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Xavier MERCIER
Paul LANOIE
Justin LEROUX

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Département d’économie appliquée
HEC Montréal
3000 chemin de la Côte-Sainte-Catherine
Montréal (Québec) H3T 2A7
Canada
http://www.hec.ca/iea
iea.info@hec.ca

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Costs and Benefits of the Quebec "Purchase/Lease Rebate Program for Cleaner Vehicles"*

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Mots clés: analyse coûts-bénéfices, véhicules entièrement électriques, véhicules hybrides rechargeables, rabais.

Key words: cost-benefit analysis, all-electric vehicles, plug-in hybrid vehicles, rebate program.

Authors :

Xavier Mercier
Ouranos
Montréal, Québec

Paul Lanoie
Department of Applied Economics
HEC Montréal
Montréal, Québec

Justin Leroux
Department of Applied Economics
HEC Montréal
Montréal, Québec

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Abstract

This article presents a cost-benefit analysis (CBA) of the Purchase/Lease Rebate Program for Cleaner Vehicles put in place by the Quebec government in 2012. This program provides direct rebates to all-electric and plug-in hybrid vehicles according to the capacity of their electric battery. After describing the program, we identify and monetize its principal costs and benefits. The costs are mainly related to the government expenses associated to the rebate itself, while the benefits include savings on gasoline and oil changes, as well as reductions in different polluting emissions. Because these emissions have no market price, one of our challenges is to place a value on them. For this purpose, we used the "environmental value transfer" method to obtain values from previous relevant studies. We conduct our CBA for the year 2012 and obtain an NPV of 417 812 $, with an internal rate of return of 13.5 %. Our sensitivity analysis shows that our conclusion is fairly robust to various changes in the assumptions and parameters.

Key words: cost-benefit analysis, all-electric vehicles, plug-in hybrid vehicles, rebate program.

Résumé

Cet article présente une analyse coûts-bénéfices du Programme de rabais à l'achat ou à la location de véhicules électriques neufs mis en place par le gouvernement du Québec en 2012. Ce programme procure des rabais directs aux acheteurs de véhicules entièrement électriques et hybrides rechargeables en fonction de la capacité de leur batterie. Après une description du programme, nous identifions et monétisons ses principaux coûts et bénéfices. Les coûts sont principalement reliés aux dépenses encourues par le gouvernement, alors que les bénéfices se présentent en termes d'économies au niveau de la consommation d'essence et des changements d'huile, de même qu'en termes de réductions des émissions polluantes. Comme ces émissions n'ont pas de prix sur le marché, un de nos défis a été de leur attribuer une valeur. Pour ce faire, nous utilisons la méthode du "transfert de valeurs environnementales" pour obtenir des valeurs qui viennent d'études existantes pertinentes. Nous menons notre analyse pour l'année 2012 et obtenons une valeur actuelle nette de 417 812 $, avec un taux de rendement interne de 13.5 %. Notre analyse de sensibilité montre que notre conclusion principale est robuste face à des changements d'hypothèses et de paramètres.

Mots clés: analyse coûts-bénéfices, véhicules entièrement électriques, véhicules hybrides rechargeables, rabais.

I. INTRODUCTION

Climate change and urban air pollution are two major challenges the world is currently facing. Road transportation is one of the main contributors to these problems (Environmental protection UK 2014)[1]. In economics, it is standard to consider that there is room for government intervention to correct this externality problem and reduce pollution from road transport.

Different types of policy instruments exist. First, governments can use regulation and, for instance, set limits on cars' fuel consumption (fuel efficiency standards). They can also seek to increase the population's awareness regarding road pollution issues through different advertisement or information programs. Finally, they can intervene with "market-based instruments," such as taxation or cap-and-trade systems. Examples include the British Columbia carbon tax that exists since 2008, or the Quebec participation in the Western Climate Initiative, a cap-and-trade system recently put into place involving Quebec and California.

Another type of economic instrument is subsidy. In general, economists tend to favour taxes and cap-and-trade systems over subsidies as a policy tool for pollution control. This is because these instruments send the right price signals to polluters, while subsidies can have perverse impacts, like the "rebound" effect (van den Bergh, 2011). However, subsidies could be useful in certain circumstances like promoting R&D or helping to reach a critical mass of a desirable activity.

Subsidies can be of different types, one of them is providing rebates on the purchase of cleaner cars. These rebates or tax credit incentive systems have been fairly popular in the last decade. One example is the federal tax credit in the U.S. allowing as much as $7,500 to purchasers of plug-in hybrids and all-electric vehicles. In Canada, during the first decade of the years 2000, at least five provinces were providing rebates of various types (flat rebates, rebates eliminating the provincial sales tax, or a fraction of it, etc.). In 2014, 17 of the 27 countries of the European Union have some form of financial incentive for the

[1] http://www.environmental-protection.org.uk/committees/air-quality/air-pollution-and-transport/car-pollution/ accessed on June 26th 2014.

purchase of hybrid or electric vehicles[2]. Since the beginning of 2012, the Quebec government offers a purchase/lease rebate for those who acquire an all-electric or plug-in hybrid vehicle.

Surprisingly, there is little research on the impacts of these "incentive for cleaner vehicles" programs. Diamond (2009) evaluates the relative impact of state incentives and gasoline price on hybrid electric vehicles (HEV) adoption. He finds that, while gasoline prices have a very strong relationship with hybrid vehicle adoption, government incentives have a weaker link. Gallagher and Muehlegger (2011) study the relative effect of tax incentives, gasoline prices, social preferences and other non-monetary incentives (e.g., preferential access to high occupancy lanes and parking, etc.). The authors attribute 6% of existing hybrid sales to tax incentive schemes, approximately 33% to personal (social) preferences, and 27% to rising gas prices. They report that sales tax incentives have a much greater effect on the demand for hybrid vehicles than income tax incentives. Chandra et al. (2010) estimate the effect of tax rebates offered by Canadian Provinces on the sales of HEV. They find that 26% of the hybrid vehicles sold during the rebate programs can be attributed to the rebate, and that intermediate cars, intermediate sport utility vehicles (SUVs) and some high-performance compact cars were crowded out as a result. In a cost-efficiency analysis, the authors also estimate that the average cost of reducing carbon emissions from these programs is 195$ per tonne.

However, these papers offer only a partial view of the impacts of these subsidies. They examine how the economic incentives have changed purchasing behavior, but they cannot conclude on whether or not these subsidies are sound policy choices. A cost-benefit analysis (CBA) provides a more comprehensive investigation of the appropriateness of these subsidies.

Certain CBA have been undertaken from a buyer's perspective [Simpson (2006), Nery Nina (2010), and CBO (2012)]. In these papers, the authors ask the question: Is it worthwhile for a consumer to buy a cleaner vehicle (hybrid, plug-in hybrid or electric) given available subsidies? Typically, a cleaner vehicle has a more important purchase price than a conventional vehicle, but this could be compensated through savings in gasoline

[2] http://www.acea.be/uploads/publications/Electric_vehicles_overview__2014.pdf accessed on July10th 2014.

and maintenance costs. In this context, a government subsidy can help turn the benefit-cost ratio positive for the car buyer. These exercises are useful, but they fail to indicate whether the social benefits provided by the subsidy are greater than its cost.

To our knowledge, there exists only one CBA of a financial incentive to buy cleaner vehicles. Fuqua (2012) analyses the costs and benefits of the U.S. tax credit of $7,500 for purchasing an electric vehicle. He concludes that the tax credit does not create $7,500 worth of public benefits. Although useful, this study cannot be applied to the Canadian context (especially in Quebec, British Columbia and Manitoba) where a large fraction of the electricity used by electric vehicle is coming from a clean hydro-power source in a monopoly position. This is not the case in the U.S. where around 40% of the electricity is produced by coal power plants[3]. Furthermore, one of the main benefits of electric vehicles identified by Fuqua is coming from reducing oil dependency. Clearly, this is less of an issue in Canada, which is a net oil exporter.

The objective of this paper is to provide a CBA of the Purchase/Lease Rebate Program for Cleaner Vehicles that exists in Quebec since the beginning of 2012. The rest of the paper is organized as follows: Section II briefly describes the Program. Section III discusses certain methodological considerations. Section IV identifies and monetizes the different benefits due to the Program, while Section V is devoted to the costs. Section VI presents the CBA, and discusses the results of a sensitivity analysis. We conclude that the program has been beneficial for the Quebec society with a net present value of 417 812 $ for the year 2012 and an internal rate of return of 13.5 %. Finally, Section VII provides concluding remarks.

II. THE PURCHASE/LEASE REBATE PROGRAM

The Drive Electric Program is a Purchase/Lease Rebate Program[4], which is part of a major action plan developed by the Quebec government for the electrification of transportation in the Province. This larger program includes, among other features, a project to develop a network of battery recharging stations, and different means to increase the electrification

[3] http://www.eia.gov/tools/faqs/faq.cfm?id=427&t=3 accessed on July 10th, 2014.
[4] The information in this section is mainly coming from http://vehiculeselectriques.gouv.qc.ca/english/particuliers/rabais.asp accessed on June 30th, 2014.

of public transit. The program of study offers a purchase/lease rebate for individuals, businesses, non-profit organizations, and Quebec municipalities upon acquiring an all-electric (AE), plug-in hybrid (PH), hybrid or low-speed electric vehicle:

Table 1: Main features of the Quebec Purchase/Lease Rebate Program

Vehicle type	Rebate Amount
All-electric vehicles, Plug-in hybrid vehicles	$4 000 or $8 000
Hybrid vehicles	$500
Low-speed electric vehicles	$1 000

The rebate granted for an AE or a PH vehicle is $4 000 or $8 000[5]. The amount of the rebate is calculated according to the capacity of the vehicle's electric battery and the vehicle must be included in a list of eligible vehicles[6]. The list is updated regularly by the program's administrator according to information provided by the manufacturers of automobiles marketed in Québec. One can obtain the government rebate on the purchase or lease of a vehicle directly from the car dealer.

The Drive Electric Program was officially launched on January 1st, 2012 by the Department of Energy and Natural Resources (DENR). It will be in force until December 31st, 2016, or until the available funds are exhausted.

An individual who has purchased or leased an AE or PH vehicle may also apply within the framework of this program for financial assistance to purchase and install a 240-volt charging station at his home.

[5] The rebate of $8 000 is offered for a vehicle whose electric battery has a capacity of 15 kWh or more. The rebate of $4 000 is granted for a vehicle whose electric battery has a capacity of at least 4 kWh, but less than 15 kWh.

[6] In this study, we focus on the rebates for AE and PH vehicles. AE vehicles run on electricity only. They are propelled by an electric motor powered by rechargeable battery packs. A PH vehicle is a hybrid vehicle, with conventional and electric engines, which utilizes rechargeable batteries, or another energy storage device, that can be restored to full charge by connecting a plug to an external electric power source (usually a normal electric wall socket).

III. METHODOLOGICAL ISSUES

In a cost-benefit analysis (CBA) of an activity, project or policy or, as in this case, a program, one seeks to find out whether the program is welfare-improving for the whole of society; i.e., whether it generates more benefits than costs. A CBA generally involves four main steps. First, one has to identify the costs and benefits induced by the program. Second, one must monetize all the costs and benefits so as to compare them on the same basis. Third, the costs and benefits must be expressed in dollars of the same year (discounted), since a dollar today is worth more than a dollar in the future. Fourth, one has to perform a sensitivity analysis to assess how the conclusion of the investigation is sensitive to certain assumptions one has to make throughout the study.

In our case, a certain number of issues were raised at each step. To understand them, it is useful to first present an overview of the main benefits and costs that will be considered in our analysis. As can be seen in Table 2, the tangibles benefits due to AE or PH cars are the reductions in the quantity of gasoline used and the reduction in maintenance costs[7], and the intangible benefits are the reductions in air pollution associated with lower gasoline consumption. Among the costs, one should include the social cost of the rebates, the administrative costs of the program and the cost of producing extra electricity to recharge batteries of AE or PH vehicles.

[7] AE vehicles do not require oil changes, while oil changes are less frequent with PH than with conventional cars.

Table 2: Overview of the costs and benefits considered

	Tangibles	Intangibles
Benefits	- Reduction in the quantity of gasoline used - Reduction in maintenance costs	- Reduction in polluting emissions
Costs	- Social cost of providing the rebates - Administrative cost of the program - Cost of providing extra electricity for recharging vehicles	None

As a first methodological issue, we have to identify the portion of the purchases of AE and PH vehicles attributable to the program or, in other words, we ask ourselves the question: Would consumers have bought as many AE and PH vehicles without the program? To answer this question, following Curtin et al. (2009), we conduct a contingent valuation survey to find out the willingness-to-pay of consumers for cleaner cars (more details below).

A second issue related to the identification of the benefits of the program is to determine the number of years the benefits would occur. In this case, we consider eight years. This choice is based on the duration of the guarantee on batteries and on the electric motor of the Chevrolet Volt, the most common PH vehicle subsidised by the program (Juteau, 2013). It is possible that benefits would last longer; for instance, a consumer may be given the incentive to buy a PH vehicle through the program, that may lead him to discover a new type of car that he will appreciate and buy in the future regardless of the existence of the program. Such considerations are beyond the scope of our analysis.

One must also consider that PH vehicles run on an electric engine for a fraction of the time and on conventional engine for the rest of the time. Knowing that, on average, a Quebec citizen drives 40.5km per day[8] and that the autonomy of PH vehicles in 2012 was around

[8] See Statistique Canada (2010).

60 km, we use three scenarios in our sensitivity analysis with 50%, 70% or 100% of the kilometers traveled on the electric engine (for PH vehicles only).

Fourth, in monetizing costs and benefits, one has to refer to the real opportunity costs of inputs or resources. This implies that the analysis has to abstract, as much as possible, from any taxes, subsidies or interferences that affect the price mechanism.[9] Therefore, in our calculations, when considering the price of certain resources, such as energy or materials, we took away taxes or subsidies whenever feasible. Furthermore, since the rebate is itself a subsidy, or an economic transfer, we consider only the distortionary cost of providing it, known as the marginal cost of public funds (MCPF). We use the figure emerging from the survey of Dahlby and Ferede (2011) at 0.1962 per dollar.

Fifth, of course, the main issue in monetizing the benefits is placing a value on the reduction of polluting emissions, since these are not priced by the market. There is now a vast literature on methods for valuing non-market goods, such as the quality of the environment, leisure time, or health and safety. The methodologies involved include revealed preference methods and contingent valuation.[10] As will be seen below, we are dealing with six different types of emissions, and it would be beyond the scope of this research to conduct an original study to determine the value of each of these six types of emissions in the context of Quebec. We will thus use the environmental value transfer method, transferring environmental value estimates from previous studies, relying mainly on recent American studies published in peer-reviewed journals.

Lastly, the choice of a discount factor can always be controversial. We follow the recommendation of the Treasury Board of Canada, and use a real discount rate of 8%[11]. We will check the sensitivity of our results to the choice of the discount rate with an interval of +2% and –2%.

[9] For a complete discussion on this issue, see Boardman et al (2010), chapter 4.
[10] See Tietenberg and Lewis (2013), chapter 3 for a complete discussion.
[11] http://www.tbs-sct.gc.ca/ri-qr/documents/gl-ld/analys/analys-eng.pdf accessed on June 12 2013

IV. BENEFITS

IV.1 The proportion of purchases attributable to the program

As discussed in Section III, to obtain this proportion, following Curtin et al. (2009), we conduct a contingent valuation survey to find out consumers' willingness-to-pay for cleaner cars. Essentially, we described the characteristics of clean vehicles to the respondents (price, energy savings and pollution reductions associated with these vehicles, etc.), and we asked them to declare their probability of purchasing such a vehicle[12]. Then, we asked them to give us the same probability in the presence of a rebate of the same magnitude as those provided by the Quebec program. The difference between these two probabilities can be used to find the impact of the rebate[13]. This exercise suggests that 46.6% of the beneficiaries of the PH rebate and 50.1% of the beneficiaries of the AE rebate have bought a cleaner car because of the existence of the rebate program. Given that contingent valuation estimates may be controversial[14] and that these figures are central in our analysis, it is useful to discuss their reliability. We adopt three approaches to do so.

First, we look at the representativeness of our sample. The survey was conducted in person in the Greater Montreal Area. We met respondents in different public areas like shopping malls, hockey arenas or parks and collected 100 questionnaires. The following table presents the socio-demographic characteristics of our sample in comparison with the whole Quebec population.

[12] The exact wording of the question was: "On a scale from 0 to 100, where 0 would mean that you would certainly not buy the vehicle and 100 would mean that you would certainly buy the vehicle, what would be your chances to buy an AE vehicle in the future?" Then, the same question was asked for HP vehicles.
[13] The *Proportion of the vehicles bought because of the rebate* = 1 – [Prob. (purchase without the rebate) / Prob. (purchase with rebate)], see Mercier (2014) for details regarding the questionnaire.
[14] See Carson et al. (2001) for a complete discussion on this subject.

Table 3: Comparison of sociodemographic variables

	Sample	Population
Median Age	42	46.5
Average age	41.35	48.25
Median Income ($)	52 500	54 155.98
Average Income ($)	68 696.81	69 160.07
% of women	48%	50.96%
Mother tongue – French	85%	83%
College Diploma or Academic Degree	65%	49.5%

As one can see, our sample is fairly representative of the Quebec population in terms of income, gender and language, but overall a bit younger and more educated than the whole population. This is not particularly worrying given that the average age of car purchasers is probably lower than the average age of the general population. Indeed, people over 65 years have a tendency to drive less and to change their car less frequently, if at all. In fact, in 2011, only 64.9%[15] of the 65 year-old and older Quebec population had a driver license compared to 86.3% for the population aged between 25 and 64.

Second, we conducted a "construct validity" exercise. Most contingent valuation studies present an estimated equation that relates some indicator of the respondent's willingness-to-pay to the respondent's characteristics and to the characteristics of the good. Construct validity is obtained if estimated coefficients are compatible with economic theory or with common sense (Carson et al., 2001).

Using a simple Probit specification, we ran a regression where the dependent variable was the probability to buy a PH vehicle if it cost $4,000 more than an equivalent conventional vehicle (once the rebate was taken into account, which was the most representative situation in our sample). Among the respondent's characteristics, we included income, gender, education, number of children, and variables capturing the attitude toward the environment like belonging to an ecologist group, producing compost,

[15] Driver license by age data (SAAQ, 2014) was crossed with census data (Statistique Canada, 2012) in order to estimate these percentages.

etc. Among the characteristics of the good, we included the number of kilometers traveled per day, gasoline expenses per month, the possibility of having a recharging station at home or at work, etc. Overall, 27 explanatory variables were used. The explanatory power of the regression was good (pseudo R^2 of 56% in our basic model), and almost all the significant coefficients had the predicted sign. For instance, the probability to buy a PH increased significantly with income, education, expenses on gasoline per month, access to a recharging station at work, etc.[16]

A third approach is “convergent” validity, one can compare contingent valuation estimates to other estimates based on observed behavior. We have two studies providing comparable estimates using statistical analysis. First, as discussed in the introduction, Chandra et al. (2010) investigate the effect of tax rebates offered by Canadian Provinces on the sales of hybrid electric vehicles. Essentially, they estimate different equations where the dependent variable is the market share of the vehicles subject to the rebate, and the main independent variable is a measure of the size of the rebate. They use a panel data set with variations across provinces and across periods. They find that 26% of the hybrid vehicles sold during the rebate program can be attributed to the rebate. One should note, however, that their study was completed in 2007 with a data set ending in 2006. At that time, neither AE nor PH cars were on the market, the rebates were smaller than those prevailing in Quebec[17], the hybrid technology was just starting, and the price differential between a hybrid and a conventional car was more important. All these differences suggest that the Quebec rebate on more attractive vehicles should have a more important impact.

The second comparable study is from Gallagher and Muehlegger (2011). These authors use a similar approach than that of Chandra et al. in the US context. In particular, they discuss the relative advantages of income tax credits and sale tax waivers concluding that these waivers, which are very similar to the Quebec rebate, have a much more important effect than income tax credits. In particular, “they estimate that eligibility for a sales tax waiver is associated with a 52% increase in sales”, a result similar to ours.

[16] See Mercier (2014) for complete results.
[17] In their sample, the largest rebate is $3,000 in Prince Edward Island starting in 2004.

Finally, it is worth mentioning that Curtin et al. 2009, whose contingent valuation approach has inspired us, found that, at an additional cost of $2,500, the mean purchase probability for a PH vehicle is 46%, again a result comparable to ours. Overall, we are confident that our estimate of the proportion of purchases attributable to the program is reliable and, to be more prudent, we conduct a sensitivity analysis on this parameter in section VI.

IV.2 Tangible benefits

First, AE and PH consume less gasoline. For each of the AE and PH vehicles affected by the rebate program, we found a comparable car with a conventional engine. Using data from Natural Resources Canada and data on the average distance traveled yearly with these types of car, we could established the fuel economy realised by those who bought the AE and PH vehicles because of the program for the next eight years. To forecast the evolution of the price of gasoline for the next eight years, we followed the trend observed during the period 1999-2013 (abstracting for taxes). Overall, the fuel economies are presented in the following table (the value of these fuel economies will be presented in section VI):

Table 4: Annual fuel economy (in liters)

Fuel economy	PH-50%	PH-70%	PH-100%	AE
Liters per year per Vehicle	486.57	675.88	959.84	959.84
Liters per year for all vehicles	269,266.36	374,030.99	531,177.95	245,336.25
% of vehicles bought because of the program	46.6%	46.6%	46.6%	50.08%
Liters per year saved because of the program	125,478.12	174,298.44	247,528.92	122,864.39

Regarding the reduction in oil changes, as mentioned in Section III, AE vehicles do not require oil changes, whereas the frequency of oil changes for PH vehicles is lower than for conventional vehicles. For instance, it is recommended by the manufacturer to perform an oil change only once every two years for a Chevrolet Volt, while it would be around once every 10,000 km for a conventional similar car. Taking the information recommended by the manufacturers for PH and for comparable conventional cars, and taking a low estimate of the price of an oil change[18], we end up with these savings in terms of oil changes:

Table 5: Benefits related to the reduction of oil changes

Benefits/ oil changes	AE	PH
Average frequency of oil change for the substitute (km)	11,000	11,000
Average annual mileage (km)	14,766.84	14,766.84
Cost of an oil change ($)	29.97	29.97
Average frequency of oil change for the clean vehicle	0	0.51
Annual benefit per vehicle ($)	40.23	14.81
Total annual benefits due to the program ($)	5,149.99	3,819.92

IV.3 Intangible benefits

The reduction in gasoline consumption is translated into a reduction in emissions of various air pollutants. Using the types of cleaned vehicles affected by the rebate program, their conventional counterparts, and the data from the *Urban Transport Emission Calculator* of Transport Canada, it is possible to establish the quantity of emissions saved by the program for six air pollutants: particulate matter ($PM_{2.5}$ and PM_{10}); nitrogen oxides (NO_x); sulphur oxides (SO_x), volatile organic compounds (VOC), and greenhouse gases (GHG):

[18] We take the price charged by Wal-Mart in December 2013, i.e. $29.97.

Table 6: Emissions from different types of vehicles

Emissions	Conventional Vehicles	PH	AE
CO_2(g/L)	2,289	2,289	0
NO_x(g/km)	0.362	0.101	0
SO_2(g/km)	0.00345	0.00107	0
COV (g/km)	0.432	0.0308	0
$PM_{2,5}$(g/km)	0.00694	0.00193	0.00292
PM_{10}(g/km)	0.0153	0.00427	0.00921

As mentioned in Section III, it is beyond the scope of this paper to find original values for these six pollutants for the Province of Quebec, and so we use the environmental value transfer method. As discussed in Spash and Vatn (2006), it is legitimate to do so when one can find high-quality studies covering similar environmental goods carried out in a similar geographical and institutional context.

In fact, our prices for the first five pollutants come from Muller and Mendelsohn (2007). This American study is the most sophisticated exercise we have encountered on this topic. The authors use a simulating model, the *Air Pollution Emissions Experiments and Policy* (APEEP) analysis, to value the marginal damage associated with air pollution. This damage includes impacts on agriculture, forests, ecosystems, buildings and human health. This study has been used as a reference for the same purpose in two articles published in the *American Economic Review* (Muller and Mendelsohn, 2009; Muller et al. 2011), and in the Canadian context by Lanoie and Rochon-Fabien (2012). The price for GHGs is coming from a recent meta-analysis from Tol (2011). Overall, the marginal costs of emissions used in our study are given in the following table:

Table 7: Social marginal cost of emissions

Social cost ($/kg)	USD2002	USD2011	CAD2012
CO_2		0.019	0.0195
NO_x	0.3		0.55
SO_2	1.2		2.1999
COV	0.4		0.7333
$PM_{2,5}$	2.2		4.0331
PM_{10}	0.35		0.6416

Finally, given the reduction in the quantity of emissions and their value, we obtain the intangible benefits of the program:

Table 8: Annual benefits from emissions reductions

Benefits (CAD12)	PH-50%	PH-70%	PH-100%	AE[19]
CO_2 equivalent	5 778.95	8 027.40	11 400.06	5 658.58
NO_x	546.63	631.24	758.16	376.32
SO_2	19.94	23.55	28.90	14.35
COV	1 120.34	1 154.74	1 206.35	598.79
$PM_{2,5}$	76.95	76.95	76.95	30.65
PM_{10}	26.95	26.95	26.95	7.39
Total	7 569.76	9 940.82	13 497.36	6 686.06

V. COSTS

Since the program is still ongoing, we have decided to focus on a CBA of the first year of the program: year 2012. As shown in Table 2, three main categories of costs are involved in this program. First, we have the cost of the rebates provided by the DENR. In 2012, 809 rebates were given for the AE and PH vehicles. As discussed earlier, the economic cost of the rebate is given by the MCPF provided by Dahlby and Ferede (2011) times the rebate (see Table 1).

[19] It is possible to see that the total benefits in the PH-100% case are different from the ones in the AE case. This is related to the fact that there were fewer AE vehicles which benefited from the rebate program in 2012 in comparison to the PH ones. The percentage of the vehicles bought because of the program, which is different from a type of vehicle to another, is also taken into account in order to estimate the total annual benefits from emissions reductions.

Table 9: Cost of the rebates for 2012

	2012		
	Number of accepted requests	Costs (in $1,000)	Economic Costs (in $1,000)
AE	256	2 020.111	396.346
PH	553	4 201.863	824.406
Total	809	6 221.974	1 220.752

Second, administrative expenses are incurred to pay for the personnel who manages the program, advertisement, transportation (mainly for promoting the program), and operating costs (website, paper, etc.). Since these are real costs, we count them entirely. We had access to these expenses through the DENR. However, a part of these administrative costs was allocated to manage the program subsidizing the installation of recharging stations. Since we know the total amount of subsidies devoted to rebates and the total amount devoted to recharging stations, we assume that the share of the administrative costs devoted to rebates is proportional to the amount of subsidies devoted to rebates (62.3%).

The new AE and PH vehicles consume more electricity. As we saw, 46.6% of the beneficiaries of the PH rebate and 50.1% of the beneficiaries of the AE rebate have bought a cleaner car because of the existence of the rebate program. We will thus look at the extra electricity cost for those proportions of the vehicles for which a rebate was given.

Using the average production cost of electricity provided by Hydro Quebec in 2012[20], the average electricity consumption per 100 km of the subsidized AE and PH vehicles[21], and the average number of kilometers per year traveled by these vehicles, we can deduce the extra electricity cost due to the presence of more AE and PH vehicles on the roads[22]. However, as mentioned in Section III, since it is impossible to know exactly the percentage of kilometers traveled by PH cars using the electric engine instead of the conventional

[20] See Hydro-Québec, 2012.
[21] See Natural Resources Canada 2012.
[22] See Mercier 2014 for the detailed calculations.

one, we have to use the three scenarios regarding the portion of kilometers traveled by the PH vehicles using the electric engine.

Ideally, one should also consider the environmental cost of providing this extra electricity. However, since the extra quantity of electricity used would not require building new facilities, and since the production of electricity in Quebec is almost entirely from hydro-power, a renewable source with very little GHGs emissions, we consider that the environmental cost of providing the extra kilowatt-hours is negligible.

Overall, the total costs related to the program are presented in Table 10:

Table 10: Overall costs

	2012 – Costs (in $1,000)		
	Scenario - 50%	Scenario - 70%	Scenario - 100%
Rebates on AE	396.346	396.346	396.346
Rebates on PH	824.406	824.406	824.406
Remuneration	158.883	158.883	158.883
Advertisement	12.146	12.146	12.146
Transportation fees	0.545	0.545	0.545
Operating costs - others	243.208	243.208	243.208
Total	1,635.534	1,635.534	1,635.534
Additional cost of electricity (2013 onward[23])	15.319	18.604	23.531

VI. THE COST-BENEFIT ANALYSIS

Our base case scenario is one with a discount rate at 8%, a duration of benefits of eight years and the portion of km traveled by PH cars with their electric engine at 70 %. Then, we will allow for changes in these three parameters. We will also see how our results vary when we change the proportion of sales attributable to the program, and the marginal cost of public funds.

[23] Since, in 2012, some of the cars benefiting from the rebates have been bought in different months, we start computing the extra electricity costs in 2013 onward.

The following table presents the cost, benefits and net present value (NPV) in our base case scenario:

Table 11: Costs, Benefits and NPV in the Base Case Scenario

Costs	2012	2013	2014	2015	2016	2017	2018	2019	2020	Present Value
Rebates and administration	1 635 534.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1 635 534.00 $
Electricity	0.00	18 604.00	18 604.00	18 604.00	18 604.00	18 604.00	18 604.00	18 604.00	18 604.00	106 910.47 $
Total	1 635 534.00	18 604.00	18 604.00	18 604.00	18 604.00	18 604.00	18 604.00	18 604.00	18 604.00	**1 742 444.47 $**
Benefits										
Fuel economy	0.00	239 661.83	268 057.21	299 816.90	335 339.52	375 070.89	419 509.67	469 213.61	524 806.52	2 013 161.30 $
Oil Changes	0.00	8 969.91	8 969.91	8 969.91	8 969.91	8 969.91	8 969.91	8 969.91	8 969.91	51 546.83 $
Emissions	0.00	16 626.88	16 626.88	16 626.88	16 626.88	16 626.88	16 626.88	16 626.88	16 626.88	95 548.68 $
Total	0.00	265 258.62	293 654.00	325 413.69	360 936.31	400 667.68	445 106.46	494 810.40	550 403.31	**2 160 256.81 $**
NPV	(1 635 534.00) $	228 383.91 $	235 811.04 $	243 555.43 $	251 624.47 $	260 026.12 $	268 768.90 $	277 861.86 $	287 314.62 $	**417 812.34 $**

The NPV for the base case is positive at $417,812.34 with an internal rate of return of 13.5%.

In the following table, as discussed earlier, we consider three different discount rates (6%, 8% and 10%) and three different portions of km traveled by PH cars using their electric engines (50%, 70% and 100%):

Table 12: NPV with different discount rates and portions of km traveled by PH cars using their electric engine

Portion of km traveled with the electric engine	Discount rate 6%	Discount rate 8%	Discount rate 10%
50% of km traveled	**$ 80,299.77**	**$ (62,916.66)**	**$ (189,243.76)**
70% of km traveled	**$ 607,244.68**	**$ 417,812.34**	**$ 250,778.25**
100% of km traveled	**$ 885,252.92**	**$ 674,508.70**	**$ 488,636.88**

Not surprisingly, since the benefits continue to occur after the costs are incurred, a lower discount rate places relatively more weight on the benefits and results in a higher NPV, while a higher discount rate results in a lower NPV. Of course, when the percentage of km traveled by PH cars using their electric engine goes up, the NPV follows in the same direction. Out of nine NPV values presented in Table 12, only two are negative at 8 and 10% discount rates with the portion of km using the electric engine at 50%. As discussed in Section III, given the average distance Quebec citizens drive per day and the average autonomy of PH vehicles available in 2012, these scenarios resulting in a negative NPV are not very likely.

In the next table, we allow for different durations for the benefits; i.e. 6, 7 and 12 years (8 years is the benchmark):

Table 13: NPV for different durations of the benefits

Number of years	NPV
6	$ (135,635.98)
7	$ 130,502.37
8	$ 417,812.34
12	$ 1,672,727.66

As can be seen, the AE and PH vehicles have to be used by their owners at least seven years for the program to be socially beneficial. As discussed in Section III, given the different guarantees provided by the manufacturers of PH and AE vehicles, a period of seven years seems reasonable.

In the following table, we consider different shares of the purchases of AE and PH vehicles attributable to the program. As discussed in Section IV, our analysis suggests that 46.6% of the purchases of PH and 50.1 % of AE vehicles are due to the program. This is our realistic scenario. In our pessimistic scenario, we assume that the program was responsible for only half of these proportions, and in our optimistic scenario, we assume a 100 % impact.

Table 14: NPV with various portions of purchases attributable to the program

Portion of purchases attributable to the program	NPV
Effect of the program - Pessimistic	$ (319,507.26)
Effect of the program - Realistic	$ 417,812.34
Effect of the program - Optimistic	$ 3,334,226.85

As one can see, this parameter seems to have a fairly important influence on the conclusion, as the NPV varies drastically from one scenario to the other. Further calculations show that the portions of purchases due to the program should be at 32.9% for each type of vehicle for the program to break even. Overall, given our discussion in Section IV on the validity of our results concerning these portions, we feel fairly confident about our realistic scenario.

Finally, we allow for the marginal cost of public funds to vary. In the next table, we show the MCPF necessary to reach a zero NPV under different scenarios concerning the discount rate and the fraction of km traveled by PH vehicles using their electric engine.

Table 15: Breakeven MCPF with different discount rates and portions of km traveled by PH cars using their electric engine

Portion of km traveled with electric engine	Discount rate 6%	Discount rate 8%	Discount rate 10%
50% of km traveled	1.2091	1.1861	1.1658
70% of km traveled	1.2938	1.2634	1.2365
100% of km traveled	1.3385	1.3046	1.2747

Of course, the lower the MCPF, the higher is the NPV. As we saw in Table 12, only two scenarios out of nine could lead us to a negative NPV. In our realistic case (middle cell in Table 15), the MCPF could be 34 % higher than the number we used and we would still have a positive NPV.

VII. CONCLUSION and DISCUSSION

The objective of this article was to provide a cost benefit analysis of the Purchase/Lease Rebate Program for Cleaner Vehicles put in place by the Quebec government in 2012. This program provides direct rebates for all-electric and plug-in hybrid vehicles according to the capacity of their electric battery, for cars and light trucks included on a list of eligible vehicles.

After describing the program, we identified and monetized its principal costs and benefits. The costs were related mainly to the expenses incurred by the government, while the benefits included savings in gasoline and oil changes, as well as reductions in different polluting emissions. Since these emissions have no market price, one of our challenges was to place a value on them. For this purpose, we used the “environmental value transfer” method to obtain values from previous relevant studies.

We conducted our CBA for the year 2012 and obtained a NPV of $417,812, with an internal rate of return of 13.5%. Our sensitivity analysis showed that our conclusion is fairly robust to various changes in assumptions and parameters.

From a policy perspective, this analysis has its limitations that raise a certain number of questions. First, from a theoretical view, subsidies for the purchase of AE and PH vehicles can be justified in order to help reaching a critical mass. In this particular case, this critical mass is necessary to develop a sustainable recharging network and for manufacturers to reach economies of scale. Before 2012, there were around 325 AE and PH vehicles in Quebec; with 809 new AE and HP purchased in 2012 (around 50 % attributable to the program), the progress seems substantial. According to SAAQ data about registration per fuel type, 1962 electric-powered vehicles were allowed to circulate on Quebec’s roads on December 31st of 2013. Still, there were over 6 million vehicles in Quebec in 2012, so that the share of AE and PH vehicles in the market remains negligible. Will the rebate program have the desired ripple effects? It is not clear.

Second, it is possible that a subsidy is not the best means to increase the share of AE or PH vehicles in the market. As suggested by Gallagher and Muehlegger (2011), increases in gasoline taxes could be very powerful, especially given that these taxes are so low in North America compared to Europe[24]. Increases in gasoline taxes would also give incentives to all drivers to be cautious about their gasoline consumptions, a beneficial impact that could be substantial.

Lastly, in jurisdictions where electricity is produced with fossil fuels, large increases in the number of AE or PH vehicles could result in non-negligible environmental costs associated with the production of the required additional electric power. It is not sure that the main conclusion of our study would remain valid in such a context.

[24] See http://www.oecd.org/env/tools-evaluation/env%20policy-natural%20resources%20brochure.pdf accessed on August 22, 2014

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