écomobile

Bureau de l'efficacité et de l'innovation énergétiques

ECO-DRIVING TRAINING PILOT PROJECT FOR LIGHT VEHICLES

SUMMARY FINDINGS

Québec

Ministère des Ressources naturelles et de la Faune

Secteur de l'énergie

Bureau de l'efficacité et de l'innovation énergétiques
Direction des secteurs du transport, de l'industrie et de l'innovation technologique
5700, 4e Avenue Ouest, B-406
Québec G1H 6R1

Telephone: 418 627-6379
Toll free: 1 877 727-6655
Fax: 418 643-5828
Website: www.efficaciteenergetique.mrnf.gouv.qc.ca
Email: efficaciteenergetique@mrnf.gouv.qc.ca

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1. BACKGROUND

In the spring of 2009, the Agence de l'efficacité énergétique (AAE)[1] launched a large-scale eco-driving training pilot program for light vehicles. The project was a preliminary step towards implementing a future training program for eco-driving in Quebec. The main goals of the project were:

- To test two approaches for the delivery of the new eco-driving training program developed by AEE;
- To measure the impact of eco-driving training on participants' fuel consumption;
- To evaluate the incidence of eco-driving training on the habits of the participants;
- To estimate the impact of eco-driving training over time;

To reach these goals, the pilot project monitored the energy performance and driving habits of 93 drivers representing 5 different companies from July 2009 to July 2010. Each vehicle was equipped with sensor units that continuously recorded information used to quantify and qualify the participants' driving. For comparison purposes, data was gathered before and after a one-day eco-driving course. Figure 1 illustrates the conceptual analytical approach adopted in the pilot project.

Fig. 1 – *Principal phases of the project*

Among the 93 drivers participating in the project, 69 of them followed the formal and practical training segments of the ecodriving course while the remaining 24 comprised the control group (no training). Table 1 draws a list of the principal activities carried out by the participants during the course of the pilot project as well as the time spent on each activity.

TABLE 1 – *PRINCIPAL PARTICIPANT ACTIVITIES DURING THE PILOT PROJECT*

Participant Activities	Dates	
	Groups 1, 2 and 3	Groups 4 and 5
Installation of Sensor Units in Vehicles	May and June 2009	December 2009 and January 2010
Pre-test	June and July 2009	n/a
Data Collection (Reference Period)	July-November 2009	December 2009 - March 2010
Training Activity	October and November 2009	February and March 2010
Data Collection (Post-training follow-up)	October 2009 - July 2010	February-July 2010
Removal of Sensor Units from Vehicles	September 2010	September 2010
Final Participant Survey	October 2010	October 2010

[1] As of July 1, 2011, the operations of the Agence de l'efficacité énergétique have been combined with those of the Ministère des Ressources naturelles et de la Faune (MRNF).

2. METHODOLOGY

2.1 PARTICIPANT SELECTION

Special care was given to selecting a sample group with respect to the technologies and limitations imposed by the companies. To begin, each company provided a complete list of all employees it wished to participate in the project. Candidates then were asked to fulfill eligibility requirements, namely:

- Availability to participate for the duration of the pilot project;
- A single driver for each vehicle;
- A recent model vehicle that uses the OBD-II CAN communication protocol and provides fuel consumption data.

These requirements were used to create a broad sample population including participants whose recruitment was mandated (60%) and those who volunteered (40%.) Participants used the vehicles primarily for work (60%) or for personal use (40%.)

2.2 DATA COLLECTION

Data collection for the pilot project was achieved via sensor units (on-board computers) manufactured by ISAAC Instruments. These units provide access to engine data via a connection with an OBD-II connector that continuously recorded several parameters with a sampling rate of up to 5 samples per second[2]. As Figure 2 illustrates, using sensor units was a transparent choice for the participant so as to minimize potential bias.

Fig. 2 – *Examples of units visible to the participant (connector, wire and sensor unit)*

Once the data is registered by the sensor unit, it is transmitted via cellular communication to the pilot project Analysis Manager. To avoid using the information networks of the companies participating in the pilot project, cellular communication rather than short-range communication (Wi-Fi, Bluetooth or 900 MHz) were used. Furthermore, cellular communication network provided direct access in real time to data, no matter where the vehicle was located in the covered area.

[2] The OBD-II CAN Protocol in the vehicles is limited to 50 queries per second.

2.3 CONTROL GROUP

A control group was created based on the global sampling by taking into account different factors, including the distribution within companies, the covered geographical areas, the types of vehicles as well as the participant's availability to participate in the training activities. It is made up of participants who did not participate in any of the eco-driving activities but who were monitored with the help of sensor units similar to those given to the other drivers. The control group reflects the natural trend, which is the average fuel consumption trend and the driving habits that should have been observed among all participants who do not have training. This condition makes it possible to quantify the impact of external factors such as seasonality that influence the outcome while not being linked to training.

The creation of a control group is critical for a rigorous analysis of a project such as this one. Indeed, it allows for the extrapolation of external factors in order to obtain the net effect of training activities on participants representing different companies.

2.4 TRAINING

AEE's new eco-driving training for light vehicles was put to the test to satisfy the needs of the pilot project with the goal of developing more efficient driving skills among participants in terms of energy and security. More specifically the aim is to better understand the factors that influence the vehicles' fuel consumption so as to recognize and adapt the most efficient behavior behind the wheel.

The pilot project was conceived in two versions. The first version had a theoretical component and a traditional practical component, ie. on the road driving, while the second version was made up of the theoretical component along with a practical component using a driving simulator. In both cases the training period was about six hours (non always consecutive) and included the evaluation activities. The training was given by the same qualified instructor who used the same teaching techniques from one group to the next.

It should be noted that at the conclusion of the training activities, participants were not given any follow-up training of the principles taught nor was the data collected shared with them.

2.5 DURATION OF STUDY

The duration of study was made up of continuously monitored data for a period of almost one year. For analysis purposes, weeks were grouped in five monitoring periods as described in Table 2.

TABLE 2 – *DETAILS ON THE DURATION OF THE STUDY*

Period	Details	Dates	
		Groups 1, 2 and 3	Groups 4 and 5
Reference	Weeks before the training activities	July - November 2009	December 2009 - March 2010
M1 (1 month)	Weeks 1 to 5 following the training activities	October - December 2009	February - April 2010
M3 (3 months)	Weeks 6 to 14 following the training activities	November 2009 - February 2010	March - June 2010
M6 (6 months)	Weeks 15 to 26 following the training activities	January - May 2010	May - July 2010
M9 (9 months)	Weeks 27 to 44 following the training activities	April - July 2010	n/a

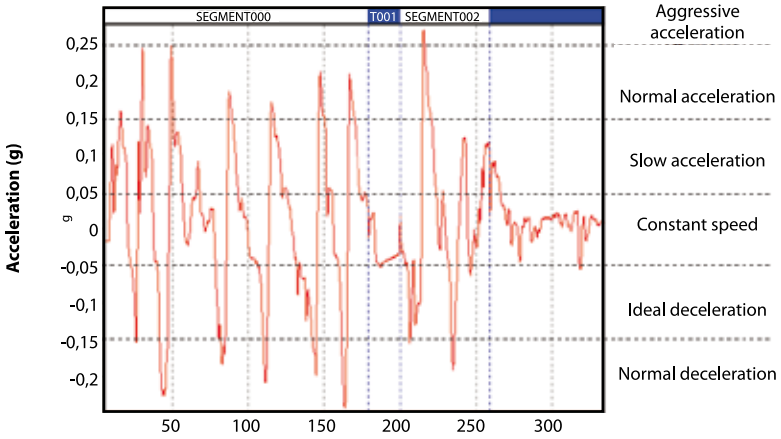
2.6 DATA ANALYSIS

The use of sensor units over such a long study period made it possible to compile data to evaluate the impact of training activities on fuel consumption and driving habits of the participants. By focusing on the principles taught during the training activities, different evaluation factors were determined including:

- Distance travelled;
- Fuel consumption;
- Acceleration;
- Deceleration (braking);
- Driving time at a constant speed;
- Anticipation;
- Driving speed;
- Engine idling;
- Driving time in the electric mode (hybrid vehicles only);
- Engine speed;
- Accelerator pedal position;
- Vehicle temperature while in operation.

Average values were compiled for each selected factor and for each participant for both highway and city driving[3] and for each week of use before and after training activities. Figure 3 gives an example of the basic data used to analyze driving habits in relation to acceleration, braking and constant speed.

Fig. 3 – *Example of Data Used for Analysis*



The results of the pilot project are generally presented in terms of statistically significant net relative variation. The values correspond to observed changes expressed in percentages in relation to the control group and that cannot be reasonably attributed to chance. Figure 4 illustrates in simplified form the mathematical operations that preceded the statistical tests.

Fig. 4 – *Outline of the Data Analysis*

Results of the Trained Participant
(After - Before)

Compared to

Results of the Control Group
(After - Before)

[3] City driving is defined by a speed of less than 70 km/h while highway driving corresponds to speeds of over 70 km/h or more.

3. RESULTS IN TERMS OF FUEL CONSUMPTION

3.1 FUEL CONSUMPTION IN THEORY

A vehicle's fuel consumption is estimated as the product of two factors, ie. the average rate of fuel consumption and the distance travelled. Hence:

$$C = TCC * D$$

Where : C = Fuel Consumption (l);

TCC = Average Fuel Consumption Rate (l/100km);

D = Distance Travelled (km).

Eco-driving training has an effect on the average fuel consumption rate by reducing the number of liters of fuel consumed over 100 km to travel the same route. Therefore, this is not a measurement which has a direct effect on the distance travelled.

In order to evaluate the overall impact of eco-driving training on the average rate of fuel consumption in a given group, three factors must be considered: the eco-driving implementation rate, the variation of the average rate of fuel consumption among those who applied eco-driving as well as decreased motivation over time.

It should be noted that the results of group 2, which is made up exclusively of hybrid vehicles, are excluded from the analysis of fuel consumption but were included in the analysis of driving habits. This decision was made given the difficulty of comparing variations in fuel consumption of hybrid vehicles with that of traditional vehicles, especially in the control group.

3.2 IMPLEMENTATION RATE OF ECO-DRIVING

The eco-driving implementation rate[4] corresponds to the number of trained participants who demonstrated a significant statistical reduction[5] of the average rate of fuel consumption in relation to the total number of participants. This can be interpreted as an indication of the drivers' motivation. If the rate did not reach 100%, this means that some of the drivers have chosen not to apply eco-driving or that their implementation is not sufficiently consistent to produce significant improvements.

The results of the pilot project show that the majority of trained drivers did apply eco-driving in the short term. Table 3 illustrates observations made for the project participants as a whole ("Global") as well as for each of the four groups that were created.

[4] The eco-driving implementation rate excludes participants who provide non-valid data.

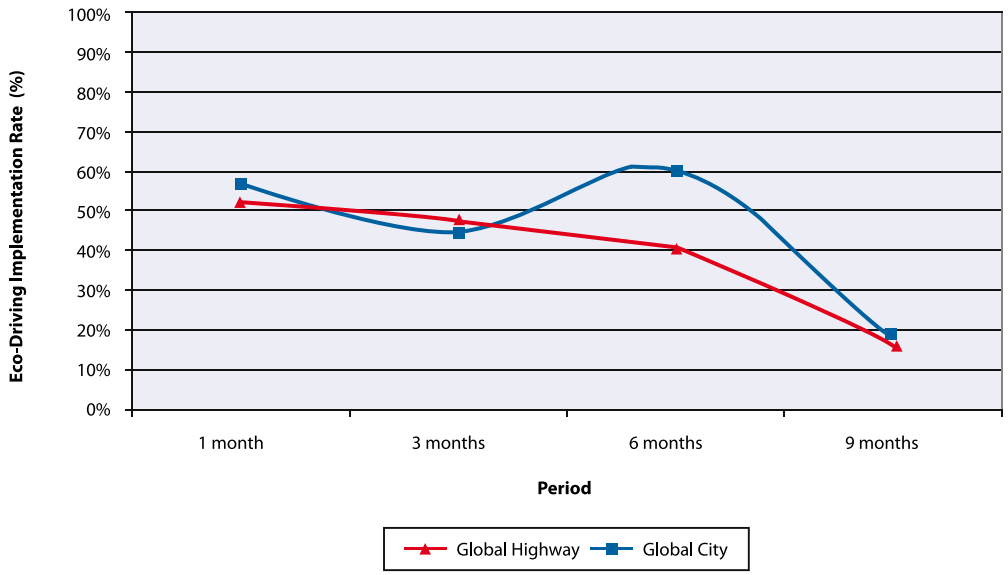
[5] With a significance threshold of 10%.

TABLE 3 – *SHORT-TERM ECO-DRIVING IMPLEMENTATION RATE (1 MONTH) BY TRAINED PARTICIPANTS*

	Global	Group 1	Group 3	Group 4	Group 5
Highway					
Implementation Rate	51.9 %	31.6 %	52.9 %	70.0 %	83.3 %
City					
Implementation Rate	55,8 %	42,1 %	55,6 %	77,8 %	66,7 %

With the exception of Group 1, all groups obtained implementation rates superior to the rate of the global group on the highway (51.9%) during the first five weeks following the training. Groups 4 and 5 also showed relatively high implementation rates in the city, 77.8% and 66.7% respectively. Generally speaking, more drivers implemented eco-driving in the short-term in the city than on the highway. Graph 1 analyzes the time evolution of the data for the group as a whole.

GRAPH 1 – *TIME EVOLUTION OF THE ECO-DRIVING IMPLEMENTATION RATE BY TRAINED PARTICIPANTS*



The eco-driving implementation rate in the city is relatively stable and even improves slightly in the first six months following the training from 44.0% to 60.0%. This stability also manifests itself on the highway although no improvement was found. A significant drop in the implementation reappears nine months after the training with final values on the highway and in the city of 15.6 and 17.6% respectively. The later finding can be explained in part by a decreasing motivation with time and the absence of feedback and follow-up with the participants.

3.3 AVERAGE FUEL CONSUMPTION RATE

The variation of the average fuel consumption rate is linked to the improved energy efficiency obtained by drivers who implemented the advice and techniques learned immediately following the (short-term) training. Generally speaking, previous studies place the decrease of the average rate of fuel consumption when applying eco-driving at 10%.

In the short term, the results of the pilot project correspond to the expectations drawn from the literature on the subject. Table 4 summarizes the averages obtained for participants as a whole of the pilot project (global) and for each of the four sub-groups and only take into account the statistically significant variations[6] among drivers who implemented eco-driving.

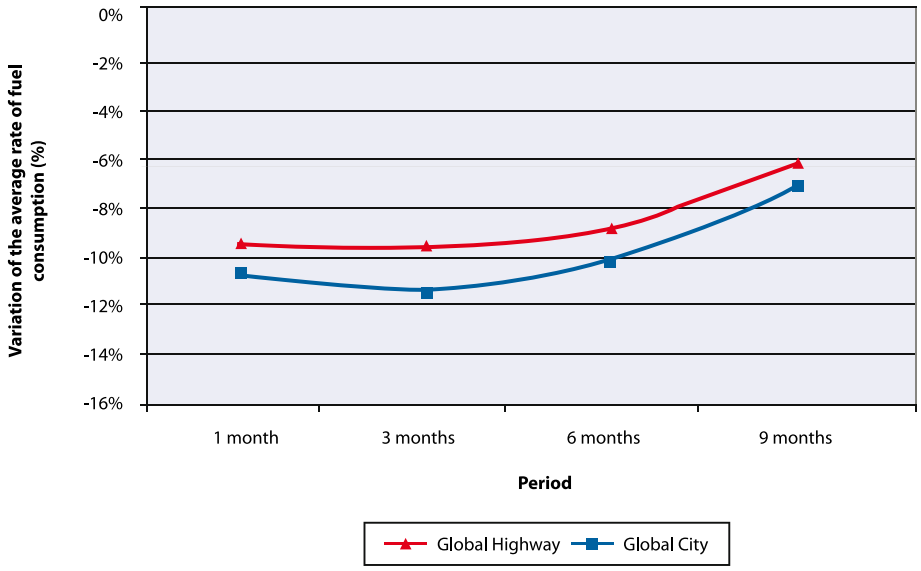
TABLE 4 – *SHORT-TERM (1 MONTH) VARIATION OF THE AVERAGE RATE OF FUEL CONSUMPTION FOLLOWING TRAINING*

	Global	Group 1	Group 3	Group 4	Group 5
Highway					
Variation of the Average Fuel Consumption Rate	-9,5 %	-6,5 %	-9,3 %	-8,6 %	-15,0 %
City					
Variation of the Average Fuel Consumption Rate	-10,7 %	-9,0 %	-11,9 %	-9,7 %	-13,0 %

The data shows that during the first five weeks following the training, the average decrease of the mean rate of fuel consumption varied among the groups from 6.5% to 15.0% on the highway and from 9.0% to 13.0% in the city. The ranking of the results among the groups is the same for the highway and for the city. In other words, the highest values were observed in group 5, followed by groups 3 and 4 and finally group 1. For a long-term analysis, Graph 2 illustrates the time evolution of the data for the global group.

[6] With a significance threshold of 10%

GRAPH 2 – *TIME EVOLUTION OF THE AVERAGE FUEL CONSUMPTION RATE FOLLOWING TRAINING*



The initial impact of training on the average rate of fuel consumption for the global group remained steady during the first six months following the training both on the highway and in the city. These results are interesting given the complete absence of refresher training on the basics of eco-driving throughout the project. Starting at six months a certain loss in motivation in applying eco-driving begins to appear and becomes more pronounced after nine months. At the conclusion of the pilot project, the participants who applied eco-driving were still obtaining respectable values of 6.2% on the highway and 7.2% in the city. It should be noted that the data gathered on the highway and in the city manifested similar trends throughout the duration of the pilot project, with a differential of about one percentage point in favor of the city.

3.4 OVERALL IMPACT OF ECO-DRIVING TRAINING

To determine the overall impact of eco-driving training, the eco-driving implementation rate presented in section 3.2 needs to be combined with the average variation of the mean fuel consumption rate among drivers who applied eco-driving as described in the previous section. The result obtained indicates the average variation of the mean rate of fuel consumption for the entirety of the group.[7] If one supposes that the travel distance is constant and equally distributed among drivers then one can isolate the net fuel savings for the group.

The results of the pilot project show noticeable reductions in fuel consumption in the short term, both in the city and on the highway, all other factors remaining equal. Table 5 summarizes the total impact of the training for all participants in the pilot project (global) as well as for each of the four groups created.

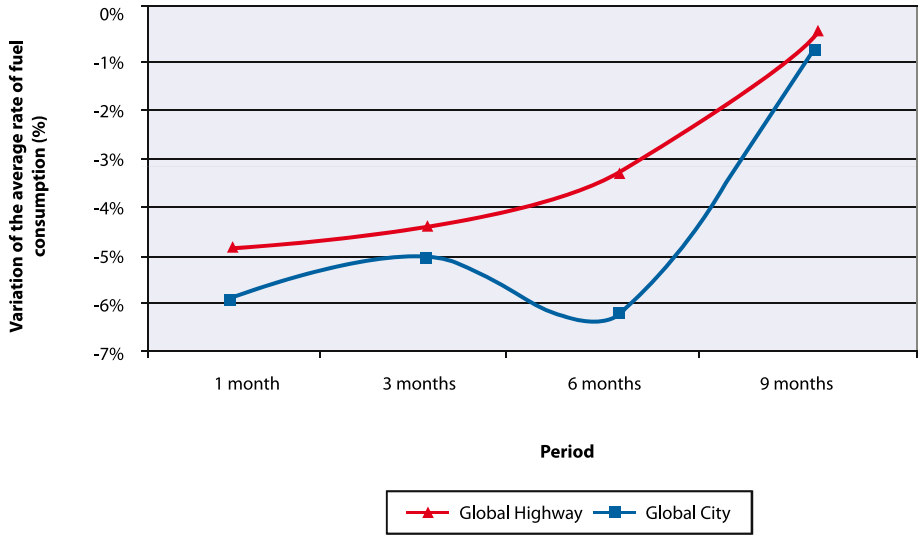
[7] More specifically, the average fuel consumption rate for the group should be pondered in relation to the distance travelled by each participant having applied eco-driving.

TABLE 5 – *TOTAL SHORT-TERM (1 MONTH) IMPACT OF ECO-TRAINING ON THE AVERAGE FUEL CONSUMPTION RATE*

	Global	Group 1	Group 3	Group 4	Group 5
Highway					
Variation of the Average Fuel Consumption Rate	-4,9 %	-2,0 %	-4,9 %	-6,0 %	-12,5 %
City					
Variation of the Average Fuel Consumption Rate	-6,0 %	-3,8 %	-6,6 %	-7,6 %	-8,6 %

The data show a drop in the average rate of fuel consumption for the group as a whole by 4.9% on the highway and 6.0% in the city during the first five weeks following the training. Once again, the best groups on the highway were also the most efficient in the city. For a long-term analysis of this impact, Graph 3 illustrates the time evolution of the data in Table 5 for the global group.

GRAPH 3 – *TIME EVOLUTION OF THE OVERALL IMPACT OF ECO-DRIVING TRAINING ON THE AVERAGE FUEL CONSUMPTION RATE*



The curve illustrating the results of the global group on the highway is placed under the curve corresponding to the city data for the duration of the pilot project. This shows that the reduction of the average rate of fuel consumption is higher in the city. City data is particularly stable during the first six months while the highway data gradually decline. Once again, we should mention the noticeable decline that occurs at nine months, mainly because the trained participants did not get any kind of feedback. Fuel savings for the entire group at the end of the pilot project is about 1%.

4. RESULTS IN TERMS OF DRIVING HABITS

By adopting the same analytical approach used for fuel consumption, different driving habits were studied during the pilot project. Changes in driving habits are frequent among different groups. Tables 6 and 7 illustrate significant results[8] in favor of eco-driving both on the highway and in the city.

TABLE 6 – *IMPACT OF ECO-DRIVING TRAINING ON DRIVING HABITS ON THE HIGHWAY*

Indicator	Group 1	Group 2	Group 3	Group 4	Group 5	Total
Weak Accelerations	--	Yes	Yes	--	Yes	**3**
Ideal Deceleration	--	Yes	Yes	--	Yes	**3**
Constant Speed	--	--	Yes	--	Yes	**2**
Speed above 110 km/h	--	Yes	Yes	Yes	Yes	**4**
Average Speed	--	Yes	--	--	--	**1**
Aggressive Acceleration	--	--	--	Yes	Yes	**2**
High Engine Speed	Yes	Yes	Yes	--	Yes	**4**
Partial Total	**1**	**5**	**5**	**2**	**6**	

On the highway, groups 2, 3 and 5 show several changes in driving habits that can lead to a reduction in fuel consumption. In light of these results, it seems reasonable to presume that group 2 also showed a reduced fuel consumption in the magnitude of the improvements made in groups 3 and 5. Worthy of note is a decreased of time for speeds above 110 km/h along with a reduction of high engine speeds in four of the five groups in the pilot project.

[8] With a significance threshold of 10% in addition to respecting a criterion of predominance.

TABLE 7 – *IMPACT OF ECO-DRIVING TRAINING ON DRIVING HABITS IN THE CITY*

Indicators	Group 1	Group 2	Group 3	Group 4	Group 5	Total
Weak Acceleration	--	Yes	Yes	Yes	Yes	**4**
Ideal Deceleration	--	--	Yes	--	--	**1**
Constant Speed	--	Yes	Yes	--	Yes	**3**
Average Speed	--	--	--	--	--	**0**
Overall Engine Slowdown	Yes	Yes	Yes	--	--	**3**
Aggressive Acceleration	--	--	--	--	--	**0**
High Engine Speed	--	--	Yes	--	--	**1**
Partial Total	**1**	**3**	**5**	**1**	**2**	

In the city, groups 2 and 3 showed several changes in driving habits that could lead to a reduction in fuel consumption. Once again, it seems reasonable to presume that group 2 also reduced its fuel consumption in the magnitude of the improvements obtained by group 3. The three behaviors that showed the most improvement among the groups were the increase of weak accelerations, the increased time spent driving at a constant speed as well as drop in idle-time. It is interesting to note that two of the three elements are linked to the issue of managing accelerations that was more prevalent in city conditions.

5. CONCLUSION

The eco-driving training pilot project for light vehicles makes it possible to measure the impact of eco-driving training on the average fuel consumption rate. Results prove that the benefits of eco-driving are substantial and achievable in real-life situations.

Overall, more than one of two drivers both on the highway and in the city applied eco-driving in the weeks that followed the training. These drivers obtained an average reduction of the mean fuel consumption rate in the range of 9.5 % on the highway and 11 % in the city. This positive benefit was maintained approximately six months after which a significant drop was observed, particularly in terms of the eco-driving implementation rate. This drop in motivation has brought to the surface the need to provide feedback to the trained drivers in the months following the training activities. There are many opportunities for refresher training such as positive reinforcement given by companies to the drivers, a shortened version of the training and an awareness campaign.

On the issue of driving habits, changes in behavior which could have an impact on fuel consumption were confirmed repeatedly in several groups, especially in highway conditions. We should point out the improvements in increased engine speeds at speed above than 110 km/h and the high engine speeds obtained on the highway, the amount of time spent driving at constant speeds as well as the total amount of idle time in the city.

According to the Ministère des Ressources naturelles et de la Faune[9], the results of the pilot project are positive and are a source of new and valuable information. The Ministère is also of the opinion that the participation of the different companies greatly contributed to the success of the pilot project eco-driving training program for light vehicles.

[9] As of July 1, 2011, the activities of the Agence de l'efficacité énergétique had been taken over by the Ministère des Ressources naturelles et de la Faune (MRNF).

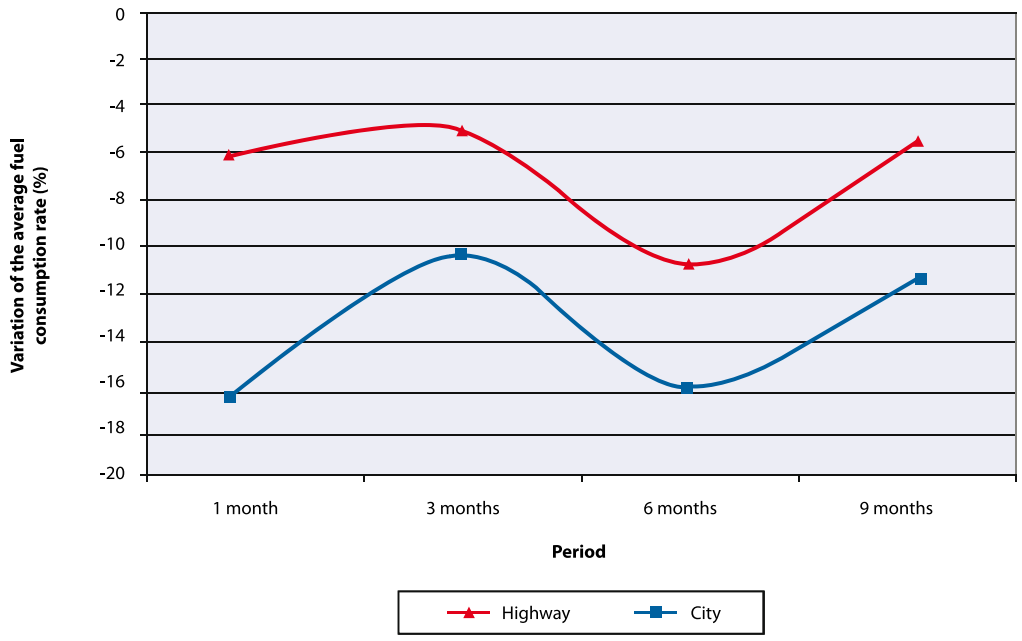
APPENDIX – INDIVIDUAL SUCCESS STORIES

EXEMPLE 1

Description of the participant			Type of vehicle		
Group	Sex	Recruitment	Vehicle Class	Gear Box	Type of Use
1	Male	Mandatory	Van	Automatic	Professional

Participant Result on the Highway		Participant Result in the City	
Average Fuel Reference Consumption Rate	Variation of the Average Fuel Consumption Rate (1 month)	Average Fuel Reference Consumption Rate	Variation of the Average Fuel Consumption Rate (1 month)
14.2 l/100km	-6,1 %	25,6 l/100km	-16,4 %

Time Evolution



Savings (9 months)[10]:	324 $
Savings over one year:	432 $

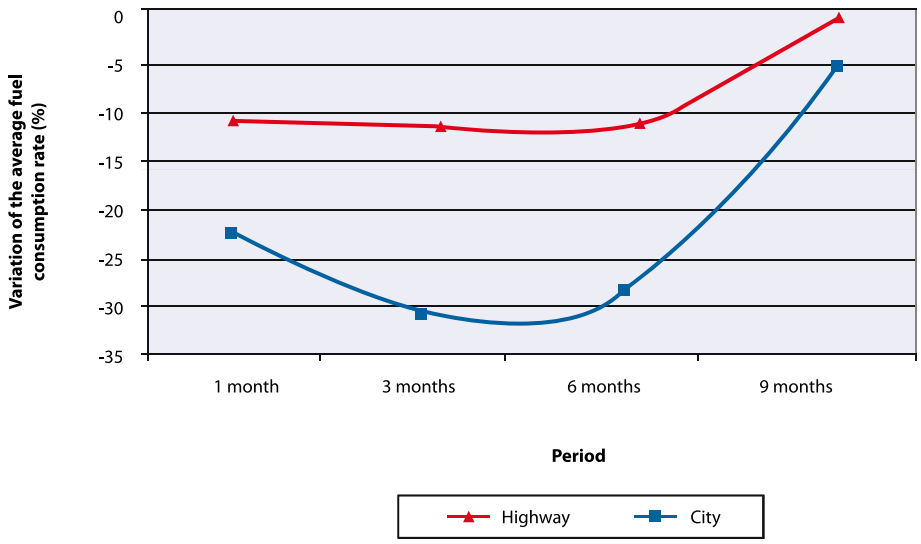
[10] Exclusively during the post-training period of the pilot project at a price of 1.40$ per liter.

EXEMPLE 2

Description of the participant			Vehicle Type		
Sex	Recruitment	Vehicle Class	Gear Box	Type of Use	Type d'utilisation
Male	Volontary	Sport Utility	Manual	Personal and Professional	Personnelle et professionnelle

Participant Results on the Highway		Participant Result in the City	
Average Fuel Reference Consumption Rate	Variation of the Average Fuel Consumption Rate (1 month)	Average Fuel Reference Consumption Rate	Variation of the Average Fuel Consumption Rate (1 month)
7,3 l/100km	-11,2 %	11,3 l/100km	-23,8 %

Time Evolution



Savings (9 months)[11]:	214 $
Savings over one year:	285 $

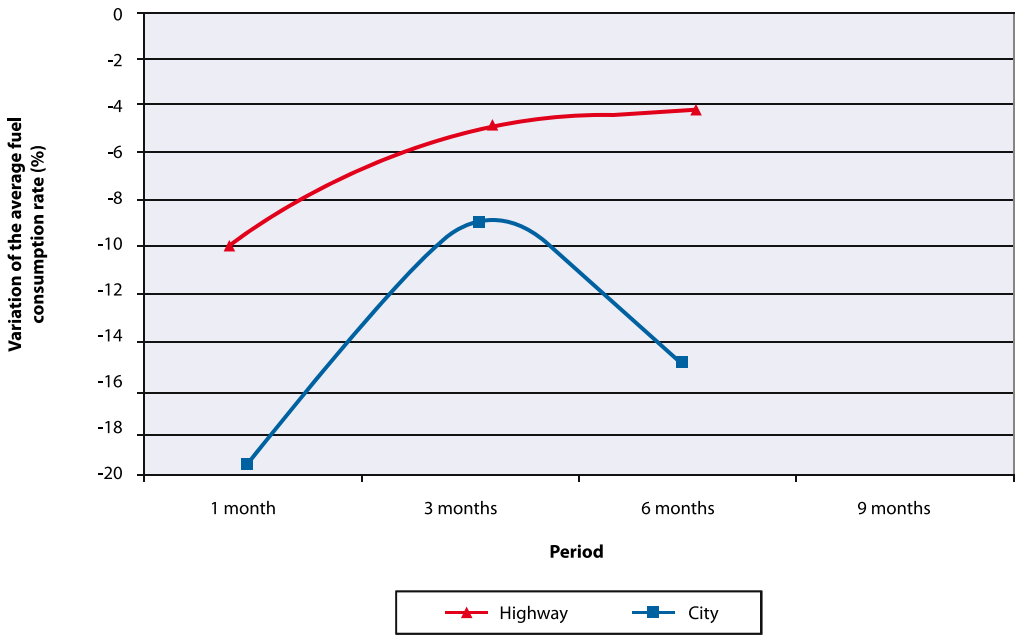
[11] Exclusively during the post-training period of the pilot project at a price of 1.40$ per liter.

EXEMPLE 3

Description of the participant			Type of vehicle		
Sex	Recruitment	Vehicle Class	Gear Box	Type of Use	Type d'utilisation
Male	Voluntary	Mini-van	Automatic	Personal	Personnelle

Participant Result on the Highway		Participant Result in the City	
Average Fuel Reference Consumption Rate	Variation of the Average Fuel Consumption Rate (1 month)	Average Fuel Reference Consumption Rate	Variation of the Average Fuel Consumption Rate (1 month)
10,1 l/100km	-9,8 %	22,6 l/100km	-19,4 %

Time Evolution



Savings (6 months)[12]:	143 $
Savings over one year:	286 $

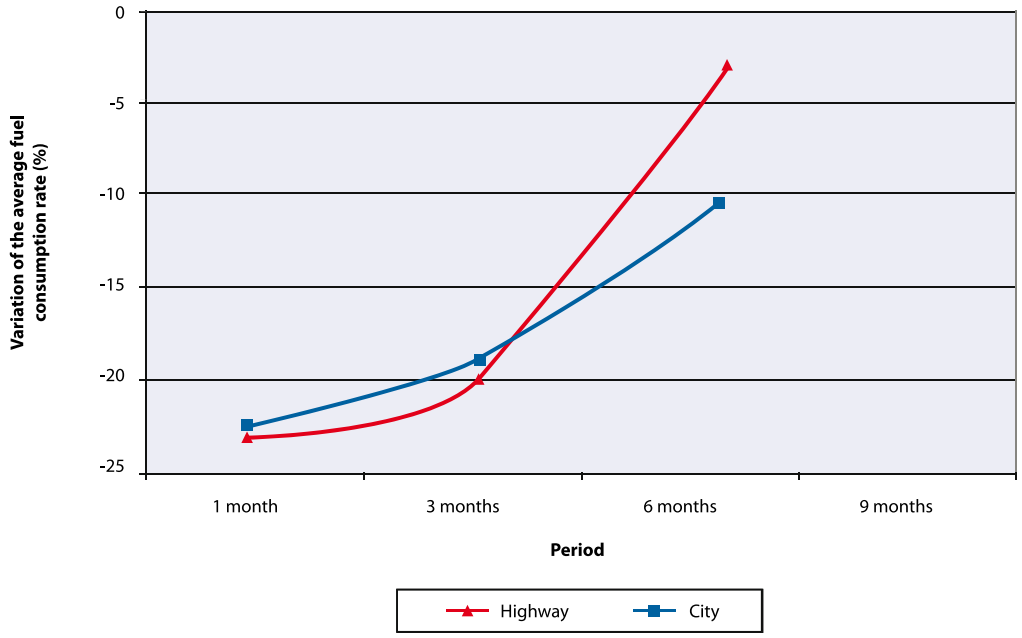
[12] Exclusively during the post-training period of the pilot project at a price of 1.40$ per liter.

EXEMPLE 4

Description of the participant			Type of vehicle		
Sex	Recruitment	Vehicle Class	Gear Box	Type of Use	Type d'utilisation
Male	Voluntary	Sedan	Manual	Personal	Personnelle

Participant Result on the Highway		Participant Result in the City	
Average Fuel Reference Consumption Rate	Variation of the Average Fuel Consumption Rate (1 month)	Average Fuel Reference Consumption Rate	Variation of the Average Fuel Consumption Rate (1 month)
7,5 l/100km	-23,2 %	12,3 l/100km	-23,0 %

Time Evolution



Savings (6 months)[13]:	178 $
Savings over a year:	356 $

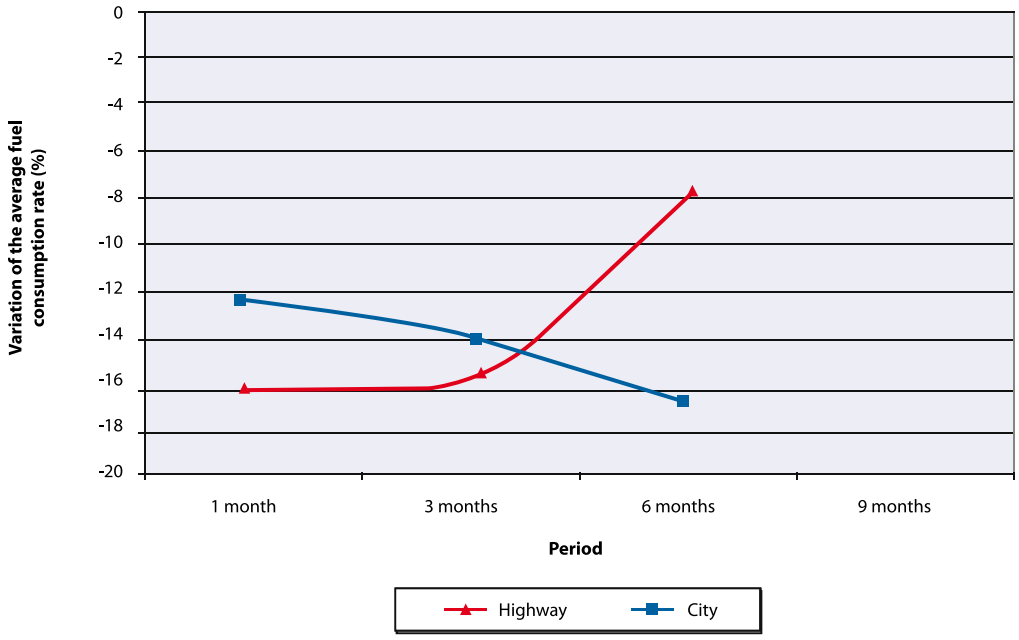
[13] Exclusively during the post-training period of the pilot project at a price of 1.40$ per liter.

EXEMPLE 5

Description of the participant			Type of Vehicle		
Sex	Recruitment	Vehicle Class	Gear Box	Type of Use	Type d'utilisation
Female	Voluntary	Sedan	Automatic	Personal	Personnelle

Participant Result on the Highway		Participant Result in the City	
Average Fuel Reference Consumption Rate	Variation of the Average Fuel Consumption Rate (1 month)	Average Fuel Reference Consumption Rate	Variation of the Average Fuel Consumption Rate (1 month)
6,1 l/100km	-16,1 %	10,7 l/100km	-12,6 %

Time Evolution



Savings (6 months)[14]:	150 $
Savings over one year:	300 $

[14] Exclusively during the post-training period of the pilot project at a price of 1.40$ per liter.

INFORMATION:

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1 877 727-6655

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