Guernsey Electricity Limited

HEATING CARBON INTENSITY STUDY 2023

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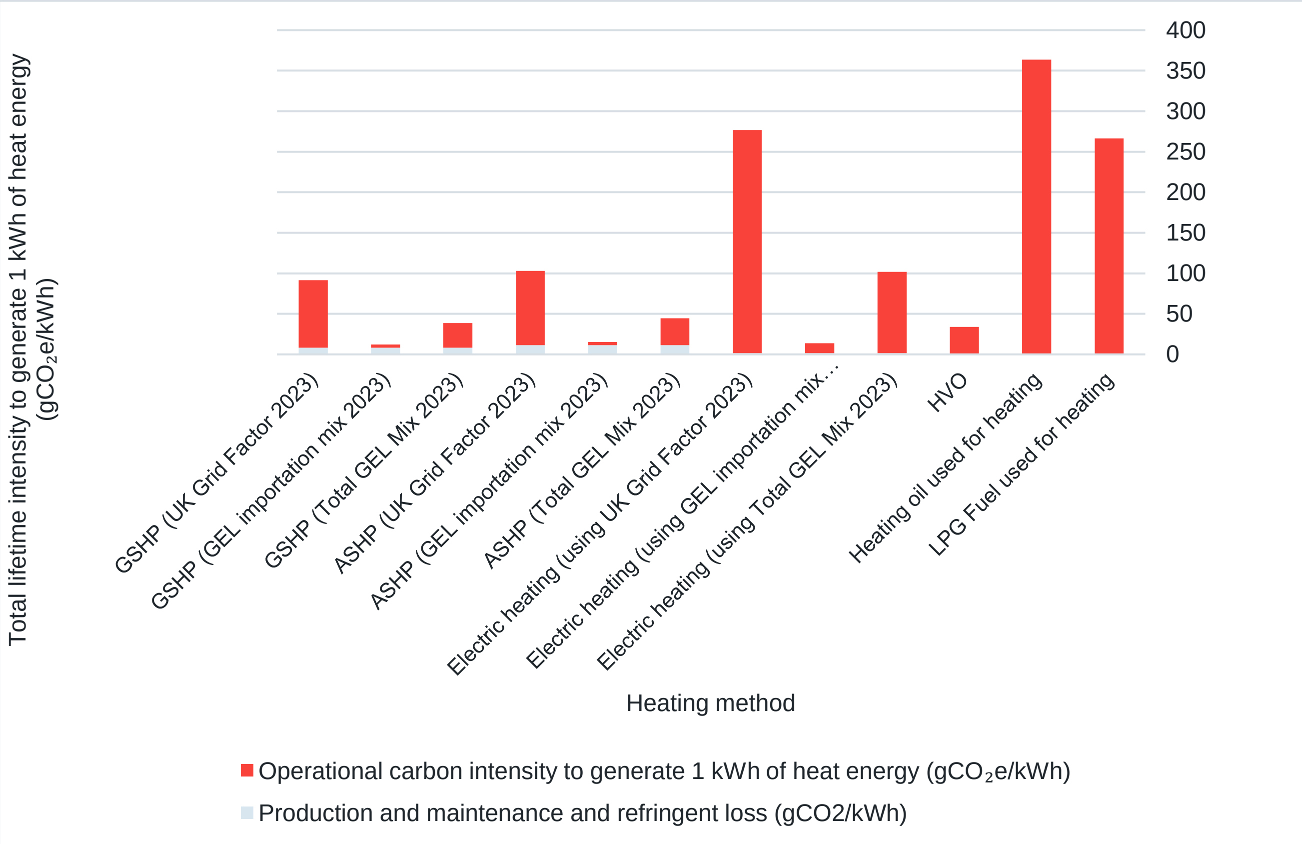
EXECUTIVE SUMMARY

This study investigates and compares the carbon intensity of various heating methods. These methods include Air Source Heat Pumps (ASHPs), Ground Source Heat Pumps (GSHPs), electric heating via an electric boiler or overnight storage heaters (here on referred to as 'electric heating'), Liquified Petroleum Gas (LPG) boiler (condensing), heating oil boiler (condensing) and hydrotreated vegetable oil (HVO) boilers (the latter being a biofuel utilized by Rubis Channel Islands, a fuel company that serves the Islands of Jersey and Guernsey).

Much like the preceding studies, the objective of this study is to estimate the greenhouse gas emissions (GHG) released per kWh of heat supplied to GEL customers (measured in grams of CO_2 equivalent (gCO_2e) per kWh), encompassing emissions throughout the entire lifecycle of the heating method.

Figure – Carbon intensity of heating sources



LPG and heating oil boilers have the highest carbon intensity due to the large quantity of emissions produced upon the combustion of the fuels.

HVO boilers have a lower carbon intensity when compared to GSHP and ASHP that utilise electricity from the Total GEL Mix 2023 and the UK Grid. However, while HVO's life cycle GHG emissions are considered lower than conventional fossil fuels (circa 90%) this value is not zero due to the production of non-CO_2 GHGs upon the combustion of the biofuel, most notably methane and nitrous oxide. The CO_2 emissions produced upon combustion of biofuels are assumed to be net ‘0’ to account for the CO_2 absorbed by fast-growing bioenergy sources during their growth.

On a per kWh of heat output basis, GSHPs, ASHPs and electric heating using GEL Importation Mix 2023 have the lowest carbon intensity when compared to the other heating technologies. This is due to the higher efficiency of GSHPs and ASHPs and the lower carbon intensity of GEL Importation Mix 2023 relative to GEL Total GEL Mix 2023 and the UK Grid electricity carbon intensity. GSHPs, ASHPs and electric heating have the highest potential to decrease in carbon intensity in the future as the electricity they are powered by decarbonises. ASHPs, GSHPs and electric heating are the only technologies discussed in this study that can be considered Net Zero as LPG and heating oil boilers use fossil fuels and HVO boilers use a biofuel.

INTRODUCTION

Guernsey Electricity Ltd (GEL) is an integrated utility company that generates, transmits and distributes electricity across the island of Guernsey. GEL also manages an interconnector with France, through which a large proportion of electricity is imported and for which the associated emissions are quantified using a market-based approach.

WSP UK has verified the intensity of the electricity that GEL distributes by undertaking a study aimed to calculate greenhouse emissions (GHGs) released for every kilowatt hour (kWh) of electricity consumed by GEL customers (gCO_2e/kWh), also taking into consideration emissions across the full lifecycle of the electricity production. The MS Excel file containing the verified calculations for the GEL intensities is: *GEL Corporate GHG Emissions 2023_v1.11_18032024_FINAL.*

This study investigates and compares the carbon intensity of various heating methods. These methods include Air Source Heat Pumps (ASHPs), Ground Source Heat Pumps (GSHPs), electric heating via an electric boiler or overnight storage heaters (here on referred to as ‘electric heating’), Liquified Petroleum Gas (LPG) boiler (condensing), heating oil boiler (condensing) and hydrotreated vegetable oil (HVO) boilers (the latter being a biofuel utilized by Rubis Channel Islands, a fuel company that serves the Islands of Jersey and Guernsey).

Much like the preceding studies, the objective of this study is to estimate the greenhouse gas emissions (GHG) released per kWh of heat supplied to GEL customers (measured in grams of CO_2 equivalent (gCO_2e) per kWh), encompassing emissions throughout the entire lifecycle of the heating method.

METHODOLOGY

This study investigates and compares the carbon intensity of various heating methods. Whole life cycle carbon assessments (WLCCAs) have been collated for each heating method. A WLCCA measures the GHG emissions impact of a product or service across its lifetime. A full lifecycle assessment has not been included in this study as only the GHG emissions impacts are considered.

LIFE CYCLE ASSESSMENT STAGES INCLUDED

Figure 1 provides a summary of the lifecycle stages considered for the heating technologies.

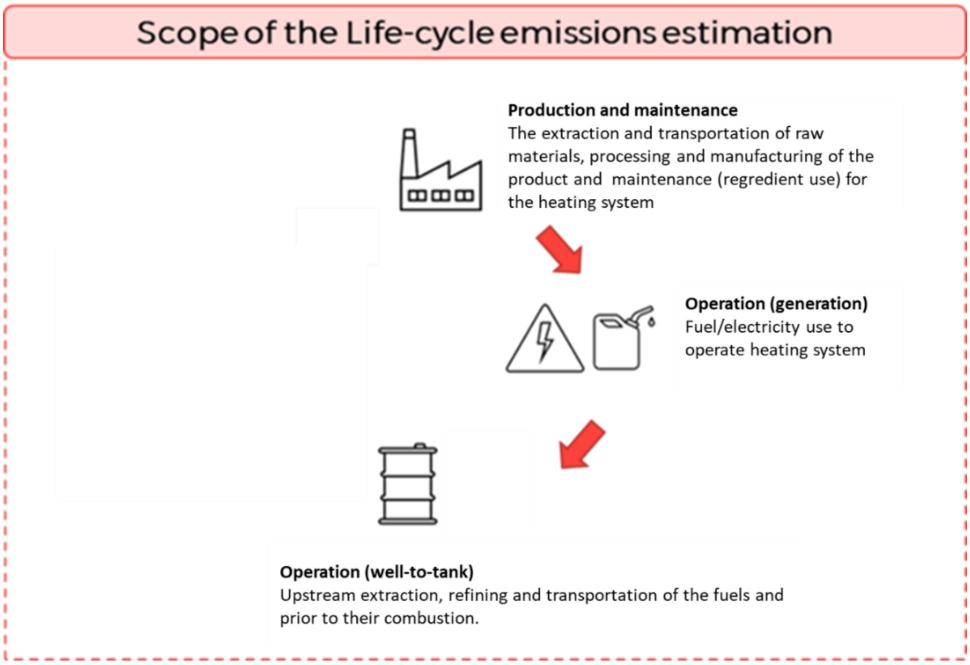


Figure 1 - Scope of the life-cycle emissions estimation

End of life is not considered in this study as it is expected to be negligible compared to other lifecycle stages.

PRODUCTION AND MAINTENANCE EMISSION FACTORS

Production and maintenance emissions from LPG, heating oil (condensing) and HVO boilers is negligible,[1] therefore no emission factors for the production and maintenance of these boilers have been sourced.

The emission from production, maintenance and refrigerant losses for ASHP and GSHP have been estimated to account for 5% of the total lifecycle emissions from 'A Comparative Environmental Assessment of Heat Pumps and Gas Boilers towards a Circular Economy in the UK'.[1]

[1] A Comparative Environmental Assessment of Heat Pumps and Gas Boilers towards a Circular Economy in the UK

Using the literature ‘Integration of LCA and LCCA through BIM for optimized decision-making when switching from gas to electricity services in dwellings’[2] it is assumed the embodied carbon of electric heating is 15% of the embodied carbon of an ASHP.

OPERATIONAL EMISSION FACTORS

Emission factors for the combustion of the fossil fuels are sourced from the Department of Energy, Security and Net Zero (DESNZ).[3]

Emission factors for the combustion of HVO is sourced from Rubis Channel Islands[4] and DESNZ.[3]

Emission factors for the upstream extraction, refining and transportation of the fossil fuels and biofuel prior to their combustion (well-to-tank (WTT)) of fossil fuels are sourced from DESNZ.[3]

The electricity emission factors (therefore emissions) are different dependent on the source of electricity. The emissions factors for ‘Total GEL Mix’ (electricity from all GEL sources) and ‘GEL Importation Mix’ (electricity from GEL imports only) for 2023 have been given in Table 1. To note, these emissions factors include emissions form transmission and distribution (T&D) loses and WTT. GELs emission factors have been compared to the UK gird emission factor from DESNZ for 2023. The DESNZ emissions factor includes T&D loses and WTT to align with the GEL factors.

Table 1 - Emission factors 2023

Emission factor	Emissions factor (gCO_2e/kWh)
Total GEL Mix (Total Lifecycle Emissions Intensity of Distributed Electricity).	100.3
GEL Importation Mix (Lifecycle Emissions Intensity of Distributed Electricity from only imported sources). Currently only supplied overnight to customers in Guernsey.	12.1
UK grid emission factor (T&D loses and WTT to align with the GEL factors)	274.9

EFFICIENCY

To be able to make comparisons between the technologies, boiler efficiencies have to be considered. GEL have outlined the boiler types and their efficiencies, for use in this study, below.

Table 2 – Boiler efficiencies used in this study (GSHP and ASHP are discussed after Table 1)

Boiler Type	Efficiency
LPG boiler (condensing)	90%[5]
Oil boiler (condensing)	90%[5]
HVO boiler	90%[5]
Electric heating	100%[6]

[2] Integration of LCA and LCCA through BIM for optimized decision-making when switching from gas to electricity services in dwellings
[3] UK Government: Greenhouse gas reporting: conversion factors 2023
[4] Rubis: Comparative Running Costs for Home Heating in Guernsey
[5] British Gas: How efficient is my gas boiler?
[6] Boiler Guide: Electric Boiler Efficiency Explained

Coefficients of Performance (COPs) of 3.0 and 3.3 are assumed in this study, for ASHPs and GSHPs respectively.[7] It should be noted that many ASHPs and GSHPs can achieve greater COP and the value is expected to increase as the technology improves. Using a COP of 3 means that 3kW of heating power is generated while the compressor only needs 1kW of power to provide the associated heat (a ratio of 3:1). So, the GEL factor has been multiplied by 0.33333 to give the operational emissions (gCO_2e) per kWh. Multiplying the factor by this value converts the emissions per unit energy input to emissions per unit of heating output. This adjustment accounts for the increased efficiency of the ASHPs and GSHPs.

Figure 1 demonstrates the relationship between the energy input and the heating energy output, considering the efficiencies of boilers, the electric heating and the COP of ASHPs and GSHPs.

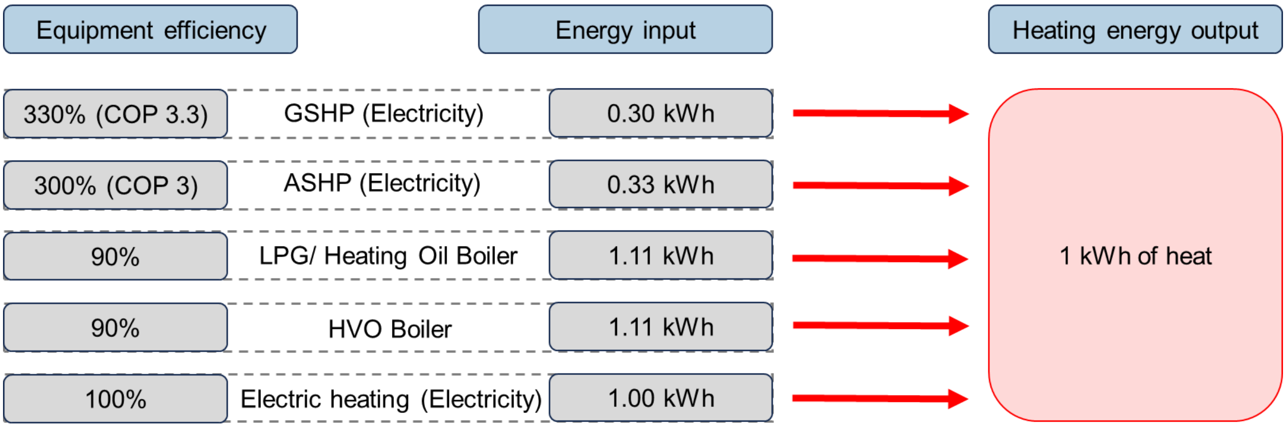


Figure 2 – Relationship between energy input and heating energy output

ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations apply to this study:

1. This study references 'carbon' but this is used as short hand for 'carbon dioxide equivalents (CO_2e)', which accounts for all of the GHG impacts as identified in the Kyoto Protocol[8].
2. This study assumes Heating oil, LPG and HVO do not have other embodied impacts as such contributions would be expected to be negligible relative to operational emissions.[9]
3. Carbon emissions from the combustion of fuels for the LPG boiler, Heating Oil boiler and biodiesel HVO boiler includes emissions from the combustion of the fuels (Operation – generation) and the upstream emissions for the supply of the fuel (Operation – WTT). This

[7] Department for Energy Security and Net Zero: Electrification of Heat Demonstration Project. The report states an average ASHP performance of 2.94 across 750 homes in the UK. Due to Guernsey's higher ambient temperatures than the UK, GEL confirmed that a COP of 3 is appropriate for use in this study as higher ambient air temperatures lead to higher COPs for ASHPs and GSHPs (KensaHeat Pumps: Fact Sheet). Guernsey's mean daily air temperature was 11.7°C between 1991 and 2020 with only one month (February) having a mean daily air temperature lower than 7°C (Guernsey Met Office: 2022 Annual Weather Report). The UK's annual mean temperature between 1991 and 2020 was 9.1°C with five months having a mean temperature below 7°C. (Met Office: State of the UK Climate 2022). GSHPs tend to have a 10% higher COP than ASHPs (UK Collaborative Centre for Housing Evidence: BLOG: The great heat pump mystery: where's the COP?). A COP for GSHPs of 3.3 has therefore been assumed for this study.
[8] United Nations Climate Change: What is the Kyoto Protocol?
[9] A Comparative Environmental Assessment of Heat Pumps and Gas Boilers towards a Circular Economy in the UK

information has been sourced from 'DEFRA Greenhouse gas reporting: conversion factors 2023'.[10]

4. RUBIS state the heat produced by the HVO fuel they provide is 10.26 kWh/L.[11] A 90% equipment efficiency has also been assumed.[12]
5. The emission from production, maintenance and refrigerant losses for ASHPs and GSHPs have been estimated to account for 5% of the lifecycle missions from the study from ‘A Comparative Environmental Assessment of Heat Pumps and Gas Boilers towards a Circular Economy in the UK’.[13] The remaining emissions are from the operation of the ASHP and GSHP.
6. Using the literature ‘Integration of LCA and LCCA through BIM for optimized decision-making when switching from gas to electricity services in dwellings’[14] it is assumed the emissions from production, maintenance and refrigerant losses of electric heating is 15% of the embodied carbon of an ASHP.
7. The study uses the GEL lifecycle emissions intensity (gCO_2e per kWh for 2023) and UK Grid carbon intensity to operate ASHPs, GSHPs and electric heating.
8. The lifetime carbon intensity assumes the use of GEL electricity in ASHPs and GSHPs with a COP of 3 and 3.3 respectively. GEL confirmed that the COP of 3 and 3.3 for ASHPs and GSHPs are appropriate due to the higher ambient temperature of Guernsey compared to the UK.[15]
9. Considering the efficiency of the boilers and electric heating means that the results reflect the emissions associated with 1 kWh of heating energy provided to GEL’s customers. This is different to the emissions associated with the energy input (kWh) required for heating.
10. A full lifecycle assessment has not been included in this study as only the GHG emissions impacts are considered.

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[10] UK Government: Greenhouse gas reporting: conversion factors 2023
[11] Rubis: Comparative Running Costs for Home Heating in Guernsey
[12] British Gas: How efficient is my gas boiler?
[13] Domestic heat pumps: Life cycle environmental impacts and potential implications for the UK
[14] Integration of LCA and LCCA through BIM for optimized decision-making when switching from gas to electricity services in dwellings
[15] Guernsey’s mean daily air temperature was 11.7°C between 1991 and 2020 with only one month (February) having a mean daily air temperature lower than 7°C (Guernsey Met Office: 2022 Annual Weather Report). The UK’s annual mean temperature between 1991 and 2020 was 9.1°C with five months having a mean temperature below 7°C.

RESULTS

The carbon intensity of different heating technologies are described in Figure 3 and Table 3. The results (Total lifetime intensity to generate 1 kWh of heat energy (gCO_2e/kWh) accounts for the efficiency of equipment and allows for comparison between different technologies by normalising the result to 1 kWh of heating energy provided by the equipment to GEL's customers (i.e., heating output).

To avoid any misinterpretation of the results, WSP recommends that care is taken when disseminating this data, on the difference between the carbon intensity of the energy inputs per kWh and the carbon intensity of heating energy outputs per kWh.

LPG and heating oil boilers have the highest carbon intensity due to the large quantity of emissions produced upon the combustion of the fuels.

HVO boilers have a lower carbon intensity when compared to GSHP and ASHP that utilise electricity from the Total GEL Mix 2023 and the UK Grid. However, while HVO's life cycle GHG emissions are considered lower than conventional fossil fuels (circa 90%) this value is not zero due to the production of non-CO_2 GHGs upon the combustion of the biofuel, most notably methane and nitrous oxide. The CO_2 emissions produced upon combustion of biofuels are assumed to be net '0' to account for the CO_2 absorbed by fast-growing bioenergy sources during their growth.

The results show that on a per kWh of heat output basis, GSHPs, ASHPs and electric heating using GEL Importation Mix 2023 have the lowest carbon intensity when compared to the other heating technologies. This is due to the higher efficiency of GSHPs and ASHPs and the lower carbon intensity of GEL Importation Mix 2023 relative to GEL Total GEL Mix 2023 and the UK Grid electricity carbon intensity. GSHPs, ASHPs and electric heating have the highest potential to decrease in carbon intensity in the future as the electricity they are powered by decarbonises. ASHPs, GSHPs and electric heating are the only technologies discussed in this study that can be considered Net Zero as LPG and heating oil boilers use fossil fuels and HVO boilers use a biofuel.

Figure 3 – Carbon intensity of heating sources

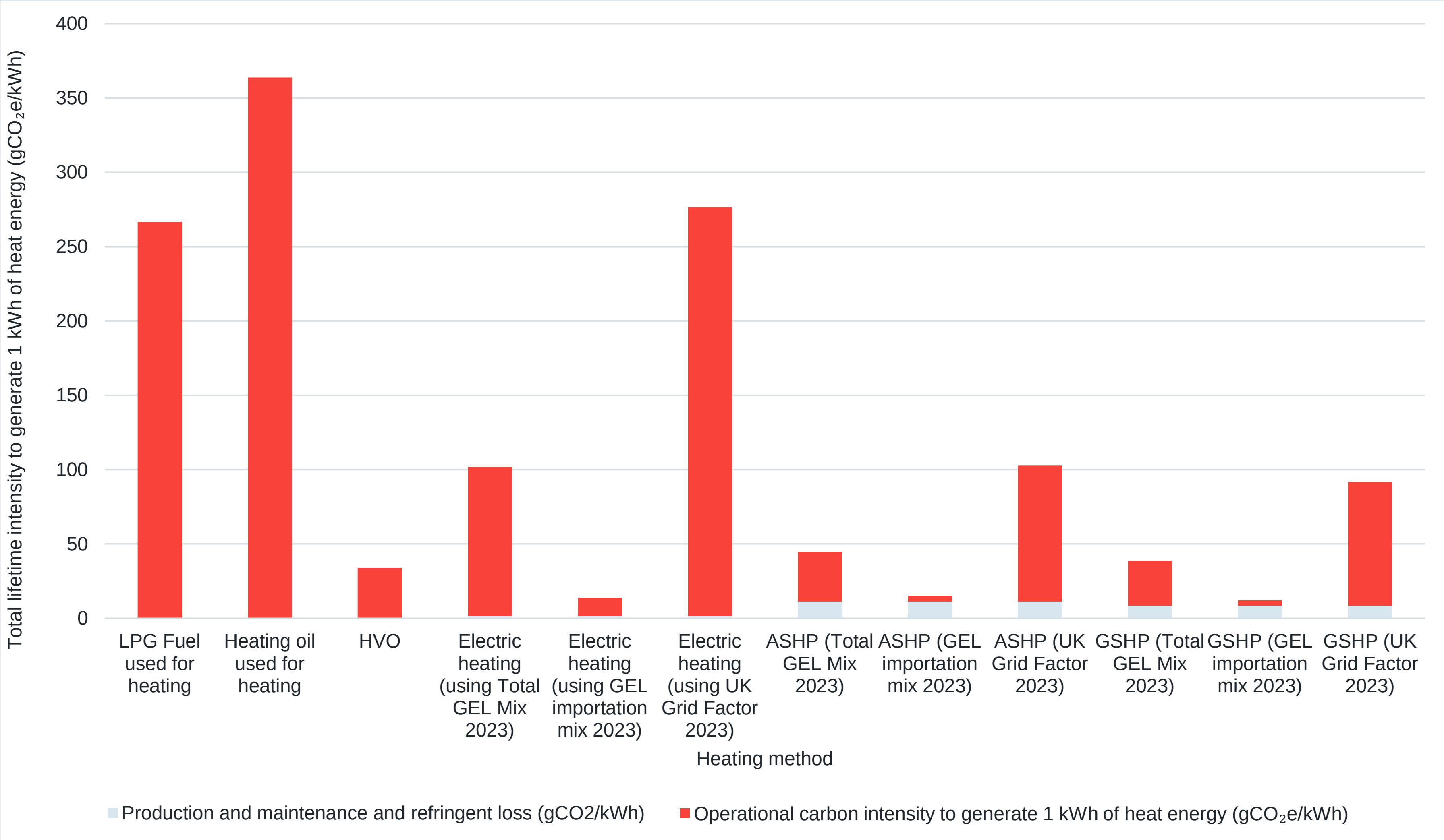

Table 3 – Carbon intensity of heating sources

Source	Production and maintenance and refringent loss (gCO_2/kWh)	Operational (generation) carbon intensity (gCO_2e/kWh)	Operational (WTT) carbon intensity (gCO_2e/kWh)	Operational efficiency of equipment	Operational carbon intensity to generate 1 kWh of heat energy (gCO_2e/kWh)	Total lifetime intensity to generate 1 kWh of heat energy (gCO_2e/kWh)
LPG Fuel used for heating	Excluded – emissions negligible	214.50	25.48	90%	266.64	266.64
Heating oil used for heating	Excluded – emissions negligible	268.13	59.13[1]	90%	363.63	363.63
HVO	Excluded – emissions negligible	3.47	27.14[1]	90%	34.01	34.01
Electric heating (using Total GEL Mix 2023)	1.69	100.30	WTT included in operation - generation	100%	100.30	101.99
Electric heating (using GEL importation mix 2023)	1.69	12.10	WTT included in operation - generation	100%	12.10	13.79
Electric heating (using UK Grid Factor 2023)	1.69	274.86	WTT included in operation - generation	100%	274.86	276.55
ASHP (Total GEL Mix 2023)	11.25	100.30	WTT included in operation - generation	300%	33.43	44.68
ASHP (GEL importation mix 2023)	11.25	12.10	WTT included in operation - generation	300%	4.03	15.28

Source	Production and maintenance and refringent loss (gCO_2/kWh)	Operational (generation) carbon intensity (gCO_2e/kWh)	Operational (WTT) carbon intensity (gCO_2e/kWh)	Operational efficiency of equipment	Operational carbon intensity to generate 1 kWh of heat energy (gCO_2e/kWh)	Total lifetime intensity to generate 1 kWh of heat energy (gCO_2e/kWh)
ASHP (UK Grid Factor 2023)	11.25	274.86	WTT included in operation - generation	300%	91.62	102.87
GSHP (Total GEL Mix 2023)	8.40	100.30	WTT included in operation - generation	330%	30.39	38.79
GSHP (GEL importation mix 2023)	8.40	12.10	WTT included in operation - generation	330%	3.67	12.07
GSHP (UK Grid Factor 2023)	8.40	274.86	WTT included in operation - generation	330%	83.29	91.69

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