GHGenius
GREENHOUSE GAS MODEL
A lifecycle analysis of hydrogen pathways

The Government of Canada is committed to the transformative, long-term change required to make reductions in greenhouse gas (GHG) emissions while ensuring continued economic growth. Encouraging innovation and the development of environmental technology is a key aspect of the Government's approach to climate change in the longer term. New technologies can provide Canadians with the ability to reduce GHG and other harmful emissions. Fuel cell and hydrogen technologies will help Canada meet its emission obligations over the longer term and across many sectors of the economy.

In the past, the use of different methods of calculating GHG emissions and an absence of complete and accurate information has lead to conflicting statistics for past, present and future GHG emissions. Natural Resources Canada (NRCan) has developed the GHGenius lifecycle emissions model to enable a systematic approach to modeling the GHG emissions of both technology and fuels across the transportation sector. NRCan's Canadian Transportation Fuel Cell Alliance (CTFCA) has assembled a comprehensive set of hydrogen pathways and their associated GHG emissions, which are based on actual Canadian conditions and fuel standards. This will allow industry, governments and the media to utilize consistent numbers derived from a common database and GHG model.

Natural Resources Canada / Ressources naturelles Canada

Canada

What is GHGenius?

GHGenius is an analytical tool that can be used to predict GHG and criteria air contaminant (CAC) emissions for on-road transportation systems. This model can be run for any year between 2000 and 2050. To do this, it employs historical data and correlations for changes over time in energy and processing parameters. GHGenius uses a complete fuel cycle approach. This means that the overall emissions of a process are assigned to various stages of the fuel's lifecycle – from the time a feedstock is extracted (e.g. natural gas) or cultivated (e.g. corn) through to it's end use on the road. This methodology enables the user to easily compare new and existing fuels and the technologies that use them.

Regardless of whether a fuel is burned in an internal combustion engine (ICE) or transformed in a fuel cell, GHGenius identifies:

- The amount of GHG and CAC emissions generated by a wide variety of fuels and technologies;
- The amount of energy used and generated; and
- The cost-effectiveness of the entire fuel lifecycle.

Since GHGenius can be used to compare the GHG benefits and cost-effectiveness of different fuelling pathways, it is particularly beneficial in evaluating new programs and policies.

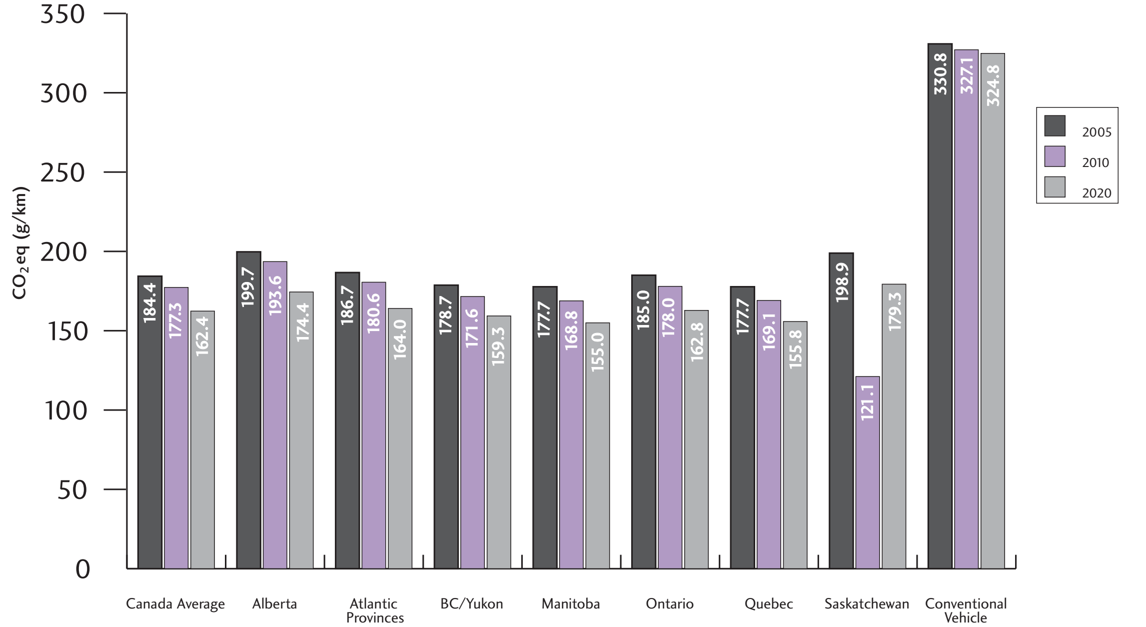
Assumptions

The charts provided in this publication have been calculated based on the following assumptions:

- Hydrogen production pathways are compared to conventional internal combustion engine vehicles which use the new standard reformulated gasoline (RFG) as a baseline.
- All calculations assume a decentralized production model. In other words, the hydrogen is produced where it will be used.
- The electricity generation mix was taken from the National Energy Board's 2003 supply and demand forecast, *"Canada's Energy Future, Scenarios for Supply and Demand to 2025"*.
- Fuel for internal combustion engines (ICE):
  - From 2005 to 2019, the sulphur content of RFG is regulated at 30ppm.
  - Beginning in 2020, it is predicted that the sulphur content of RFG will be regulated at 1ppm at the refinery.
- Beginning in 2020, 10% of $C0_2$ emissions coming from natural gas, coal or oil-fired power plants will be sequestered.
- Compressed hydrogen is stored on the vehicle at 350 bar (5,000 psi) from 2005 to 2009, and at 700 bar (10,000 psi) beginning in 2010.
- The Canada average electricity mix provides the energy required to compress the hydrogen.
- In 2005, it is assumed that a hydrogen fuel cell vehicle (H_2FCV) is 2.1 times more efficient than an equivalent internal combustion light-duty vehicle (LDV). It is predicted that a H_2FCV will be 2.2 times more efficient than a LDV in 2010 and 2.3 times more efficient than a LDV in 2020.
- All wood biomass is from short rotation forestry; that is to say, from crops that are grown specifically for the purpose of being used for energy generation.
- All units are expressed as grams per kilometer (g/km).
- The CO_2 equivalent factor (CO_2eq) used within the model is the sum of the following GHGs multiplied by their global warming potential (GWP): CO_2 (carbon dioxide GWP=1), N_2O (nitrous oxide GWP=310) and CH_4 (methane GWP=21).

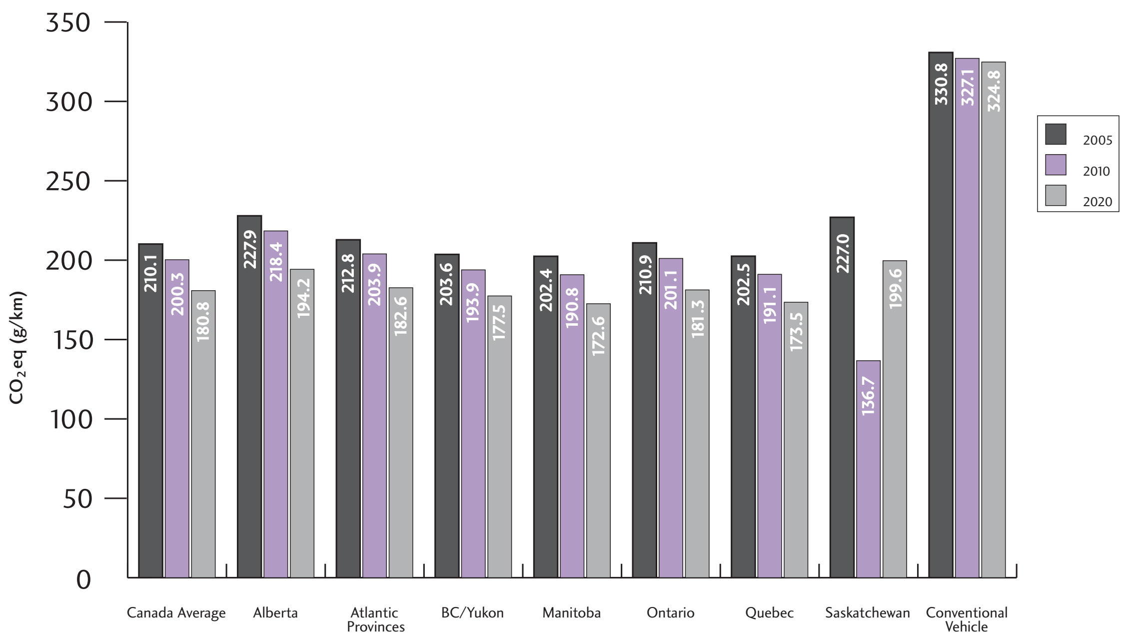
The following charts illustrate the lifecycle GHG emissions from various hydrogen production pathways for end use in fuel cell vehicles, as compared to an equivalent conventional gasoline internal combustion engine (ICE) vehicle.

Hydrogen Production from the Steam Methane Reforming (SMR) Pathway*



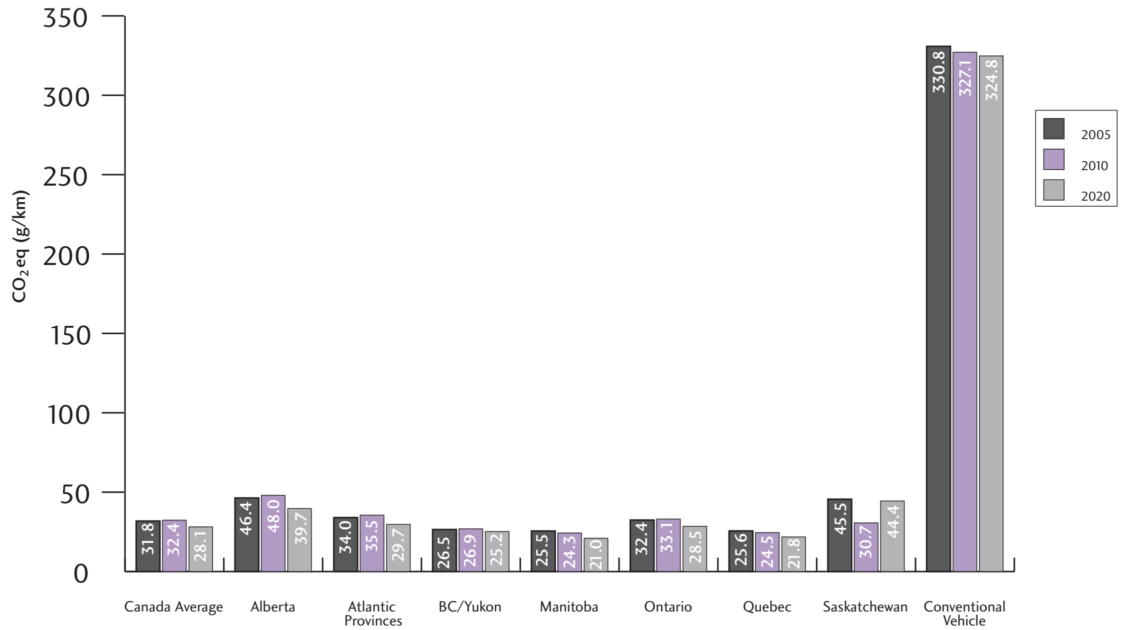
**Steam at a high temperature and pressure is mixed with natural gas - made up primarily of methane - in a reactor/reformer to produce hydrogen and carbon dioxide.*

Hydrogen Production from the Methanol Reforming Pathway*



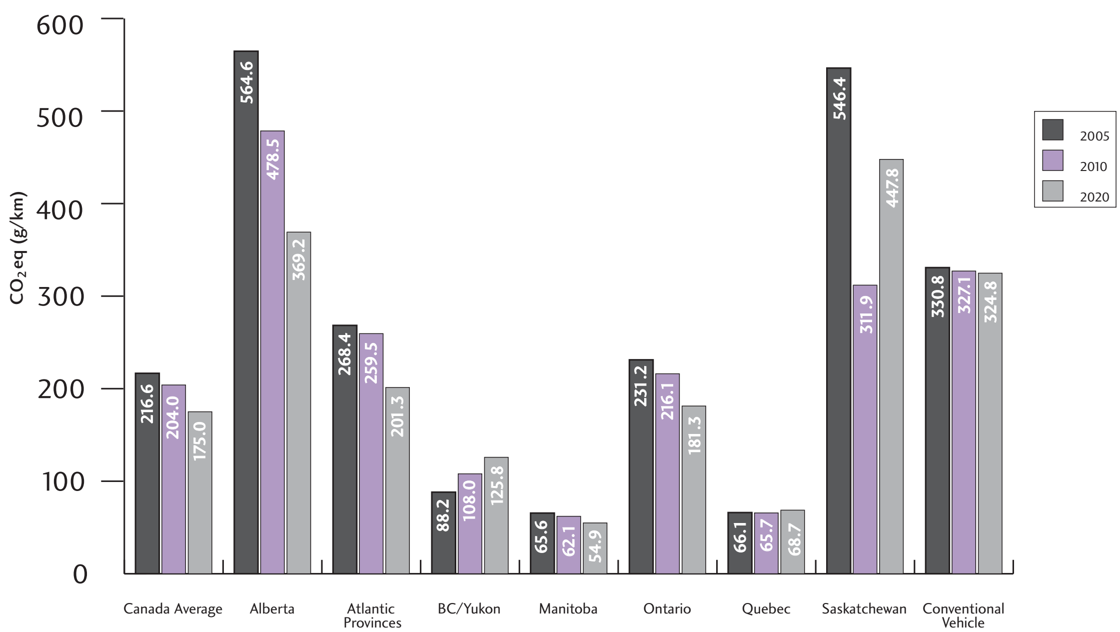
**A mixture of vaporized methanol and steam is passed through heated reactors to produce hydrogen and carbon dioxide.*

Hydrogen Production from the Biomass Gasification Pathway*



**Gasification converts biomass feedstocks, such as wood wastes or crop wastes, into gaseous components – primarily hydrogen and carbon dioxide – by applying heat and pressure in the presence of steam.*

Hydrogen Production from the Electrolysis Pathway*



**Electrolysis separates water into its constituent elements - hydrogen and oxygen - by passing an electrical current through water.*

For information on GHGenius visit: **www.ghgenius.ca**

For information on the CTFCA visit: **www.ctfca.nrcan.gc.ca**