Quebec is a particularly interesting case that allows us to evaluate the environmental and economic potential of electric vehicles. Since its plan for the electrification of transportation is the most ambitious in Canada and it has abundant hydroelectricity produced with very low GHG emissions, it would seem to provide the ideal conditions for the adoption of electric vehicles. Should the Quebec government pursue its strategy for the electrification of personal transportation? Do the environmental benefits justify the costs?

The Environmental Benefits of Electric Vehicles

When someone decides to buy a gasoline-powered automobile, he or she does not generally take into account the negative environmental impact of the combustion of gasoline and the GHG emissions that result. In economic jargon, this is called a negative externality. An externality occurs when a third party not directly involved in an exchange receives a benefit or incurs a cost. In other words, there is a social impact that is not taken into consideration by the parties to the exchange, who are focused solely on the direct benefits of the transaction.

From a societal point of view, it is possible that the respective proportions of gasoline-powered cars and electric cars will not be optimal if the impact of GHG emissions are not taken into account. In theory, therefore, the concept of externalities could justify government subsidies to stimulate the growth of electric vehicle sales by making them relatively more attractive.

There are two kinds of electric cars: the fully electric car and the rechargeable hybrid. The former is equipped with an electric motor and a rechargeable battery, which must be connected to an external energy source. A hybrid, in addition to an electric motor and a battery, also has an internal combustion engine that can take over or provide extra power as needed.

Three factors influence the environmental impact of using an electric car compared to using a conventional car. This impact is more positive when the fuel consumption per kilometre of the vehicle...
that is replaced is high. For example, if an electric car replaces a Yaris with fuel consumption of 6.3 L/100 km, there is less of a reduction in GHG emissions than if it replaces a Ford F150 pickup with fuel consumption of 19.1 L/100 km. The principle is the same for annual mileage. The greater the distance travelled in a year in an electric car instead of a conventional car, the greater the reduction in GHG emissions. Finally, we must take into account the emissions related to the electricity used to recharge the battery, which appear to be negligible in the case of Quebec.

The environmental impact of an electric car can also be calculated over its entire life cycle, by including the emissions due to its manufacture. The manufacture of a fully electric car produces 13.7 tonnes of GHGs (including 5.2 just for the battery) compared to 6.5 for a conventional automobile. This extra 7.2 tonnes of GHGs emitted during the manufacture of an electric car is then integrated into the calculation of GHG emissions avoided during its use. The same analysis can be carried out for rechargeable hybrid vehicles. The environmental cost of their manufacture, at 9.9 tonnes of GHGs, is lower than for entirely electric vehicles, but unlike these, hybrids generate emissions when they are used.

The Results Obtained in Norway

Norway is the country that is considered to be the leader in terms of the adoption of electric vehicles, which explains why the Quebec government’s most recent transportation electrification plan is openly inspired by it. Like Quebec, Norway produces almost all of its electricity using hydroelectric dams. The GHGs emitted to recharge the battery are therefore negligible.

**The subsidies offered by various governments are motivated in large part by reduction targets for greenhouse gases.**

This country had 39,520 electric cars on the road in November 2014, for a ratio of 7.7 per 1,000 inhabitants, the highest in the world. This ratio is around 0.28 in Canada and 0.5 in Quebec.

The Norwegian government has expended considerable efforts to encourage the population to embrace electric transportation. First of all, it has established purchase subsidies in the form of exemptions from the sales tax (25%) and the registration tax. It then subsidizes the use of these vehicles primarily through an exemption from the annual tax on motor vehicles, exemptions from toll road charges, and free parking.

Over an electric car’s useful lifespan of 10 years, these measures represent around $5,324 in annual rebates. Based on the number of kilometres driven by Norwegians and the quantity of GHGs emitted by an average European automobile, however, the use of an electric car leads to a reduction of just 0.77 tonnes of GHGs per year.

The Norwegian government’s support of electric cars therefore does not seem to be efficient, since it costs them $6,925 per tonne of GHGs not emitted, whereas the average price of emission quotas in Europe during the first nine months of 2014 was 5.73 euros ($7.84) per tonne. The avoidance cost for one tonne of GHGs from subsidizing electric vehicles is thus 883 times higher than the observed price per tonne on the carbon market. By including emissions due to the manufacture of the electric vehicle, we obtain the astronomical sum of $108,878 per tonne of GHGs avoided (see Figure 1).

These disappointing results are largely due to the fact that electric vehicles in Norway travel just 5,721 km a year on average, which is a lot less than the 12,560 km travelled...
by passenger vehicles in 2013.\textsuperscript{11} This low mileage is not surprising since 85% of households that own an electric car own two or more cars, and only 15% of owners use their electric cars for all of their daily trips. Given the limited range of electric cars, they are generally used by households as additional vehicles.\textsuperscript{12}

The Norwegian Model in Quebec

Quebec provides ideal conditions for reducing GHG emissions through the electrification of passenger vehicles. The annual mileage of cars in North America is higher than in Europe, and cars are also heavier here on average, entailing greater fuel consumption. Replacing a gasoline-powered car by an electric car is therefore more beneficial in Quebec than in Norway.

For several years now, the government of Quebec has been subsidizing the purchase or lease of fully electric or rechargeable hybrid vehicles. This subsidy is either $4,000 or $8,000 per electric vehicle depending on the capacity of the battery. The government also pays 50% of the cost of acquiring and installing a residential charging station, up to a maximum of $1,000.\textsuperscript{13}

In Norway, the avoidance cost for one tonne of GHGs from subsidizing electric vehicles is 883 times higher than the observed price for one tonne of GHGs on the carbon market.

Despite this government support, only about 4,000 of the 4.5 million passenger vehicles on the road in Quebec are electric vehicles.\textsuperscript{14} In its \textit{2011-2020 Action Plan for Electric Vehicles}, the government of Quebec set a goal of having 300,000 electric cars on the road in the province by 2020, which would represent around 5.8% of all passenger vehicles.\textsuperscript{15} By comparison, the proportion of electric cars in Norway is only 1.35%, despite much larger government subsidies.\textsuperscript{16} It is therefore logical to assume that tax incentives in Quebec would have to be at least comparable to those in Norway to reach such an ambitious goal, which means the equivalent of $4,046 in annual subsidies per vehicle.\textsuperscript{17} All told, it would cost $12.1 billion to subsidize the purchase and use of 300,000 electric vehicles.

What would be the environmental impact of reaching this goal? To carry out this calculation, we supposed that each new electric car on the road would replace an average gasoline-powered car that travels 15,681 km\textsuperscript{18} per year and consumes 8.2 L/100 km. In addition to these very conservative hypotheses, we also assume that the proportion of fully electric and rechargeable hybrid vehicles remains the same as it currently is.

It follows that the use of an electric vehicle leads to an annual reduction of 2.6 tonnes of GHG emissions at a cost of $1,560 per tonne avoided. Including the extra emissions from the manufacture of the electric car, the cost per tonne avoided climbs to $1,912. For the reasons mentioned above, we can see that it is much less expensive to avoid a tonne of GHG emissions by subsidizing electric cars in Quebec than in Norway.

However, this cost is much higher than the price of a tonne of GHG emissions on the \textit{Western Climate Initiative} carbon market to which Quebec belongs, namely $11.39 in 2014\textsuperscript{19} (see Figure 2). In other words, to avoid the production of a given quantity of GHGs, the Quebec government could buy emission permits for the sum of $88 million instead of spending $12.1 billion to subsidize the purchase and use of 300,000 electric vehicles. It could therefore achieve the same objective at 1/137 of the cost.
Conclusion

Whether to reduce one’s ecological footprint or to enjoy fuel savings and lower maintenance costs, buying an electric car can make sense on an individual level. However, while the range of an electric car is sufficient for daily trips in town, it remains much more limited than that of a gasoline-powered car. Furthermore, this range is reduced in winter, by up to 53% when the temperature drops to -25 degrees Celsius. For these reasons, until there are major technological improvements, electric cars will undoubtedly remain just an attractive niche product for those who travel very little in town only or who have the means to own more than one car.

The Quebec government could achieve the same objective at 1/137 of the cost.

An ambitious government subsidy program to encourage the purchase and use of electric vehicles will do nothing to alter this reality and will not achieve its primary objective, which is the reduction of greenhouse gas emissions. Indeed, even if Quebec is an ideal environment for reducing GHG emissions through the electrification of personal transportation, the relatively modest environmental benefits that could be obtained do not justify such a program. It would be much more effective and much less costly for the government to achieve the same results by purchasing emission quotas.

References

9. See the Technical Annex on the MEI’s website for other scenarios corresponding to different lifespans.
13. Government of Quebec, Running on Green Power!
14. GreenCarReports, Canadian Plug-in Electric Vehicle Sales. This is an estimate based on Quebec’s share of electric vehicles on the road in Canada in July 2013 and on the total number of electric vehicles on the road in Canada in October 2014. Société de l’assurance automobile du Québec, Données et statistiques 2013, p. 19. This figure does not include motorcycles, mopeds or motorhomes.
17. So that discounted government subsidies at the date of purchase represent 88% of the purchase price of a standard electric vehicle, like in Norway. See the Technical Annex on the MEI’s website for further details.
21. Overall, the presence of 300,000 electric cars in the automotive fleet would allow for at most a 1% annual reduction of emissions in Quebec. Environment Canada, Greenhouse Gas Emissions Data, April 2014.