Guernsey Electricity Limited

HEATING CARBON INTENSITY STUDY 2022

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EXECUTIVE SUMMARY

Guernsey Electricity Ltd (GEL) is an integrated utility 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 previously verified the intensity of the electricity that GEL distributes. That 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: *WSP GHG Review Spreadsheet_RP of 2022_v1.0_14042023.xlsx.*

For this study, WSP UK has been commissioned by GEL to undertake an update of the previous study. This study investigates the carbon intensity of various heating methods. These methods include Air Source Heat Pumps (ASHPs), Ground Source Heat Pumps (GSHPs), and electric, Liquified Petroleum Gas (LPG), heating oil and hydrotreated vegetable oil (HVO) boilers – the latter being a biofuel utilized by Rubis Channel Islands,[1] a fuel company that serves the Islands of Jersey and Guernsey. Much like the preceding study, the objective of this study is to compute the greenhouse gas emissions (GHG) released per kilowatt-hour (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 associated electricity/fuel production.

The results show that on a per kWh of heat output basis, GSHPs and ASHPs using Total GEL Mix 2022 and GEL Importation Mix 2022 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 electricity relative to the UK Grid electricity carbon intensity. HVO boilers have a lower carbon intensity when compared to GSHPs and ASHPs that utilise electricity from the UK Grid. LPG and Heating oil boilers have the highest carbon intensity. It should be noted that GSHPs and ASHPs have the highest potential to decrease in carbon intensity in the future as the electricity they are powered by decarbonises. ASHPs, GSHPs and electric boilers 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 used a biofuel. 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.

[1] https://rubis-ci.co.uk/news/ecoheat100-100-renewable-heating-oil/

METHODOLOGY

This section of the report outlines how the study has been completed.

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

Boiler Type	Efficiency
LPG boiler (condensing)	90%[2]
Oil boiler (condensing)	90%[2]
HVO boiler	90%[2]
Electric Boiler	100%[3]

Coefficients of Performance (COPs) of 3.0 and 3.3 are assumed in this study, for ASHPs and GSHPs respectively.[4] It should be noted that many ASHPs and GSHPs can achieve greater COP and the value is expected to increase as the technology improves, these COP has been used as a lower estimates in this study. 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 and the COP of ASHPs and GSHPs.

[2] 'A condensing boiler will always be at least 90% efficient' - https://www.britishgas.co.uk/home-services/boilers-and-heating/guides/boiler-efficiency.html

[3] 'Electric boilers are often labelled as being 99-100% efficient' - https://www.boilerguide.co.uk/articles/electric-boiler-efficiency-explained

[4] https://es.catapult.org.uk/wp-content/uploads/2023/03/EoH-Interim-Heat-Pump-Performance-Data-Analysis-Report-1.pdf reports 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. Higher ambient air temperatures lead to higher COPs for ASHPs and GSHPs (https://www.kensaheatpumps.com/wp-content/uploads/2014/03/Factsheet-COP-Variation-V2.pdf). 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 (http://www.metoffice.gov.gg/AnnualReports/2022%20Annual%20Report.pdf). The UK's annual mean temperature between 1991 and 2020 was 9.1°C with five months having a mean temperature below 7°C. (https://rmets.onlinelibrary.wiley.com/doi/epdf/10.1002/joc.8167). GSHPs tend to have a 10% higher COP than ASHPs (https://housingevidence.ac.uk/the-great-heat-pump-mystery-wheres-the-cop/). A COP for GSHPs of 3.3 has therefore been assumed for this study.

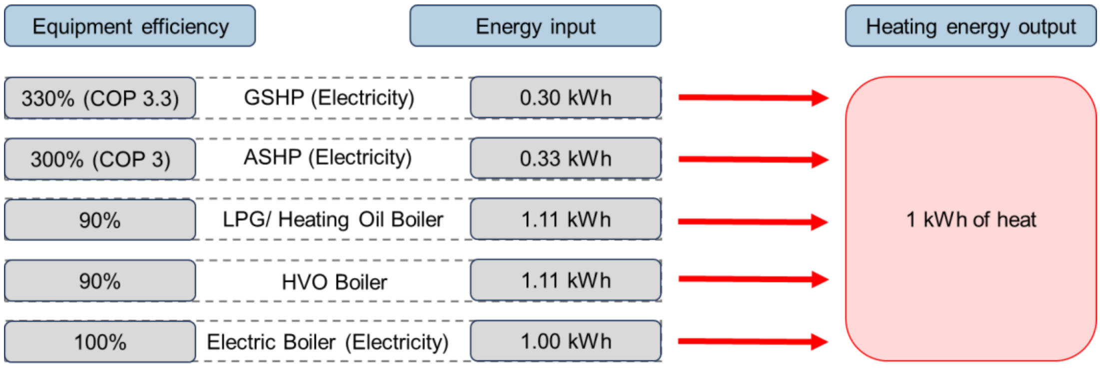

Figure 1 – Relationship between energy input and heating energy output

<u>Life cycle assessment stages included</u>

Figure 2 provides a summary of the lifecycle stages considered for the heating technologies.

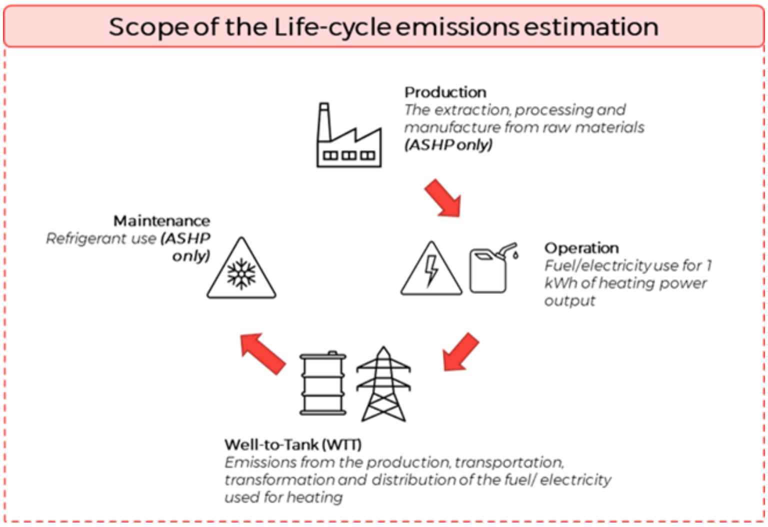

Figure 2 - Scope of the life-cycle emissions estimation

Table 2 states how each life-cycle assessment stage is treated for each technology. End of life is not considered in this study as it is expected to be negligible compared to other lifecycle stages.

Table 2 – How life-cycle assessment stage is treated for each technology

Technology	Production and maintenance (gCO_2/kWh)	Operation – generation (gCO_2/kWh)	Operation – Well-to-tank (WTT) (gCO_2/kWh)
LPG boiler	Excluded - negligible	230[5]	27[7]
Heating Oil boiler	Excluded - negligible	285.26[2]	62.64[2]
Biodiesel HVO boiler	Excluded - negligible	3[6]	34[3]

[5] Net calorific value emissions factors (gCO2/kWh) sourced from DEFRA Greenhouse Gas Reporting: Conversion Factors 20222. https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2022
[6] The DEFRA Greenhouse Gas Reporting: Conversion Factors 2022[2] has emissions factors for Biodiesel HVO per litre. https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2022. gCO_2e/L were converted to gCO_2e/kWh using heat Rubis states their HVO fuel provide (10.26 kWh/L[6]). https://rubis-ci.co.uk/wp-content/uploads/2023/05/Comparative-Running-Costs-GSY-May-2023.pdf

Technology	Production and maintenance (gCO_2/kWh)	Operation – generation (gCO_2/kWh)	Operation – Well-to-tank (WTT) (gCO_2/kWh)
ASHP (Total GEL Mix)	11[7]	29[8]	Excluded no WTT
ASHP (GEL importation mix)	11[8]	3[9]	Excluded no WTT
ASHP (UK Grid Factor)	11[8]	70[9]	Excluded no WTT
GSHP (Total GEL Mix)	8[8]	26[9]	Excluded no WTT
GSHP (GEL importation mix)	8[8]	3[9]	Excluded no WTT
GSHP (UK Grid Factor)	8[8]	64[9]	Excluded no WTT
Electric boiler (Total GEL Mix)	11[8]	87[9]	Excluded no WTT
Electric boiler (GEL importation mix)	11[8]	9[9]	Excluded no WTT
Electric boiler (UK Grid Factor)	11[8]	211[9]	Excluded no WTT

ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations apply to this study:

- 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[9].
- 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.
- Embodied carbon emissions for ASHPs, GSHPs and electric boilers are 5% of the operational emissions '*For all the systems (Air/ Ground/ Water Source Heat Pumps and Gas Boilers), CO_2 emissions from electricity generation and natural gas combustion are the main contributor to GWP [global warming potential], causing over 95% of the impact.'*[10]
- HVO, LPG and oil fuel boilers are assumed to be 90% efficient.[11]
- The study uses the GEL lifecycle emissions intensity (gCO_2e per kWh for 2022) and UK Grid carbon intensity to operate ASHPs, GSHPs and electric boilers.
- Considering the efficiency of the boilers 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.

[7] The embodied carbon of equipment, maintenance and refrigerant losses have been estimated to account for 5% of the ASHP, GSHP and electric boiler lifecycle, with the remaining 95% accounting for the operation of the ASHP, GSHP and electric boiler (https://www.escholar.manchester.ac.uk/api/datastream?publicationPid=uk-ac-man-scw:178995&datastreamId=POST-PEER-REVIEW-PUBLISHERS.PDF). 5% of emissions from: https://mdpi-res.com/d_attachment/energies/energies-14-03027/article_deploy/energies-14-03027-v2.pdf?version=1621917291 has been used to estimate production and maintenance emissions.

[8] For ASHPs, GSHPs and electric boilers, the operational emissions have been calculated using GEL's 'Total GEL Mix' intensity, 'GEL importation mix' intensity and a UK Grid Factor from the Department for Business, Energy and Industrial Strategy. This figure includes emissions from the generation of the electricity as well as any emission from transmission and distribution.

[9] https://unfccc.int/kyoto_protocol

[10] https://www.escholar.manchester.ac.uk/api/datastream?publicationPid=uk-ac-man-scw:178995&datastreamId=POST-PEER-REVIEW-PUBLISHERS.PDF

[11] https://www.idealheatsolutions.co.uk/ideal-heat-to-offer-hvo-as-a-fuel-option/

RESULTS

The carbon intensity of different heating technologies are described in 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 energy 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.

Table 3 – Carbon intensity of heating sources

Source	Production and maintenance (gCO_2/kWh)	Operational 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 (Total GEL Mix 2022)*	11	87	300% (COP 3)	29	40
ASHP (GEL importation mix 2022)*	11	9	300% (COP 3)	3	12
ASHP (UK Grid Factor 2022)*	11	211	300% (COP 3)	70	81
GSHP (Total GEL Mix 2022)*	8	87	300% (COP 3)	26	35
GSHP (GEL importation mix 2022)*	8	9	300% (COP 3)	3	11
GSHP (UK Grid Factor 2022)*	8	211	300% (COP 3)	64	72
LPG Fuel used for heating**	Negligible	258	90%	286	286
Heating oil used for heating**	Negligible	348	90%	387	387
HVO***	Negligible	38	90%	42	42
Electric boiler (using Total GEL Mix 2022)	11	87	100%	87	98
Electric boiler (using GEL importation mix 2022)	11	9	100%	9	20
Electric boiler (using UK Grid Factor 2022)	11	211	100%	211	222

*The lifetime carbon intensity assumes the use of GEL electricity in ASHPs and GSHPs with a coefficient of performance (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. The intensity figure includes an estimation of refrigerant losses and the embodied carbon of the equipment; associated assumptions have been sourced from academic literature.

**This includes carbon emissions from the combustion of fuel for heating and the upstream emissions for the supply of the fuel (well-to-tank emissions). This information has been sourced from 'DEFRA Greenhouse gas reporting: conversion factors 2022'. The intensity does not include embodied carbon of the equipment used or emissions from the downstream distribution of fuel, which are both deemed to be negligible in the context of the results.

*** This includes carbon emissions from the combustion of the fuel for heating and the upstream emissions for the supply of the fuel (well-to-tank emissions). RUBIS state the heat produced by the HVO fuel they provide is 10.26 kWh/L. A 90% equipment efficiency has also been assumed. The intensity does not include embodied carbon of the equipment used or emissions from the downstream distribution of fuel, which are both deemed to be negligible in the context of the results.

The results show that on a per kWh of heat output basis, GSHPs and ASHPs using Total GEL Mix 2022 and GEL Importation Mix 2022 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 electricity relative to the UK Grid electricity carbon intensity. HVO boilers have a lower carbon intensity when compared to GSHP and ASHP that utilise electricity from the UK Grid. LPG and Heating oil boilers have the highest carbon intensity. It should be noted that GSHPs and ASHPs have the highest potential to decrease in carbon intensity in the future as the electricity they are powered by decarbonises. ASHPs, GSHPs and electric boilers 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 used a biofuel. 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.

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