Guernsey Electricity Limited

LIFE CYCLE STUDY OF VEHICLE GHG IMPACTS IN GUERNSEY

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EXECUTIVE SUMMARY

Guernsey Electricity Ltd (here on referred to as GEL) is an integrated utility company that generates, transmits and distributes electricity across the island of Guernsey. GEL undertakes operations that use electricity including works power, office activities and the charging of company electric vehicles.

WSP UK was commissioned by GEL to conduct a study into the life cycle greenhouse gas (GHG) emissions intensity of different types of passenger modes of transport. This study builds on studies undertaken annually for at least the last 3 years, and was conducted to provide a comparison between:

- battery electric vehicles (BEVs);
- conventional internal combustion engine (ICE) vehicles using petrol, diesel or biofuel diesel (hydrotreated vegetable oil (HVO)) as fuel;
- fuel cell electric vehicles (FCEVs) which use hydrogen from different production methods; and
- electric bicycles (here on referred to as E-bikes).

GEL stated E-bikes were of particular interest and as a result, WSP have included E-bikes in the 2023 study. Additional detail on E-bikes has also been provided in this study.

Approximately 95% of the emissions from the use of E-bikes is from their production. Despite the total lifecycle of E-bikes being circa 10% of that of a passenger vehicle, emissions from the production, use and EOL of E-bikes are significantly lower than that of all passenger vehicles regardless of the type of vehicle.

The results of the 2023 study show that the ICE vehicle fuelled by RD100 (HVO diesel biofuel) results in the lowest emissions in gCO_2e per km compared to other passenger vehicle types. It should also be noted that RD100 is a diesel biofuel. While biofuels have lower life cycle GHG emissions than conventional fossil fuels (circa 90%)[1] 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 '0' to account for the CO_2 absorbed by fast-growing bioenergy sources during their growth[2].

BEVs and FCEVs have higher production emissions than ICE vehicles (circa 40%), the reason for the difference being higher emissions from battery production for BEVs and FCEVs[3]. This results in BEVs and FCEVs GHG emissions (gCO_2e per km) being higher than HVO powered vehicles. However, it is expected there will be a steep reduction in the carbon emissions from EV battery production in the next five to ten years through the introduction of regulation and circular economy[1,]

[1] https://www.supplychainschool.co.uk/wp-content/uploads/2023/05/Collaboration-Group-on-HVO-Sponsorship-opportunity.pdf
[2] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2022
[3] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-race-to-decarbonize-electric-vehicle-batteries

[4]. Future BEVs and FCEVs have the potential to produce less gCO_2e per km compared to RD100 vehicles in the near future.

Vehicles operating on petrol and diesel (non-biofuel) represent the highest contributors to GHG emissions, primarily as a result of the operation life cycle stage i.e., in-use fuel consumption which significantly outweighs the higher production and end of life emissions associated with BEVs and FCEVs.

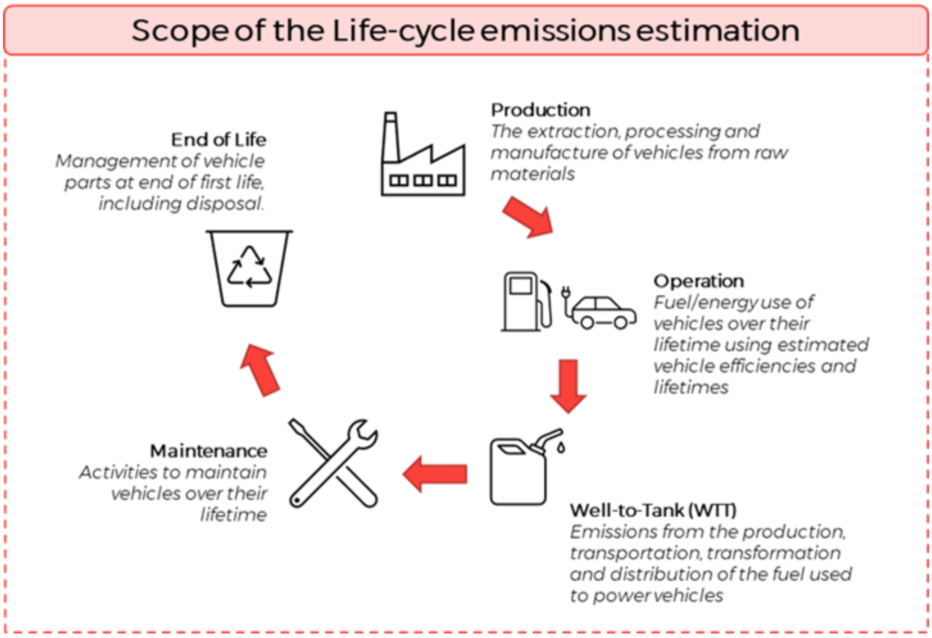
OBJECTIVE

The objective of this study was to calculate the GHG emissions released per km driven for popular modes of transport, accounting for the GHG emissions across the complete life cycle of production, operation and end-of-life (EOL). For BEV/E-bikes charging, the life cycle intensity of GEL's electricity supply (both Total GEL mix and GEL importation mix only) was considered, in comparison with the UK grid factor (values shows in Table 1). The study also compares three types of hydrogen production: steam methane reformation, both with and without carbon capture, and renewable electrolysis.

METHODOLOGY

For this study, WSP assessed the emissions from the production, operation and EOL life cycle stages of each in-scope vehicle type. Production emissions are those arising from raw materials extraction and processing. Operational emissions included the emissions generated by the combustion of fuel or the generation of electricity/hydrogen, well-to-tank emissions from the production of each fuel and vehicle maintenance activities. EOL emissions occur from the management and disposal of parts at the end of a vehicles' lifetime.

A summary of the life cycle stages assessed are in Figure 1-1.



[4]https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/943714/Modelling-2050-Electricity-System-Analysis.pdf

Figure 1-1 – Scope of the life cycle emissions estimation

As part of this assessment, a literature review was conducted to obtain GHG emission values for the production and EOL stages of the vehicle's life cycle. The following steps have then been used to calculate the operational GHG emissions for each vehicle:

- **Emissions from energy usage (diesel/petrol) (Equation 1a)**
  Vehicle fuel efficiency x average lifetime usage x fuel emissions factor
- **Emissions from energy usage (electric) (Equation 1b)**
  Vehicle/E-Bike electricity efficiency x average lifetime usage x GEL electricity intensity or UK average grid emissions intensity (including transmission and distribution)
- **WTT emissions (diesel/petrol/HVO vehicles) (Equation 2a)**
  Lifetime fuel used x WTT fuel emission factor for diesel/petrol/HVO vehicles
- **WTT emissions (hydrogen) (Equation 2b)**
  Vehicle electricity efficiency x average lifetime usage x GHG emission factor for the production of hydrogen
- **Operation emissions (Equation 3)**
  Equation 1 + Equation 2 + maintenance activity emissions

The final step to calculate life cycle emissions is:

- **Life cycle emissions (Equation 4)**
  Operation emissions + Production emissions + EOL emissions

Where this information was not available, they were estimated using available literature. The full list of emission values for each vehicle's life cycle stage can be found in Table 2 which is found in the Appendix along with the corresponding literature source.

Average lifetime usage: According to available scientific literature, different brands of ICE vehicles, BEVs and FCEVs lifetimes range significantly depending on the study. Some studies show BEVs and FCEVs with longer lifetimes than ICE vehicles and others show ICE vehicles have longer lifetimes than BEVs and FCEVs. An average lifetime usage (184,000 km) was assumed for all vehicles in this study. [5] An average lifetime usage (20,000 km) was also used for all E-bikes.[6]

Vehicle fuel efficiency: Is defined as a measure of how much a vehicle/E-bike will convert energy in fuel into kinetic energy to travel. Vehicle efficiencies have been sourced from a variety of sources which are summarised as part of the data summary in Table 2,found in the Appendix.

Vehicle types: Based on the available literature[7] and vehicle sales statistics in the UK[8], WSP used professional judgement to select representative ICE vehicles, BEVs and FCEVs for inclusion in this

[5] https://www.mdpi.com/2071-1050/12/22/9390/htm.
[6] https://www.polytechnique-insights.com/en/columns/energy/what-is-the-carbon-footprint-of-electric-bikes/%20e-bikes/
[7] https://www.mdpi.com/2071-1050/12/22/9390/htm.
[8] https://www.best-selling-cars.com/britain-uk/2022-full-year-britain-best-selling-car-models-in-the-uk/

study. An average E-Bike was used in this study. Additionally, an average diesel and petrol vehicle along with a BEV were also included. The types of vehicles incorporated in this study are therefore:

- BEV GEL Imports Only – Average Car
- BEV GEL Imports Only – Fiat 500 EV
- BEV GEL Imports Only – Tesla M3
- BEV Renewable Charged (0 gCO2e/kWh) – Average
- BEV Total GEL Mix – Average Car
- BEV Total GEL Mix – Fiat 500 EV
- BEV Total Gel Mix – Tesla M3
- BEV UK Charged – Average Car
- BEV UK Grid Charged – Fiat 500 EV
- BEV UK Grid Charged – Tesla M3
- Diesel – Average Car
- Diesel – BMW 3 series, Euro 6
- Diesel – VW Golf Tdi
- E-Bike - UK Grid Charged
- E-Bike - Total GEL Mix
- E-Bike - GEL Imports Only
- E-Bike - Renewable Charged (0 gCO2e/kWh)
- FCEV – Toyota Mirai [Renewable electrolysis]
- FCEV – Toyota Mirai [Steam methane reformation with carbon capture]
- FCEV – Toyota Mirai [Steam methane reformation without carbon capture]
- HVO – Average (RD100) Car
- Petrol – Average Car

The following updates have been made in this revision of study:

- Department for Energy, Security and Net Zero (DESNZ) emission factors updated with the latest UK Greenhouse Gas Reporting Conversion Factors for 2023[9]. Please see Table 1 below for additional information on the electricity emission factors used.
- The emission factors specific to GEL, GEL's electricity supply life cycle intensity, have been updated. These factors were sourced from the Annual Greenhouse Gas Emissions Database for 2023.[10]

[9] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023
[10] GEL Corporate GHG Emissions 2023_v1.11_18032024_FINAL

- Fuel efficiency values, average lifetime usages, production, maintenance and EOL emissions have been reviewed. Sources are summarised in Table 2 which is found in the Appendix.
- The inclusion of E-bikes is new for the 2023 study. Additional detail is provided below.

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 (Carbon Intensity (Lifecycle electricity supplied) for imported sources only)	12.1
UK grid emission factor (includes transmission and distribution (T&D) loses and well-to-tank (WTT) to align with the GEL factors)	274.9

E-BIKES

For the 2023 review GEL requested WSP UK include E-bikes in the emission study. E-bikes are defined as "*a bicycle with an electric motor that helps to move the bicycle forward even when the rider is not turning the pedals*"[11].

A 20kg aluminium bike (excluding electric assistance) manufactured in China with a 20kg battery was determined to represent an average E-bike.[12] The average lifetime usage for an E-bike was assumed to be 20,000 kms for all E-bikes.[13] The efficiency of a BOSCH E-bike (0.007 kWh) was assumed to represent the average efficiency for all E-bikes.[14]

ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations apply to this study:

- In the absence of Guernsey-specific data on the average lifetime usage of a car, 184,000 km was assumed, based on estimates available from literature[15].
- In the absence of Guernsey-specific data on the average lifetime usage of a E-bike, 20,000 km was assumed, based on estimates available from literature[16].
- The results for the purposes of comparison for the study have been normalised to per km.

[11] https://dictionary.cambridge.org/dictionary/english/e-bike#google_vignette
[12] https://www.polytechnique-insights.com/en/columns/energy/what-is-the-carbon-footprint-of-electric-bikes/%20e-bikes/
[13] https://www.polytechnique-insights.com/en/columns/energy/what-is-the-carbon-footprint-of-electric-bikes/%20e-bikes/
[14] https://www.bosch-ebike.com/en/help-center/asset-asf-00328
[15] https://www.mdpi.com/2071-1050/12/22/9390/htm.
[16] https://www.polytechnique-insights.com/en/columns/energy/what-is-the-carbon-footprint-of-electric-bikes/%20e-bikes/

- The production, maintenance and EOL life cycle stage emissions for all vehicle types are based on averages of these vehicle types from a range of Life Cycle Assessment (LCA) studies from the following review paper: *Review and Meta-Analysis of EVs: Embodied Emissions and Environmental Breakeven (Dillman et al 2020.*[17] The FCEV (the MIRAI) has been assumed to have the same production, maintenance and EOL life cycle stage emissions as a BEV due to the similarity in the MIRAI emission profile stated in Life Cycle Assessment Report "The MIRAI Life Cycle Assessment for communication" produced by Toyota[18]. The production, maintenance and EOL life cycle stage emissions for E-bikes is from a review by the Insitut Polytechniques De Paris[19].

- EOL emissions from cars have been discerned from the following review paper: *Review and Meta-Analysis of EVs: Embodied Emissions and Environmental Breakeven (Dillman et al 2020)*[20]*.* It should be noted that the review highlighted an inconsistency regarding emissions from the EOL stage and battery replacement; the review asserted that this was because of a lack of available data on recycling technologies and their success (as BEVs and FCEVs have only relatively recently entered the mass market and many are yet to reach EOL). The BEV EOL emissions factor is the average of the meta-analysis of a range of EV Life Cycle Assessments, of which a few of these studies included recycling aspects.

- EOL emissions from e-bikes are assumed to be 0 tCO_2e. Recycling batteries and materials can reduce the carbon footprint however there is a lack of confidence in how many e-bikes are currently recycled[21].

[17] https://www.mdpi.com/2071-1050/12/22/9390/htm.
[18] https://www.zemo.org.uk/assets/reports/Zemo_Hydrogen_Vehicle_Well-to-Wheel_GHG_and_Energy_Study_2021.pdf
[19] https://www.polytechnique-insights.com/en/columns/energy/what-is-the-carbon-footprint-of-electric-bikes/%20e-bikes/
[20] https://www.mdpi.com/2071-1050/12/22/9390/htm.
[21] https://www.polytechnique-insights.com/en/columns/energy/what-is-the-carbon-footprint-of-electric-bikes/%20e-bikes/

RESULTS 2023

Figure 1-2 presents a comparison of life cycle emissions (gCO_2e/km) of different types of vehicles/modes of transport (some operating with various fuels). Table 2, which is found in the Appendix, contains the full set of results and associated sources.

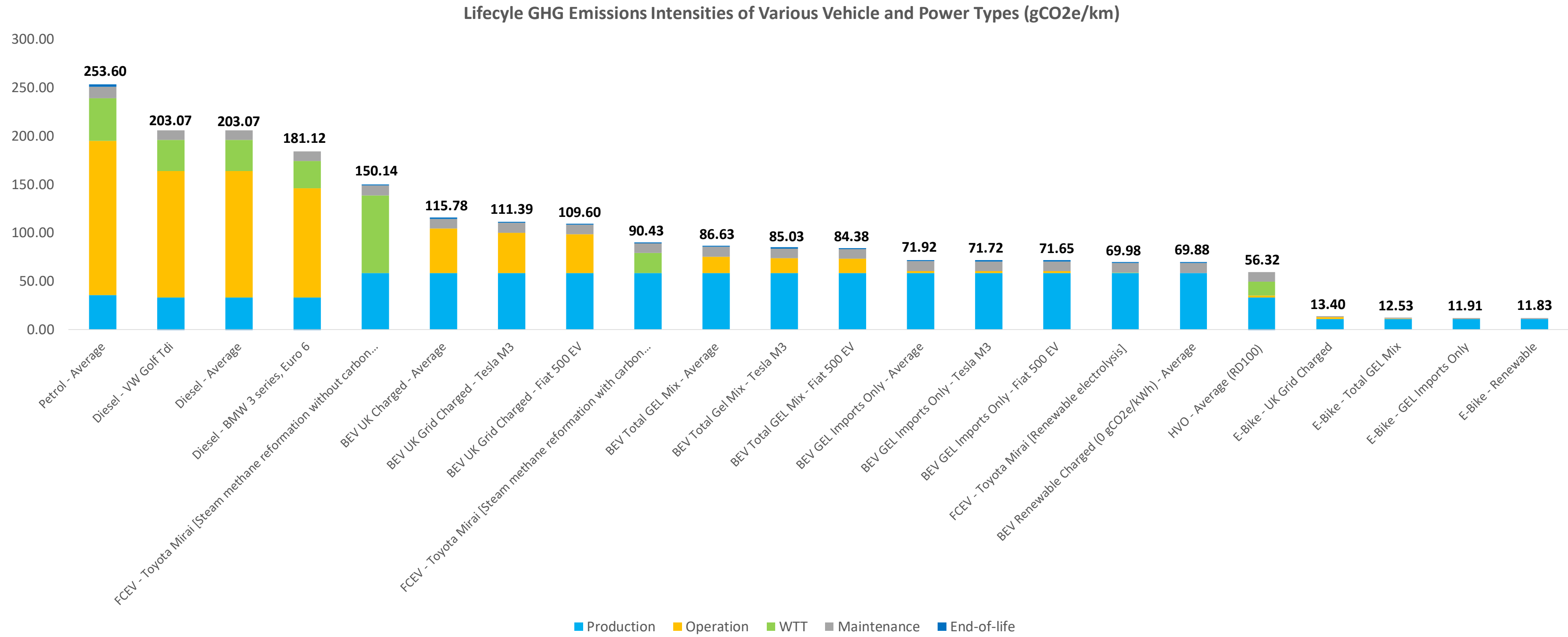


Figure 1-2 Life Cycle Emissions Intensities 2023

Circa 95% of the emissions from the use of E-bikes is from their production. Despite the total lifecycle of E-bikes being roughly 10% of that of a passenger vehicle, emissions from the production, use and EOL of E-bikes are significantly lower than that of all passenger vehicles regardless of the type of vehicle.

The results show that the ICE vehicle HVO – Average (RD100) that is fuelled with RD 100 (a HVO diesel biofuel) has the lowest emissions in gCO_2e per km compared to other vehicle types and fuel consumption. This is primarily the result of the lower emissions for the production of diesel cars compared to BEVs and FCEVs at present. While biofuels have lower life cycle GHG emissions than conventional fuels (circa 90%)[22], 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 '0' to account for the CO_2 absorbed by fast-growing bioenergy sources during their growth[23].

Production emissions from BEVs and FCEVs are 40% higher than ICE vehicles, the reason for the difference being higher emissions from battery production for use in BEVs and FCEVs[24]. However, it is expected there will be a steep reduction in the carbon emissions from EV battery production in the next five to ten years through the introduction of regulation and circular economy initiatives[16, 25]. Future BEVs and FCEVs have the potential to produce less gCO_2e per km compared to RD100 vehicles in the near future.

As stated in the methodology, BEVs and FCEVs are assumed to produce the same emissions during the production, maintenance and EOL life cycle stages. The difference in life cycle emissions between BEVs and FCEVs are solely the result of differing operational emissions. As hydrogen production via steam methane reformation without carbon capture is the most GHG intensive process, the FCEV that is fuelled through this method of hydrogen production has significantly higher life cycle emissions compared to other BEVs and FCEVs.

Vehicles operating on petrol and diesel (non-biofuel) represent the highest contributors to GHG emissions, primarily as a result of the operation life cycle stage i.e., in-use fuel consumption which significantly outweighs the higher production and EOL emissions associated with BEVs and FCEVs.

[22] https://www.supplychainschool.co.uk/wp-content/uploads/2023/05/Collaboration-Group-on-HVO-Sponsorship-opportunity.pdf
[23] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2022
[24] https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/the-race-to-decarbonize-electric-vehicle-batteries
[25] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/943714/Modelling-2050-Electricity-System-Analysis.pdf

APPENDIX – FULL RESULTS

Table 2 - Emissions (gCO_2e/km) from a typical vehicle over its life cycle

Vehicle type	Emissions (gCO_2e/km)					
	Production	Operation	WTT	Maintenance	EOL	Total
Petrol - Average	35.87[1]	159.41[1,7]	44.15[1]	12.00[1]	2.17[1]	253.60
Diesel - VW Golf Tdi	33.15[1]	130.63[1,7]	32.45[1]	10.10[1]	-3.26[1]	203.07
Diesel - Average	33.15[1]	130.63[1,7]	32.45[1]	10.10[1]	-3.26[1]	203.07
Diesel - BMW 3 series, Euro 6	33.15[1]	113.04[2,7]	28.08[1]	10.10[1]	-3.26[1]	181.12
FCEV - Toyota Mirai [Steam methane reformation without carbon capture]	58.70[1]	0.00[3]	80.26[2,3]	10.10[1]	1.09[1]	150.14
BEV UK Charged - Average	58.70[1]	45.59[1,7]	0.00	10.10[1]	1.09[1]	115.78
BEV UK Grid Charged - Tesla M3	58.70[1]	41.50[4,7]	0.00	10.10[1]	1.09[1]	111.39
BEV UK Grid Charged - Fiat 500 EV	58.70[1]	39.72[5,7]	0.00	10.10[1]	1.09[1]	109.60
FCEV - Toyota Mirai [Steam methane reformation with carbon capture]	58.70[1]	0.00[3]	20.54[2,3]	10.10[1]	1.09[1]	90.43
BEV Total GEL Mix - Average	58.70[1]	16.75[1,8]	0.00	10.10[1]	1.09[1]	86.63
BEV Total Gel Mix - Tesla M3	58.70[1]	15.15[4,8]	0.00	10.10[1]	1.09[1]	85.03
BEV Total GEL Mix - Fiat 500 EV	58.70[1]	14.49[1,8]	0.00	10.10[1]	1.09[1]	84.38
BEV GEL Imports Only - Average	58.70[1]	2.02[1,8]	0.00	10.10[1]	1.09[1]	71.90
BEV GEL Imports Only - Tesla M3	58.70[1]	1.83[4,8]	0.00	10.10[1]	1.09[1]	71.71
BEV GEL Imports Only - Fiat 500 EV	58.70[1]	1.75[5,8]	0.00	10.10[1]	1.09[1]	71.63
FCEV - Toyota Mirai [Renewable electrolysis]	58.70[1]	0.00[3]	0.10[2,3]	10.10[1]	1.09[1]	69.98
BEV Renewable Charged (0 gCO2e/kWh) – Average	58.70[1]	0.00[1]	0.00	10.10[1]	1.09[1]	69.88

HVO - Average (RD100)	33.15[1]	1.85[1,7]	14.48[1]	10.10[1]	-3.26[1]	56.32
E-Bike - UK Grid Charged	10.90[2]	1.92[6,7]	0.00	0.93[2]	0.00[2]	13.75
E-Bike - Total GEL Mix	10.90[2]	0.70[6,8]	0.00	0.93[2]	0.00[2]	12.53
E-Bike - GEL Imports Only	10.90[2]	0.08[6,8]	0.00	0.93[2]	0.00[2]	11.91
E-Bike - Renewable	10.90[2]	0.00[6]	0.00	0.93[2]	0.00[2]	11.83

Production

[1] All vehicles production emissions: https://www.mdpi.com/2071-1050/12/22/9390/htm

[2] All e-bike production emissions: https://www.polytechnique-insights.com/en/columns/energy/what-is-the-carbon-footprint-of-electric-bikes/%20e-bikes/

Operation - Efficiencies

[1] https://www.mdpi.com/2071-1050/12/22/9390/htm

[2] https://www.cars-data.com/en/bmw-318d-specs/95188/tech

[3] https://www.zemo.org.uk/assets/reports/Zemo_Hydrogen_Vehicle_Well-to Wheel_GHG_and_Energy_Study_2021.pdf

[4] https://ev-database.org/car/1060/Tesla-Model-3-Standard-Range

[5] https://www.parkers.co.uk/fiat/500-electric/specs/

[6] https://www.polytechnique-insights.com/en/columns/energy/what-is-the-carbon-footprint-of-electric-bikes/%20e-bikes/

Operation - Emission factors for fuel use

[7] https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2023

[8] GEL Corporate GHG Emissions 2023_v1.11_18032024_FINAL

WTT

[1] All ICE WTT emissions: https://www.mdpi.com/2071-1050/12/22/9390/htm

[2] https://www.zemo.org.uk/assets/reports/Zemo_Hydrogen_Vehicle_Well-to Wheel_GHG_and_Energy_Study_2021.pdf

[3] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1011283/UK-Hydrogen-Strategy_web.pdf

To note: WTT for BEVs and E-Bikes included in the operation

Maintenance

[1] All vehicles maintenance emissions: https://www.mdpi.com/2071-1050/12/22/9390/htm

[2] All e-bike maintenance emissions: https://www.polytechnique-insights.com/en/columns/energy/what-is-the-carbon-footprint-of-electric-bikes/%20e-bikes/

EOL

[1] All vehicles EOL emissions: https://www.mdpi.com/2071-1050/12/22/9390/htm

[2] All e-bike EOL emissions: https://www.polytechnique-insights.com/en/columns/energy/what-is-the-carbon-footprint-of-electric-bikes/%20e-bikes/

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