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A comparison of alternative technologies to de-carbonize Canada's passenger transportation sector

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Abstract

Using a full systems model of Canada's economy, six alternative scenarios to de-carbonize the personal passenger vehicle fleet are compared to a business as usual non de-carbonized scenario in terms of greenhouse gas emissions, trade disposition of energy commodities, and the physical resources required for energy production. Three scenarios are analyzed to compare the impacts of increasing either ethanol 85, hydrogen, or electricity powered vehicles into the vehicle fleet, with each starting to penetrate the light vehicle stock in 2010 to reach 100% of the new vehicle market by 2050. For each of these three scenarios, we then construct a variant scenario that considers the additional effects of de-carbonizing electricity production. With a de-carbonized electricity sector, net emission reductions are 29% for ethanol 85, and 31% for both hydrogen and electricity. When considering the transportation sector only, net emission reductions equal 13% for ethanol 85, and 14% for hydrogen and electricity. However, although the ethanol scenario results in the lowest reduction in total emissions, it has significant impacts on other parts of the physical resource base. By the time ethanol reaches 5% of the fuel mix in 2015, domestic consumption of grains increases by 20%, in turn impacting crop trade disposition. At this point, emissions are reduced by less than 0.5%, owing to the fossil fuels required since most ethanol is still grain based. By 2050 it is projected that almost all ethanol will be cellulose based, generating a more significant emission reduction but in turn requiring potentially unsustainable amounts of crop residue.

Keywords: Energy system models; Ethanol; Hydrogen fuel cell; Electric car; Greenhouse gas emissions; Passenger transport

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1. Introduction

At the Kyoto Protocol to the United Nations Framework Convention on Climate Change, Canada committed to reducing its greenhouse gas (GHG) emissions to be 6% below 1990 levels by 2008–2012. By 2005, Canada's GHG emissions were approximately 26% above the 1990 base year and 33% above the country's emission reduction targets [1]. Government projections are that Canada's emissions could rise another 5% by 2010 [2].

This article focuses upon the GHG emissions associated with light duty vehicles and in particular those that make up the 'personal passenger vehicle' fleet of Canada's passenger transportation sector. With an increasing population and because Canadians are very dependent upon their personal vehicles for their mobility, personal travel has steadily increased since the 1990 base year. This trend is expected to continue as Canada's population continues to grow into the future.

Canada is a country where geography, economics, culture and history intertwine to encourage personal vehicle travel [3–5]. It is the second largest country in the world by landmass and, with 80% of Canadians living in urban areas, is also heavily urbanized. Unlike many European countries, most of Canada's urban form has been built within the last 75 years, an era when mobility was defined by the personal vehicle.

In 2005, personal passenger vehicles in Canada contributed an estimated 91 million metric tonnes of carbon dioxide equivalent (Mt CO2e) to the atmosphere, a 40% increase from the 65 Mt CO2e contributed in 1990 and far above the 26% increase in total domestic emissions. A number of socio-economic drivers contribute to this higher trend for the passenger vehicle sector. For one, Canada has a relatively high rate of population growth focused in urban areas. Exacerbating this has been a shift in the type of vehicles driven — since 1990, the number of light trucks and sport utility vehicles (SUVs) on Canada's roads has nearly doubled while the number of cars has remained relatively flat.

1.1. Article purpose

The purpose of this article is two-fold: to model the future trajectory of road-based passenger transportation in Canada and then to compare the emission and fuel-related impacts of three hypothetical climate change policies targeting zero or low carbon light duty vehicle technologies: electric vehicles, hydrogen fuel cell vehicles, and vehicles fuelled by ethanol. As well we evaluate the effects of de-carbonizing electricity production.

We consider the emissions directly associated with vehicle use as well as the upstream processes required for the production of fuels, the transformation of energy feedstocks and the production of electricity as well as energy feedstocks.

1.2. Scenarios

Seven scenarios, a business as usual and six variants, are presented and analyzed.

A 'non de-carbonized business as usual' (BAU) scenario considers the progression of the sector using conservative assumptions for changes in fuel efficiency, engine technologies, distribution over vehicle size and fuel shares.

The 'ethanol BAU electricity grid variant' scenario assumes the progressive substitution of the gasoline/diesel internal combustion engines (ICE) with ethanol 85 ICE starting in 2010 and proceeding to