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PROJECT

REPORT

Power Requirements for Charging Electric Medium- and Heavy-Duty Vehicles across Luxembourg

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Document Revisions

No.	Details	Date
1	Initial release	08/09/2023
2	Updated figure 6	08/11/2023

Contents

Abbreviations

BEV	Battery Electric Vehicle
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
MHDV	Medium- and Heavy-Duty Vehicles
MoU	Memorandum of Understanding

Executive Summary

Cenex and FIER were commissioned by the Luxembourgish Government in 2022 to support the development of a policy framework and incentive scheme to decarbonise Medium- and Heavy-Duty Vehicles (MHDV) across the country with the aim of reducing the environmental impact of the transport sector by 50% by 2030 (compared to a 2019 baseline).

The ‘Energy Transition in Luxembourg’s Logistics Sector’ report produced by Cenex and FIER in May 2023 outlines the commercial offering for low and zero emission MHDVs in Luxembourg and provides a summary of the financial incentive schemes offered by other European countries.

This report incorporates learnings from the previous work to additionally assess the need for electric vehicle charging infrastructure across Luxembourg and to better understand the additional power requirements at an individual site level.

Methodology

We identified the key truck locations and counted the number and type of trucks at these locations using satellite and aerial images from 2020 and 2021. Using the assumptions and uptake scenarios from the ‘Energy Transition in Luxembourg’s Logistics Sector’ report we determined the average daily energy consumption in low, medium, and high scenarios (low to high daily mileages and low to high uptake). Finally, we used information from a selection of fleet operators to determine how long trucks typically spend at sites and therefore how much time might be available for charging battery electric trucks each day (to convert the average daily energy consumption to site power requirements).

Limitations

In total, 977 rigid trucks and 1,116 tractor units have been identified using a combination of satellite and aerial images, this represents 22% of the vehicles registered in Luxembourg (18% of the rigid trucks and 26% of the tractor units). Reasons for the lower number of trucks counted may be due to a combination of vehicles being away from depots, not all depot locations being identified, and non logistic locations such as Council depots and construction sites not being included in the fleet depot locations. The satellite imagery was considered a low case, and as a comparison case we also used vehicle registration data provided by the Luxembourgish Government to give a maximum power that could be required to support the transition to battery electric MHDVs in each Canton.

Key Conclusions

Average Daily Energy Consumption and Charging Power

- The average daily energy requirement of battery electric trucks in Luxembourg ranges from 28 kWh for N2 Rigid Trucks, 212 kWh for N3 Rigid Trucks, and 569 kWh for N3 Tractor Units (including charging efficiency).
- MHDVs in Luxembourg are typically away from depot for 7 to 18 hours a day, leaving 6 to 17 hours of downtime a day that could be used for charging battery electric vehicles.
- The average daily charging power of battery electric trucks in Luxembourg ranges from 2 kW for N2 Rigid Trucks, 18 kW for N3 Rigid Trucks, and 52 kW for N3 Tractor Units but could be as high as 95 kW for a high mileage tractor unit or could peak at 22-250 kW if vehicles are charged at full power according to the maximum charging capabilities of the vehicle.

Truck Counts and EV Charging Infrastructure Requirements by Location Using Satellite / Aerial Imagery Data

- It is possible to reliably identify the different types of truck when they are on site, and this can be a good method for assessing individual sites if more suitable data does not exist (e.g. confirmation of the exact number of vehicles from the fleet or site owner).
- Care should be taken to ensure that the images used are representative of the site at full occupancy and it is also advantageous to use more images over time to get a better understanding of the total number of vehicles at a specific location.

- Most of the trucks that have been identified through satellite / aerial imagery are in Esch-sur-Alzette (890 vehicles, 43% of the total), Luxembourg (469 vehicles, 22% of the total), and Capellen (213 vehicles, 10% of the total) in the South West of Luxembourg. Very few trucks have been identified in the North of Luxembourg.
- Based on the satellite / aerial imagery in 2040, the top four locations identified could require between:
    - 110 to 190 battery electric trucks each.
    - 44 MWh to 96 MWh of energy per day for charging battery electric trucks.
    - 17 MW to 41 MW of additional power for charging battery electric trucks, reducing to 4 MW to 9 MW by using hardware or software-based load management systems.
- On average, using a load management system reduces the additional power required by 77% to 0.24 MW to 1.7 MW with a maximum of 8.7 MW.

Vehicle Registration Data and EV Charging Infrastructure Requirements by Canton

- Using truck registration data, by 2040 there are forecast to be anywhere between 8,589 and 11,490 battery electric MHDVs registered in Luxembourg. This would result in an average daily energy consumption of between 2,932 MWh and 3,920 MWh and an additional power requirement of 261 MW to 1,407 MW.
- Tractor units only account for 44% of the vehicles but 73% of the daily energy consumption and 75% of the additional power required. The uptake of battery electric tractor units, the amount of charging done in Luxembourg, and the wide scale adoption of hardware or software-based load management systems are the main factors in determining the overall EV charging infrastructure needs for MHDVs in Luxembourg.
- If vehicles are based where they are registered, then each Canton could require between:
    - 98 and 3,322 battery electric trucks each.
    - 33 MWh to 1,123 MWh of energy per day for charging battery electric trucks.
    - 3 MW to 404 MW of additional power for charging battery electric trucks.

1 Introduction

Cenex and FIER were commissioned by the Luxembourgish Government in 2022 to support the development of a policy framework and incentive scheme to decarbonise Medium- and Heavy-Duty Vehicles (MHDV) across the country with the aim of reducing the environmental impact of the transport sector by 50% by 2030 (compared to a 2019 baseline).

The 'Energy Transition in Luxembourg's Logistics Sector' report produced by Cenex and FIER in May 2023 outlines the commercial offering for low and zero emission MHDVs in Luxembourg and provides a summary of the financial incentive schemes offered by other European countries.

1.1 Purpose

This report incorporates learnings from the previous work to additionally assess the need for electric vehicle (EV) charging infrastructure across Luxembourg and to better understand the additional power requirements at an individual site level.

The purpose of the report is to provide further insights into the following:

- A broader understanding of power requirements for different truck locations across Luxembourg.
- Assessment of future electricity grid demands as the number of battery electric trucks increases.
- Development of a relationship between the number of battery electric trucks at a location and the additional power required for charging electric vehicles.

Vehicle registration data is available for Luxembourg but it is not guaranteed that vehicles are based where they are registered. As such Cenex has also engaged with Geospatial Insights to use machine learning to automatically detect, count, and classify different types of trucks at a selection of key locations.

2 Methodology

Figure 1 shows the overall methodology used to model the energy and power requirements of battery electric MHDVs at each of the locations studied.

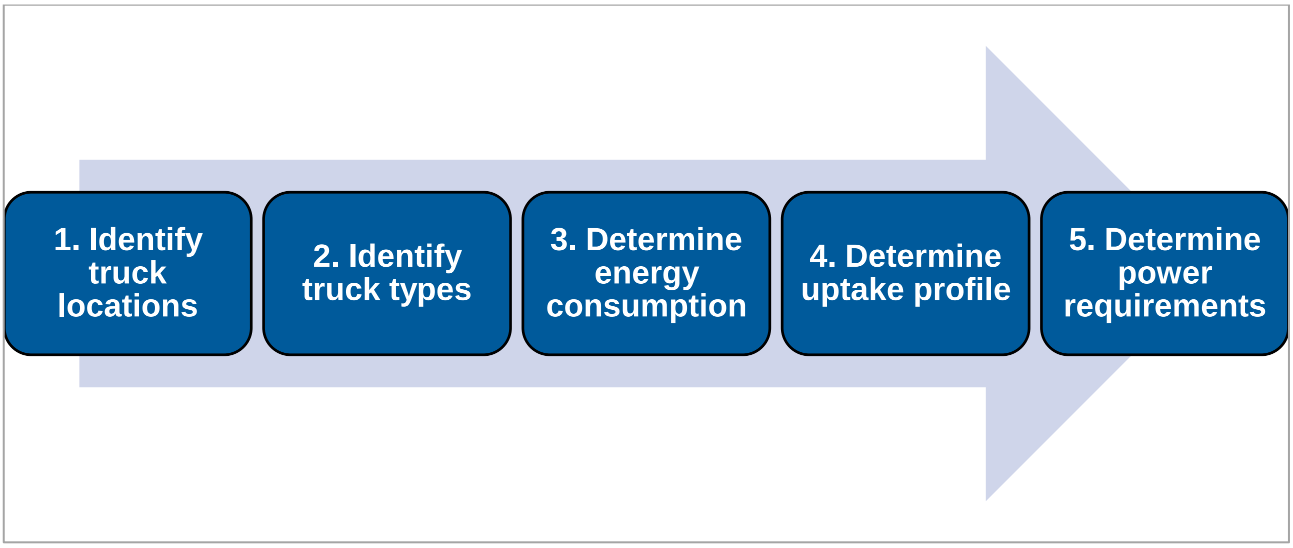


Figure 1 – Summary of Methodology

Firstly, we identified the key truck locations and counted the number and type of truck using satellite and aerial images from 2020 and 2021.

Next, we used the assumptions and uptake scenarios from the ‘Energy Transition in Luxembourg’s Logistics Sector’ report to determine the average daily energy consumption in low, medium, and high scenarios (low to high daily mileages and low to high uptake).

Finally, we used information from a selection of fleet operators to determine how long trucks typically spend at sites and therefore how much time might be available for charging battery electric trucks each day (to convert the average daily energy consumption to power).

2.1 Identify Truck Locations

Truck locations were identified using the following three data sources:

- Locations of major industrial zones provided by the Luxembourgish Government.
- Locations identified by Fraunhofer ISI, on behalf of the European Automobile Manufacturers’ Association, based on GPS data from 400,000 trucks in operation throughout Europe from seven different truck manufacturers[1] (6% of the 6.4 million MHDVs in the European Union).
- Responses to survey results in the MHDV project.

Between these datasets we identified nearly 100 unique truck locations. Where several areas overlap each other we have combined them into a single location. As a result, 50 consolidated locations have been included in this study.

2.2 Identify Truck Types

Geospatial Insights undertook two counts of trucks at the identified locations.

To provide best coverage, the first detection was undertaken using satellite images from March and April 2020 during the COVID lockdown (covering ~65% of the truck locations) and aerial images from various dates in 2020 provided by the Luxembourgish Government (covering the remaining locations).

[1] Interactive maps – Electric trucks: stop locations, western Europe - ACEA - European Automobile Manufacturers' Association

A second detection was undertaken using aerial images from various dates in 2021 (covering 100% of locations) and the maximum number of vehicles counted across all images was taken as the baseline number of trucks at each location.

Figure 2 shows an example of how trucks have been identified at some of the largest sites in Luxembourg.

Figure 2 - Identifying Truck Types

For each truck Geospatial Insights also determined the length of the vehicle and whether it was a cab only or a truck / trailer combination. Trucks were then categorised by length as follows:

- 4.5 to 12 metres (truck / trailer combination) = Rigid Truck
- 4.5 to 12 metres (cab only) = Tractor Unit, Over 12 metres = Tractor Unit

Vans and other vehicles that are less than 4.5 metres in length have been excluded from the counts, this includes large vans up to 7.5 tonnes gross vehicle weight that are categorised as N2 vehicles by the European Union (vehicles used for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes).

2.3 Determine Energy Consumption

Table 1 shows the assumptions that have been used to calculate the average daily energy consumption based on the median annual mileage for each type of truck. The energy consumption factors (kWh / km) and daily mileages have been taken directly from the 'Energy Transition in Luxembourg's Logistics Sector' report.

Low and high energy / power scenarios have also been developed; these use the 10th and 90th percentiles for annual mileage and can be found in the appendix.

Table 1 - Average Daily Energy Consumption (Median Annual Mileage)

Medium Energy Consumption and Power Scenario	N2 Rigid	N3 Rigid	N3 Tractor
Use Case	Urban	Regional	Long Haul
Energy Consumption (kWh / km)	0.4	1.32	1.65
Daily Mileage (km)	60	140	365
Typical Battery Electric Vehicle Range (km)	170	250	300
Average Daily Energy Consumption (kWh)	24	185	602
Depot Charging (%)	100%	100%	82%
Average Daily Charging Requirement (kWh)	**28**	**212**	**569**

This shows that the average daily energy consumption is 28 kWh for a N2 Rigid Truck, 212 kWh for a N3 Rigid Truck and 569 kWh for a N3 Tractor Unit. This assumes that only the first full charge occurs at the depot and charging efficiency is 87% based on previous Cenex research.

For example, an N3 Tractor Unit does 365 km a day on average and would consume 602 kWh of electricity to drive the vehicle. The typical real-world range of these vehicles today is 300 km so 82% of the energy would be supplied at the depot (300 km / 365 km = 82%, 602 kWh x 82% = 494 kWh). With an assumed charging efficiency of 87% this increases to 569 kWh that must be supplied by the depot (494 kWh / 87% = 567 kWh including rounding).

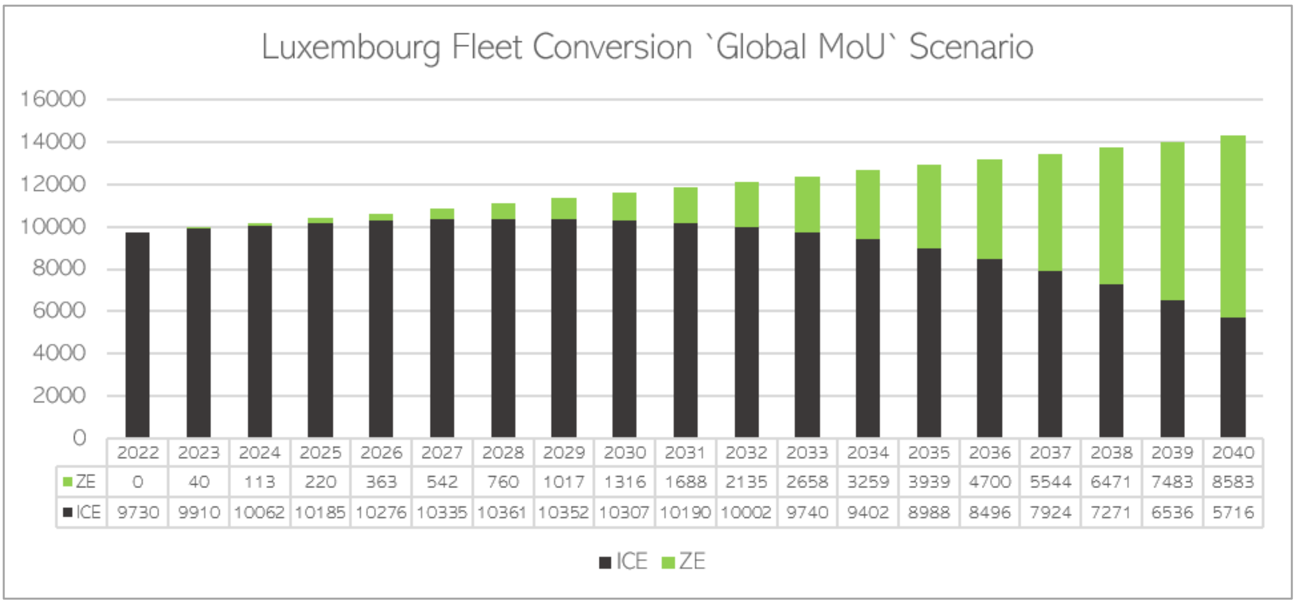
2.4 Determine Uptake Profile

Figure 3 shows the two uptake scenarios that have been modelled. The uptake scenarios were taken directly from the 'Energy Transition in Luxembourg's Logistics Sector' report.

In the 'Global Memorandum of Understanding (MoU)' scenario leading countries, including Luxembourg, have committed to a target for all new MHDVs sold to be zero emission vehicles by 2040 with an interim target of 30% by 2030[2].

In the 'German' scenario there is a linear growth based on the target of 33% of the fleet being zero emission vehicles by 2030.

[2] Global Commercial Drive To Zero Program — Global Memorandum of Understanding on Zero-emission Medium- and Heavy-duty Vehicles (globaldrivetozero.org)



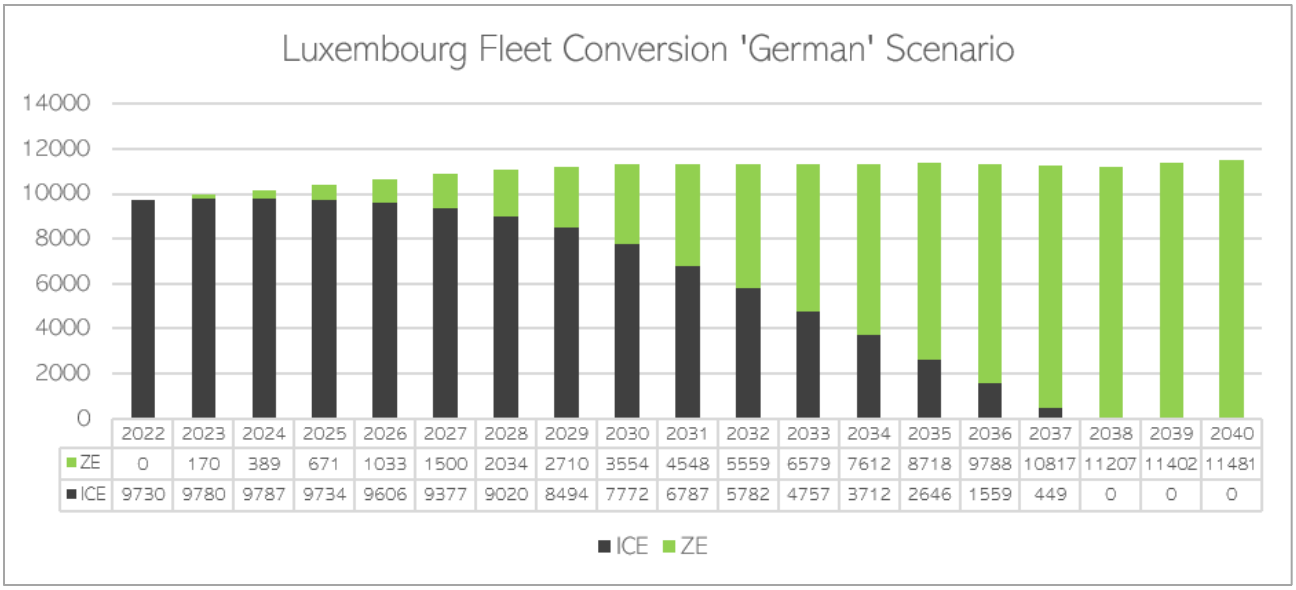


Figure 3 – Low (Global MoU) and High (German) Uptake Scenarios

To apply the uptake scenarios, we have calculated the percentage difference in battery electric vehicles each year compared the number of diesel trucks in 2022 (9,730 vehicles).

We have then applied these percentage differences to the number of trucks that have been identified at each location.

2.5 Determine Power Requirements

To determine the charging power requirements, a selection of Luxembourgish fleets were surveyed to understand the typical amount of time available in a day for charging battery electric MHDVs.

Table 2 shows how power has been calculated in the medium energy consumption and power scenario. Based on the survey results a medium time available for charging is 12 hours which is representative of a 03:00 to 15:00 shift in a logistics hub (or a similar length shift at a depot).

Low and high energy / power scenarios have also been developed; these use the minimum dwell time (an 18 hour shift with 6 hours dwell time e.g. a 03:00 to 21:00 shift in a warehouse) and maximum dwell time (a 7 hour shift with 17 hours dwell time e.g. a 07:00 to 14:00 shift in a logistics hub) from the survey and can also be found in the appendix.

Table 2 - Average Daily Charging Power Requirement (Median Annual Mileage)

Medium Energy Consumption and Power Scenario	N2 Rigid	N3 Rigid	N3 Tractor
Use Case	Urban	Regional	Long Haul
Energy Consumption (kWh / km)	0.4	1.32	1.65
Daily Mileage (km)	60	140	365
Typical Battery Electric Vehicle Range (km)	170	250	300
Average Daily Energy Consumption (kWh)	24	185	602
Depot Charging (%)	100%	100%	82%
Average Daily Charging Requirement (kWh)	**28**	**212**	**569**
Time Available for Charging (hours)	12.0	12.0	11.0
Average Charging Power - Load Managed (kW)	**2**	**18**	**52**
Maximum AC Charging Power - Unmanaged (kW)	22	22	43
Maximum DC Charging Power - Unmanaged (kW)	80	150	250
Maximum Charging Power Required - Unmanaged (kW)	**22**	**22**	**250**

This shows that the average daily charging power is 2 kW for a N2 Rigid Truck, 18 kW for a N3 Rigid Truck and 52 kW for a N3 Tractor Unit (assuming that the charging power is managed over the total time available for charging using a hardware or software-based load management system).

If the vehicles are instead charged at full power this increases to 22-250 kW depending on the maximum amount of power required to charge the vehicle in the time available and the AC or DC charging capabilities of the vehicle.

2.6 Limitations

The obvious limitation of this approach is that we can only identify the number of trucks at each location at the time the images were captured, and a proportion of the vehicles will be on the roads at any given time (both in Luxembourg and internationally).

Likewise, whilst we have focused on the main industrial areas and best available data for where trucks operate in Europe it is likely that we haven't identified all possible truck locations in Luxembourg.

Due to these limitations, we would expect the trucks that have been identified to represent the absolute minimum number of trucks and locations that could require electric vehicle charging infrastructure in the future.

In addition to the known limitations around identifying truck locations, the following considerations should be made when reviewing the findings of this report:

- The analysis is limited to two vehicle types only (rigid trucks and tractor units), it is not possible to provide a more detailed breakdown of truck types.
- The same average energy consumption factors have been applied to all vehicles and locations in different scenarios. The actual energy consumption will vary by use case and duty cycle.
- Public charging has not been considered and it is assumed that only the first full charge occurs at the depot / site.

This means that the analysis is most representative on a regional and national basis rather than on a site-by-site basis.

As such, the main outputs of this report are highlighting the areas of Luxembourg that could require the most additional power for charging battery electric trucks and determining the relationship between the number and type of trucks and the amount of additional power required.

3 Results

This section presents the key results of the analysis and is reported in two parts.

Firstly, we discuss the EV charging infrastructure requirements for the locations and trucks that have been identified using the methodology described previously. Secondly, we compare these results to vehicle registration data by Canton to estimate the additional power that could also be required if trucks are based where they are registered.

The model used for the calculations has also been made available for update and further analysis should more accurate data on truck locations become available in the future.

3.1 EV Charging Infrastructure Requirements by Location

This section is based on the locations and trucks that have been identified by Cenex and Geospatial Insights. There is no scaling to account for any locations or trucks that we may not have identified, and the results therefore represent the absolute minimum power that could be required to support the transition to battery electric MHDVs at various locations across Luxembourg.

Table 3 shows the total number of rigid trucks and tractor units that have been counted compared to the number of vehicles registered in Luxembourg.

Table 3 - Number of Trucks Identified

	Rigid Trucks	Tractor Units	Total
Number of Trucks Identified	977	1,116	2,093
Number of Trucks Registered	5,416	4,315	9,730
% of Trucks Identified	18%	26%	22%

In total, 977 rigid trucks and 1,116 tractor units have been identified using a combination of satellite and aerial images, this represents just 22% of the vehicles registered in Luxembourg (18% of the rigid trucks and 26% of the tractor units).

Based on a visual inspection of larger individual sites it is apparent that whilst the algorithm can successfully identify trucks when they are on site as many as 40-50% of the vehicles can be off-site at any given time (based on two sites only where we have compared the number of trucks counted to the survey responses).

Likewise, we have also managed to identify a few truck locations from industries like construction and waste collection that have not been identified or included in the analysis. As such care should be taken when interpreting the results from individual sites and it is suggested that the images are reviewed in detail to make sure that the number of vehicles counted looks representative and if better information is available it is updated in the provided spreadsheet model.

Figure 4 shows the forecast number of battery electric MHDVs at each location in 2040 based on the Global MoU scenario (the baseline or low uptake scenario).

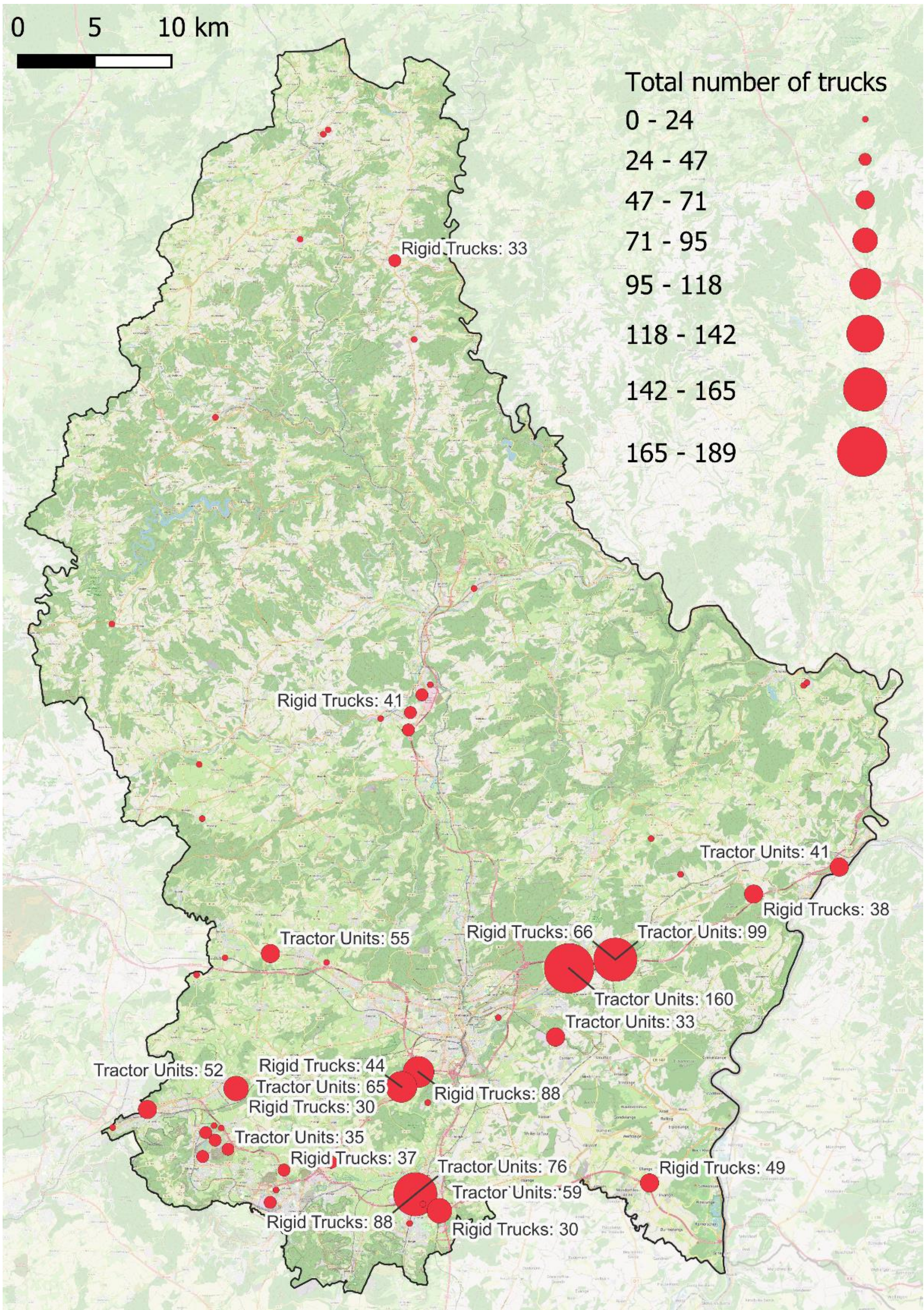


Figure 4 - Number of Battery Electric MHDVs by Location in Global MoU Scenario (2040)

This shows that most of the trucks that have been identified are in Esch-sur-Alzette (890 vehicles, 43% of the total), Luxembourg (469 vehicles, 22% of the total), and Capellen (213 vehicles, 10% of the total) in the South West of Luxembourg. Very few trucks have been identified in the North of Luxembourg.

In 2040, half of the locations identified could have at least 22 battery electric MHDVs with the top four locations having between 110 and 190 vehicles each.

Figure 5 shows the amount of energy required per day to charge battery electric MHDVs at each location in 2040 based on the median annual / daily mileage (the medium energy consumption scenario).

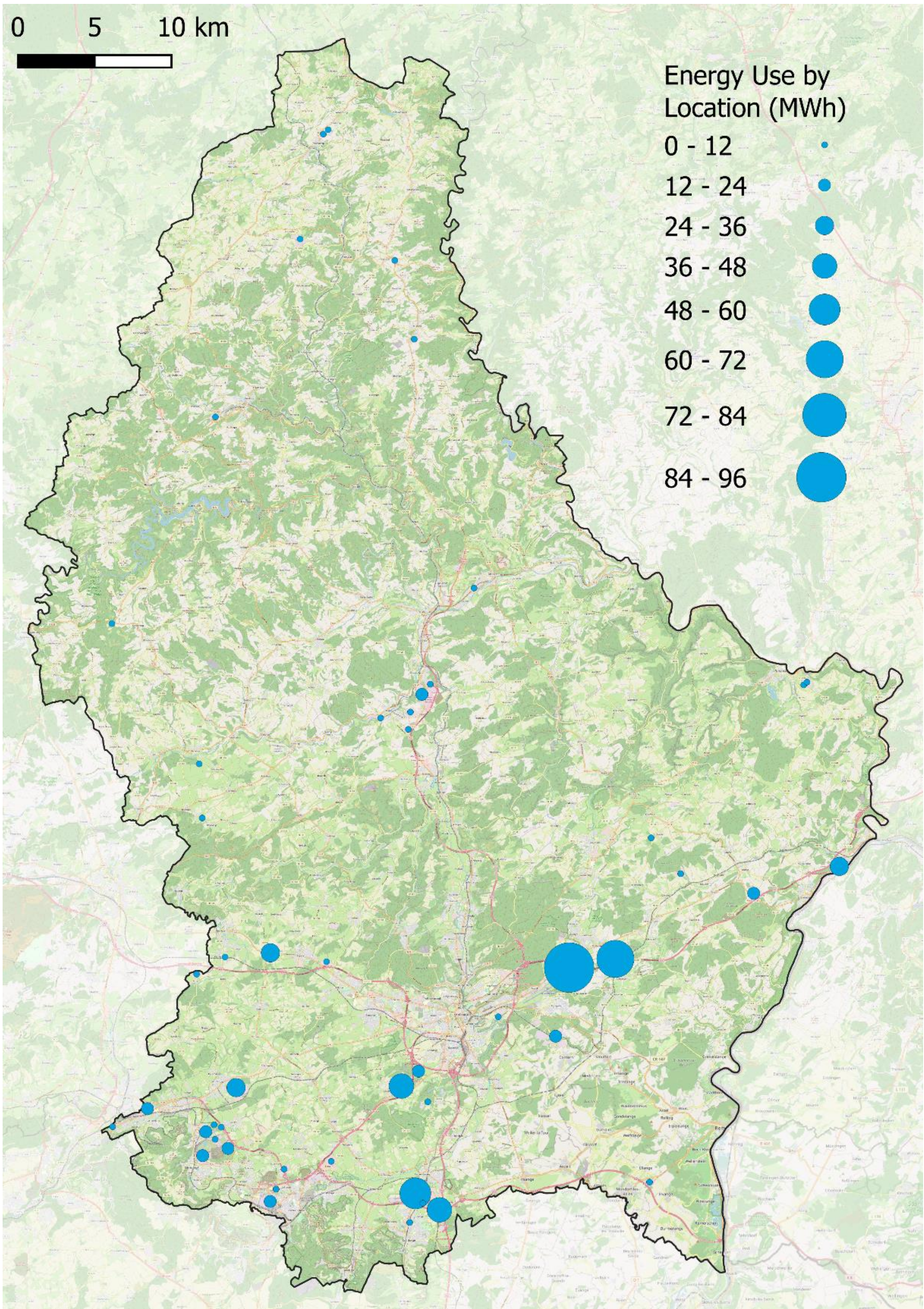


Figure 5 – Daily Energy Consumption for Battery Electric MHDVs by Location in Global MoU Scenario (2040)

Assuming that rigid trucks are used for 250 days a year and tractor units are used for 300 days a year, the vehicles identified above could consume in the region of 203 GWh of electricity a year by 2040 (an average of 14 MWh per location per day).

In 2040, half of the locations identified could require at least 7.8 MWh of energy for charging battery electric MHDVs with the top four locations requiring between 44 MWh and 96 MWh each.

Figure 6 shows the amount of power required to charge battery electric MHDVs at each location in 2040 based on the median dwell times with and without the use of load management systems (low and high power scenarios).

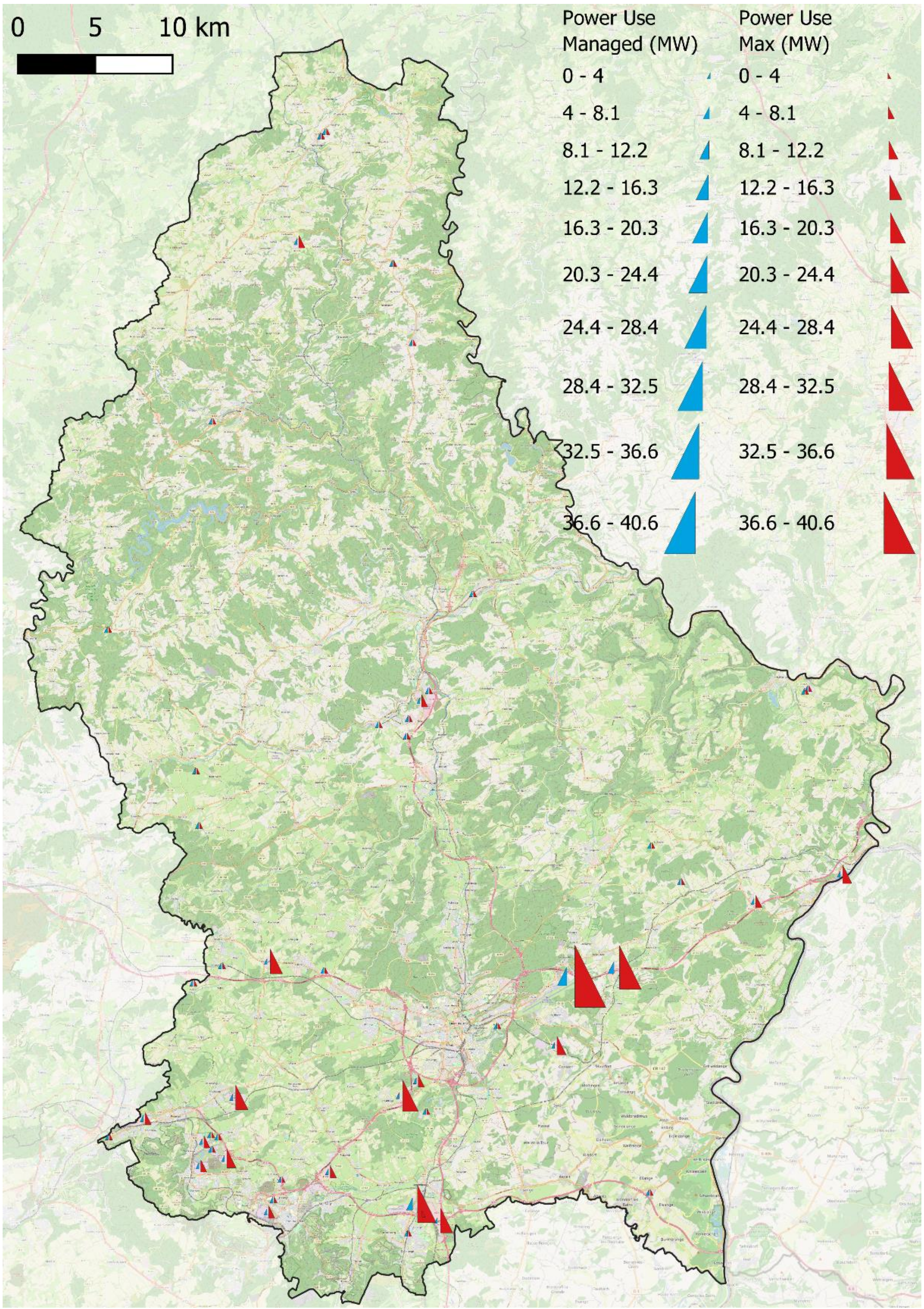


Figure 6 – Additional Power Required for Battery Electric MHDVs by Location in Global MoU Scenario (2040)

This shows that without load management systems the locations studied could typically require between 0.8 MW and 6.3 MW of additional power to charge battery electric MHDVs (25th to 75th percentile) with a maximum of nearly 41 MW to charge 189 battery electric vehicles at the largest location. It is worth noting that some of the locations studied are large industrial areas that could have multiple grid connections so this load could be distributed over several different power supplies.

On average, using a load management system reduces the additional power required by 77% to 0.24 MW to 1.7 MW with a maximum of 8.7 MW.

3.2 EV Charging Infrastructure Requirements by Canton

This section uses vehicle registration data provided by the Luxembourgish Government to scale the results from the previous section to give a realistic maximum power that could be required to support the transition to battery electric MHDVs in each Canton.

Although we can't guarantee that vehicles are based in the same Canton that they are registered in it is the best available data to provide a regional and national view of the potential vehicle uptake, energy, and power requirements.

3.2.1 Luxembourg Summary – 2025 to 2040

Figure 7 shows the number of battery electric trucks (top row), daily energy consumption (middle row), and additional power (bottom row) required to charge battery electric MHDVs in the Global MoU scenario (left column) and German scenario (right column) with and without load management respectively.

This represents the best- and worst-case scenarios that have been modelled and is intended to show the potential range of values between 2025 and 2040 in five-year intervals.

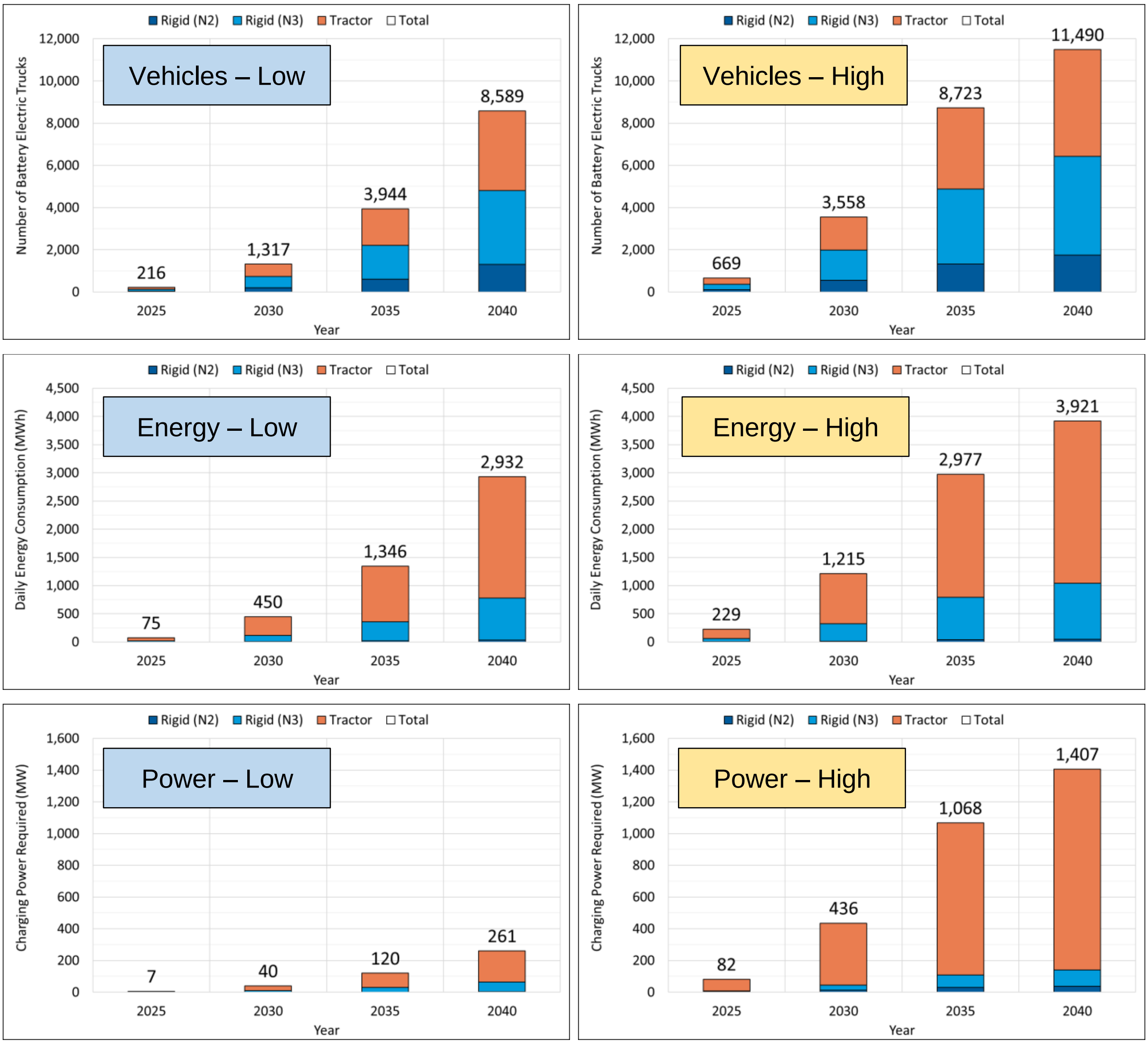


Figure 7 – EV Charging Infrastructure Requirements for MHDVs (Luxembourg 2025 to 2040)

The purpose of these charts is to show the potential growth in EV charging infrastructure needs over time but there are also some useful conclusions relating to the sensitivities of the various parameters.

Firstly, the ratio of the number of vehicles and energy consumption between the Global MoU and German scenarios is approximately 1.34 by 2040. Whilst significant, there is a much larger difference in the low and high power scenarios with the high power scenario 5.4 times greater than the low power scenario if all vehicles are charged at full power.

Additionally, although tractor units only account for 44% of the vehicles they account for 73% of the daily energy consumption and 75% of the additional power required.

The uptake of battery electric tractor units, the amount of charging done in Luxembourg, and the wide scale adoption of hardware or software-based load management systems are therefore the main factors in determining the overall EV charging infrastructure needs for MHDVs in Luxembourg.

3.2.2 Summary by Canton – 2040

Figure 8 shows the number of battery electric MHDVs in the Global MoU uptake scenario (left) and German uptake scenario (right) in 2040 based on the number of vehicles registered in each Canton.

Both charts are on the same scale and the same uptake rates have been applied to each Canton, hence the maps look similar.

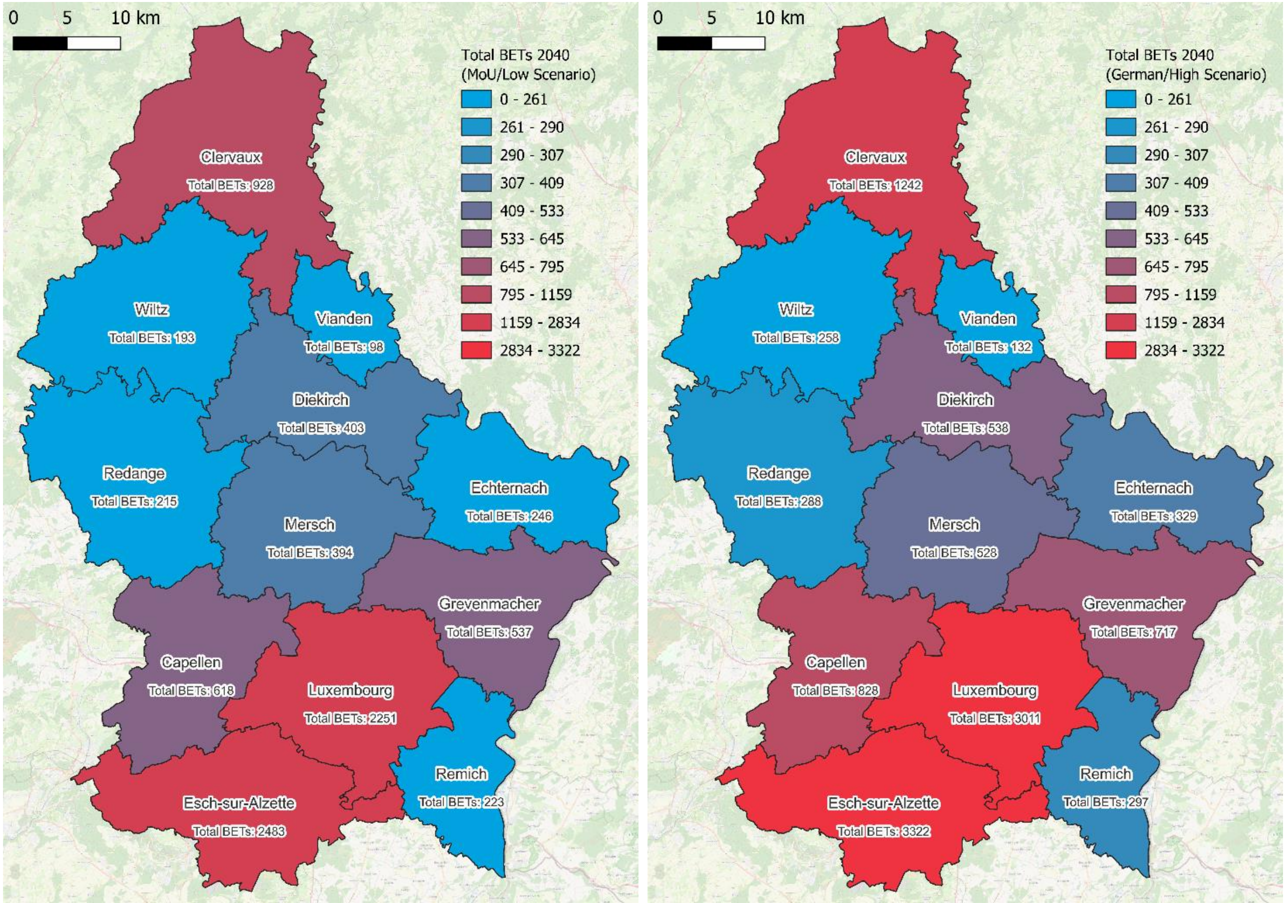


Figure 8 – Number of Battery Electric MHDVs in 2040 based on Registration Data (Global MoU and German Scenario)

The highest number of battery electric MHDVs are forecast in the German scenario in Esch-sur-Alzette (3,322 vehicles), Luxembourg (3,011 vehicles), and Clervaux (1,242 vehicles).

Figure 9 shows the corresponding daily energy consumption based on the medium energy consumption scenario.

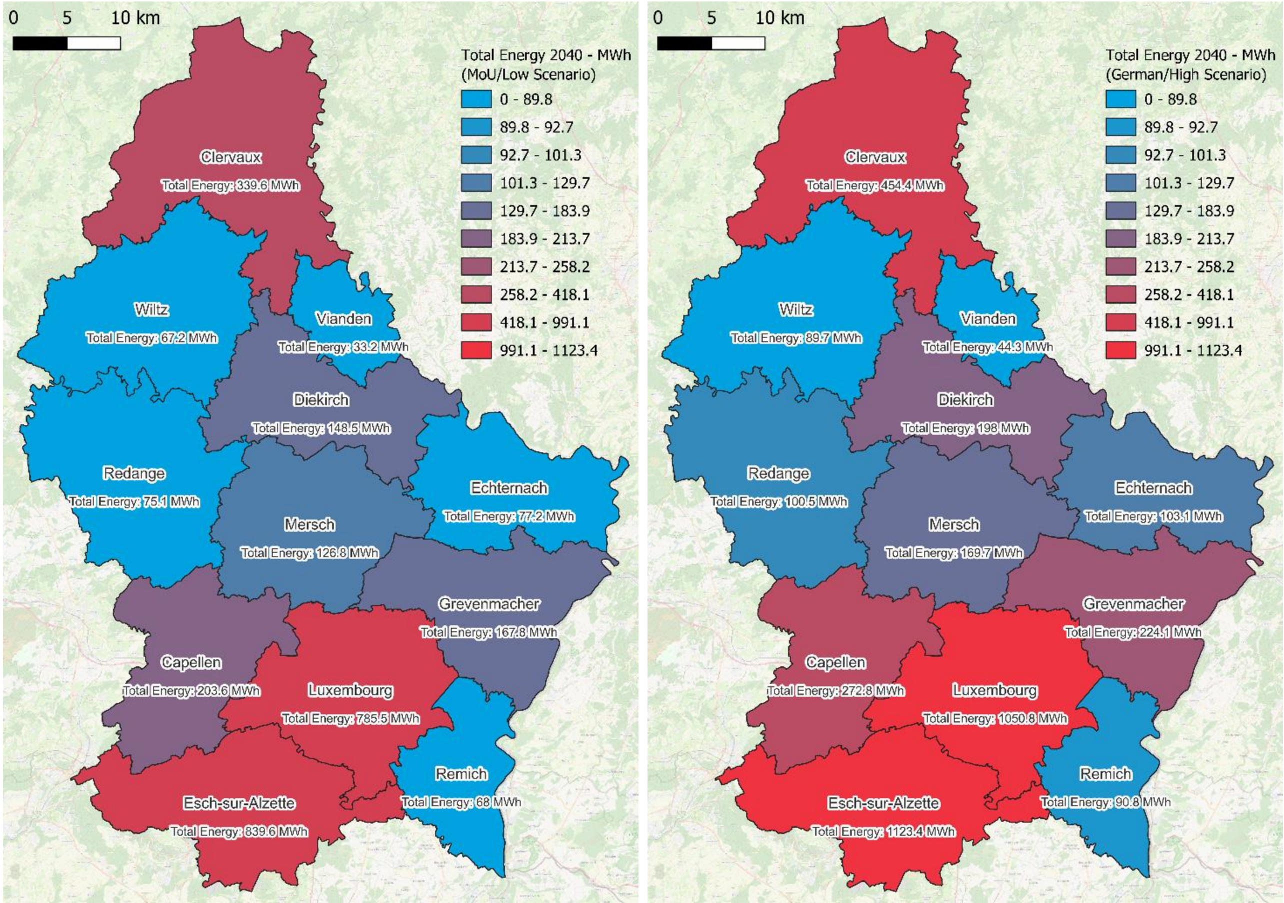


Figure 9 – Daily Energy Consumption in 2040 based on Registration Data (Global MoU and German Scenario)

If vehicles are based in the Canton that they are registered in, the average daily energy consumption in 2040 could range from 33 MWh in Vianden to 1,123 MWh in Esch-sur-Alzette.

Figure 10 shows the amount of additional power required in a low scenario (Global MoU uptake with load management) and high scenario (German uptake without load management).

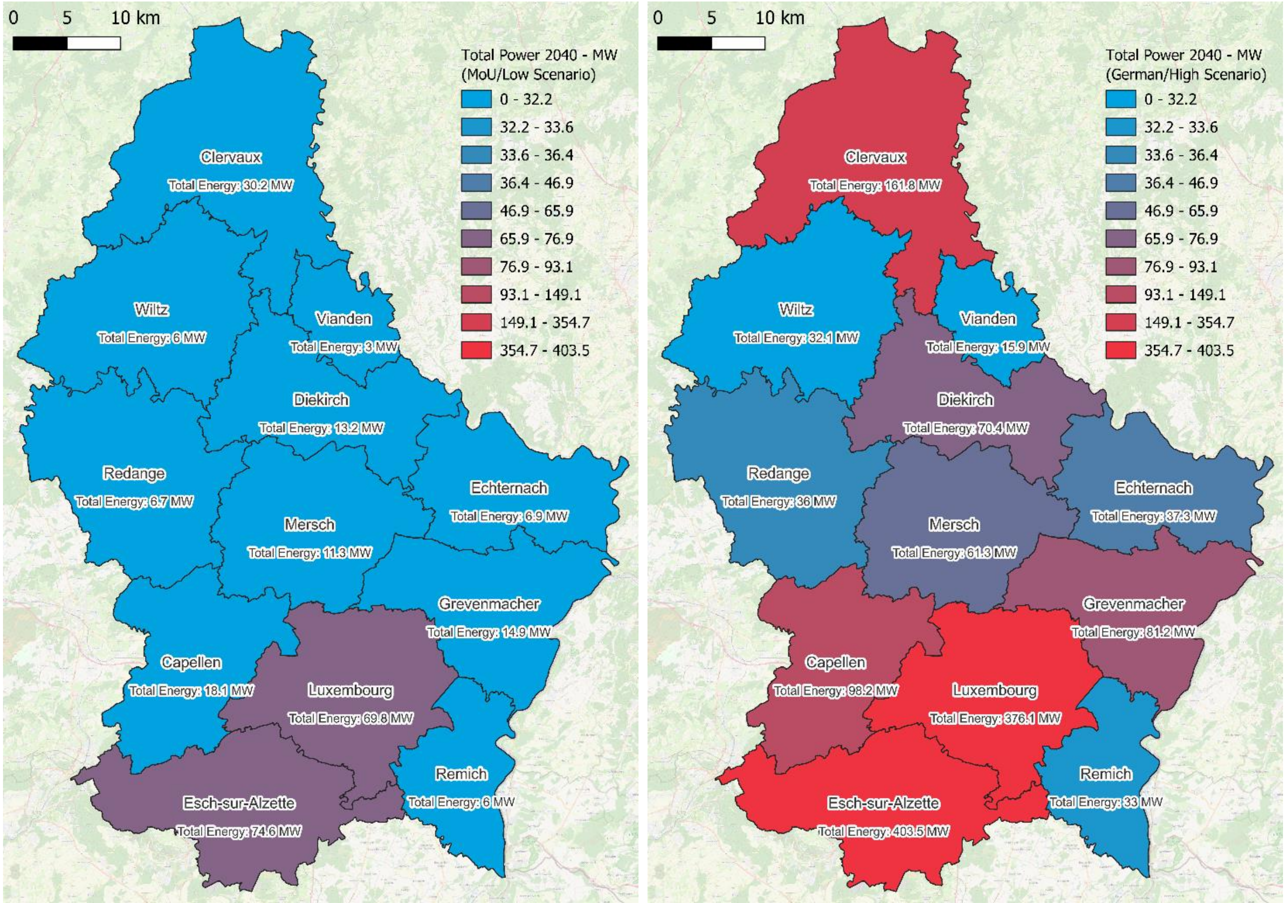


Figure 10 – Additional Power Required in 2040 based on Registration Data (Low and High Scenarios)

If vehicles are based in the Canton that they are registered in, the additional power required in 2040 could range from 3 MW in Vianden to 404 MW in Esch-sur-Alzette.

This analysis gives a realistic minimum and maximum power that could be required by Canton, but it will be important to better understand where vehicles are actually based with Clervaux an obvious example of where the satellite / aerial imagery and vehicle registration data clearly diverge.

4 Conclusions

Based on the analysis presented in this report the following conclusions can be made.

Average Daily Energy Consumption and Charging Power

- The average daily energy requirement of battery electric trucks in Luxembourg ranges from 28 kWh for N2 Rigid Trucks, 212 kWh for N3 Rigid Trucks, and 569 kWh for N3 Tractor Units (including charging efficiency).
- MHDVs in Luxembourg are typically away from depot for 7 to 18 hours a day, leaving 6 to 17 hours of downtime a day that could be used for charging battery electric vehicles.
- The average daily charging power of battery electric trucks in Luxembourg ranges from 2 kW for N2 Rigid Trucks, 18 kW for N3 Rigid Trucks, and 52 kW for N3 Tractor Units but could be as high as 95 kW for a high mileage tractor unit or could peak at 22-250 kW if vehicles are charged at full power according to the maximum charging capabilities of the vehicle.

Truck Counts and EV Charging Infrastructure Requirements by Location

- In total, 977 rigid trucks and 1,116 tractor units have been identified using a combination of satellite and aerial images, this represents just 22% of the vehicles registered in Luxembourg (18% of the rigid trucks and 26% of the tractor units).
- It is possible to reliably identify the different types of truck when they are on site, and this can be a good method for assessing individual sites if more suitable data does not exist (e.g. confirmation of the exact number of vehicles from the fleet or site owner).
- Care should be taken to ensure that the images used are representative of the site at full occupancy and it is also advantageous to use more images over time to get a better understanding of the total number of vehicles at a specific location.
- Most of the trucks that have been identified are in Esch-sur-Alzette (890 vehicles, 43% of the total), Luxembourg (469 vehicles, 22% of the total), and Capellen (213 vehicles, 10% of the total) in the South West of Luxembourg. Very few trucks have been identified in the North of Luxembourg.
- In 2040, the top four locations identified could require between:
    - 110 to 190 battery electric trucks each.
    - 44 MWh to 96 MWh of energy per day for charging battery electric trucks.
    - 17 MW to 41 MW of additional power for charging battery electric trucks, reducing to 4 MW to 9 MW by using hardware or software-based load management systems.

Vehicle Registration Data and EV Charging Infrastructure Requirements by Canton

- By 2040 there are forecast to be anywhere between 8,589 and 11,490 battery electric MHDVs registered in Luxembourg. This would result in an average daily energy consumption of between 2,932 MWh and 3,920 MWh and an additional power requirement of 261 MW to 1,407 MW.
- Tractor units only account for 44% of the vehicles but 73% of the daily energy consumption and 75% of the additional power required. The uptake of battery electric tractor units, the amount of charging done in Luxembourg, and the wide scale adoption of hardware or software-based load management systems are the main factors in determining the overall EV charging infrastructure needs for MHDVs in Luxembourg.
- If vehicles are based where they are registered, then each Canton could require between:
    - 98 and 3,322 battery electric trucks each.
    - 33 MWh to 1,123 MWh of energy per day for charging battery electric trucks.
    - 3 MW to 404 MW of additional power for charging battery electric trucks.

Appendix A – Low and High Power Scenarios

The two tables below show the low and high power scenarios that have also been modelled in addition to the medium scenario discussed in the main report.

Low Energy Consumption and Power Scenario	N2 Rigid	N3 Rigid	N3 Tractor
Use Case	Urban	Regional	Long Haul
Energy Consumption (kWh / km)	0.4	1.32	1.65
Daily Mileage (km)	15	40	160
Typical Battery Electric Vehicle Range (km)	170	250	300
Average Daily Energy Consumption (kWh)	6	53	264
Depot Charging (%)	100%	100%	100%
Average Daily Charging Requirement (kWh)	7	61	303
Time Available for Charging (hours)	14.0	17.0	14.0
Average Charging Power - Load Managed (kW)	0	4	22
Maximum AC Charging Power - Unmanaged (kW)	22	22	43
Maximum DC Charging Power - Unmanaged (kW)	80	150	250
Maximum Charging Power - Unmanaged (kW)	22	22	43

High Energy Consumption and Power Scenario	N2 Rigid	N3 Rigid	N3 Tractor
Use Case	Urban	Regional	Long Haul
Energy Consumption (kWh / km)	0.4	1.32	1.65
Daily Mileage (km)	150	385	460
Typical Battery Electric Vehicle Range (km)	170	250	300
Average Daily Energy Consumption (kWh)	60	508	759
Depot Charging (%)	100%	65%	65%
Average Daily Charging Requirement (kWh)	69	379	569
Time Available for Charging (hours)	8.5	6.0	6.0
Average Charging Power - Load Managed (kW)	8	63	95
Maximum AC Charging Power - Unmanaged (kW)	22	22	43
Maximum DC Charging Power - Unmanaged (kW)	80	150	250
Maximum Charging Power - Unmanaged (kW)	22	150	250

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