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Comparative life cycle assessment of electric and conventional vehicles used in Québec, Canada

Pierre-Olivier Roy[1], Jean-François Ménard[1], Sophie Fallaha[1]

[1]*Pierre-Olivier Roy (corresponding author), CIRAIG, 3333 Queen Mary, Montreal, Qc, pierre-olivier-3.roy@polymtl.cal*

Short Abstract

This study evaluates the potential environmental benefits of using an electric over a conventional vehicle in the province of Québec, Canada; a province characterised with an electric grid mix mostly based on hydroelectricity. To do so, we applied an environmental life cycle assessment approach whose results suggest that use of the electric vehicle should be promoted in the province of Québec but only if the vehicle lifetime is optimised.

1 Introduction

Should an electric vehicle be promoted comparatively to its conventional counter-part in Québec, Canada, considering their potential environmental issues?

While this question seems simple, an answer cannot be easily provided from existing studies related to vehicles comparison since the province of Québec has several distinguishing characteristics that set it apart: 1) an electrical grid mix mostly based on hydroelectricity [1], 2) a lack of fossil fuel production or 3) vehicles production, 4) variable driving patterns [2] and 5) extremely (-40ºC to 40ºC) variable yearly climatic conditions which affect the energy efficiency of the vehicles [2].

Furthermore, some existing studies have focus their assessment on greenhouse gas (GHG) emissions during the use phase [3]. While important, GHG emissions and the use phase alone do not allow an overall evaluation of the vehicles environmental impacts. Multiple potentials impacts during the vehicles entire life cycle must be assessed.

1.1 Method

To provide such assessment, we used environmental life cycle assessment (henceforth referred to as LCA) which is a decision supporting tool aiming to compile and evaluate the inputs, outputs, and potential environmental impacts of a product or service throughout its entire life cycle, from material extraction to end-of-life.

Our main comparison scenario is based on two comparable electric and conventional vehicles of the same class, produced in Japan and used in Québec for a lifetime of 150 000 km; 55% of which occurred in urban settings [2]. Several other driving scenarios were considered with different lifetimes, energy consumption and different road settings. The assessment was based on five different indicators: *Human health* which aggregates the indicator results from *global warming, human toxicity, ozone layer depletion, photochemical oxidation and respiratory effects*; *Ecosystem quality* which aggregates the indicator results from *global warming, terrestrial, aquatic and ocean acidification, aquatic and oceanic eutrophication, land use and ecotoxicity;* and we finally added the *global warming, fossil fuel depletion* and *mineral resource depletion* indicators.

2 Results and discussion

2.1 Electric vehicle life cycle environmental profile

Figure 1 shows the electric vehicle environmental impact profile. It highlights the importance of the production of the vehicle electric motor and battery. In comparison, use of the electric vehicle in Quebec, using its electric grid mix, was shown to be a small contributor (≈5 %) to the environmental indicators.

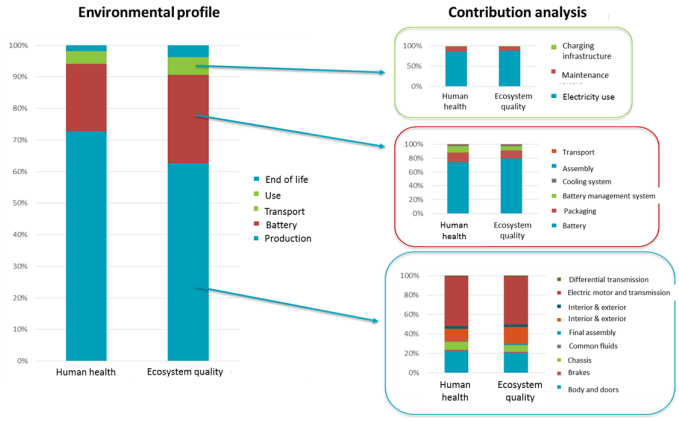

Figure 1: Electric vehicle environmental impact profile (note: results for the *global warming, fossil fuel depletion* and *mineral resource depletion* are not shown)

2.2 Electric vehicle life cycle environmental profile

Applying LCA to conventional vehicles intended for use in Québec, we showed the importance of the GHG emissions of the conventional vehicle use phase to *global warming* and its implication towards *Human health* and *Ecosystem quality*.

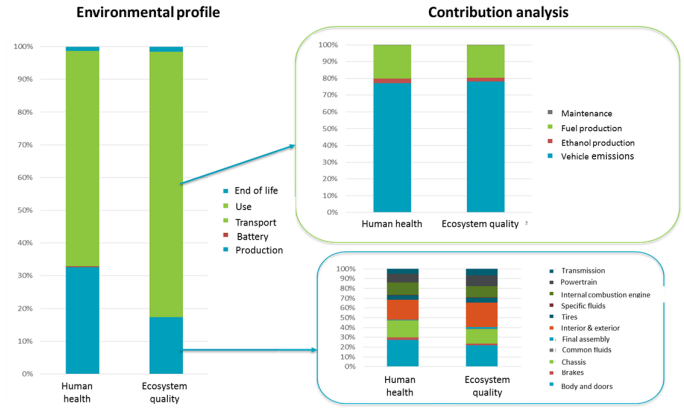

Figure 2: Conventional vehicle environmental profile (note: results for the *global warming, fossil fuel depletion* and *mineral resource depletion* are not shown)

2.3 Vehicles life cycle environmental profile comparison

Figure 3 shows the comparison of the different vehicles for several plausible lifetimes and driving conditions. Results show that the electric vehicle is mostly independent of the driving scenarios while the conventional vehicle shows high variability with increasing lifetime over different scenarios. Results also show environmental benefits for electric vehicle for the *Human health*, *Ecosystem quality*, *global warming* and *fossil fuel depletion* indicators over all possible scenarios of the conventional vehicle if the lifetimes of the vehicles are over 100 000 km. However, for shorter lifetime, some of the driving scenarios of the conventional vehicle could be preferable. The *mineral resource depletion* indicator which will not favour the electric vehicle during its lifetime in its current configuration. Our study also showed that in Québec (results not shown), the efficiency of the charging station (80 to 100 %), the plant production location

(Japan or the United States), the type of electric battery (LiNCM over $LiFePO_4$) or the electric vehicle battery end of life had little to no consequences on the study conclusions.

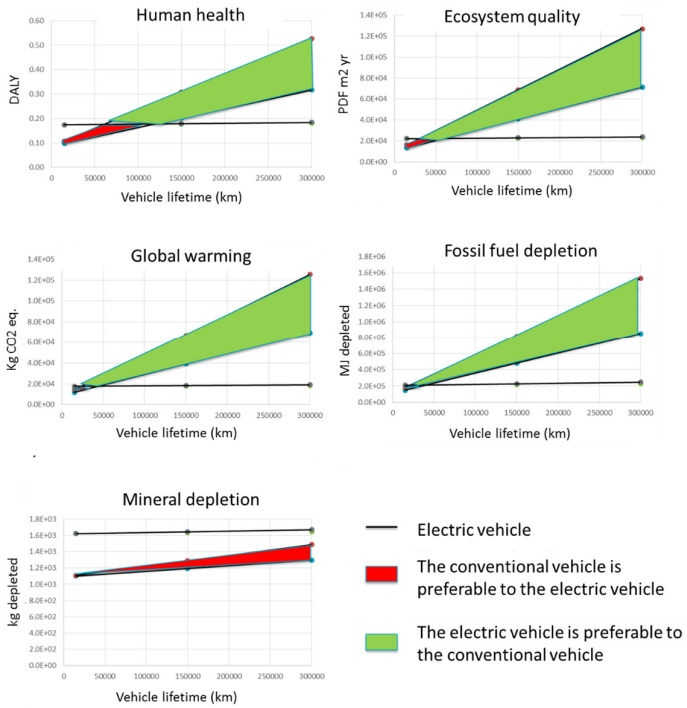

Figure 3: Comparison of the environmental profiles of the conventional and electric vehicles according to several driving scenarios

3 Conclusion

Consequently, it could be argued that use of the electric vehicle should be promoted in the province of Québec but only if the vehicle lifetime is optimised.

Acknowledgments

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Authors

Pierre-Olivier Roy, PhD., CIRAIG. PhD., B. Eng.

Pierre-Olivier graduated in 2006 from Ecole Polytechnique de Montreal in chemical engineering and has completed both a masters (2009) and a PhD (2012) at the interuniversity research centre for the life cycle of products, processes and services (CIRAIG). During which, he develop a regional and global scale environmental modeling expertise. In 2012 he became an environmental consultant at CIRAIG. He has since work on several projects including the operationalization of the new life cycle impact assessment method IMPACT World + and several GHG emissions accounting projects including the prospective Quebec's shale gas exploitation and the carbon footprint project for the Quebec government.

Jean-François Ménard., CIRAIG. B.Eng., B.Sc.

Jean-François graduated in 2001 from Ecole Polytechnique de Montreal in chemical engineering, He then immediately joined the start-up team of the CIRAIG in 2002. Now Senior Analyst, he has participated in numerous LCAs in various sectors, such as aluminum production waste management, municipal waste treatment, electricity distribution, road pavement and oil sands exploitation. He has an extensive knowledge of the most used LCA software.

Sophie Fallaha., CIRAIG. M. Sc.A. B.Eng.,

Sophie Fallaha, who trained as an engineer and has attained a Master's degree in applied science from Polytechnique Montréal, joined the CIRAIG team in 2011. She has been, successively, a senior analyst and the Acting director of industrial affairs, and, in November 2014, became Director of industrial relations for the International Life Cycle Chair, CIRAIG's main research unit. The Chair's industrial partners see Ms. Fallaha as having set herself apart, in the performance of her duties, as an attentive, credible and reliable listener, and she has acquired a solid background in managing multi-disciplinary projects with the industry.