

Third Progress Update

October 2007

**MEMORANDUM OF
UNDERSTANDING
RESPECTING
AUTOMOBILE
GREENHOUSE GAS
EMISSIONS**



Canadian Vehicle
Manufacturers' Association
L'Association canadienne
des constructeurs de véhicules



Association of International Automobile
Manufacturers of Canada
L'Association des fabricants
internationaux d'automobile du Canada

Prepared by the Joint Government-Industry GHG MOU Committee



Government
of Canada

Gouvernement
du Canada

Canada

Prepared by the Joint Government-Industry Greenhouse Gas (GHG) Memorandum of Understanding (MOU) Committee.

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Table of Contents

1. Introduction	3
2. Achievements and Progress to Date	4
2.1 Joint Government-Industry GHG MOU Committee Activities	4
2.2 Advanced Technology Introductions	5
2.3 Outreach Activities	6
3. The Path Forward	7
Appendix A – Advanced Technology Introductions by the Automotive Industry	8



1. Introduction

On April 5, 2005, the Government of Canada and the automotive industry reached a landmark voluntary agreement to reduce annual greenhouse gas (GHG) emissions from Canada's vehicle fleet by 5.3 megatonnes (Mt) in 2010. The Memorandum of Understanding (MOU) sets out a comprehensive approach to reduce GHG emissions. It is founded on a framework of key principles that are outlined in the MOU.

The MOU voluntarily commits the Canadian automotive industry to achieve a 5.3-Mt reduction in GHG emissions from passenger cars and light-duty trucks in 2010, relative to the reference case. It clearly outlines interim GHG emission-reduction goals that the Canadian automotive industry has committed to meet. The interim reduction goals are 2.4 Mt in 2007, 3.0 Mt in 2008 and 3.9 Mt in 2009. It provides for a joint government industry committee to monitor progress and industry performance against interim GHG reduction goals as a means of ensuring accountability for the MOU.

This is the *Third Progress Update* respecting the MOU. It provides information on the activities and progress under the MOU through the second quarter of 2007.

The Joint Government-Industry GHG MOU Committee (the Committee) recognizes the importance of continued sharing of information on its activities. Periodic progress updates, like this one, are not a requirement under the terms of the MOU, and are in fact above and beyond the reporting requirements. The report on progress towards the 2007

interim goal will be the first report specified under the MOU.

The *First Progress Update* of June 2006 provided details on the MOU, its approach and benefits, and the 5.3-Mt Reduction Goal, and it outlined the mandate and terms of reference for the joint government-industry committee. The *Second Progress Update* of April 2007 provided information on the joint government-industry GHG MOU activities, including information on the data aspects and the analytical framework to measure progress on the MOU, and an update on the Operational Plan and Key Deliverables and the latest advanced vehicle technology introductions. The first and second progress updates can be obtained from the following Web sites: oee.nrcan.gc.ca/transportation/ghg-memorandum, www.cvma.ca, and www.aiamc.com.

The government and the auto industry remain committed to delivering on the MOU and its goal to reduce GHGs. In October 2006, the government announced its intention to regulate vehicle fuel consumption after the expiry of this MOU. The government has indicated that these regulations pertaining to the auto industry will take effect for the 2011 model year. The government has stated, in its *Regulatory Framework for Air Emissions*, May 2007, that the standard "will be designed for Canada to maximize our environmental and economic benefits and will be benchmarked against a stringent, dominant North American standard." In the interim, the Committee will continue its work so as to deliver the results outlined in the MOU.

2. Achievements and Progress to Date

2.1 Joint Government-Industry GHG MOU Committee Activities

The Committee serves as the accountability mechanism under the MOU, and its work is primarily technical in nature. Since the last progress update, the Committee has continued its work regarding the data aspects and analytical framework to monitor the goals of the MOU.

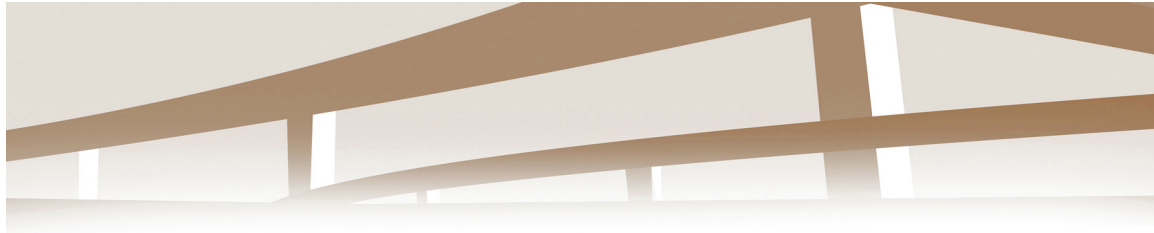
The *Second Progress Update* briefly described refinements to the analytical framework, or model, that were being undertaken by the Committee. The refinements are being undertaken as the 5.3-Mt reduction goal is based on updating the work of the 1999 Government Transportation Climate Change Table and its projections of vehicle-related GHG emissions and *Canada's Emissions Outlook: An Update*, published in December 1999. The 5.3-Mt target is measured against a "reference case" level of emissions.

Since the model developed and used by the Transportation Table in 1999 ("CHAMPAGNE model") was designed to forecast GHG emissions from the transportation sector at five-year intervals, the Committee has been developing a modified analytical framework that will permit tracking of actual GHG emissions on an annual basis, while maintaining consistency and correlation to the model as outlined in the MOU. Tracking actual emissions also requires that appropriate data sources be identified for this model (referred to as the Tracking Model) and for all factors that contribute to emissions reductions.

To measure performance under the MOU, the Tracking Model needs to calculate reference case emissions and compare them to actual levels. Thus, the model will calculate GHG emissions under a reference case and an actual performance case scenario each year, and the difference between these two scenarios will indicate performance against the goal for the subject year.

To maintain a methodology that is consistent with the approach taken by the 1999 Transportation Table, the Tracking Model will incorporate the same factors included in the original model – such as vehicle fuel consumption reported by manufacturers under the voluntary fuel consumption program, vehicle stock and vehicle kilometres travelled by age, passenger car and truck categories – as well as various adjustment factors for converting laboratory fuel consumption numbers to on-road performance.

Updates of factors outside of industry's control (exogenous factors) will be made, and the reference case adjusted to ensure that the calculated impact to meet the emissions reduction target fairly reflects industry's efforts. There will not normally be reference case updates of factors directly under the control of industry (endogenous factors). Any improvement in actual performance against these factors throughout the period of the MOU will be the means by which industry makes progress against the emission target.



This work has been the primary focus of the Committee's activities since the last progress update, and the Committee is now in the process of finalizing these refinements and the data requirements associated with the model so that the necessary analytical framework is in place in advance of the first required interim report under the MOU. Once all data is received in 2008, the Committee will use the model to assess industry progress against the first (2.4 Mt) emission target for 2007.

2.2 Advanced Technology Introductions

Since the signing of the MOU, the industry continues to introduce many new models that incorporate technologies that can reduce GHGs. Appendix A provides a detailed listing of models or technologies that have been introduced.

This list is by no means comprehensive. It is intended to show that new models are incorporating many advances in new vehicle technology. Only the latest introductions are noted in the Appendix A, as the *Second Progress Update* report provided very detailed information on the technology introductions in 2007 and 2008. The Appendix in this report supplements the information contained in the *Second Progress Update* report.

Technologies available in the Canadian market for the 2008 model year include:

Transmission Improvements

- 6-speed transmissions
- continuously variable transmissions

Engine Improvements

- cylinder deactivation
- variable valve timing

Other Vehicle Improvements

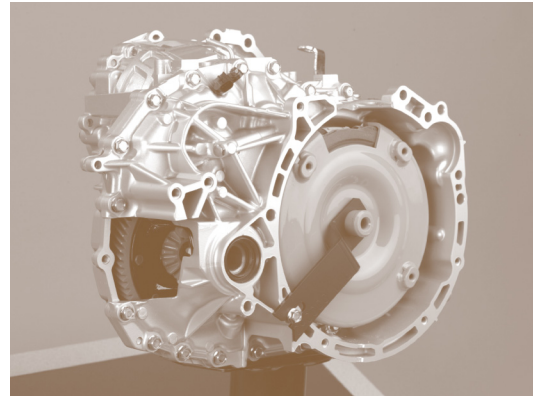
- lightweight materials (aluminum, magnesium)
- tire-pressure monitoring systems
- low rolling resistance tires
- new engine technologies that use a diversity of fuels – ethanol, diesel, biodiesel, etc.

Advanced Technology Vehicles

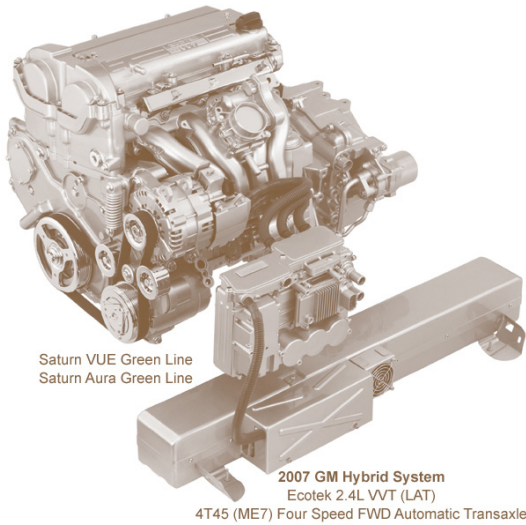
- hybrid electric vehicles
- advanced diesel vehicles

The above-mentioned technologies have penetrated the market. The graphics below serve to highlight some of these technologies.

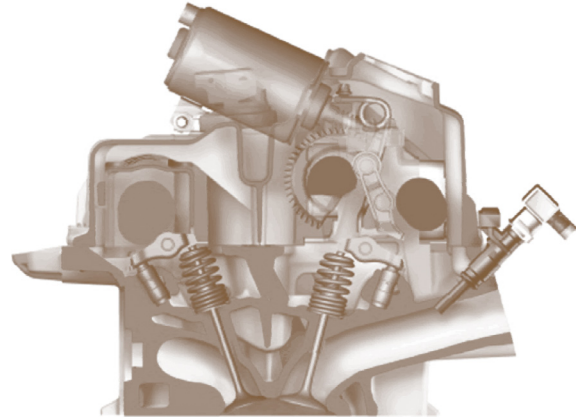
Technology: 6-speed transmission



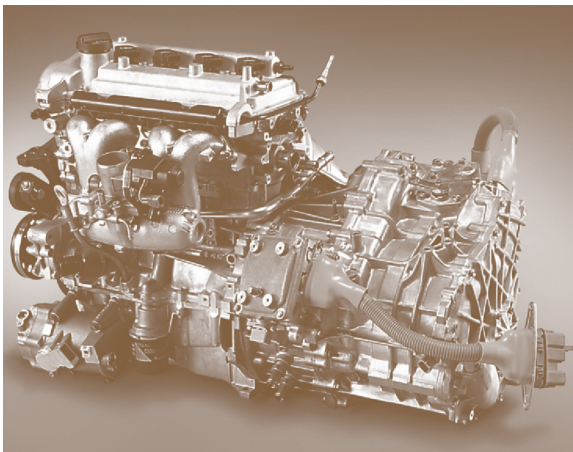
Technology: Hybrid



Technology: Valvetronic system (both variable timing and variable valve lift)



Technology: Hybrid



2.3 Outreach Activities

Since the signing of the MOU, the government and industry have participated in outreach activities to discuss and share information on the MOU and its intent. The most recent example of this action was the release of the *Second Progress Update* in April 2007.

The *Second Progress Update* has been distributed to government, industry, non-governmental organizations, the academic community and the general public. As was the case for the Committee's *First Progress Update*, the *Second Progress Update* can be found on government and industry Web sites:

oee.nrcan.gc.ca/transportation/ghg-memorandum, www.cvma.ca and www.aiamc.com.



3. The Path Forward

Progress has been made in terms of solidifying the tracking model framework, and work is underway to identify appropriate data sources to populate the model as the Committee prepares for its first required report under the MOU.

New vehicle technologies and models continue to be introduced to the market, and companies in the automotive industry are making progress in their vehicle fleets that will contribute to the overall industry GHG reductions over the period of the agreement.

The Committee is committed to sharing information on its activities and will continue to meet its responsibilities as defined and for the duration of the MOU. The Committee will report on its progress and the 2007 Interim Goal in the fall, 2008.

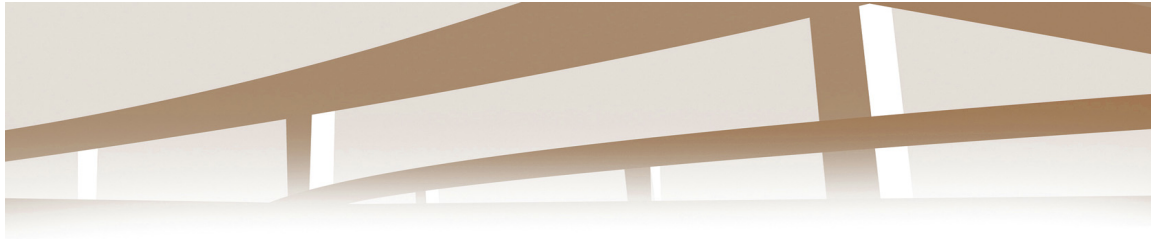
Appendix A – Advanced Technology Introductions by the Automotive Industry

BMW Canada Inc.

- 2008 MY 535i, 535xi Sedan, Touring and 550i: introduction of active cruise control with stop and go feature
- 2008 MY 535i, 535xi Sedan and Touring: introduction of new 3.0-litre twin-turbo engine incorporating high-precision direct fuel injection
- 2008 MY 5 Series: addition of standard tire pressure monitoring system
- 2008 MY 323i: addition of standard cruise control
- 2008 MY 328i and 335i: addition of electronic limited slip differential
- 2008 MY 1 Series: new model variants incorporating the following technology:
 - valvetronic technology on 128i – incorporates both variable valve timing and variable valve lift
 - 6-speed manual and 6-speed automatic transmissions
 - magnesium-aluminum engine crankcases to reduce weight
 - 135i variant to incorporate 3.0-litre twin-turbo engine incorporating high precision direct injection
- 2008 MY M3: incorporates the following lightweight construction technology:
 - all new V8 engine utilizing aluminum/silicon alloy
 - seamless stainless steel exhaust pipes
 - carbon-fibre-reinforced plastic roof
 - nearly all front and rear suspension components made of aluminum
 - aluminum hood

Chrysler Canada Inc.

- 2008 model year: new Dodge Grand Caravan / Chrysler Town & Country uses new 6-speed automatic transmission with 3.8-litre and 4.0-litre engines
- 2008 model year: new Dodge Grand Caravan FFV (ethanol-E85 flexible fuel vehicle) now standard with 3.3-litre engine
- New Viper SRT10's 8.4-litre engine breathes through new cylinder heads equipped with Computer Numerically Controlled (CNC)-shaped combustion chambers, larger valves and Variable Valve Timing (VVT). VVT electronically adjusts when the exhaust valves are open and closed according to engine speed and load, allowing the engine to “breathe” cleaner and more efficiently.



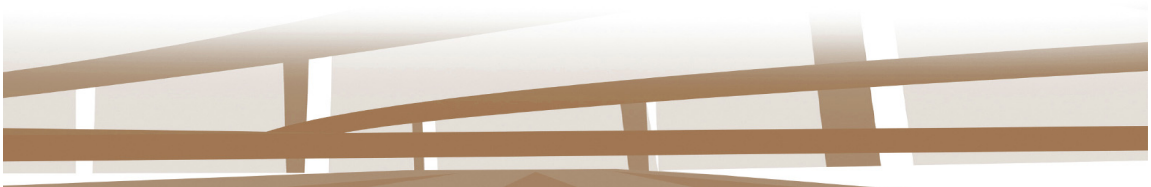
- 2008 model year: 5.7-litre HEMI®-powered Chrysler 300C, Dodge Charger and Dodge Magnum with MDS (multi-displacement system) now offer a “Fuel Saver Mode” display, included as part of the Electronic Vehicle Information Centre (EVIC), that tells drivers when they are in 4-cylinder mode, allowing them to modify their driving habits for improved fuel efficiency.
- 2008 Navigator, Expedition, Escape, Explorer, Ranger: improved lubricants for lower engine parasitic losses
- 2008 Expedition, Explorer, F-Series: reduced engine parasitic losses through improved accessory drives
- 2008 model year: Tire Pressure Monitor System standard on Edge, MKX, Ranger, Escape, Escape Hybrid, Sport-Trac, Explorer, F150, Mark LT, Expedition, Navigator, Mustang and Focus

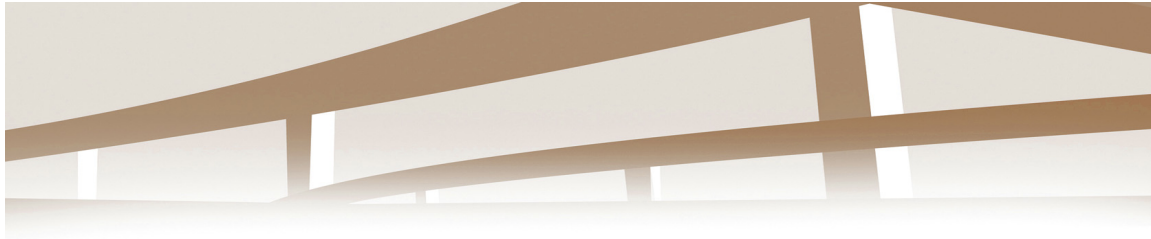
Ford Motor Company of Canada, Limited

- 2008 model year 4.6-litre Explorer Sport-Trac: 6-speed automatic transmission
- 2008 model year 3.5-litre Ford Edge and Lincoln MKX: 6-speed automatic transmission and variable cam timing
- 2008 model year: 5.4-litre Expedition: 6-speed automatic transmission
- 2008 model year: Ford will offer ethanol (E85) flexible fuel vehicle (FFV) capability on F-Series trucks, Crown Victoria, Grand Marquis and Town Car.
- 2008 Focus, Explorer, Navigator: higher-efficiency torque converters for automatic transmissions
- 2008 Focus: F-Series, select Explorers: low rolling resistance tires

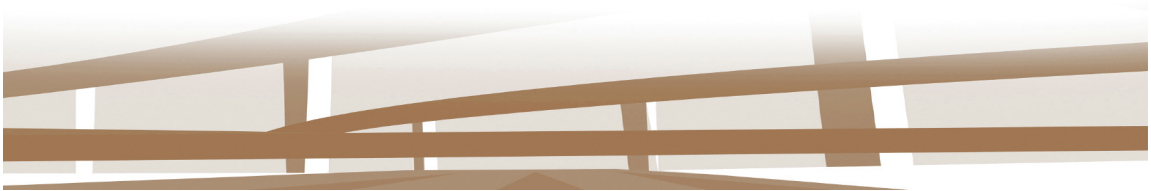
General Motors of Canada Limited

- Active Fuel Management (AFM) seamlessly deactivates 3 or 4 cylinders under light loads to provide fuel savings on a wide array of V6 or V8 engine applications: 2008 Trailblazer / Envoy, 2008 Saab 9-7X, 2008 Tahoe / Suburban, 2008 Yukon / Yukon XL, 2008 Grand Prix GXP, 2008 Impala SS, 2008 Impala LTZ, 2008 Avalanche, Silverado and Sierra
- Ethanol (E85) blended fuel standard or optional on 2008 Chevrolet Impala V6 models, GMC and Chevrolet full-size pickup trucks and SUVs, including the 2008 Tahoe, Suburban, Avalanche, Silverado, Yukon, Yukon XL and Sierra and 2008 Chevrolet Uplander, Pontiac Montana SV6, Chevrolet Express and GMC Savana





- Improved power density through supercharging and turbocharging facilitates the use of smaller-displacement engines: 2008 Chevrolet Cobalt SS, Saab 9-3, Saab 9-5, 2008 Pontiac Solstice and Saturn Sky
 - Spark Ignition Direct Injection (SIDI) gasoline engines on 2008 Pontiac Solstice, Saturn Sky, Chevrolet Cobalt SS and HHR SS, and Cadillac CTS and STS provide improved power output while using less fuel.
 - 2008 Saturn Vue and Aura Green Line and 2008 Malibu Hybrids: combination of price and reduced fuel-consumption benefits is intended to make these the best-value hybrid systems on the market
 - 2008 Tahoe / Yukon Two Mode Hybrid: leverages GM's leadership in automatic transmissions and electronic controls with integrated, powerful and compact electric motors to provide full hybrid capability and fuel efficiency as well as superior acceleration and continuous power
 - Fuel-saving 6-speed automatic transmissions offered on: 2008 Cadillac CTS, STS, SRX, XLR and Escalade, Chevrolet Corvette, Malibu, Equinox and Tahoe, Pontiac G6 and Torrent, Saturn Aura, Vue and Outlook, Saab 9-3, Buick Enclave, GMC Acadia, Yukon, Yukon Denali and Sierra Denali
 - Fuel saving 6-speed Allison 1000 series automatic transmission applied to certain pickup trucks: 2008 Chevrolet Silverado and GMC Sierra
- Honda Canada Inc.**
- 3/6-cylinder mode Variable Cylinder Management: 2008 Odyssey (EX-L and higher trims), Pilot (2WD)
 - 4th-Generation Integrated Motor Assist (IMA) hybrid system with Variable Cylinder Management: 2008 Civic hybrid
 - Revolutionary new 3/4/6-cylinder mode Variable Cylinder Management: 2008 Accord V6 AT
 - Dual Spark Plug Ignition (DSI): 2008 Civic hybrid
 - Continuously Variable Transmission (CVT): 2008 Civic hybrid
 - Low rolling resistance tires: 2008 Civic Hybrid, select Civics
 - Hybrid air conditioning system: 2008 Civic hybrid
 - Drive by Wire (DBW): all 2008 models
 - Tire Pressure Monitoring System (TPMS): standard on 2008 Acura CSX, TSX, TL, RL, RDX and MDX and 2008 Honda: Pilot, Ridgeline, Odyssey, Element, CR-V and Accord



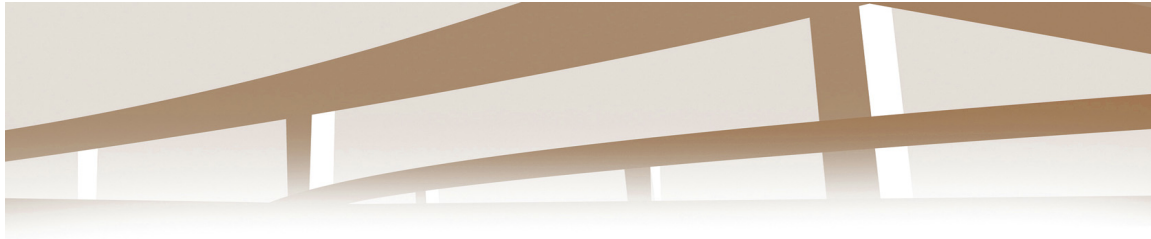
- High-output Turbocharged 4-cylinder engine (in lieu of 6 cylinder): 2008 Acura RDX
- Variable Torque Management System “on demand 4WD” (VTM-4): standard on 2008 Acura RDX (with Super Handling), Acura MDX (with Super Handling), Acura RL (with Super Handling) and Honda Ridgeline; optional on Honda Pilot
- Real Time 4WD (on demand 4WD): optional on 2008 Honda CR-V and Honda Element
- Smart A/C: 2008 MDX (The air-conditioning system can monitor the cabin conditions and shut of the A/C compressor and turn to partial recirculation mode in order to reduce the load on the engine and improve fuel economy when the HVAC is set to AUTO mode.
- Intelligent Variable Valve Timing and Lift Electronic Control + Variable Timing Control (i-VTEC + VTC): 2008 Honda Civic, Acura RDX, Acura CSX, Acura TSX, Honda Accord (4-cylinder) and Honda CR-V
- Intelligent Variable Valve Timing and Lift Electronic Control + Variable Cylinder Management (i-VTEC + VCM): 2008 Honda Odyssey, Honda Accord V6 AT and Honda Pilot 2WD
- VTEC: 2008 Acura TL, Acura RL, Acura MDX, Honda Pilot, Honda S2000 and Honda Ridgeline

Hyundai Auto Canada

Refer to the *Second Progress Update* for a listing of recently introduced technologies.

Kia Canada Inc.

- Continuously Variable Valve Timing (CVVT): improves fuel economy and reduces emissions by controlling valve overlap: all 2008 models (except V6 Sportage)
- Variable Force Solenoid (VFS): improves fuel economy by eliminating unnecessarily high automatic transmission pump loads while cruising: 2008 Spectra, Magentis, Rondo, Amanti and Sedona
- Electronic Throttle Control (ETC): improves fuel economy and reduces emissions by computer-controlled throttle blade angle: 2008 Rondo, Magentis, Amanti, Sorento and Rondo
- Variable Intake System (VIS): increases torque and horsepower at low, middle and high engine speeds: all 2008 V6 engines
- Graphite-coated piston skirts: improves fuel economy due to reduced friction and reduces NVH upon startup: 2008 Rio, Magentis, Rondo, Amanti, Sorento and Sedona

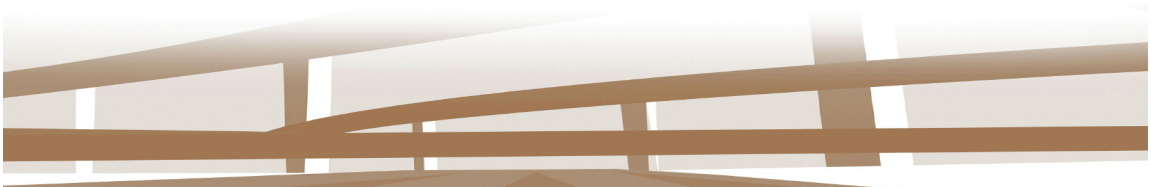


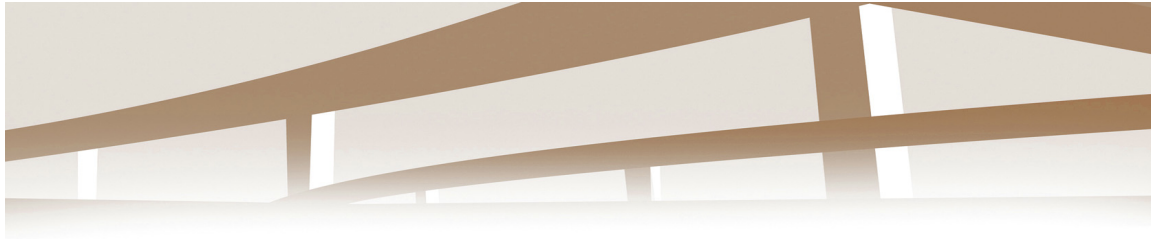
- Pulse-width modulated cooling fan controller reduces power draw and improves engine temperature control: 2008 Sedona
- Dual-stage oil pump: provides the lubrication benefits of a high-volume oil pump at low rpm, but switches to a low-drag oil pump at mid-high rpm to eliminate unnecessary drag, therefore improving fuel economy: 2008 Magentis
- Variable A/C compressor: improves fuel economy and reduces parasitic power loss by controlling swash plate angle: 2008 Rio, Magentis, Amanti and Spectra
- Fuel-saving 5-speed automatic transmissions: 2008 Rondo, Magentis, Amanti, Sorento and Sedona
- Weight reductions: Aluminum engine blocks and heads: 2008 Rio, Spectra, Magentis, Rondo, Amanti, Sorento and Sedona
- Weight reductions: Aluminum chassis components: 2008 Amanti
- Weight reductions: Magnesium seat frames: 2008 Amanti
- 2008 Mazda5 change to a 5-speed automatic transmission
- 2008 6-speed automatic transmission: CX-9, RX-8, Mazda6 (3.0 litres), CX-7 and MX-5
- 2008 6-speed manual transmission: RX-8, Mazdaspeed3 (DISI: 2.3 litres) and MX-5

Mercedes Benz Canada Inc.

Mazda Canada Inc.

- Direct-injection spark-ignition gasoline engine: 2008 Mazdaspeed3 and CX-7
- 2008 next-generation smart fortwo
- Alternator with on-demand power generation
- V6 and V8 engines with electrical 2-disc engine cooling thermostat; engine quickly obtains operating temperature
- 2008 C-Class: new optimized all wheel drive system to reduce weight and improve fuel economy
- 2008 C-Class: new electronic 7-speed automatic transmission
- 2008 C300 flexible fuel vehicle (FFV)
- 2008 C-Class: friction-reduced differentials and lubrication
- 2008 C-Class: added use of high-strength steel to reduce weight
- 2008 C-Class: new fuel supply system with on-demand fuel supply





Mitsubishi Motor Sales of Canada Inc.

- Tire pressure monitoring system (TPMS) standard on all 2008 Lancer models
- 2008 Lancer: equipped with Mitsubishi Innovative Variable Valve Timing and Lift Electronic Control (MIVEC) technology, reduced-weight engine components to improve fuel economy
- 2008 Lancer available with fuel-saving CVT transmission (replaces 4-speed automatic)
- 2008 Outlander available with new 2.4-litre MIVEC technology equipped 4-cylinder engine with reduced-weight engine components to improve fuel economy and efficiency
- 2008 Outlander 2.4-litre, 4-cylinder engine with CVT transmission for improved fuel economy

Nissan Canada Inc.

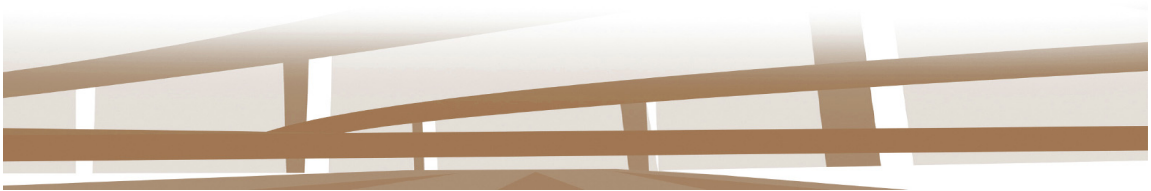
- Expansion of Continuously Variable Transmission (CVT) offering to Versa Sedan, Altima Coupe and Rogue (Small Crossover SUV) in 2008 MY:
 - 8–10% improvement in fuel economy versus 4-speed automatics
 - Over 65% of the NCI lineup will be offered with a CVT alternative by the end of CY 2007.

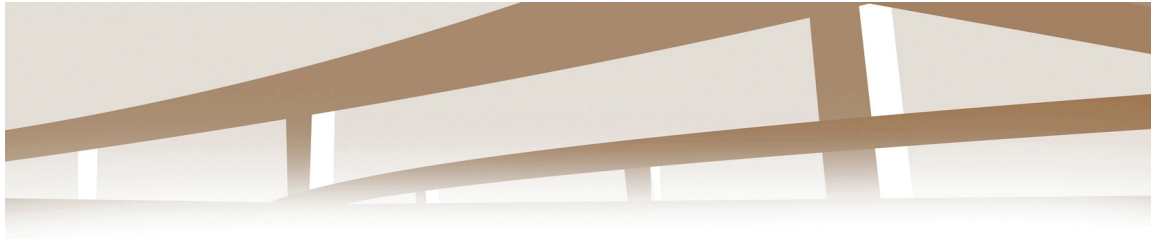
Porsche Cars Canada Ltd.

- 2008: all Cayenne models equipped with Direct Fuel Injection (DFI) engine technology
- 2008: all Cayenne models rated for up to 25% ethanol content of fuel (E25)
- 2008: all V8 Cayenne models equipped with variable valve timing and variable valve lift (VarioCam Plus)
- Porsche is developing a hybrid electric vehicle in conjunction with Volkswagen Canada Inc.

Subaru Canada, Inc.

- Partial Zero Emissions Vehicle (PZEV) introduced to Canadian fleet market
- 2008: all Outback 6-cylinder models equipped with SI-Drive (Subaru Intelligent Drive) engine management system allowing 3 levels of engine performance; Intelligent, Sport and Sport Sharp (economy, normal, high performance)
- 2008: introduces the harmonically balanced 3.6-litre horizontally opposed 6-cylinder engine (H6) on the redesigned Tribeca
- 2008: dual Active Valve Control System (AVCS) introduced on Tribeca, offering variable valve timing on intake and exhaust for improved drivability, fuel efficiency and reduced emissions





- 2008: new Tribeca 3.6-litre engine introduces parallel-flow engine cooling system for improved cooling efficiency while providing the use of regular grade (87 octane) fuel for lower operating expenses

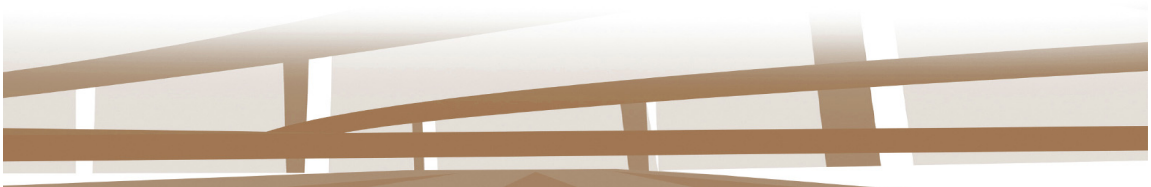
Suzuki Canada Inc.

- All 2008 models: electric throttle, improved combustion efficiency
- 2008 XL-7: roller rockers, decreased valve train friction
- 2008 XL-7: variable intake and exhaust valve timing, increased combustion efficiency
- 2008 XL-7: “beehive”-style valve springs, lower friction/improved valve seating and sealing
- 2008 XL-7: tuned intake runners, improved combustion efficiency at midrange cruising

Toyota Canada Inc.

- Hybrid (Toyota Hybrid Synergy Drive – Full Series/Parallel System): 2008 Prius, Camry Hybrid, Highlander Hybrid, Lexus RX 400h, GS 450h Hybrid, LS 600h L
- VVT-I on all 2008 models: optimal valve timing is set to suit the engine conditions in various speed ranges

- Dual VVT-i: In addition to the intake valve of the VVT-i, the new mechanism also controls the exhaust valve. According to engine rpm and accelerator opening, the computer continually adjusts the timing of the intake and exhaust openings to optimize air-fuel ratio: 2008 Avalon, Camry, Lexus IS 250/350, ES 350, LS 460, GS 350/430; select LDT (2008 RAV4, RX350, Tundra 5.7 litre and Sequoia 5.7 litre)
- Direct Injection Gas Engine: directly injects highly pressurized fuel into the cylinders, giving comprehensive control of the fuel injection timing, air-fuel ratio, throttle valve position, etc. to realize improved efficiency: 2008 Lexus IS 250/350, GS 350, SC 430, LS 460 and GS 450h
- 5-speed automatics: 2008 Camry 4 cylinder, all V6/V8 applications
- 6-speed automatics: 2008 Camry V6, Avalon, Tundra, Sequoia, Lexus IS 250/350, ES 350, SC 430, LS 430, GS 350/430 and LX 570
- 8-speed automatics: 2008 LS 460, GS 460 RWD
- Electric power steering: 2008 Prius, Yaris Sedan/Hatchback, Camry HV, RAV4, Highlander, Highlander HV, Lexus IS 250/350, GS 350/430, RX 400h, LS 460





- Flex Lock-up Torque Converters on all 2008 Toyota and Lexus models: To obtain higher efficiencies, flex lock-up torque converters contain an additional clutch-like mechanism to mechanically lock the pump and motor portions together. The segments are locked when the transmission's computer elements determine that the vehicle is cruising at near constant speed.
- ECT-i on all 2008 models: facilitates smooth gear change on top of improved response, leading to better fuel economy
- Super ECT-i: 2008 Yaris Sedan and H/B, RAV4, FJ Cruiser, 4Runner, Tacoma 4WD, Tundra, Sequoia, Avalon, Lexus IS 250/350, ES 350, GS 350/430, SC 430, LS 460, RX 350 and Lexus LX 570
- Weight reductions: aluminum engine blocks: all 2008 4-cylinder, V6 applications
- Weight reductions: aluminum body panels: 2008 Prius and Lexus SC 430
- Electronic throttle control on all 2008 Toyota and Lexus models: The vehicle's on-board electronic systems are able to control all of the engine's operation with the exception of incoming air. The use of throttle actuation ensures that the engine will only receive the correct amount of throttle opening for any given situation.

Tire Pressure Monitoring System:

- selected 2008 Toyota cars, all trucks and all Lexus products

Volkswagen Canada Inc.

- 2008: Jetta City and Golf City entry-level products with 6-speed automatic transmission
- 2008: introduction of Audi Valve System (AVS); increased power with lower fuel consumption
- Direct injection gasoline engines: offered on all 2008 VW and Audi product lines
- Direct injected gasoline combined with turbocharging: selected 2008 models
- Diesel available: 2009 Jetta
- 2008: increased use of 6-speed automatically shifted manual transmissions (DSG technology)
- 2008: weight reduction through aluminum/steel space-frame design
- 2008: extensive use of lightweight aluminum and carbon-reinforced materials

