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# Testing and Verification Protocol for Engine and Vehicle After-market Devices



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**Performance  
Innovation  
Transport**  
An FPIInnovations Group

# Testing and Verification Protocol for Engine and Vehicle After-market Devices

**March 28, 2013**

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## Summary

Environmental quality and energy efficiency are priority areas for Environment Canada. Environment Canada manages Canadian Environmental Technology Verification (ETV) Program, which offers independent verification of environmental performance claims for innovative technologies, processes, and products.

The challenges and opportunities presented by engine and vehicle after-market devices is a specific technology area of interest to a range of stakeholders.

This testing and verification protocol helps guide the demonstration and deployment of effective engine and vehicle technologies and solutions. The protocol meets the requirements of the Canadian ETV Program and the program's General Verification Protocol.

In consultation with Environment Canada and the Canadian ETV Program's delivery agent, GLOBE Performance Solutions, a Technical Advisory Committee (TAC) was formed to engage sectorial stakeholders, experts and municipalities in a round table discussion leading to the development of a suitable testing and verification protocol for engine and vehicle after-market devices. The TAC provided input and technical expertise into the development of this technology testing and verification protocol.

The following generic process is proposed:

- Screening of the application: the objective is to determine if the technology meets basic requirements prior to proceeding with performance testing and verification;
- Testing of technology to evaluate performance: the focus of testing is to determine, with a 95% level of confidence, the statistical significance of changes in the fuel consumption and/or emissions of the engine or of the vehicle on which the tested technology is used;
- Verification of the test report: the verification process is a third party expert evaluation of the technology and of the independent third party testing based on the requirements of the Canadian ETV Program General Verification Protocol.

This protocol presents the general test methodology and existing test methods that can be used for engine and vehicle after-market devices, with reference to applicable standards and regulations, and in a manner that is consistent with the framework of the Canadian ETV Program General Test Protocol.

Considering that specific regulations and standards are already in place across a number of jurisdictions, the protocol does not detail test procedures. However, because unique technologies may require specific test plans that cannot be found in existing standards, particular testing methods may be accepted, depending on the equipment covered by the application.

It is recognized that while the process must be accurate, it must also be cost effective to facilitate technology supplier access to verification.



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# Introduction

## Context

Environment Canada's ETV Program is based on sound science, high-quality data, and recognized protocols. The Program offers independent verification of environmental performance claims for innovative technologies, processes, and products. According to Environment Canada (2012a), for the purposes of the ETV Program, environmental technologies are products and processes that offer an environmental benefit or address an environmental problem. This definition includes products and processes whose primary purpose is environmental protection or remediation. It also includes products or processes that contribute to environmentally sound production, including alternative production processes and materials.

Fuel costs continue to escalate and "green" transportation technologies are increasingly in demand. Obstacles to the adoption of innovative technologies include the lack of credible information from independent qualified sources. Therefore, one of the ways to support the industry is to provide reliable information resulting from the rigorous testing of fuel-efficient and emissions technologies, and to present this information to key stakeholders in the transportation, fleet and freight sectors.

The challenges and opportunities presented by engine and vehicle after-market devices (EAMDs) is a specific technology area of interest to a range of stakeholders.

Previous work has assessed the need and characterized the scope for the independent performance verification of vendor claims related to energy and emissions improvements. A general EAMD draft protocol was developed (ETV Canada – OCETA 2007), and a study was completed in 2010 for Transport Canada, Natural Resources Canada and Environment Canada indicating the size of this market and the range of technologies being promoted (OCETA 2010).

## Protocol Development Process

In consultation with Environment Canada and the Canadian ETV Program's delivery agent, GLOBE Performance Solutions, a Technical Advisory Committee (TAC) was formed, to engage sectorial stakeholders, experts and municipalities in a round table discussion leading to the development of a suitable testing and verification protocol for engine and vehicle after-market devices. The TAC provided input and technical expertise into the development of the testing and verification protocol. Appendix A presents the composition of the TAC.

The first stage of the protocol development process was to present a background document to TAC members for analysis. The background document presented:

- An analysis of existing test methods and verification protocols for engine and vehicle after-market devices, including a review of the Canadian ETV Program General Test Protocol and the General Verification Protocol (GVP);
- A tabular summary of a comparative analysis of existing testing and verification protocols for engine and vehicle after-market devices (Appendix B);
- A proposed set of screening and evaluation parameters, and testing and verification protocols.

Based on the feedback received from the first TAC meeting, screening and evaluation parameters and testing and verification protocols were revised, and a complete draft protocol was consequently presented for review. The feedback received during the second TAC meeting allowed to refine and finalize the protocol.

## Objectives

- This protocol aims to guide and support the review and approval of performance verification claims by any manufacturer or vendor of EAMDs in a transparent and credible manner.
- The protocol aims to be mutually acceptable to both technology users and proponents so that valid and credible data is in place to support performance claims: acceptable for technology users means accurate and independent results, while proponent looks for credibility at the lowest cost.

## Protocol Outline

- The protocol meets the requirements of the Canadian ETV Program and the program's General Verification Protocol (Environment Canada 2012a), such as:
  - Overall guidance through a General Verification Protocol;
  - Quality-assured test procedures and analytical techniques to measure performance parameters;
  - Testing and analysis by an independent third-party test agent;
  - Verification and report by an independent verification organization.

A generic verification process, outlined below, is proposed.

- Screening of the application
  - The scope is to determine if technology meets basic requirements prior to proceeding with performance testing and verification.
  - The first stage is an initial self-assessment pre-screening application, common for all the components of the Canadian ETV Program.
  - The second screening consists of a technical review of the documentation by a qualified independent expert, or a committee of independent experts.
- Testing of technology to evaluate performance
  - This protocol presents the general test methodology and existing test methods that can be used, with reference to applicable standards and regulations, in a manner that is consistent with the framework of the General Test Protocol. Considering that specific regulations and standards are already in place across a number of jurisdictions, the protocol does not detail test procedures.
  - However, because unique technologies may require specific test plans that cannot be found in existing standards, and depending on the equipment covered by the application, particular testing methods may be accepted by the expert or committee of experts reviewing the application. For some particular technologies, the protocol specifies test procedures, such as testing on duty cycles, testing of refrigeration units, and testing of idle reduction technologies.



- The focus of testing is to determine, with a confidence level of 95%, the statistical significance of changes in the fuel consumption and/or emissions of the engine, equipment or vehicle on which the tested technology is used, according to the specific performance parameter.
- The nominal values for the changes in the fuel consumption and/or emissions are determined from the analysis of the measured fuel or emission data and reflect the changes resulting from the modification being tested on the test vehicle, engine, or equipment. The confidence interval must be less than the nominal result for having a statistically valid result.
- Verification of the test report
  - The verification process is based on the General Verification Protocol..
  - The verification organization must be an independent third party organization.
- Life cycle analysis (LCA) is not the objective of this protocol: verification can only be applied against measurable performance criteria. LCA is an important decision-making tool, but environmental performance verification of technologies based on a full-range of comprehensive systemic parameters would be extremely difficult to implement.

Cost analysis is not an exclusory stage of the process, but it provides additional information to the user of the technology under consideration.



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# Testing and Verification Protocol

## 1. Screening of the Application

The proposed screening process is presented in Figure 1 (based on OCETA 2010 and Canadian ETV 2012).

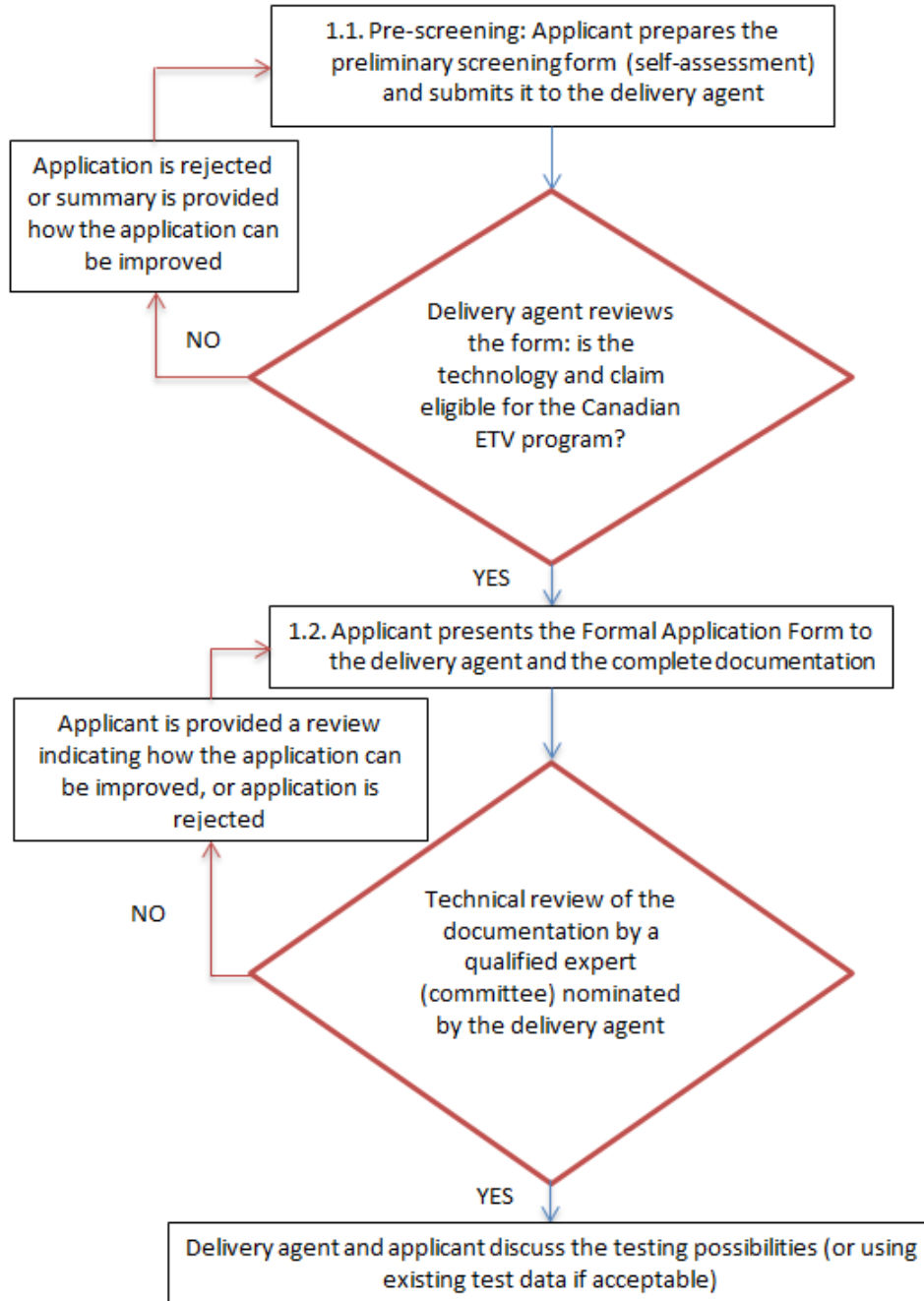


Figure 1. Screening process.

## 1.1. Self-assessment Pre-screening Application

If the applicant considers that his/her technology meets the following requirements, he/she submits an Online Screening Form (Appendix C), common for all the components of the Canadian ETV Program:

- It must be an environmental technology as defined by the General Verification Protocol (Environment Canada 2012a);
- The performance claim must meet minimum Canadian standards and/or national guidelines for that technology and where it is being used;
- The performance claim must be measurable;
- The applicant must own the intellectual property of the technology to be verified, or can obtain a written permission from the owners to pursue the verification; and
- The technology must be currently commercially available or commercially ready for full-scale application.

The technology undergoes a preliminary screening to determine if it meets minimum eligibility requirements for verification.

If the technology meets the minimum eligibility requirements for verification, the applicant submits a Formal Application (according to the general procedure of the Canadian ETV Program).

## 1.2. Screening

With the Formal Application, the applicant must provide (Canadian ETV 2012):

- An original signed letter attesting to the applicant's ownership of the intellectual property of the technology to be verified or, if the applicant is an authorized user, manufacturer or distributor(rights-holder), an original letter from the owner attesting to the existence of a licensing or similar agreement in force as of the date of formal application;
- Information to support the verification, including more detailed technology data, the claim to be verified, and the data and information to support the claim.

The delivery agent of the Canadian ETV program reviews the Formal Application for completeness and determines if the technology can proceed further.

The screening method involves a technical review of the documentation by a qualified independent expert, or a committee of independent experts, from or nominated by the delivery agent. If the delivery agent lacks particular expertise, outside experts can be used.

Five key screening areas were identified (OCETA 2010):

1. Company or vendor status
2. Technology
3. Product details
4. Potential environmental impacts
5. Existing test results



Table 1 presents guidelines to help the experts in the evaluation of the applications in a uniform manner (based on OCETA 2010).

**Table 1. Proposed guidelines for screening**

<b>Company or vendor status</b>	Reputation <sup>1</sup>
	Relevant business experience in the sector
	Experience with the specific technology or similar designs
<b>Technology</b>	Description
	Applicability
	Customers
	How technology works
	Installation, operating criteria and constraints
	Patents
	Technical papers
<b>Product</b>	Performance claim and basis for performance claim
	Potential unique testing needs
	Health effects and safety data (MSDS or EPA registered if available)
	Compatibility with OEM equipment
	Impact on original warranty
	Liability insurance coverage
<b>Environmental impact</b>	Meeting applicable regulations and standards
	Disposal
	No hazardous or toxic effects
	Does not increase emissions
<b>Existing test results</b>	Preliminary test results for fuel savings or GHG emission reduction
	Preliminary test results for emission of pollutants reduction
	Test data generated by third party
	Test data not older than 3 years (Make sure that test data are for the current technology)

<sup>1</sup> The applicant has not been found responsible for or guilty of violations of the law.

If the application passes the screening, the delivery agent discusses the method of verification with the applicant, which could be either:

- Using existing test data, if the data are generated by third party, no older than three years, and meet the quality requirements outlined in the Application Guide, or
- Working with a third party test agent to develop an appropriate testing plan and generate data as per the test plan.

Note that technical experts may be consulted as part of this process.





## 2. Testing of Technology to Evaluate Performance

### 2.1 Canadian ETV Program General Test Protocol

The General Test Protocol (GTP) provides guidance to vendors and testing agencies for:

- Developing and executing a test program to assess the performance of an environmental technology;
- Preparing a report that summarizes the test results in support of an application to the ETV Program for performance claim verification.

The protocol has been structured according to a four-step process to facilitate the collection of sound data for claim verification (Environment Canada 1998):

1. Design of test program
  - Test agency develops a draft experimental plan with the vendor.
  - Draft plan submitted to the delivery agent for review.
  - Delivery agent revises and acknowledges the plan.
  - Test agency proceeds with implementation of the plan.
2. Data collection: performance parameters and operating conditions
3. Data assessment: based on the principles of relevance and quality
4. Reporting the results.

### 2.2. Performance Parameters

#### 2.2.1 Emissions of pollutants and GHG

- a) For pollutant emissions, it is recommended to measure the regulated pollutants (according to Canadian or EPA regulations), such as carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>), non-methane hydrocarbons (NMHC), and particulate matters (PM). For comparative technology evaluation purposes, the measurement of PM emissions is not required for vehicles complying with EPA 2007 emission requirements or later, considering the very high efficacy of particulate filters, and the extremely low PM emissions level of these vehicles. This exclusion does not apply for the technologies intended to reduce PM emission. Total hydrocarbons (THC) can be measured instead of NMHC, according to EPA requirements and stipulations (for heavy-duty diesel vehicles, for example, subtract two percent from the measured THC value to obtain an NMHC value).
- b) For greenhouse gas (GHG) emissions, it is recommended to measure carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), and nitrous oxide (N<sub>2</sub>O). However, Table 2 (Environment Canada 2012b) shows that for diesel and gasoline engines CH<sub>4</sub> and N<sub>2</sub>O emissions are negligible in comparison to CO<sub>2</sub> emissions, thus only the CO<sub>2</sub> emission reduction can be used for comparative evaluation purposes for these types of engines. For natural gas vehicles, it is imperative to measure CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O.



**Table 2. GHG emission factors for heavy-duty diesel vehicles**

Type of engine control system	Emission factor (g/L of fuel)		
	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
Diesel Heavy-duty Advanced Control	2 663	0.11	0.151
Diesel Light-duty Advanced Control	2 663	0.068	0.22
Diesel Off-road	2 663	0.15	1.1
Gasoline Light-duty Tier 2	2 289	0.14	0.022
Gasoline Off-road	2 289	2.7	0.05

- c) The focus of testing is to determine, with a confidence level of 95%, the statistical significance of the reduction in emissions of the vehicle or engine, on which the tested technology is used. The nominal values for the changes in emissions are determined from the analysis of the measured emission data and reflect the reductions resulting from the modification being tested on the test vehicle or engine.
- d) The performance criteria is the percentage improvement (decrease of emissions) over the baseline correlated with the baseline absolute values, which means that the percentage improvement must be presented in the context of the baseline value. For example a reduction in NO<sub>x</sub> from 0.11 to 0.10 g/bhp-hr is a reduction of 9%, but is practically minor in the context of the baseline value, which is already very low and the variation in testing conditions and results.
- e) Emission tests are conducted on a vehicle (engine, equipment) representative of the typical vehicle (engine, equipment) for which the technology is intended.
- f) At least three baseline segment tests without the technology followed by three final segment tests with the technology fitted would be the minimum acceptable in both laboratory and track (road) tests.
- g) The result is expressed as a nominal value plus and minus the confidence interval. If the confidence interval value for a test is greater than or equal to the nominal test value, as determined by the statistical analysis results, it is recommended that additional tests be conducted to reduce the confidence interval value to less than nominal test value. For example, if the nominal value of the tests result is 3% and the confidence interval is 4%, the results is expressed as 3% ±4%. In this example additional tests must be conducted to lower the confidence interval. If additional tests do not show statistically conclusive results, the conclusion must be that the test does not show a statistically valid change in emissions (the change is less than the test precision, or the change in emissions is influenced by variations in the test conditions).
- h) The device manufacturer is responsible for meeting emissions and diagnostic standards (OBD compliance). Technologies intended to reduce the emission of pollutants must not increase fuel consumption or GHG emissions, which include CO<sub>2</sub>, CH<sub>4</sub>, and N<sub>2</sub>O. However, for diesel and gasoline engines only the CO<sub>2</sub> emissions can be measured for comparative evaluation purposes. Technologies intended to reduce the GHG emissions must not increase regulated emissions, which include CO, NO<sub>x</sub>, NMHC, and PM. The measurement of PM emissions is not required for vehicles complying with EPA 2007 emission requirements or later, considering the very high efficacy of particulate filters, and the extremely low PM emissions level of these vehicles.

- i) For technologies intended to reduce the emission of pollutants, which are installed on an engine and its auxiliary systems – exhaust system, antipollution system, air intake, fuel delivery system etc. – durability testing is recommended to verify performance over time. Once the technology is verified and 500 units are sold, the applicant is responsible for reporting to the delivery agent of the Verification Program. The delivery agent will analyze and decide on the necessity and opportunity of developing an appropriate test plan (experts can be consulted in this process). In the case of regulated technologies and devices, such as catalytic convertors, exhaust gas recirculation system components, and selective catalytic reduction systems components, the durability testing stipulated by the applicable regulations or standards must be conducted.

### 2.2.2 Fuel Efficiency

- a) The focus of testing is to determine, with a confidence level of 95%, the statistical significance of changes in the fuel consumption of the vehicle, engine, or equipment, on which the tested technology is used. The nominal values for the changes in fuel consumption are determined from the analysis of the measured fuel data and reflect the fuel consumption reduction resulting from the modification being tested on the test vehicle, engine, or equipment.
- b) Fuel consumption tests are conducted on a vehicle (engine, equipment) representative of the typical vehicle (engine, equipment) for which the technology is intended.
- c) At least three tests without the fuel saving technology (baseline segment), followed by three tests with the fuel saving technology installed on the test vehicle (final segment) would be the minimum acceptable in both laboratory and track (road) tests.
- d) The proposed performance criterion is the achievement of fuel savings of 3% (minimum nominal value) over the baseline.
- e) The result is expressed as a nominal value plus and minus the confidence interval. If the confidence interval value for a test is greater than or equal to the nominal test value, as determined by the statistical analysis results, it is recommended that additional tests be conducted to reduce the confidence interval value to less than nominal test value. For example, if the nominal value of the tests result is 3% and confidence interval is 4%, the results is expressed as 3%  $\pm$ 4%. In this example, additional tests must be conducted to decrease the confidence interval. If additional tests do not show statistically conclusive results, the conclusion must be that the test does not show a statistically valid change in fuel consumption (the change is less than the test precision, or the change in fuel consumption is influenced by variations in the test conditions).
- f) The technology manufacturer is responsible for meeting emissions and diagnostic standards (OBD compliance). The fuel-saving technology must not increase regulated emissions, which include CO, NO<sub>x</sub>, NMHC, and PM. The measurement of PM emissions is not required for vehicles complying with EPA 2007 emission requirements or later, considering the very high efficacy of particulate filters, and the extremely low PM emissions level of these vehicles.

### 2.2.3 Indirect Parameters and Criteria for Evaluating the Impact on Fuel Efficiency or GHG Emissions

For some verification processes, indirect parameters and criteria for evaluating the impact of a technology on fuel efficiency or GHG emissions can be accepted.

- a) For technologies intended to reduce rolling resistance, the performance parameter is the rolling resistance coefficient.
  - i. Each 3% decrease in rolling resistance could improve fuel efficiency by as much as 1%, according to tire manufacturers<sup>2</sup>. According to the GHG Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles (EPA and NHTSA 2011), a 10% reduction in tire rolling resistance would reflect fuel savings of 2%.
  - ii. The proposed performance criterion is a 10% reduction (minimum) of the rolling resistance coefficient over the baseline average value.
  - iii. At least three rolling resistance tests with conventional tires (baseline segment), followed by three tests with the low rolling resistance tires (final segment) would be the minimum acceptable in laboratory tests.
- b) For technologies intended to reduce aerodynamic drag, the performance parameter is the wind averaged coefficient.
  - i. Each 2% decrease in aerodynamic drag could improve fuel efficiency by as much as 1%, according to Kenworth (2008) and based on dynamic equations (Surcel et al. 2008).
  - ii. The proposed performance criterion is a reduction of 6% (minimum) of the wind averaged coefficient of drag over the baseline average value.
  - iii. At least three tests without the aerodynamic technology or modification (baseline segment), followed by three tests with the aerodynamic technology or modification applied to the test vehicle or test vehicle model (final segment) would be the minimum acceptable in wind tunnel tests.
- c) For technologies intended to reduce vehicle tare weight, such as lighter van boxes or body components, the performance parameter is relative mass reduction compared to the original configuration.
  - i. Dynamic equations show that for a Class 8 tractor-semitrailer combination with gross vehicle mass of 30,000 kg, a mass reduction of 1,500 kg (5% of the gross vehicle mass, and 12% of the tare mass) could reflect a 4% fuel consumption reduction for the loaded vehicle.
  - ii. The proposed performance criterion is a reduction of a minimum of 9% of the tare mass of the vehicle in its normal operating configuration. For example, for the mass reduction of a tractor or a semi-trailer, the normal operating configuration is the tractor-semi-trailer combination. Other constructive parameters of the vehicle, such as aerodynamic performances, or rolling resistance, must not be negatively affected.

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<sup>2</sup> <http://www.michelintruck.com/michelintruck/tires-retreads/xone/xOne-fuel-savings.jsp>

- d) For evaluating the impact of a technology on GHG emissions, an indirect performance parameter is the reduction of fuel consumption. The CO<sub>2</sub> equivalent GHG emission factor can be calculated, using the equivalent GHG potential of 298 times for nitrous oxide, and of 25 for methane compared to that of carbon dioxide on a per unit mass basis (IPCC 2007), with equation (1):

$$GHG \text{ Factor } CO_2^{Equiv} = \text{Factor } CO_2 + 25 * \text{Factor } CH_4 + 298 * \text{Factor } N_2O \quad (1)$$

For example, using equation (1) and the values presented in Table 2, the CO<sub>2</sub> equivalent GHG emission factors are:

- i. For diesel engines with advanced engine control systems (i.e., the majority): 2.71 kg CO<sub>2</sub> equivalent per litre of diesel fuel;
- ii. For gasoline light-duty, Tier II engines the CO<sub>2</sub>: 2.30 kg CO<sub>2</sub> equivalent per litre of diesel fuel.

## 2.3 Test Methods

### 2.3.1 Proposed Testing Methods

The goal of technology verification is to accelerate technology implementation by providing credible data to fleet managers. This is why fuel consumption track testing is a test method preferred by many organizations, such as EPA SmartWay and MTQ, and it is used for evaluating various technologies, like aerodynamic devices, rolling resistance reduction technologies, and technologies for improving powertrain efficiency. Track testing directly measures the fuel consumption in real conditions, which is what the user wants. Track tests are critical to establish the potential of a technology for fleet operators interested in pursuing the implementation of any technologies, and from the point of view of the impact on fuel consumption the final validation should be a track test. Experience with fleets shows that the chances are very small that a technology is adopted solely on the basis of simulation or wind tunnel test results.

Table 3 presents the proposed testing methods according to the tested technology.

**Table 3. Proposed testing methods according to the tested technology**

<i>Technology</i>	<i>Performance target</i>	<i>Test method</i>	<i>Performance parameter</i>
<i>Aerodynamic technologies</i>	Fuel efficiency	Fuel consumption track test	Fuel savings
	Aerodynamic drag reduction	Wind tunnel test (full scale vehicle or a high fidelity detailed 1/8 scale or larger model)	Cdw reduction
		Standardized or regulated procedures using CFD simulations	Cdw reduction
<i>Rolling resistance technologies</i>	Fuel efficiency	Fuel consumption track test	Fuel savings
	Rolling resistance reduction	Rolling resistance tests	RR coefficient reduction
<i>Technologies for powertrain, and auxiliary systems ( exhaust system, antipollution system, air intake, fuel delivery system etc.)</i>	Fuel efficiency	Chassis dynamometer test	Fuel savings
		Engine dynamometer test	Fuel savings
		Fuel consumption track tests or field test	Fuel savings
	Emissions	Chassis dynamometer test	Emissions reduction
		Engine dynamometer test	Emissions reduction
		Emissions track tests or field test	Emissions reduction
<i>Mass reduction technologies</i>	Mass reduction	Weighing	Mass reduction
	Fuel efficiency	Fuel consumption track test	Fuel savings
<i>Other technologies (idle reduction, heaters, APUs, reefer etc.)</i>	Fuel efficiency	Custom test	Fuel saving
	Emissions	Custom test	Emissions reduction

## 2.3.2 Emission Test Methods

### 2.3.2.1 Engine Dynamometer Testing

The accepted test methods are (as amended from time to time):

- a) Highway engine dynamometer tests: according to the Federal Test Procedure (FTP) Transient Test and Smoke Test Procedures, such as 40 CFR Part 86 (for older engines), and Part 1065 for heavy-duty highway engines, including both diesel and Otto-cycle engines (for 2010 and later model years);
- b) Non-road engines: according the applicable non-road FTP test cycle, such as for Tier 1, 2, and 3 standards, using the procedures in 40 Code of Federal Regulations (CFR) Part 89 Subpart E, California Regulations for New 1996 and Later Heavy-Duty Off-Road Diesel Cycle Engines. For Tier 4 standards, engines are tested for transient and steady-state exhaust emissions using the procedures in 40 CFR Part 1039 Subpart F; Smoke emissions according to 40 CFR Part 86 Subpart I; 40 CFR Part 1048 for Spark Ignition engines etc.;
- c) Other recognized standard or regulation test procedures and particular test methods could be accepted;
- d) A mobile (portable) emission measurement system can be used for laboratory testing according to EPA Title 40 Part 1065 – Subpart J PEMS testing, §1065.901;
- e) Test conditions (ambient temperature, humidity, test equipment specification, including accuracy and precision of instruments and equipment, etc.) according to the applicable test procedure. If a particular test method is developed, the requirements of similar standards or regulations must be met, such as 40 CFR Part 1065.

### 2.3.2.2 Chassis Dynamometer Testing

The accepted test methods are listed below.

- a) Light duty vehicles
  - i. Testing according to the Federal Test Procedure (FTP), such as 40 CFR Part 86, and Part 1065, FTP 72, FTP 75, or SAE J1082 (SAE International 2008)
  - ii. Test cycles such as:
    - Urban Dynamometer Driving Schedule (UDDS);
    - US SC03 (test cycle operating the air conditioning system);
    - US 06 (SFTP, aggressive driving cycle);LA92 "Unified" Dynamometer Driving Schedule
    - New York City Cycle (low speed city driving).
- b) Heavy duty vehicles
  - i. Testing according to the Federal Test Procedure (FTP) Transient Test Procedures, such as 40 CFR Part 86 (for older engines), and Part 1065 for heavy-duty highway engines, including both diesel and Otto-cycle engines (for 2010 and later model years); SAE J1094 (SAE International 2011), SAE J2711 (SAE International 2010).



ii. Test cycles such as:

- Regional/City driving cycles: EPA Urban Dynamometer Driving Schedule (UDDS), Heavy Heavy-Duty Diesel Truck (HHDDT) from California Air Resource Board (CARB); Business Arterial Commuter (Transit Coach Operating Duty Cycle) – a composite heavy-duty cycle, City Suburban Cycle and Route (CSC), New York Composite test;
  - Highway/constant speed driving cycles: EPA Highway Line Haul, NESCAUM / SwRI Highway Line Haul, Commuter Cycle, WVU 5–Peak (a five-speed cycle for developed by the West Virginia University – WVU);
  - Bus driving cycles: New York Bus (NYBus), Manhattan Bus Cycle, Orange County Bus Cycle, Central Business District (transient city test cycle);
  - Local pick-up and delivery: Local Delivery – Class 4 (Neighborhood) and Class 6 (Business) from the Hybrid Truck Users Forum (HTUF)- Parcel Delivery Working Group ;
  - Refuse truck cycle: New York Garbage Truck Cycle (NYGTC, for refuse trucks), Neighborhood Refuse Truck (from NREL), Orange County Refuse Truck Cycle (OCRTC, from WVU);
  - Utility service truck: Combined International Local and Commuter Cycle (CILCC) from NREL, Eaton and International Truck and Engine.
- c) Test cycles may be adjusted or combined, or cycles can be proposed based on an operational observation of one or more vehicles in order to meet specific testing requirements.
- d) Other recognized standard or regulation test procedures and particular test methods and driving cycles could be accepted. These include , but are not limited to, the European test procedures (ECE-UN Regulation 49, 83, 96, UE Directive 2006/51, 2008/74 etc.).
- e) A mobile (portable) emission measurement system can be used for laboratory testing according to EPA Title 40 Part 1065 – Subpart J PEMS testing, §1065.901.
- f) Test conditions (ambient temperature, humidity, drive trace accuracy, test equipment specification, including accuracy and precision of instruments and equipment, etc.) according to the applicable test procedure. If a particular test method is developed, requirements of similar standard of regulations must be fulfilled, such as SAE J2711, or 40 CFR Part 1065.
- g) For testing hybrid vehicles, specific requirements stipulated by applicable standards and regulations must be satisfied, such as SAE J2711 (SAE International 2002) or SAE J 1711 (SAE International 2010). The rechargeable energy storage system state of charge must be measured at the beginning and at the end of the test run. A minimum three test runs must be conducted for each different test cycle to provide sufficient data for a state of charge correction. It is recommended that at least one test run have a net positive energy change value and another one a net negative energy change value so that net state of charge calculations are based on interpolation and not extrapolation (EPA 2007).





### 2.3.2.3 Field Testing

- a) A mobile (portable) emission measurement system (PEMS) can be used for field-testing according to EPA Title 40 Part 1065 – Subpart J PEMS testing.
- b) PEMS field-testing would provide real world quantification of emissions from on-road vehicles and off-road vehicles and equipment.
- c) PEMS offer the possibility for testing for emissions where traditional equipment is not available or in conditions that cannot be simulated in laboratories. Testing of different mobile sources and for various work cycles is possible, such as the evaluation of forestry, earth moving, mining, refuse, and farming equipment, boats and locomotives, without modifying, removing the engine or taking the equipment out of service.
- d) Testing using PEMS is cost-effective, allowing the performing of more tests in a shorter period, and with fewer personnel. The cost of testing is a fraction of that of laboratory testing, especially for heavy-duty trucks and off-road equipment. The repeatability and the accuracy of measurements are enhanced by increasing the number of tests done in a given period, and by simultaneously monitoring emission, environmental and activity data. Adequate quality control procedures can limit the uncertainties (EPA 2007).
- e) Testing can be tailored to meet the needs of the specific location and vehicle applications. Field emission tests with specific equipment (off-road vehicles, utility vehicles, auxiliary power units, refrigeration units, heaters etc.) can be conducted in accordance with specific test procedures which reflect the operational characteristics of the technologies under consideration. Idling reduction technologies, such as heaters and auxiliary power units, can be tested in a climatic chamber (temperature controlled). The committee responsible for assessing applications may accept a particular method of assessment, depending on the equipment covered by the application.
- f) Track tests can be conducted at constant speed or using various duty cycles (standardized or based on an operational observation of one or more vehicles in order to meet specific testing requirements). For example specific cycles were developed for testing on test track hybrid vehicles (pick-up and delivery vehicles, and utility vehicles for installing road sign posts), based on specific operational data (Proust and Surcel 2012, Surcel et al 2011).
- g) The PEMS must be properly calibrated, used and maintained, as required by 40 CFR Part 1065 Subpart J, and as recommended by the PEMS manufacturer.
- h) In order to ensure test repeatability, consistency of results and data quality, test conditions must respect the stipulations of applicable or similar standards and regulations for field testing, such as those of SAE J1321 (SAE International 2012a), concerning weather, weather data collection, variation in weather conditions between tests and between test segments etc. Additional requirements concerning air density variation between test segments and test run are stipulated (Appendix D).

### 2.3.3 Fuel Efficiency Test Methods

#### 2.3.3.1 General Requirements and Stipulations for Fuel Efficiency Testing

- a) Test conditions (ambient temperature, humidity, test equipment specifications, including accuracy and precision of instruments and equipment, etc.) according to the applicable test procedure.
- b) The preferred methods for measuring fuel consumption are the gravimetric method (consumed fuel by mass) or the volumetric method (consumed fuel by volume). Fuel consumption can be calculated using the carbon balance method, as described in SAE J1094 (SAE International 2011). The laboratory equipment measures and records the concentration of carbon-based compounds emitted in the exhaust as well as the exhaust flow. The concentrations and densities of the carbon-based compounds, and exhaust flow values, are used to calculate the mass of fuel consumed (EPA 2007). However, considering that this method is a calculation and does not directly measure the consumed fuel, it is recommended to use the gravimetric or the volumetric method.
- c) Fuel consumption data from any vehicle or engine electronic control module must not be used for evaluating the fuel consumption (SAE International 2012): extensive research has shown that this data is not reliable (Surcel and Michaelsen 2009).

#### 2.3.3.2 Engine Dynamometer Testing

- a) Test methods and cycles for emission testing as presented above can be used for fuel consumption testing.
- b) Other recognized standard or regulation test procedures and particular test methods could be accepted.
- c) Combinations of test procedures or cycles can be accepted.

#### 2.3.3.3 Chassis Dynamometer Testing

- a) For light duty vehicles: US FTP 75 Highway Fuel Efficiency Test (HFET), U.S. FTP-72 (cold test cycle), Urban Dynamometer Driving Schedule (UDDS), US SC03 (test cycle operating the air conditioning system), US 06 (SFTP, aggressive driving cycle), or SAE J1082 (SAE International 2008).
- b) For heavy duty vehicles: CFR 40 Part 86 or Part 1065, SAE J1094 (SAE International 2011), SAE J2711 (SAE International 2010).
- c) The test cycles presented above for emission testing can be used for fuel consumption testing.
- d) Combinations of test procedures or cycles are accepted. Examples:
  - i. For heavy-duty and vocational vehicles: the weighting factors for duty cycles according to CFR 40 Part §1037.510;
  - ii. For light duty vehicles (Figure 2):
    - The two-cycle testing (combination of HFET and UDDS, simulating highway and city driving), used to determine fuel consumption according to Canadian regulations;
    - The five-cycle testing, used by the United States Environmental Protection Agency (EPA), which utilizes cycles simulating city driving, highway driving, aggressive



driving style, city driving in cold temperature (at -7°C), and driving with an electrical load due to air conditioning. This test method typically results in fuel consumption values that are 10 to 20% higher than those determined using the two-cycle method (Transport Canada 2011).

- e) Test cycles may be adjusted, or cycles can be proposed based on an operational observation of one or more vehicles in order to meet specific testing requirements (Transports Quebec 2012).
- f) Other recognized standard or regulation test procedures and particular test methods can be accepted. These include, but are not limited to, the European test procedures (ECE-UN Regulation 84, ECE-UN Regulation 101, UE Directive 80/1268 etc.).

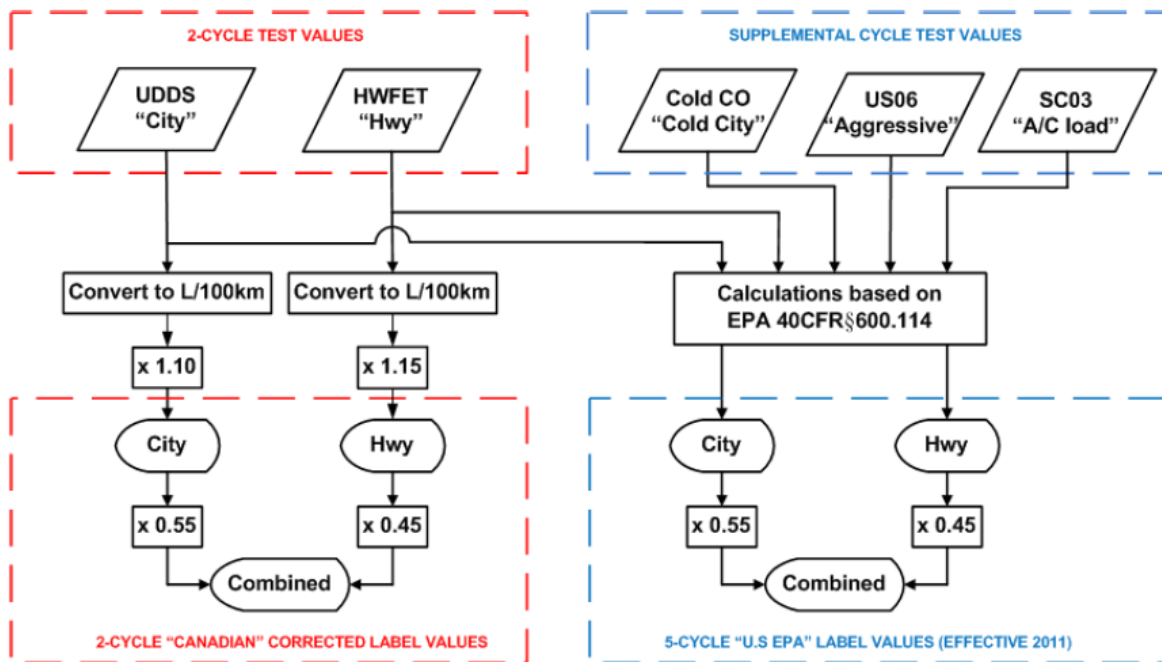


Figure 2. Two-cycles and Five-cycles fuel consumption test diagrams (from Transport Canada 2011).

- g) For testing hybrid vehicles, specific requirements stipulated by applicable standards and regulations must be satisfied, such as SAE J2711 (SAE International 2002) or SAE J 1711 (SAE International 2010). The rechargeable energy storage system state of charge must be measured at the beginning and at the end of the test run. A minimum of three test runs must be conducted for each different test cycle to provide sufficient data for a state of charge correction. It is recommended that at least one test run have a net positive energy change value and another one a net negative energy change value so that net state of charge calculations are based on interpolation and not extrapolation (EPA 2007).

#### 2.3.3.4 Field Testing

- a) Field tests recreate real conditions, and give a direct result, which is closer to the real life performance of a product. Therefore, field tests are critical to establish a credible potential return of investment for fleet operators interested in pursuing the implementation of any technology, and especially aerodynamic technologies.
- b) Previous standards for track (road) fuel consumption tests, such as the previous version of the SAE J1321 (SAE International 1986), lacked statistical analysis of test data, and constraints on test criteria required to resolve current and anticipated fuel consumption measurement increments. The actual superseding version of the standard (SAE International 2012), stipulates very strict test conditions and data analysis, which ensure the quality and the repeatability of the test results.
- c) These standards describe a rigorous fuel consumption test procedure utilizing industry accepted data collection and statistical analysis methods. These test procedures can be conducted on a track or on the road under controlled conditions and supported by extensive data collection and data analysis results. The SAE Type II test procedure uses identical test and control vehicles, for obtaining reference data. This type of testing determines, with a confidence level of 95%, the statistical significance of changes in the fuel consumption of the vehicle on which the tested technology is used. The result is expressed as a nominal value plus and minus the confidence interval. Extensive testing using the 2012 version of SAE J1321 standard showed that the results respond to all the mentioned data quality and analysis criteria, and for technologies providing fuel savings the confidence interval was always less than the nominal value (Surcel 2012b and 2012c).
- d) Proposed test procedures for fuel consumption track (road) tests:
  - i. Light duty vehicles: SAEJ1082 Fuel Economy Measurement Road Test Procedure (SAE International 2008);
  - ii. Heavy duty vehicles: SAE J1321 Fuel Consumption Test Procedure Type II (SAE International 2012a).
- e) Other recognized standard or regulation test procedures and particular test methods can be accepted. Track tests can be conducted at constant speed or using various duty cycles (standardized or based on an operational observation of one or more vehicles in order to meet specific testing requirements). For example specific cycles were developed for testing on test track hybrid vehicles (pick-up and delivery vehicles, and utility vehicles for installing road sign poles), based on specific operational data (Proust and Surcel 2012, Surcel et al 2011).
- f) Testing can be tailored to meet the needs of specific locations and vehicle applications. Field fuel consumption tests with specific equipment (such as off-road, utility vehicles, auxiliary power units, refrigeration units, heaters etc.) can be conducted in accordance with specific test procedures, which reflect the operational characteristics. Idling reduction technologies, such as heaters and auxiliary power units, can be tested in a climatic chamber (temperature controlled). The committee responsible for assessing applications may accept a particular method of assessment, depending on the equipment covered by the application. For example, a specific test procedure was developed for fuel consumption testing of refrigeration units in climatic chamber, on specific duty cycle (Surcel 2012a).
- g) In order to ensure test repeatability, consistency of results and data quality, test conditions must respect the stipulations of applicable or similar standards and regulations for field testing, such as

those of SAE J1321 (SAE International 2012a), concerning weather, weather data collection, variation in weather conditions between tests and between test segments etc.

## 2.3.4 Test Methods for Indirect Parameters for Evaluating Impact on Fuel Efficiency or GHG Emissions

### 2.3.4.1 Rolling Resistance Coefficient Testing

- a) Tire manufacturers must demonstrate that low rolling resistance tires meet the rolling resistance performance criteria using the ISO 28580 (2009) test method, when compared to similar current conventional tires (which are not designated as a low rolling resistance tires). For both baseline test segment (with conventional tires) and final test segment (with low rolling resistance tires) :
  - i. A minimum sampling set of three tires is tested;
  - ii. The tests are conducted with new tires (minimum 800 km and maximum 1600 km of use);
  - iii. It is recommended that a second set of tests be conducted with worn tires with a tire tread depth of 4 mm (5/32 in);
  - iv. For both conventional and low rolling resistance tires, the report presents the rolling resistance coefficients, their averages, and the percentage rolling resistance reduction between the two sets of tires. If the test with worn tires is conducted, the report presents rolling resistance coefficients, their averages, and the percentage rolling resistance reduction between the two sets of tires for both conditions (new and worn tires).
- b) EPA test procedures can be also used:
  - i. For low rolling resistance: tire manufacturers must demonstrate that a tire model has a rolling resistance coefficient at or below the target, using the SAE J1269 tire rolling resistance test method under the conditions set forth in Table 3 of SAE J1269 (SAE International 2006), or the ISO 28580 rolling resistance test method and the performance criteria set forth in Appendix E, Figure 2 (EPA 2011a);
  - ii. For the determination of low rolling resistance performance or tire retread technologies, the: performance criteria set forth in Appendix E, Figure 3 (EPA 2011b).
- c) The usage of ISO 28580 is preferred. According to ETRTO (2009):
  - i. A study indicated that rolling resistance results may vary up to 20% when measuring identical tires on different machines;
  - ii. ISO 28580:2009 includes a method for correlating measurement results to allow inter-laboratory comparisons;
  - iii. The alignment will be done between a “Reference Laboratory” and a “Candidate Laboratory” using pre-determined alignment tyres;
  - iv. The alignment process vs. a Reference Laboratory may shift data of the individual Candidate Labs up or down. This shift depends on the absolute RR level as measured in the Reference Laboratory;
  - v. The choice of the Reference Laboratory is very important.



#### 2.3.4.2. Wind Averaged Coefficient of Drag Testing

- a) CFD simulations and wind tunnel testing should be a normal stage of the development of an aerodynamic drag reduction product.
- b) Wind tunnel tests are conducted in very controlled conditions and the direct result of such tests is a reduction of the drag coefficient: the probable fuel consumption reduction is only estimated based on this drag reduction. However, wind tunnel testing could be considered for comparative testing, such as obtaining approval extensions for minor modifications to technologies that have been already approved on the basis of track testing, similar to California Air Resources Board (CARB) requirements (CARB 2012). These modifications must not affect the position, the size, and the installation angles of the device. The wind tunnel tests must be conducted on full-scale vehicle, or on a high fidelity detailed 1/8 scale or larger model.
- c) The CARB wind tunnel test protocol defines the wind tunnel-based method for obtaining approval for modifications to SmartWay trailer technologies that have not been pre-approved. The test procedure is in accordance with SAE J1252 (SAE International 2012b), with some exceptions and provisions:
  - i. The minimum acceptable test Reynolds number shall be 1 million;
  - ii. The aerodynamic tests will include yaw angles of 0, 9, 6, 3, 1, 0, -1,-3, -6, -9, and 0 degrees;
  - iii. The coefficient of drag results from the first and last 0 degree yaw angle runs are used to check for repeatability; the remaining 9 collection points are used to calculate the wind average coefficient of drag (C<sub>dw</sub>) for vehicle operational speeds of 50 mph, 55 mph, 60 mph, 65 mph, 70 mph, and 75 mph;
  - iv. The independent wind tunnel test facility shall run three repeats of the baseline tractor-trailer test, taking into account the measurement sensitivity of the wind tunnel.
- d) CFD simulations can be used if they meet the requirements of existing applicable standards or regulations. For example a SAE standard is presently under development (SAE J2966, “Guidelines for Aerodynamic Assessment of Medium and Heavy Commercial Ground Vehicles Using Computational Fluid Dynamics”).

#### 2.3.3.3. Mass Reduction Testing

The proposed procedure is similar to the process used by the Ministère des Transports du Québec (Transport Quebec 2012) outlined below.

- a) Specify the type of equipment that represents the basis for comparison (baseline scenario): three similar and current models must be selected in order to establish a representative basis for comparison. Specifications must be provided for the models selected. The average mass of these models is the mass against which the equipment is compared.
- b) Determine the masses of the replacement equipment and of the original equipment by weighing. The mass of the equipment to be assessed must be compared against the average mass of the baseline selected equipment.
- c) Mass reduction technology must not negatively affect other constructive parameters of the vehicle, such as aerodynamic performance, rolling resistance, or safety. If the Verification Organization considers that any of these parameters could be affected, the necessary additional testing must be conducted, such as fuel consumption track test, or structural tests.



## 2.4. Test Report

The report must adhere to the requirements of the ETV General Test Protocol (Environment Canada 1998) and the specific requirements of the applicable standard and regulation (SAE International 2012, Transports Quebec 2012). The report must be issued in accordance with the legal requirements of the province where it is drawn up (prepared, verified and signed by a professional registered engineer).

The report must include at minimum elements listed below,

- a) Introduction
  - i. Background of the testing process
  - ii. Testing facility name, location and testing date and time, testing personnel and report author
- b) Technology description
  - i. Scope, applicability, functioning mode, installation, operational requirements, constraints
  - ii. Declared impact on emissions and fuel efficiency, as well as on safety
  - iii. Sufficient pictures, drawing or schematics of the technology installed on the test object (vehicle, engine, equipment etc.)
- c) Objectives
  - i. Technology performance claims evaluated
  - ii. The potential to reduce emissions or improve fuel efficiency must be among the objectives.
- d) Testing Methodology
  - i. Type of data collected (emissions, fuel consumption);
  - ii. Method for the evaluation of emissions or fuel consumption, including the description of relevant standards or regulations
  - iii. Test duty cycle description
  - iv. If applicable: test track (site) description, drawings or photos, and details
  - v. If applicable: test track (site) weather data collection sites (location)
  - vi. Detailed characteristics of the vehicles or equipment used for testing
- e) Data analysis
  - i. According to GTP and applicable standard or regulation
  - ii. The focus of testing is to determine, with a confidence level of 95%, the statistical significance of changes in the emissions of the vehicle or engine, on which the tested technology is used. The nominal values for the changes in emissions are determined from the analysis of the measured emission data and reflect the changes resulting from the modification being tested on the test vehicle or engine.



f) Results

- i. These are the results of the evaluation, fuel savings or emission reduction attributable to the equipment compared to the chosen reference scenario.
- ii. Results must be expressed as a nominal value plus and minus the confidence interval.
- iii. The nominal values for the changes in the fuel consumption and/or emissions are determined from the analysis of the measured fuel or emission data and reflect the changes resulting from the modification being tested on the test vehicle or engine.
- iv. The confidence interval must be less than the nominal result for having a statistically valid result.

g) Discussion

- i. Explanation of the results obtained in comparison with the anticipated results
- ii. Identification and explanation of the parameters that could have influenced the results
- iii. Presentation of the limitations of the test procedure and the applicability of the results. For example, if indirect methods are used and fuel savings are calculated based on the results of such methods, mention that fuel savings are the results of calculation and not of direct measurements.
- iv. Quantification of the environmental impact

h) Conclusions and recommendations

- i. Summary of test results
- ii. Description of how test results support performance claim(s)
- iii. Relation of results to relevant regulatory requirements where appropriate
- iv. Recommendations regarding the tested technology

i) References

- i. All relevant technical literature and appropriate materials referenced during the testing design and/or planning phase.

j) Raw Data

- i. Vehicle, engine or equipment data form
- ii. Test forms describing test conditions, measured parameters, and data analysis
- iii. Time history plot of all environmental or weather conditions during testing



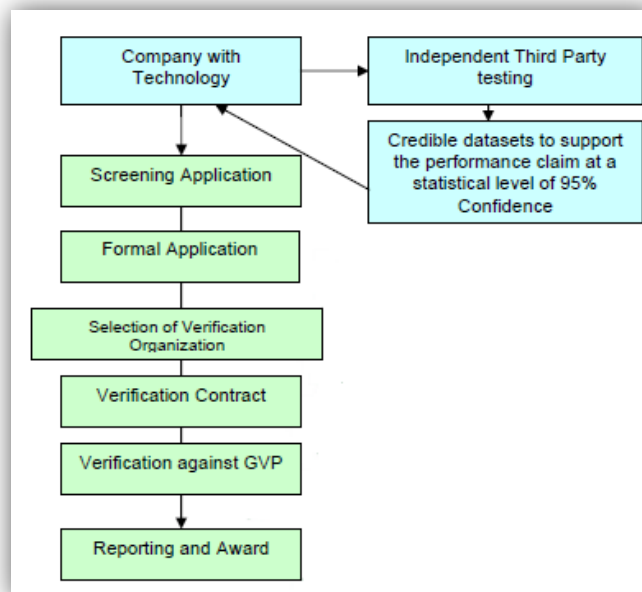
### 3. Verification

The verification process is a third party expert evaluation of the technology and of the independent third party testing based on the General Verification Protocol (GVP).

The GVP outlines the principles of verification. If supplemental documents are necessary, the applicant, the Canadian ETV Program and the Verification Organization (VO) will discuss the appropriate requirements, if required. Figure 3 presents the verification process (Environment Canada 2012).

Several types of applicants are eligible to apply to the ETV program for verification:

- Environmental technology vendors who have new technology;
- Vendors who provide equipment-based environmental services that can make claims based solely on measurable performance of the equipment or technology used;
- Technology developers that have early stage technology.



**Figure 3. ETV Canada verification process (from Environment Canada 2012).**

Following the GVP, a VO evaluates the integrity of supplied data, and the validity of the associated performance claims based on this data. The following requirements must be met for a claim to be verified:

- The technology must provide a net environmental benefit;
- The technology is based on sound scientific and engineering principles;
- The claim is fully supported by independently generated, peer-review quality data, which are supplied by the applicant or generated upon the applicant's request through a test program conducted by a qualified testing agency;
- The conditions of performance for the claim are clearly defined.

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## Discussion and Recommendations

Cost analysis is not a component of the verification, but could provide additional information to the user of the technology under consideration, and it is likely to be demanded by fleet managers as a requirement for purchasing the technology. The cost analysis should:

- Indicate the additional cost attributable to the equipment;
- Present the hypothesis used for analysis: distance travelled, number of vehicles, baseline fuel consumption or emissions, cost of fuel, etc.;
- Using the results obtained and the additional cost of the equipment, estimate the return on investment in months or years.

In the verification process, test reports and certifications obtained in other countries should be considered and could be accepted, depending on the results of the screening and of the verification. Moreover, there is an ISO initiative for standardizing ETV process, such that an ETV verification issued in one country could be accepted in other countries.

Life cycle analysis (LCA) is not the objective of this protocol: verification can only be applied against measurable performance criteria. LCA is an important decision-making tool, but environmental performance verification of technologies based on a full-range of comprehensive systemic parameters would be extremely difficult to implement.

It should be mentioned that while the process must be accurate, it should also be cost effective to facilitate access to verification for technology suppliers.

## Conclusions

This testing and verification protocol helps guide the demonstration and deployment of effective engine and vehicle technologies and solutions. The protocol meets the requirements of the Canadian ETV Program and the program's General Verification Protocol. The protocol has been developed in consultation with a Technical Advisory Committee, which provided input and technical expertise.

The protocol presents the screening, testing and verification process. It also presents the general test methodology and existing test methods that can be used, with reference to applicable standards and regulations, in a manner that is consistent with the framework of the Canadian ETV Program General Test Protocol.

Considering that specific regulations and standards are already in place across a number of jurisdictions, the protocol does not detail test procedures. However, because unique technologies may require specific test plans that cannot be found in existing standards, it is acknowledged that particular testing methods may be accepted, depending on the equipment covered by the application.



## Acknowledgements

The authors would like to thank the members of the Technical Advisory Committee for their participation and the very valuable input and feedback provided in the process of developing the testing and verification protocol.

The support of Globe Performance Solutions and Environment Canada is gratefully acknowledged.



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## Appendix A. Technical Advisory Committee

**Table 4. Technical advisory committee**

No.	Name	Company / Organization	Position	Category
<b>TAC MEMBERS</b>				
1	A. Siddiq Khan, Ph.D.	ACEEE	Senior Researcher, Transportation Lead	Research
2	Brian Rennie	Bridgestone Firestone	Director, Engineering	Industry : OEM
3	Geoffrey Wood	Canadian Trucking Alliance	Vice-president, Operations & Safety	Industry : Transport
4	Alain Vallée, Eng.	City of Levis	Manager, Environment Division	Municipality
5	Jean-Marc Lavigne	City of Montreal	Division Manager Municipal Fleet	Municipality
6	Robert Russell	City of St-John	Manager, Fleet Administration	Municipality
7	Drew Shintani	City of Toronto	Business Analyst Fleet Services Division	Municipality
8	Sam Waltzer	EPA, Office of Transportation Air Quality	Manager, SmartWay Technology	Government
9	Jim Fearn	ERMD, Environment Canada	Engineer	Research and testing: Government
10	Jan Michaelsen, F.E.	FPInnovations	Research Leader, Transport & Energy	Research and testing
11	John Neate	GLOBE Performance Solutions	CEO	Technology Verification organization
12	Philippe Bellon, B. Eng., MBA	Metrolinx Transit Procurement Initiative	Manager	Government
13	François Beauchamp	Michelin North America (Canada) Inc.	Special Project Coordinator	Industry: OEM
14	Frédéric Côté, Eng.	MTQ	Engineer, Technical Standardization Department, Trucking Division	Government
15	Cristian Tabra, P.Eng.	NRC	Manager, Commercial Vehicles NRC-Surface Transportation	Research and testing: Government
16	Jeff Patten, P. Eng.	NRC	Manager, Test & Evaluation Engineering Road Vehicle and Military System Division	Research and testing: Government
17	Jim Wassermann	PAMI	Vice-president	Research and testing
18	Claude Sauvageau	PMG Technologies	Vice-president, Testing	Research and testing
19	Marc Belzile	Transport Canada	Vehicle Programs Division	Government



**Table 4. Technical advisory committee (continuations)**

<b>No.</b>	<b>Name</b>	<b>Company / Organization</b>	<b>Position</b>	<b>Category</b>
<b>TAC MEMBERS</b>				
20	Yves Maurais, Eng.	Transport Robert	Technical Director	Industry : Transport
21	Ken Webster,	Transportation Research Center Inc.	Manager Operations	Research and testing
22	Philippe Desjardins	Transtex Composite	Engineer	Industry : OEM
23	Zhongchao Tan, Dr.	University of Waterloo	Associate Professor	Academia
24	M. Zengh, Dr.	University of Windsor	Professor, Clean Diesel Engine Technologies CR Chair	Academia
25	Kevin Oversby	Westport Innovations Inc.	Emissions Certification Engineer	Industry : OEM
<b>OBSERVERS</b>				
26	Benoit Desforges, Eng., M.Sc.	Environment Canada	Section Head, Technology Programs Science and Technology Branch	Government
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28	Kelly Vandelight	Environment Canada	Senior Project Officer Technology Programs Science & Technology Branch	Government
<b>ORGANIZING TEAM</b>				
29	Bernard Ouellet	FPIInnovations-PIT	PIT Leader of Operations	Research and testing
30	Adime Bonsi	FPIInnovations-PIT	Researcher PIT	Research and testing
31	Falama Souley	FPIInnovations-PIT	Researcher PIT	Research and testing
32	Marius Surcel	FPIInnovations-PIT	PIT Technical Leader	Research and testing



## Appendix B. Summary of existing testing and verification protocols

**Table 5. Summary of existing testing and verification protocols**

Organization	Performance target	Performance parameters	Screening	Vehicle Type	Testing	Verification
ETV Canada	Emissions: air pollutants CO, NO <sub>x</sub> , NMHC, PM	Percentage improvement over baseline	Review of technical documents and existing test data regarding performance and durability	Heavy Duty	Engine or chassis dyno (FTP CFR 40 et al.)	- Scope :provide consistency and transparency for vendor claims; - Method: third party expert evaluation of the technology and of the independent third party testing based on the ETV GVP.
	Light Duty					
MTQ	Fuel efficiency/ GHG emission reduction	Fuel savings / GHG emission reduction: percentage improvement over baseline: min. 3%	Application form	Heavy Duty	- Chassis dyno: SAE J1094, J2711, CFR 40 Part 86 or 1065 et al. (PEMS accepted); - Track (road): SAE J1321, SAE J1526; -Particular methods could be accepted.	- Scope: promote the use of technologies intended to improve energy efficiency and reduce GHGs emission in road transportation; - Method: report according to specific requirements approved by a technical committee.
PIT	Emissions reductions: air pollutants (CO, NO <sub>x</sub> , NMHC) and GHG (CO <sub>2</sub> )	Percentage improvement over baseline correlated with the baseline absolute values	Application form	Light Duty	- Chassis dyno: PEMS – FTP et al; - Track (road): PEMS CFR 40 Part 1065 et al.	- Scope: provide unbiased information to the trucking industry; - Method: - Internal verification and approval process; - Verification and approval by the organizations where the reports are presented.
				Heavy Duty	- Chassis dyno: PEMS - SAE J2711; - Track (road): PEMS - CFR 40 Part 1065 et al.	
	Light Duty	- Chassis dyno: HFET, UDDS et al.; - Track (road): SAEJ1082.				
	Heavy Duty	- Chassis dyno: PEMS - SAE J2711 at al.; - Track (road): SAE J1321, SAE J1526				
	Fuel efficiency/ GHG emission reduction	- Fuel savings / CO <sub>2</sub> reduction: percentage improvement over baseline; - Minimum performance for recommending to members: 3 % in conjunction with ROI.				

**Table 5. Summary of existing testing and verification protocols (continuation)**

<b>Organization</b>	<b>Performance target</b>	<b>Performance parameters</b>	<b>Screening</b>	<b>Vehicle Type</b>	<b>Testing</b>	<b>Verification</b>
US EPA Aftermarket Retrofit Devices	Emissions reductions: air pollutants (CO, NO <sub>x</sub> , NMHC)	Percentage improvement over baseline	Application form	Light Duty (less than 6,000 lbs.)	Chassis dyno: using FTP and HFET	- Scope: provide unbiased product info to the customers; - Method: review of the final test report, published in the Federal Register, and posted on the website.
	Fuel efficiency					
US EPA Diesel Retrofit Technology	Emissions reductions: air pollutants (CO, NO <sub>x</sub> , NMHC, PM)	Percentage improvement over baseline	Review of technical documents and existing test data regarding performance and durability	Heavy Duty	Chassis dyno: using FTP CFR 40 Part 86 and in-use testing	- Scope: improve air quality by reducing pollution from mobile sources; - Method: review of the final test report, published in the Federal Register and posted on the website.
CARB					- Chassis dyno: using FTP CFR 40 Part 86 and in-use testing; - Engine test (FTP Heavy-Duty Transient)	
US EPA SmartWay Fuel Saving Technologies	Fuel efficiency GHG emission reduction	Percentage improvement over baseline (1% for gap and rear devices, 4 % for trailer skirts, 5% for advanced trailer skirts and advanced trailer end fairings; various parameters for other technologies)	Application form	Heavy Duty	- Track test: Aerodynamic Technology Verification Protocol (interim test method amending SAE J1321); - Rolling resistance tests for tires : SAE J1269) or ISO 28580;	- Scope: provide unbiased product info to the customers; - Method: review of the technology and of the test data, obtained from prescribed test protocols; Include the technology on the Verified Technologies List.

## Appendix C. Self-assessment Application Form



World Trade Centre,  
578-999 Canada Place,  
Vancouver, BC V6C 3E1  
Canada  
Email [info@globepformance.com](mailto:info@globepformance.com)  
Visit [www.globepformance.com](http://www.globepformance.com)

Date: \_\_\_\_ / \_\_\_\_ / \_\_\_\_  
Day Month Year

### Self-Assessment - Technology Developers and Vendors

#### Company / Organization Information

Name \_\_\_\_\_ Phone \_\_\_\_\_  
Address \_\_\_\_\_ Email \_\_\_\_\_  
Town/City \_\_\_\_\_ Can we post your responses? Yes  No   
Country \_\_\_\_\_ Can we contact you to follow up? Yes  No   
Postal / Zip Code \_\_\_\_\_ Preferred Method of Contact \_\_\_\_\_

Please briefly describe your company or organization:

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Please briefly answer the following questions and submit the completed survey to:

[info@globepformance.com](mailto:info@globepformance.com)

#### 1. Technology Ownership (vendor perspective)

- 1.1 Do you own the technology? Yes  No  Don't know
- 1.2 Do you have proof of ownership? Yes  No  Don't know
- 1.3 Is your technology patented? Yes  No  Don't know
- 1.4 Is your technology licensed to other vendors? Yes  No  Don't know
- 1.5 What is driving the need for your technology?  
New regulations/ bylaws   
Public opinion   
Environmental/sustainability concerns   
Cost   
Other

Other Comments:

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## 2. Market Acceptance (vendor perspective)

2.1 Have you clearly defined the target market(s) application(s) for your technology? Yes  No  Don't know

Please list them (if any) \_\_\_\_\_  
\_\_\_\_\_

2.2 Have you successfully sold your technology to customers in this target market? Yes  No  Don't know

Please indicate number of sales (if any) \_\_\_\_\_  
\_\_\_\_\_

2.3 Are your customers generally satisfied with your technology? Yes  No  Don't know

2.4 Are there things that need to be done to improve market acceptance of your technology? Yes  No  Don't know

Please list them (if any) \_\_\_\_\_  
\_\_\_\_\_

Other Comments:

\_\_\_\_\_  
\_\_\_\_\_

## 3. Technology Performance (vendor perspective)

3.1 Have you defined the performance advantages of your technology? Yes  No  Don't know

3.2 How many distinct performance advantages can you define for your technology? None

1-3

4-6

More than 6

Don't know

Please list these advantages (if any) \_\_\_\_\_  
\_\_\_\_\_

3.3 Are these performance advantages measurable? Yes  No  Don't know

If yes, please list the measurable performance advantages

\_\_\_\_\_  
\_\_\_\_\_

3.4 Are there potential environmental or other impacts associated with the use of your technology? Yes  No  Don't know

Please list these impacts (if any) \_\_\_\_\_  
\_\_\_\_\_



3.5 Does your technology perform better than minimum standards? Yes  No  Don't know

Other Comments:

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#### 4. Technology Performance Data (vendor perspective)

4.1 Do you have data on the performance of your technology? Yes  No  Don't know

4.2 Was the performance data prepared by an independent testing organization? Yes  No  Don't know

4.3 Is the performance testing organization accredited? Yes  No  Don't know

Please list these accreditations (if any) \_\_\_\_\_

4.4 Was the performance testing done in accordance with existing international standards? Yes  No  Don't know

If yes, please list these standards \_\_\_\_\_

Other Comments:

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#### 5. Performance Verification and Reporting (vendor perspective)

5.1 Has the performance test data been reviewed by an independent verification organization? Yes  No  Don't know

5.2 Is the performance verification organization accredited or part of a recognized national or international program? Yes  No  Don't know

Please list these accreditations and/or programs (if any) \_\_\_\_\_

5.3 Is there a report available on the performance testing and verification of your technology? Yes  No  Don't know

If yes, please indicate how this can be obtained \_\_\_\_\_

5.4 Is the performance of your technology posted on the internet? Yes  No  Don't know

If yes, please indicate where the performance of your technology is posted

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Other Comments:

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## Appendix D. Performance Criteria for Tires

EQUIVALENT TARGET VALUES (Rolling Resistance Coefficient in kg force/metric ton)			
	Steer	Drive	Trailer
J1269 Application Test Point (1.7 meter drum)	6.6	7.0	5.5
J1269 Test Point 2 (1.7 meter drum)	6.7	6.9	5.5
J1269 5 point average (1.7 meter drum)	6.9	7.0	5.6
ISO 28580 (2 meter drum)	6.5	6.6	5.1

Figure 4. Performance criteria for low rolling resistance tires (from EPA 2011a).

RETREAD TIRE PRODUCT TARGET VALUES (Rolling Resistance Coefficient in kg force /metric ton, ISO 28580)		
Tire position	Drive	Trailer
Test casing	7.2	6.0
Alternate casing	6.5	5.4

Figure 5. Performance criteria for retread tires (adapted from EPA 2011b).

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## Appendix E. Test Conditions for PEMS Emissions Field Testing

**Table 6. Test conditions for PEMS emissions field testing**

<i>Test condition</i>	<i>Requirement</i>
Mean wind speed during a test run	≤ 19.3 km/h (12 mph)
Maximum wind speed (gusts)	≤ 24.1 km/h (15 mph)
Mean wind speed change between segments and runs	≤ 8 km/h (5 mph)
Temperature range	4°C (40°F) - 38°C (100 F°)
Mean temperature change between segments and between runs	≤ 17°C (30 F°)
Precipitations and fog	None
Weather measurement sampling	Max. 60 s
Air density variation between segments and between runs	0.1 kg/m <sup>3</sup>

Note: Air density can be computed from measurements of ambient temperature, humidity, and barometric pressure (Jones 1978).



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