**	**384.1**	**395.7**	**405.1**	**414.6**	**423.7**	**431.1**	**438.6**	**445.0**	**452.9**	**462.7**
Spatial cooling	0.36	0.37	0.38	0.39	0.40	0.40	0.41	0.42	0.43	0.43	0.44
Spatial heating	1.51	1.52	1.57	1.60	1.64	1.68	1.71	1.74	1.76	1.79	1.83
Water Heating	4.75	4.80	4.94	5.06	5.18	5.29	5.39	5.48	5.56	5.66	5.78

Year	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Industry Total Final Electricity Consumption	**607.1**	**614.4**	**623.3**	**632.4**	**642.0**	**651.9**	**662.2**	**672.5**	**682.9**	**693.5**
Spatial cooling	70.80	71.66	72.68	73.75	74.86	76.02	77.22	78.42	79.64	80.88
Spatial heating	5.17	5.23	5.31	5.38	5.47	5.55	5.64	5.73	5.81	5.90
Water Heating	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Year	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**	**2042**	**2043**
Industry Total Fuel Consumption	**468.2**	**474.6**	**482.2**	**490.0**	**497.9**	**506.1**	**514.4**	**522.8**	**531.2**	**539.8**
Spatial cooling	0.45	0.45	0.46	0.47	0.48	0.48	0.49	0.50	0.51	0.52
Spatial heating	1.85	1.88	1.91	1.94	1.97	2.00	2.04	2.07	2.10	2.14
Water Heating	5.85	5.93	6.02	6.12	6.22	6.32	6.43	6.53	6.64	6.74

Year	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**	**2051**	**2052**	**2053**
Industry Total Final Electricity Consumption	**704.3**	**715.3**	**726.4**	**737.7**	**749.2**	**760.8**	**772.7**	**784.7**	**796.9**	**809.3**
Spatial cooling	82.14	83.41	84.71	86.03	87.37	88.73	90.10	91.51	92.93	94.37
Spatial heating	6.00	6.09	6.18	6.28	6.38	6.48	6.58	6.68	6.78	6.89
Water Heating	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Year	**2044**	**2045**	**2046**	**2047**	**2048**	**2049**	**2050**	**2051**	**2052**	**2053**
Industry Total Fuel Consumption	**548.6**	**557.5**	**566.5**	**575.7**	**585.0**	**594.5**	**604.1**	**613.9**	**623.8**	**633.9**
Spatial cooling	0.52	0.53	0.54	0.55	0.56	0.57	0.58	0.59	0.60	0.61
Spatial heating	2.17	2.21	2.24	2.28	2.32	2.35	2.39	2.43	2.47	2.51
Water Heating	6.85	6.96	7.08	7.19	7.31	7.43	7.55	7.67	7.79	7.92