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Abstract : Under pressure to reduce greenhouse gas emissions, the global passenger car market is currently experiencing a shift from vehicles powered by internal combustion engines towards hybrid and fully electric models. Through an analysis of registered light-duty vehicles in Quebec, Canada, from 2011 to 2021, this study forecasts the evolving fleet's electricity demand under various electrification scenarios. The data indicates a yearly average fleet growth of 67,276 vehicles and an annual mass increase of 11 kg per vehicle from 2011 to 2021. Based on these trends, our projections estimate an electricity demand of 7.68 TWh in 2030, 17.84 TWh in 2035, and 29.03 TWh if the fleet continues evolving similarly. However, stabilizing the electric vehicle mass at the 2021 level reduces electricity demand by 17.6% in 2040 at a cost of a fleet that's 25.9% lighter.

Impact of the car fleet evolution on electricity demand in Québec.

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Introduction

Canada ranks as the **tenth largest** greenhouse gases (GHG) emitter worldwide [1]. Among Canada's emissions, the **transport sector** alone contributes a **significant 30%** [2]; understanding the impact of decarbonizing the sector is therefore **crucial**.
In Quebec, the transport sector is responsible for **43.3% of GHG emissions** [3]. To address this issue, the **2030 Plan for a Green Economy** announces the goal to reach **2 million electric vehicles** (EVs) on the road by 2030, while phasing out the sales of new fossil-fuel powered cars by 2035 [4].
Our research aims to assess how the **evolution of fleet size and weight** will impact the **electricity demand** in cold climates and how it affects the GHG emissions from internal combustion engine vehicles (ICEVs) and battery electric vehicles (BEVs) in a low carbon electricity mix.

Methodology

Databases from the Société de l'Assurance Automobile du Québec (SAAQ).

- 9,749,916 records of registered light-duty vehicles (LDVs) with 227,368,858 recorded transactions and 1,130,324 entries of vehicles taken off the road from 2011 to 2021.
- Information such as the manufacturer, the model, the fuel type, the vehicle year and the car weight.
- Supplementary information like the category, the fuel consumption and the electricity consumption is gathered from the Fuel Consumption Guide (FCG) from Natural Resources Canada's database [5].

Projected evolution of the EV fleet: scenario definition. We consider three scenarios for the weight evolution of BEVs: the first, business as usual (BAU), in which historical trends in mass increase continues, the second, mass restriction 1 (MR1) where only electric vehicles get heavier by converting the weight from a ICEV to a BEV and a third, mass restriction 2 (MR2) where the average mass is fixed at the 2021 value. In all cases, the growth in the total number of LDV is maintained at the averaged growth from the 2011 to 2021 fleet.
How to project the electricity demand?

1. Compare the mass of an ICEV to its equivalent BEV.
2. Estimate the typical electricity consumption relative to the mass of the BEV.
3. Knowing the number of vehicles, the mileage and the temperature, we project the electricity consumption.

Life-cycle assessment (LCA). As detailed in [6], a vehicle's total CO_2-eq. life-cycle emissions $E_{\text{life,tot}}$ is calculated as

$$E_{\text{life,tot}} = E_{\text{prod,tot}} + E_{\text{util,tot}} + E_{\text{recyc,tot}}$$

where $E_{\text{prod,tot}}$, $E_{\text{util,tot}}$ and $E_{\text{recyc,tot}}$ represent the total production, utilization and recycling emissions, respectively.

Results - Fleet evolution and electricity consumption

Figure 1 presents the weight and number evolution of the LDV fleet from 2011 to 2021. The fleet increases by an average of **67,276 vehicles each year**, with **492,216 new vehicles** added and an average mean mass per vehicle **yearly increase of 11 kg**.

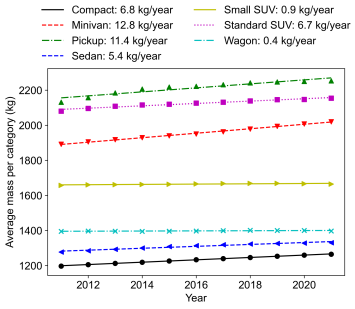

Figure 1: Mean mass per category for ICEVs relative to the year.

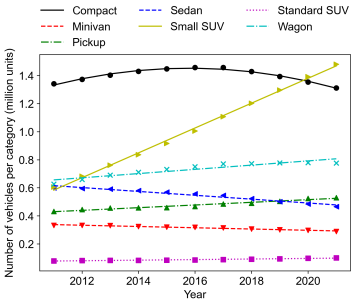

Figure 2: Number of ICEVs per category relative to the year.

Table 1 provides the electricity and power demand of the current automobile fleet as well as three milestones of the electrification. In 2040, the MR1 scenario lowers the power demand by 6.6%, with a fleet 9.6% lighter. For the MR2 scenario, the fleet would be **25.9% lighter** and would lead to a **17.6% decrease in electricity consumption**.

Table 1: Projected electricity demand for three scenarios of fleet evolution.

	Year	2021	2030	2035	2040	Unit
Fleet composition	Number of BEVs	72,199	2,000,000	4,366,356	6,733,712	
	Proportion of total fleet	1.3%	32.9%	68.2%	100%	
Total yearly electricity consumption	Business as usual	0.24	**7.68**	17.84	29.03	TWh
	Mass restriction 1	0.24	7.42	16.93	27.12	TWh
	Mass restriction 2	0.24	7.10	15.50	23.91	TWh
Power needed for a 24h day at -20°C	Business as usual	44	1392	**3232**	5261	MW
	Mass restriction 1	44	1344	3067	4915	MW
	Mass restriction 2	44	1287	2810	4332	MW

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Results - LCA

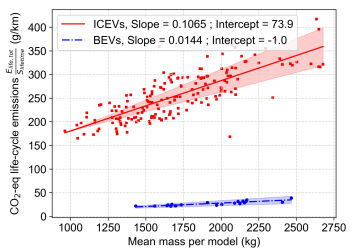

Figure 3: CO_2-eq. cradle-to-grave emissions of ICEVs and BEVs specific to Quebec's electricity mix, fleet composition and driving behavior.

Conclusion

This paper estimates the electricity needed to operate the future BEVs fleet and achieve a net-zero transport sector in the context of an evolving LDV fleet. We underscore the considerable challenges associated with the electrification of the transportation sector in Quebec, particularly in the province's seasonal variations. Evaluating whether it is more effective to increase electricity production to accommodate heavier BEVs or to limit the mass increase of the fleet to mitigate the electricity demand is crucial.
Furthermore, over the same average distance per category, we showed that **BEVs have significantly lower GHG emissions compared to ICEVs**, with a difference that increases for heavier vehicles.