Driving Electric
UNDERSTANDING ELECTRIC VEHICLE TECHNOLOGY AND ENVIRONMENTAL BENEFITS
Automobiles provide us with freedom and mobility, but there are environmental consequences to their use. Burning hydrocarbon fuels, such as gasoline and diesel, to power vehicles contributes to climate change and poor air quality, ultimately affecting our health and well-being. Hybrid-electric and electric vehicles can offer freedom and mobility without burning as much fuel (and sometimes no fuel at all) or producing as many emissions.

Why Electrify Vehicles?

Transportation activity was the source of one quarter of Canada’s total greenhouse gas (GHG) emissions in 2007. Canada’s transportation-related GHG emissions are primarily caused by the burning of hydrocarbon fuels in conventional internal combustion engines to power locomotives, marine vessels, aircraft, trucks and automobiles. Nearly one half of these emissions are produced by personal vehicles.

In addition to GHG emissions, the combustion of hydrocarbon fuels in the engine of a vehicle causes air pollutants, also called criteria air contaminants (CACs), to be emitted from the vehicle. CAC emissions are a factor that contributes to poor air quality and smog, which can cause respiratory illness as well as acid rain.

By incorporating hybrid-electric and electric vehicle technology into personal vehicles, GHG and CAC emissions from the vehicle can be substantially reduced or eliminated altogether. Motors powered by electricity can work in combination with combustion engines to deliver power to the wheels, or can eliminate the need for an engine entirely. The electric energy supplied to the motor can come from a battery on board that may, or may not, be plugged in to charge up, or it can come from a hydrogen fuel cell. The environmental and human health impacts associated with vehicles that plug in vary, based on the energy source used to generate the electricity (e.g., coal-fired power plants produce harmful emissions, whereas wind is a renewable and emissions-free source of energy). Similarly, the emissions benefits associated with using hydrogen fuel cells depend on the type of energy used to synthesize the hydrogen. Hydrogen can be produced by electrolysis (using electricity to split water), reformed from a fossil fuel (such as natural gas, which causes GHG emissions), or recovered from industrial processes where hydrogen is produced as a by-product.

Increasingly, new vehicle models that are appearing on the market are incorporating varying levels of electrification. The purpose of this brochure is to present information about the different types of hybrid-electric and electric vehicles, and the advantages and disadvantages of each.

What Types of Hybrid-Electric and Electric Vehicles Exist?

Similar to the rate of technological development seen in other consumer products, hybrid-electric and electric vehicle technology is rapidly evolving. Some vehicles incorporate a degree of electrification suitable for powering vehicle accessories, such as power steering, while others incorporate full electric drive power. Generally, the more a vehicle relies on electric motors for propulsion, the farther it can travel without burning hydrocarbon fuels. Accordingly, this usually means a larger battery or fuel cell, which in turn, results in a higher purchase price.
**Hybrid-Electric Vehicle (HEV)**

Hybrid-electric vehicles (HEVs, often called “hybrids”) are moved by two or more power sources: a conventional internal combustion engine (ICE) supplied with gasoline or diesel from the fuel tank, and one or more electric motors supplied with electricity from a battery pack. In today’s hybrids, the battery packs are usually nickel metal hydride and can store about 1 to 2 kWh. The electric motor draws electricity from the battery pack to help power the vehicle by supplementing or replacing engine power, particularly during idling or cruising at a low speed.

Hybrids can provide the power, range and fuelling convenience of an internal combustion engine vehicle (ICEV), but with reduced fuel consumption and fewer emissions. From the driver’s perspective, operating a hybrid is essentially the same as operating a conventional vehicle, except that hybrids tend to run quieter (due to a smaller combustion engine and/or engine shut-off during idling and low-speed cruising).

The electric energy system in a hybrid can power the vehicle to varying degrees.

A **Micro Hybrid** system enables the automatic shut down of the engine when the vehicle comes to a stop, thus saving fuel that would otherwise be consumed during idling. The combustion engine remains the primary power source used to propel a Micro Hybrid vehicle.

A **Mild (or Power-Assist) Hybrid** also relies primarily on the combustion engine to propel the vehicle and the electric motor only provides supplementary power.

In a **Full Hybrid**, drive power can be supplied entirely by the engine or entirely by the electric motor, or a combination of the two. By combining the outputs of the engine and the electric motor, full hybrid systems can generate substantial power while consuming much less fuel.

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**Regenerative Braking**

Friction is the force used in conventional brakes to slow down a vehicle. The heat produced by this friction is then lost to the surrounding air. In hybrid-electric and electric vehicles, the electric motor can supplement the braking force by running in reverse. This has the effect of charging the battery with energy otherwise lost to friction and heat and is called **regenerative braking**. Because regenerative braking requires an electric motor and a battery, it is a feature used in most hybrid-electric, battery electric and fuel cell electric vehicles.
The parallelhybridsystem isthe simplesthybrid design. The combu stionengine is powered by the burning of fuel, and the electric motor receives electric energy from the battery. Both the engine and the electric motor provide power to the wheels. They can operate independently or simultaneously; however, the combustion engine usually serves as the main power source and is assisted by the electric motor during start-up and periods of acceleration. The battery is solely charged through regenerative braking.

For all hybrids, from micro to plug-in, power from the electric motor and combustion engine is delivered to the wheels in one of three ways: in parallel, in series or a combination of both.

**Parallel Hybrid System**

The parallel hybrid system is the simplest hybrid design. The combustion engine is powered by the burning of fuel, and the electric motor receives electric energy from the battery. Both the engine and the electric motor provide power to the wheels. They can operate independently or simultaneously; however, the combustion engine usually serves as the main power source and is assisted by the electric motor during start-up and periods of acceleration. The battery is solely charged through regenerative braking.

**Plug-In Hybrid Electric Vehicle (PHEV)**

Plug-in hybrid electric vehicles and extended range electric vehicles (EREVs) are hybrids with additional battery capacity (expected to be a 5 to 15 kWh lithium-ion battery pack). These vehicles can be charged from an electric outlet when parked. Using this store of externally supplied electric energy, plug-in hybrids are able to travel in all-electric mode at higher speeds and for extended distances without using the combustion engine. This contrasts with non plug-in hybrids, which offer limited all-electric capability. An EREV is a special category of plug-in hybrid that operates solely on stored electricity until the battery is depleted. Only then does the EREV use the combustion engine as an auxiliary power source that charges the battery, which powers the electric motor.

**Rechargeable Battery Pack**

Most conventional vehicles already have a 12V lead acid battery that powers the starter motor, lights and ignition system. Because hybrid-electric and electric vehicles need more electric energy than the starter battery can store, they come equipped with a larger rechargeable battery pack. This battery pack stores enough energy to provide power for sustained periods of time.

**Other models:** HONDA INSIGHT
**Series Hybrid System**

The series hybrid system is unique in that the combustion engine does not directly power the wheels, but drives a generator that produces electricity. This electricity is then stored in the battery for use later on, or delivered immediately to the electric motor to drive the wheels. As a result, motive force is delivered entirely by the electric motor. As for the battery, it is charged by the combustion engine via the generator, as well as through regenerative braking. Series hybrids are particularly well suited for plug-in charging, further reducing fuel consumption in stop-and-go driving, such as in urban conditions.

**Series-Parallel Hybrid System**

In the series-parallel system, the combustion engine can power the wheels directly or it can power a generator that supplies electricity to the battery. The combustion engine is able to do this via a power diverter device, which is why series-parallel hybrids are also known as power-split hybrids. Series-parallel hybrids share characteristics of parallel hybrids, in that the wheels can be powered by the engine and the electric motor. They also share characteristics with series hybrids, in that the battery is charged by the combustion engine via the generator and through regenerative braking.

**Hydrogen Fuel Cell**

A fuel cell directly converts fuel (most commonly hydrogen gas) into electricity. Electrochemical reactions involving hydrogen and oxygen produce an electric current, heat and water.
**Battery Electric Vehicle (BEV)**

Battery electric vehicles do not have combustion engines or fuel tanks. The electric motor provides 100 per cent of the motive force and is powered by a rechargeable battery pack (higher capacity than those used in hybrids and plug-in hybrids – expected to be a lithium-ion pack with over 40 kWh of capacity) that can be charged by being plugged into an electric outlet. While driving, regenerative braking extends the charge. Because battery electric vehicles do not burn fuel or produce harmful emissions, they offer tangible improvements to street-level air. The environmental impact of battery electric vehicles is primarily associated with the manufacturing of the high-capacity rechargeable battery and the generation of electricity used to charge the battery.

**Fuel Cell Electric Vehicle (FCEV)**

In FCEVs, the fuel cell provides electricity to the electric motor, which drives the wheels. The fuel cell is supplied with hydrogen that is stored on board the vehicle in a pressurized gas tank. Like battery electric vehicles, FCEVs do not emit harmful pollutants (only water and heat). The environmental impact of an FCEV is primarily associated with the energy required to synthesize the hydrogen.

FCEVs also utilize a battery to provide additional power for acceleration and to capture energy from the regenerative braking system.

**Other anticipated models:** MINI E ELECTRIC CAR; MITSUBISHI MIEV; SMART FOR TWO BEV; TESLA ROADSTER; FORD FOCUS BEV

**Other anticipated models:** DAIMLER, FORD, TOYOTA, GM, HONDA, NISSAN, HYUNDAI, and VOLKSWAGEN have fuel cell electric vehicle development programs with an anticipated commercial release date of 2015.
**How Can I Tell the Difference?**

The chart below shows the primary power source, energy storage technologies, and electric drive functionality of each of the vehicle types referenced in this brochure. Regardless of the degree of electrification, however, an electric motor and battery pack are essential components to vehicles using electric energy as a power source. Most importantly, all hybrid-electric and electric vehicles are different and are best applied in particular driving situations for different lifestyles.

<table>
<thead>
<tr>
<th>Power Sources and Energy Storage</th>
<th>No Electric</th>
<th>Some Electric</th>
<th>All Electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICE and Fuel Tank</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Electric Motor</td>
<td>✗</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Battery Pack</td>
<td>✗</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Grid Rechargeable Battery Pack</td>
<td>✗</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Fuel Cell and Hydrogen Tank</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional Features</th>
<th>No Electric</th>
<th>Some Electric</th>
<th>All Electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regenerative Braking</td>
<td>✗</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Electric-only Range</td>
<td>✗</td>
<td>✗</td>
<td>✔</td>
</tr>
</tbody>
</table>

*The FCEV is a technology that is easily adaptable to plug-in and conventional hybridization.*
What Works for Me?

As explained in this brochure, there are many different types of hybrid-electric and electric vehicles. The type that is right for you will depend on your needs. The environmental benefits of the different types of vehicles discussed in this brochure vary with application. The table below summarizes the pros and cons of each type.

<table>
<thead>
<tr>
<th>Environment &amp; Lifestyle Advantages</th>
<th>Financial &amp; Lifestyle Disadvantages</th>
<th>Best For...</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Micro HEV</strong></td>
<td>• Reduced fuel consumption at start-up, idling and powering accessories • No need to plug in • Small- to full-size vehicles are available</td>
<td>• Estimated to be $300-$400 more than an equivalent ICEV</td>
</tr>
<tr>
<td><strong>Mild HEV</strong></td>
<td>• Reduced fuel consumption • Lower harmful emissions • Idle-off • No need to plug in • Small- to full-size vehicles are available</td>
<td>• Approximately $3,500 more than an equivalent ICEV</td>
</tr>
<tr>
<td><strong>Full HEV</strong></td>
<td>• Reduced fuel consumption • Lower harmful emissions • Idle-off • No need to plug in • Able to travel in all-electric mode • Small- to full-size vehicles are available</td>
<td>• Approximately $6,000-$7,000 more than an equivalent ICEV</td>
</tr>
<tr>
<td><strong>PHEV or EREV</strong></td>
<td>• Substantially reduced fuel consumption • Very low harmful emissions • Ability to charge vehicle at home • Able to travel in all-electric mode for an extended distance (10 to 60 km) • Small- to full-size vehicles will be available</td>
<td>• Expected to be approximately $15,000 more than an equivalent ICEV • Battery charging takes time • Limited access to charging locations</td>
</tr>
<tr>
<td><strong>BEV</strong></td>
<td>• Electricity can be generated by renewable energy sources • No harmful emissions • Ability to charge vehicle at home • Small- to full-size vehicles will be available</td>
<td>• Anticipated to be approximately $13,000-$20,000 more than an equivalent ICEV • Battery charging takes time • Limited access to charging locations • Driving range limited by battery capacity</td>
</tr>
<tr>
<td><strong>FCEV</strong></td>
<td>• Hydrogen can be synthesized using renewable energy sources • No harmful emissions • Can refuel in minutes • Small- to full-size vehicles will be available</td>
<td>• Anticipated to be approximately $13,000-$20,000 more than an equivalent ICEV • Limited access to hydrogen • Substantial energy required to synthesize hydrogen • Driving range limited by hydrogen storage capacity</td>
</tr>
</tbody>
</table>

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