Report on the Pathways Initiative Workshop
ABOUT POLLUTION PROBE

Pollution Probe is a national, not-for-profit, charitable organization that exists to improve the health and well-being of Canadians by advancing policy that achieves positive, tangible environmental change. Pollution Probe has a proven track record of working in successful partnership with industry and government to develop practical solutions for shared environmental challenges.

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   - Ontario Trucking Association
   - Canadian Fuels Association
   - Railway Association of Canada
   - Toyota Canada
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The contents of this report reflect information shared by a wide variety of transportation stakeholders at the Pathways Initiative Workshop, and do not necessarily reflect the opinions or findings of Pollution Probe.

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I am pleased to announce the release of the final report of the Pathways Initiative Workshop, which took place in late March 2016 in Toronto. This multi-stakeholder session engaged 84 participants, and included leading Canadian and world experts in the transportation field representing governments, industry, not-for-profit organizations, and academia. The objective of Pollution Probe’s Pathways initiative is to identify and promote transportation pathways which will deliver deep reductions in greenhouse gases and promote economic growth, thereby contributing to national and provincial actions on climate. Private and public sector participation and sponsorship is a key foundation of the Pathways Initiative. Imperial Oil, the Canadian Fuels Association, Ontario Trucking Association, Toyota, the Railway Association of Canada and Environment and Climate Change Canada have provided valuable support which is greatly appreciated.

The final report contains a wealth of information and ideas on how to decarbonize Ontario’s transportation sector, and opportunities for low-carbon transportation pathways. The report does not cover all modes of transportation; however, it addresses many of the major sources of GHG emissions in Ontario and identifies opportunities to make progress on reducing these emissions. The report provides an overview of some of the important developments that are taking place in transportation, their actual and potential contributions to reducing GHG emissions, highlights the barriers to implementation which are being faced, and points to the related opportunities for economic and social benefits which can be realized. A key theme in the report is that Ontario should ensure that it shapes a decarbonized transportation system that reduces GHG (and other) emissions while delivering economic benefits such as industrial growth, high quality jobs, and new intellectual property.

Technology pathways that were found to have substantial potential to reduce GHG emissions from transportation and which are highlighted in the report include:

- Aggressive efficiency enhancements in conventional light- and heavy-duty vehicles which could include improved powertrain efficiency, vehicle lightweighting and enhanced aerodynamics.
- The deployment of electric vehicles and the development of hydrogen fuel cell vehicles.
- The use of autonomous vehicles for both human and freight movement as well as in resource sectors.
- The development and use of low-carbon advanced biofuels including renewable natural gas.
- Emissions reduction opportunities in the rail sector including improvements to operational efficiencies and the adoption of low-carbon technologies and fuels.

The Pathways Initiative is especially timely and salient given the aggressive GHG reduction targets recently announced by various levels of government across Canada. As transportation is a major contributor to the country’s GHG inventory, being responsible for 23% of total emissions in 2013, it is viewed as a core area where significant reductions must be secured.
The Government of Ontario is moving aggressively to reduce GHG emissions from transportation in its Climate Change Strategy. The Province has indicated that its approach to reducing transportation emissions will recognize the emissions reduction potential of different technologies and modes, and the sector has been identified as a key opportunity area for investments from cap and trade program proceeds. The development of a pan-Canadian climate strategy is also now underway, with very ambitious timelines and an extensive federal-provincial process. Pollution Probe has been engaged in this process and will be contributing its ideas and support to the Federal, Provincial and Territorial Governments now moving forward with the development of the pan-Canadian framework on clean growth and climate change. As part of this national process, Pollution Probe will be working with its partners to identify the best practices, technologies and approaches for decarbonization and clean growth in priority transportation pathways, which will include both short and long term measures.

If you require further information and would like to partner with Pollution Probe in this important work, please do not hesitate to contact me.

Sincerely,

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1.0 Introduction

Pollution Probe organized The Pathways Initiative Workshop to identify opportunities to achieve deep reductions in greenhouse gas (GHG) emissions from the transportation sector in the Province of Ontario. The Province has set an aggressive target of reducing total greenhouse gas emissions by 80% of 1990 levels by 2050. More than one-third of Ontario’s current emissions originate in the transportation sector.

The workshop engaged 84 participants, including leading Canadian and world experts in the transportation field and representatives from government, industry, not-for-profit organizations, and academia. Presentations were made in plenary and breakout sessions on a number of transportation modes and technologies that offer a high degree of GHG reduction potential. Five key considerations were set out in advance by Pollution Probe to guide and stimulate the presentations and discussions:

- GHG emissions reduction potential
- Health and social benefits
- Economic growth potential
- Technological feasibility
- Barriers to implementation

Section 2.0 profiles the workshop presenters and the topics that were explored in breakout groups and plenaries. Section 3.0 assesses the workshop results in terms of the five key considerations. Section 4.0 summarizes the opportunities for moving forward on decarbonizing Ontario’s transportation sector. Appendix 1.0 contains detailed records of all presentations and discussions.

2.0 Presentations Made and Topics Covered During the Workshop

This section provides a high-level overview of the topics explored during presentations and ensuing discussions. All workshop presentations can be downloaded from: http://www.pollutionprobe.org/pathways-workshop/.

2.1 Opening Plenary: Summary of Presentations

Mr. Alex Wood
Executive Director, Ontario Ministry of Environment and Climate Change, Climate Change Directorate

Mr. Wood provided a high-level overview of Ontario’s key policy initiatives on climate, such as its Climate Change Strategy, which lays out the government’s vision for Ontario to 2050, and the proposed Bill 172 – The Climate Change Mitigation & Low-carbon Economy Act – which will enshrine into law Ontario’s GHG emissions reduction targets and provide a foundation for a provincial cap and trade program. He highlighted that transportation was the single biggest source of GHG emissions in the province and discussed the implications of Ontario’s climate initiatives for the transportation sector. In conclusion, he provided examples of the government’s current actions and future opportunities for reducing emissions from Ontario’s transportation sector.
Mr. Peter Boag  
*President, Canadian Fuels Association*

Mr. Boag opened by highlighting that transportation has played a key role in enabling economic growth and improving citizens’ standards of living while also being a major contributor to Canada’s GHG emissions. He discussed a recent Conference Board of Canada (CBOC) study, which examined Canada’s road transport sector in the context of the 80% reduction by 2050 target. The study looked at a number of options for GHG abatement, chiefly from an economic perspective. It identified significant barriers to achieving the target and highlighted the need for changes in consumer attitudes and behaviours. Mr. Boag discussed six key areas identified by the CBOC study for moving towards a low-carbon future in the transportation sector.

Mr. Bob Oliver  
*Chief Technology Advisor, Pollution Probe*

Mr. Oliver offered some perspective on a strategic approach to confronting the challenge of decarbonizing transportation in Ontario. He touched upon the difficult position Ontario finds itself in, as it’s trying to significantly reduce the role of the oil and gas products that its economic and social well-being have been dependent upon for decades. He suggested that policy-makers need to enhance their capacity to conduct balanced, cross-disciplinary, participatory, science-based technology assessments to help foster shared expectations, coordination among stakeholders, and the design of adaptive policy. He emphasized the need to create credible scenarios of decarbonized futures and to understand the conditions for success within these scenarios. Mr. Oliver highlighted the need to focus on options that deliver deep GHG reductions while bringing economic and social benefits.

**Discussion Highlights**

During this session, participants discussed GHG emission levels in Ontario in 1990 (the baseline year for GHG reduction targets), and compared the share of emissions from different sectors with 2013 numbers. In addition, they discussed the provincial government’s efforts to model the impacts of its GHG reduction measures as well as expectations for specific contributions from the transportation sector. Participants briefly explored the effects of recent fluctuations in gasoline prices on consumer behaviour. They discussed concerns about leaks and fugitive emissions from natural gas distribution and processing infrastructure. Future transportation services for the Toronto-Waterloo innovation corridor were also explored.

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**2.2 Breakout Session A (Morning): Summary of Presentations**

**Fuel-saving light-duty vehicle technology**

Mr. John German  
*Senior Fellow, U.S. Co-Lead, The International Council on Clean Transportation*
Mr. German opened by highlighting that all technology forecasts are conservative as they do not account for emerging technologies and innovation in general. He stated that computers have been the biggest breakthrough in vehicle components in recent years, revolutionizing every aspect of light-duty vehicles. The single biggest improvement in fuel efficiency of late has come from vehicle lightweighting. Mr. German discussed a range of technologies that have served to improve the performance of modern gasoline-powered vehicles while enhancing fuel efficiency and reducing engine size. He observed that while fuel producers are the ones who ultimately pay for reduced fuel consumption, society as a whole benefits financially, as consumer savings on fuel tend to be spent elsewhere in the economy.

**Hydrogen fuel cell technology**

**Dr. David Greene**  
*Research Professor, Department of Civil and Environmental Engineering, University of Tennessee Knoxville*

Dr. Greene’s presentation focused on challenges and opportunities related to hydrogen fuel cell technologies. He discussed some substantial technological advancements as well as rapid cost reductions in both hydrogen fuel cell and electric vehicles, and identified remaining challenges for both modes. These challenges include high costs, the need for low-carbon upstream energy generation, and a lack of supporting infrastructure. Dr. Greene stated that the probability of successfully implementing a low-carbon transportation option for light-duty vehicles increases by 50% when investments are made in both hydrogen fuel cell and electric vehicles. He said that the production of low-carbon biofuels will be limited in the future, and that their use will be reserved for applications like aviation and heavy-duty transport.

**Discussion Highlights from Session A (Morning)**

Topics covered during this discussion session included safety considerations for hydrogen, the viability of region-specific roles for hydrogen fuel cell and electric vehicles, and the likely impacts of emerging approaches to transportation, such as autonomous vehicles and car sharing, on GHGs and the value propositions of hydrogen fuel cell and electric vehicles. In addition, participants discussed the suitability of fuel cell and battery technologies for applications such as aviation and on-road heavy-duty vehicles, which require an energy-dense source of power.

2.3 Breakout Session A (Afternoon): Summary of Presentations

**Active transportation and urban form**

**Mr. Ryan O’Connor**  
*Project Manager, 8 80 Cities*

Mr. O’Connor presented on active transportation, discussing the need to develop and follow best practices in designing cities and streets to promote walking and cycling. He stressed that increased active transportation levels can not only yield GHG reductions, but a wide array of health and social
benefits. Mr. O’Connor discussed the four key characteristics of a walkable city, and the four criteria used by 8 80 Cities to guide the establishment of cycling infrastructure. He cited studies which showed that if adequate active transportation infrastructure was provided, people would cycle and walk more. In general he reminded participants that mobility should not be the exclusive right of those who can own and drive a car, but should be afforded to all Canadians, including children, seniors and the 20% of households that do not own a vehicle.

Transforming public transit

Dr. Josipa Petrunic
Executive Director and Chief Executive Officer, Canadian Urban Transit Research and Innovation Consortium (CUTRIC)

Dr. Petrunic provided an overview of CUTRIC’s electric bus demonstration project, which aims to get 25 e-buses onto Ontario’s roads over the next two years. She stated that bus manufacturers and transit systems have very limited budgets with which to innovate, and therefore most e-bus trials are small-scale. This small scale makes the cost of producing alternative propulsion buses inordinately high. CUTRIC’s demonstration project seeks to examine the extent to which transit systems in Ontario would benefit from GHG reductions, cost reductions, and service improvements due to electrification, and what technical challenges (i.e., vehicle-to-grid communications, energy storage and delivery platforms, LDC roles and responsibilities) need to be overcome to achieve the mass electrification of buses. She stated that high up-front costs are a key challenge for the electrification of mass transit and that new fleet procurement business models may be needed to address the problem.

Optimizing infrastructure for electric vehicles

Dr. Matthew Stevens
Chief Executive Officer, FleetCarma

Dr. Stevens discussed the current state and the future outlook for the EV sector in Canada and Ontario. He identified the lack of a widespread DC fast charging network as a key barrier to EVs in the province. He noted that rapidly falling battery costs could be a game-changing factor for the EV market. Dr. Stevens identified steps that could facilitate increased EV adoption in Canada, such as simplified fuel economy labels and a de-coupling of EVs and environmental benefits in ad campaigns. He stressed that if EVs are ever accepted by the masses, it will due to their cost and performance advantages over conventional vehicles. Dr. Stevens concluded with an overview of FleetCarma’s ChargeTO project, which aims to explore and articulate the benefits to be derived from giving LDCs a measure of control over the timing and rate of EV charging in a given neighbourhood, based on real-time data.

Discussion Highlights from Session A (Afternoon)

During this session, workshop participants discussed the role of federal and provincial governments in driving the decarbonization of transportation, specifically with respect to the deployment of EVs. The role of utilities in the sale/lease and management of home EV charging stations was another topic addressed during this session.
2.4 Breakout Session B (Morning): Summary of Presentations

Fuel-saving heavy-duty vehicle technology

Mr. Anthony Greszler
*Engine and Vehicle Engineering and Emissions Control Consulting*

Mr. Greszler discussed some challenges and opportunities related to decarbonization within the on-road commercial transportation sector, which is expected to become the largest energy-consuming segment of the transportation sector globally by 2040. He highlighted emerging technologies and approaches for reducing GHG emissions from heavy-duty trucking, with a focus on improving fuel efficiency, reducing vehicle kilometres traveled, and utilizing low-carbon fuels. He stressed that trucks and trailers should be approached as single integrated systems, as they were in the U.S. DOE’s SuperTruck program. He discussed the health and social benefits of reducing GHGs from freight transport, as well as the economic growth potential for the sector. He identified key barriers to the improvement of on-road freight efficiency and proposed a suite of possible solutions.

Decarbonizing railway operations and prime movers

Mr. Peter Eggleton
*Principal Consultant, Telligence Group*

Mr. Eggleton provided an overview of Canada’s locomotive fleet and emphasized recent improvements in the Canadian railway sector’s fuel economy and emissions levels. Mr. Eggleton discussed railway electrification options and also highlighted the potential benefits of using hydrogen fuel cells (HFCs) in combination with buffer batteries as motive power for railway applications. Mr. Eggleton discussed a number of initiatives that were aimed at demonstrating the viability of HFCs for railway applications, with a focus on commuter trains and industrial switchers.

Discussion Highlights from Session B (Morning)

During this session, participants discussed the use of auxiliary power units (APUs) in heavy-duty trucks, U.S. tailpipe emissions testing and the effectiveness of the U.S. EPA’s SmartWay program in reducing GHG emissions from the on-road freight transport sector. In addition, they discussed the effectiveness of road pricing in terms of improving on-road freight efficiency and addressed the potential for lightweighting vehicles in the commercial sector. The costs, range and performance of HFC locomotives relative to other options was another topic of discussion. Participants also discussed the viability of natural gas as a stop-gap technology in the rail industry and explored how major reductions in GHGs could be achieved by implementing visions of electrified freight transportation systems.

2.5 Breakout Session B (Afternoon): Summary of Presentations
Renewably-sourced fuels

Ms. Carolyn Tester
Senior Regulatory Affairs and Planning Advisor, Imperial Oil

Ms. Tester opened by stating that there are multiple approaches to reducing emissions in the transportation sector and put forth four policy principles as a framework for determining which solutions are best for society. She provided an overview of the biofuels sector, noting that while first-generation biofuels are widely available today, there are major concerns around their impacts on food prices, water usage and land use. In regard to advanced biofuels, she highlighted the need for significant technological advances to enable their production at a commercial scale. Ms. Tester discussed the need for life cycle analysis (LCA) in assessing the net GHG emissions of biofuels, and highlighted the importance of including indirect land use change (iLUC) in Canadian LCAs.

Autonomous vehicle technology

Mr. Karl Simon
Director, Transportation and Climate Division, U.S. Environmental Protection Agency

Mr. Simon observed that the connected and autonomous vehicle (CAV) sector is innovating rapidly, and discussed the key factors driving CAV technology development, highlighting some of the barriers to bringing CAVs to market. Mr. Simon provided an overview of the different levels of automation. He discussed five clusters of potential benefits from CAVs from an environmental perspective and the potential for CAVs to reduce transportation-related emissions. He highlighted that automation can affect the travel and energy demands and the resulting GHG emissions of vehicles in many possible ways, both positive and negative. Mr. Simon stated that CAV technology is transferable to other transportation sectors, including commercial trucks and off-road vehicles, but that it is developing faster than the regulatory frameworks that govern transportation.

Natural gas and natural gas infrastructure in transportation

Mr. Wayne Passmore
Economic Development Manager, Union Gas

Mr. Passmore discussed the potential role of natural gas in decarbonizing transportation in Ontario, particularly within the heavy-duty vehicle sector. He shared the results of an aspirational forecast demonstrating the substantial GHG reductions and cost savings that could be achieved by displacing fuels for medium- and heavy-duty vehicles with natural gas. Mr. Passmore stated that economies of scale are critical to the deployment of natural gas vehicles, but also pose a major challenge. He highlighted that renewable natural gas (RNG) represents a major opportunity to help decarbonize the entire natural gas system. He identified a number of barriers to the widespread introduction of compressed natural gas (CNG) and RNG in the transportation sector, but also proposed solutions.

Discussion Highlights from Session B (Afternoon)
During the discussion session, the need for better regulations to drive continuous improvements in the efficiencies and environmental performance of biofuels and internal combustion engines was highlighted. Participants explored what a CAV future might look like for the commercial transport sector, including the improved use of intermodal transport and making better use of off-peak hours. They also explored some opportunities for Ontario in terms of storage and pressurization systems for CNG. Participants also discussed reporting methodologies for GHG emissions from transportation in Canada, with a focus on reporting styles that could include LCA. Lastly, participants discussed some of the benefits and drawbacks of low-carbon fuel standards (LCFSs).

2.6 Closing Plenary: Summary

During this plenary session, speakers and participants convened to discuss the key learnings, themes and questions emerging from the expert presentations. They discussed the role of carbon pricing in driving the most sustainable and cost-effective solutions to the decarbonization challenge. Other potential policy options, such as feebates and LCFSs, were also considered. The experiences of the City of Hamilton during its implementation of a CNG bus fleet were shared. In addition, participants addressed the question of whether Ontario’s decarbonization strategy should be viewed first and foremost as an economic development strategy or an environmental strategy. Participants highlighted the need for a ‘silver buckshot’ (rather than ‘silver bullet’) approach to solutions and the importance of using the right fuel in the right application. Also addressed was the question of when to let a technology fail in the process of innovation. The discussion concluded with a commentary on the Government of Ontario’s approach to the challenge of decarbonization.
3.0 Assessment of Workshop Results

A wealth of information and ideas was obtained on how to decarbonize Ontario’s transportation sector. This section presents the main points that emerged in relation to the five key considerations set out for the workshop. No attempt was made to achieve consensus among the participants on preferred low-carbon transportation pathways. The results do not cover all modes of transportation; however, they encompass many of the major sources of GHG emissions in Ontario and identify opportunities to make progress on reducing these emissions. The intent of this section is to give the reader an overview of some of the important developments that are taking place in transportation, their actual and potential contributions to reducing GHG emissions (while continuing to provide economic and social benefits), and an appreciation of the barriers to implementation that they face.

3.1 GHG Emissions Reduction Potential

This section focuses on the GHG emissions reduction potential of various transportation modes, technologies, and fuels. The context for this section is as follows:

Ontario has set targets to cut GHG emissions 15% by 2020, 37% by 2030, and 80% by 2050, below 1990 levels. These targets are expected to be enshrined in legislation in the near future.

**Transportation GHG emissions**

Petroleum fuels power about 95% of Canada’s transportation today. On a national basis, the entire transportation sector accounts for about 28% of total GHG emissions. Transportation emissions in Canada have grown by 40% since 1990. If an 80% reduction in national road transportation emissions by 2050 (below 1990 levels) had to occur, it would require an 86% decrease from the 2013 level.

Ontario faces an even bigger challenge. Transportation is the largest source of emissions in the province, accounting for 60 Mt (about 35%) of total GHG emissions in 2013.

**Light-duty vehicles**

For personal transport and light-duty vehicles, population growth has been the key driver of GHG emissions. Consumer behaviour and preference has been a major factor in light-duty vehicle emissions trends.

Although energy efficiency improvements have to date been the primary strategy for reducing GHG emissions from transportation, they will not be sufficient to reach emissions reduction goals in the order of 80% below 1990 levels by 2050. Yet despite the urgency of implementing low-carbon technologies, they are not yet mature enough to achieve a cost-effective, self-sustaining transition of sufficient magnitude to support the reduction target.
Heavy-duty vehicles

For heavy-duty trucking, the fastest growing component of transportation emissions, commercial transportation fuel demand has been rising steadily with economic growth. It is projected to become the largest emitting segment of transportation globally by 2040. U.S. projections for fuel use for heavy-duty trucks through 2050 indicate that the bulk of fuel will be consumed in class 7-8 vehicles, and 80% of this use will be from long-haul vehicles. Until recently, approaches to reducing GHG emissions focused primarily on improving the energy efficiency of the front (tractor) half of the combination truck, while attention to other areas for improvement has been limited. It was argued that policies to reduce emissions from freight movement should focus on three factors: improving fuel efficiency, reducing vehicle-kilometres travelled, and developing and implementing new low-carbon fuels for heavy-duty vehicles.

Enabling longer combination trucks (those pulling multiple trailers) is another opportunity for improvement as more cargo capacity makes trucks more efficient in terms of tonne-kilometres per litre of freight delivered. Longer combination trucks present a major potential for efficiency gains, with studies suggesting fuel savings in the range of 17 to 28% could be achieved. Mr. Greszler noted that Sweden and Finland permit 25.25 metre truck rigs, which use 20% less fuel per tonne-kilometre than the 18.75 metre rigs used in other European nations.

There are also opportunities for using connected and autonomous vehicles in the commercial sector to achieve further GHG emissions reductions.

To achieve significant GHG emissions reductions in the heavy-duty vehicle sector, a long term vision and planning process is needed that considers a host of integrated factors, including autonomous operation, loading speed, warehouse distribution, and cargo optimization.

Railway transport

Railway operations in Canada consumed around 2 billion litres of diesel fuel in 2013, with freight transport accounting for 95% of that total. Annual GHG emissions by locomotives in operation in Canada amounted to 6 million tonnes. Between 1990 and 2013, the GHG emissions intensity (kg of CO₂e/1,000 revenue tonne-km) for total freight operations decreased by 39.5%. Modern freight trains with the latest fuel efficient locomotives can haul one tonne of freight 200 km on one litre of fuel. It was claimed that trains are five times more fuel efficient than trucks, and that moving more freight by rail instead of trucks could potentially lower GHG emissions by 75%.

Biofuels

GHG reduction opportunities include the use of biofuels, but difficulties have been encountered with first-generation biofuels produced from food crops, including adverse impacts on food prices, water usage, and land use. Production levels have fallen short of targets in the U.S. Next-generation biofuels produced from non-food feedstocks such as waste, algae, and woody plants captured the majority of global investment in biofuels for the first time in 2015, suggesting that first-generation biofuels are decreasingly viewed as a long-term solution to global GHG emissions. However, commercial-scale production of next-generation biofuels has, to date, been limited due to technical hurdles, high costs,
and other challenges. Ontario’s cap and trade program considers both first and next-generation biofuels as carbon neutral, which means that the technologies will compete directly against each other. As next-generation biofuels stem from newer technologies, this poses a challenge to them.

Low-carbon fuel standards (LCFSs) have been recognized as an important driver of GHG emissions reductions in the province of British Columbia; however, a counterpoint was made during the workshop that LCFSs impose additional costs on consumers, are administratively difficult to manage, and are ineffective at driving additional reductions in GHG emissions. The claim was made that LCFSs prevent lowest-cost solutions from coming forward in a timely manner. It was asserted that Ontario’s cap and trade program will set emissions certainty and will allow reaching GHG emissions reduction targets with the use of lowest-cost technologies.

**Natural gas**

There are opportunities to achieve GHG emissions reductions by increasing the use of natural gas vehicles in Ontario. Worldwide, more than 16 million natural gas vehicles are on the road today, and their use is growing at a compound annual rate of 20%. An aspirational forecast looked at what could be achieved in Ontario by displacing diesel and gasoline fuels in the medium- and heavy-duty transportation sector with natural gas. The study investigated the potential GHG savings resulting from natural gas taking over 90% of Ontario’s on-road diesel market and 10% of the on-road gasoline market, as well as being used in the rail and marine sectors. Potential savings amounted to 6.7 billion litres of diesel-equivalent, getting up to a 2.7 Mt CO₂e reduction (using a 17% well-to-wheels GHG emissions reduction potential) and saving $3 billion per year by 2035.

Renewable natural gas (RNG), such as methane from landfills, represents an important opportunity to help decarbonize not only transportation, but the entire natural gas system. One study identified the potential for Ontario to generate RNG at an energy value of 52 PJ per year in the near term, which represents 5% of Ontario’s natural gas consumption today. In the longer term, as gasification capabilities and infrastructure become available, there could be an opportunity for additional RNG production amounting to 115 PJ of energy value per year. Ultimately, RNG could displace 16% of conventional natural gas consumed in the province, providing significant GHG emissions reduction benefits. A reduction of up to 8 Mt CO₂e/year could be achieved in Ontario’s medium- and heavy-duty transportation sector by 2035 in a scenario with 50% RNG blending.

**Autonomous vehicles**

Studies have suggested that autonomous vehicles/automation could influence travel and energy demand and resulting GHG emissions in many ways, both positive and negative. GHG savings could be achieved as a result of potential benefits of autonomous vehicles, such as platooning, improved safety, more feasible eco-driving, smaller cars, and different mobility services. But the risks include the potential for self-driving cars to increase emissions due to the ease of travelling and the opportunity to integrate more features into autonomous vehicles, which could increase total travel time. In addition, the fuel type of autonomous vehicles is an important factor affecting emissions as autonomous vehicles could be powered by internal combustion engines.
There is great uncertainty about the future of autonomous vehicles as they could catalyze fundamental changes in society’s approach to transportation. People might drive more, but the efficiency of travel could improve. Also, autonomous vehicles could facilitate the use of electrified transportation, which could result in lower-emissions travel if they are used in conjunction with low-carbon mass-transit systems. However, they could also lead to increased net energy use if they provide an incentive for people to live further away from where they work, allowing them to sleep or do work while they travel. It has been estimated that the impact of autonomous vehicles on net energy usage could be +200% or -90%.

### 3.2 Health and Social Benefits

It was argued that options considered for reducing GHG emissions from transportation should also offer a net positive array of societal benefits. However, the point was also made that governments must accept that no net social benefits associated with the implementation of policies that are favourable to low-carbon transportation technologies may be realized for 10 to 15 years or more after the introduction of such policies. But when the net benefits of low-carbon, energy efficient vehicles are estimated in the 2050 timeframe, they end up having a net worth which is an order of magnitude greater than the costs associated with the transition.

**Maximizing benefits**

There are multiple solutions to reducing emissions in the transportation sector. The question is how to determine which ones are best for society. In this regard, four policy principles were proposed as a framework for decision making: First, solutions should be market-driven, they should meet consumer needs and be compatible with transportation fuel infrastructure. Second, solutions should be based on sound science, which necessitates a full life-cycle analysis of different fuel options, looking at vehicles and fuel as a system and considering wider environmental implications in terms of GHG emissions as well as land use, air quality, water, soil, and waste impacts. Third, solutions should be evaluated in terms of both their costs and benefits to society, and options with net benefits should be selected. The options should be judged on a dollar/tonne basis, and solutions with the lowest cost should be utilized first in order to maximize benefits. Lastly, an appropriate, clear, and consistently enforced regulatory framework should be developed to promote the adoption of desirable solutions in the sector.

**Designing healthy cities**

The design of cities and streets was promoted as an area in which multiple benefits to society can be achieved. Design for cars has led to some negative impacts, such as higher obesity rates and increased traffic congestion. Moreover, the mobility of certain demographics, such as children, seniors, and the 20% of Canadian households which do not own a car, has been limited. Jurisdictions in which active
Transportation is embedded in the daily routines of citizens have been shown to have far lower obesity rates than jurisdictions that discourage the use of walking and cycling. In Ontario, the average citizen makes more than 2,000 trips under 3 kilometres in length each year. Surveys have shown that if adequate active transportation infrastructure was provided, people would make many more trips by walking or biking. In Toronto, surveys have indicated that 70% of people would cycle more if dedicated biking infrastructure was more widespread. Only 12% of all trips in Canada are made using active transit, as opposed to levels upwards of 50% in parts of Europe.

Two of the factors driving the interest in connected and autonomous vehicles include reducing road fatalities and congestion, especially in growing urban areas. In the U.S., an estimated 33,000 people were killed in car accidents in 2015 alone. In addition, autonomous vehicles could offer attractive economic benefits to consumers via car sharing programs, given that cars are parked 96% of the time yet an average new car price in the U.S. amounts to $33,340 and annual ownership costs are estimated at $9,000. Potential environmental and social benefits include greater vehicle efficiency, enhanced vehicle-to-grid and vehicle-to-vehicle connectivity, cleaner fuels (e.g., electricity), a built environment with fewer parking demands, and shared mobility.

Freight and goods could be more efficiently moved in and out of the cities at off-peak times; for example, by moving freight on dedicated lines and lanes overnight. This would reduce both GHG emissions and daytime traffic congestion.

### 3.3 Economic Growth Potential

A point of discussion at the workshop was whether Ontario’s Climate Change Strategy should be viewed first and foremost as an economic development strategy or as a decarbonization strategy. The general view was that it is a matter of both decarbonizing and improving the economy at the same time, not one or the other. It was noted, for example, that costs are paramount to fleet operators, and without a viable business case, new technologies will fail. By using the right fuel in the right application, both the economy and the environment can be improved. Hence, Ontario should ensure that it shapes a decarbonized transportation system that reduces GHG (and other) emissions while delivering economic benefits such as industrial growth, high quality jobs, and new intellectual property.

**Growing the cleantech industry**

Ontario’s cleantech industry has great access to talent and research and development funding, but the domestic market for many emerging technologies is small. Companies that succeed in their local markets have an early-mover advantage and can export their experience and expertise elsewhere. Jurisdictions such as the U.S. and Germany benefit from strong demand in domestic markets, driven by regulations, technology deployment policies and mandates, and/or higher energy prices. Changes are currently underway in Ontario to make it easier for local cleantech companies to sell technology into the
market. Setting up a technology hub in Ontario would further increase opportunities for the industry to grow sales, drive innovation, and create jobs.

Pricing carbon

Pricing carbon can be a way to incent technological innovation and related economic growth. Based on a forecast for the initial price of carbon under Ontario’s cap and trade program, which is roughly $15-$17/tonne, the pump price of a litre of gasoline would increase by 4.3 cents, and by 4.7 cents per litre for diesel. This increase is small compared to the large decreases that have occurred recently as a result of lower global prices for oil. Ontario gasoline pump prices in January 2016 were, on average, 34.4 cents per litre lower than in a comparable time period in 2014. This means that the price increase of 4.3 cents resulting from cap and trade will be more than offset by historically low prices, raising the question of how much impact the price signal is going to have.

Since the financial crisis of 2008/9, there has been a decrease in fuel consumption; however, with a stronger U.S. economy and a significant decrease in the price of gasoline, the demand for gasoline has gone up significantly over the past year or so.

A study commissioned by the Canadian Fuels Association and conducted by the Conference Board of Canada examined Canada’s road transport sector in the context of an 80% GHG emissions reduction by 2050. The study examined a number of options for GHG emissions abatement from economic and cost perspectives. It found that, at a minimum, the abatement costs of various GHG reduction opportunities started at $100 per tonne of carbon and went to as high as $600-1,000 per tonne.

Fostering economic growth

Ontario’s economic and societal structure currently relies on advanced and energy-intensive transportation systems, powered almost exclusively by the combustion of liquid fossil fuels, such as gasoline, diesel, and kerosene. These are convenient, rich forms of dense, portable energy – and it takes a lot of energy to move massive objects like vehicles. There is a need to balance the choices among a broad scope of possible transportation pathways and to focus on options that not only deliver deep reductions in GHG emissions, but also build Ontario’s capacity for valued exports, economic growth, and job creation, and that achieve other social objectives. To be able to do this well, policy-makers need to improve their institutional capacity to conduct balanced, science-based technology assessments. If such assessments are designed to be cross-disciplinary, participatory, ongoing, and grounded in scientific evidence, they can contribute to the creation of shared expectations, effective coordination among key stakeholders, and the design of adaptive policies.

3.4 Technological Feasibility

Technological feasibility encompasses many factors, but three key ones are technological readiness, cost, and consumer acceptance.
Light-duty vehicles (petroleum-powered)

Over the past four years, the biggest, and most unanticipated, breakthrough in vehicle components has been computers – computer design, computer simulations, and on-board computer controls – which are revolutionizing every aspect of light-duty vehicles. Technologies like gasoline direct injection (GDI), turbo-charging, hybridization, and continuously variable transmissions (CVTs) have defied projections for 2025 made only several years ago, achieving projected performance and cost levels by 2015 in most cases, due to innovations on the part of automakers. The single biggest advancement over the last several years has been in the field of vehicle lightweighting. In 2011, the U.S. EPA projected that by 2025 there would be an average reduction in vehicle weight of 7%, but almost all production vehicles from the 2016 model year have already achieved 5 to 7% weight reductions.

Certain types of recently developed turbo-charged engines are already becoming obsolete, and automakers are now working on dedicated exhaust gas recirculation (EGR) engines in which all of the exhaust from each cylinder is circulated back into the air intake. But even dedicated EGR engines are expected to become obsolete before entering into production. By 2050, internal combustion engines without hybridization should be able to achieve fuel economies of 3.1 L/100 km (75 mpg), while hybrid engines should achieve 2.5 to 2.0 L/100 km (95 to 120 mpg). This would amount to fuel economy improvements greater than 100% based on today’s averages. Emerging alternative vehicle technologies will have to compete with the reduced GHG footprint of increasingly fuel efficient gasoline-powered vehicles.

Electric vehicles

It takes time for new technologies to penetrate the market. There were only 15,000 plug-in electric vehicles (EVs) registered in Canada as of mid-2015, out of 23 million worldwide. At an annual rate of increase of 10% of fleet sales out to 2050, Canada’s installed EV base would still only be 7%, indicating how slowly EV technology might penetrate the market. The average age of a vehicle on the road in Canada today is approaching 10 years. Hence, vehicle turnover rates and the speed with which technology penetrates the consumer market are key parts of the decarbonization challenge.

Regarding the current state of all types of EVs in Canada, there were 18,500 of them on road as of the end of 2015, spanning 23 available models. More than 10,000 were battery electric vehicles, as opposed to hybrids. Quebec is the leading province in terms of EV adoption, followed by Ontario and British Columbia. The EV fraction of Canada’s total light-duty vehicle fleet was roughly 0.09% in 2015, while this number stood at 0.17% for Quebec and 0.08% for Ontario. The three top selling EVs in the country made up roughly 75% of all EVs sold. In terms of new vehicle sales, EVs made up 0.3% of the light-duty vehicle market in Canada in 2015, or 0.7%, excluding light trucks, minivans, and SUVs from those numbers. In order to achieve consumer acceptance, EVs need reduced battery costs, extended vehicle range, reduced recharging time, expanded recharging infrastructure, and upstream low-carbon energy production.
Two basic steps could be taken to help increase consumer acceptance of electric vehicles. The first would be to amend vehicle fuel economy labels, which are overly complex as a single format for labelling must be applied to vehicles of all types, resulting in a cluster of numbers and metrics that is difficult for consumers to make sense of. The second step would be to de-couple EVs with climate change in public ad campaigns. EVs should stand on their own technical and performance merits, rather than their indirect corollary benefits, as purchasing decisions are most often made on the basis of performance, costs and risks, rather than other considerations. The GHG emissions reduction argument will not significantly increase EV sales. It will come down to the ability of EVs to outperform other vehicles in terms of performance and price.

**Hydrogen fuel cell vehicles**

The probability of society successfully implementing a low-carbon transportation option for light-duty vehicles has been claimed to increase by 50% when investments are made in both hydrogen fuel cell and electric vehicles. To date, technological improvements in both types of vehicles are impressive, with fuel cell cars becoming viable for personal transportation over the past two decades, and lithium-ion battery costs falling by roughly 14% per year. Modern hydrogen fuel cell vehicles are expected to operate well for as far as 240,000 km. They can start in temperatures as low as -37 °C, can re-fuel in three minutes, and have ranges in excess of 480 km. Hydrogen fuel cell vehicle costs have been decreasing at rates comparable to electric vehicles in recent years. Hydrogen storage tanks, however, are a big expense, with 5 kg tanks costing roughly $2,500 each at high-volume production levels. While access to electricity is widespread, hydrogen gas refueling stations are almost non-existent, suffering from high capital costs and low utilization rates. As a result, hydrogen gas in California, for example, currently sells for about $13/kg, with station dispensing costs alone being between $6.5 - 8 per kg. With high utilization rates, it has been estimated that dispensing costs could drop to as low as 25 cents per kg. In order to become viable for mainstream use, hydrogen fuel cell vehicles need reduced fuel cell system and hydrogen storage costs, reduced costs of dispensing hydrogen, the deployment of an adequate refueling infrastructure, and upstream sources of low-carbon energy production. It has been estimated that by 2050, the costs of producing and operating hydrogen fuel cell and electric vehicles will be less than those of internal combustion engine vehicles. In the interim, it was stated that subsidies for low-carbon fuels and technologies will need to be provided for at least 10 to 20 years to have any hope of achieving transportation-related GHG emissions reductions of 80% by 2050.

**Freight trucks**

Many technology areas exist for improving the efficiency of heavy-duty trucks. Engine efficiency can be improved by utilizing technologies that enable waste heat recovery, enhancements in NOx after-treatment, engine friction reduction, and more efficient diesel combustion. However, there is a theoretical upper limit to efficiency for diesel engines – likely to be in the 55% range. As this limit is approached, the costs of improvements increase dramatically. For trucks, efficiency gains can be achieved by the application of smart transmissions, powertrain...
integration, cooling optimization, smart navigation, and idle reduction devices. Fleet operation was also highlighted as an area for improving efficiency; for example, by ensuring that trucks do not travel with low freight density, by training drivers on operating practices that reduce fuel consumption, and by expanded use of intermodal freight transport. It was stressed that these technologies and approaches can only contribute fully to the extent that they are integrated into the complete vehicle system in real-world applications.

**Railways**

Between 1990 and 2013, the GHG emissions intensity (kg of CO$_2$e/1,000 revenue tonne-km) for total freight operations decreased by 39.5%. Modern freight trains with the latest fuel efficient locomotives can haul one tonne of freight 200 km on one litre of fuel. It was claimed that trains are five times more fuel efficient than trucks, and that moving more freight by rail instead of trucks could potentially lower GHG emissions by 75%. Railway electrification options were explored, noting that conventional overhead catenary technology connected to the grid continues to be the most viable application in Canada. However, novel disruptive technologies, such as inductive power transfer and hydrogen fuel cells, are attracting increasing attention in the railway sector.

### 3.5 Barriers to Progress

Achieving Ontario’s GHG emissions reduction targets will be a huge challenge, given the barriers that must be surmounted. Many promising technologies and emissions reduction approaches exist, and some of them are ready for implementation, or at least for large-scale demonstration. But many more will require significant scientific and technological advancements in a short period of time.

This section identifies some of the major barriers to progress on achieving deep reductions in GHG emissions.

**Uncertainty and risk aversion**

There is a great deal of uncertainty in regard to calculating fuel costs over the lifetime of a new vehicle. Due to this uncertainty, the average consumer will only calculate fuel costs two or three years into the future when considering the purchase of a new vehicle. While fuel producers are the ones who ultimately pay for reduced fuel consumption, society as a whole reaps benefits financially, as consumer savings on fuel tend to be spent elsewhere in the economy.

**Feedstock limitations**

If advanced low-carbon biofuels become available at reasonable costs, quantities will be limited and will most likely be used for transportation applications like aviation and heavy-duty road vehicles.

**Research and development gaps**
Most electric bus trials are limited in scope, as they generally only test one to three buses in a given service area. The recent push on the part of governments to reduce emissions from transportation has created a situation in which bus manufacturers, which primarily build diesel-powered buses, are coming under increasing pressure to innovate, yet they have very limited budgets with which to do so. The small scale of current demonstration projects means that the costs of producing buses using alternative propulsion technologies become inordinately high. Very few transit systems in Canada have any research and development budgets at all.

**Costs and financial capital availability**

A key problem associated with the electrification of mass transit is the higher up-front costs that transit authorities will have to pay when making a bulk purchase of e-buses. While a typical diesel bus costs roughly $600,000, a typical e-bus and its charging equipment costs upwards of $2 million. These high costs may necessitate a new business model for transit operators and bus manufacturers. Rather than buying buses outright, transit operators could pay bus manufacturers a monthly or annual subscription fee for the provision of e-buses, and another fee for the vehicle-to-grid communications service provider.

Another barrier is the lack of economic (or financial) incentives for the improvement of road freight efficiency. Businesses require a return on investment to put money into highly complex and expensive fuel efficiency technology and practices, so there is a need to make a compelling economic case for efficiency, or to force technologies and practices into place through regulation.

With respect to first-generation biofuels, concerns exist about their impacts on food prices, water usage, and land use. About 40% of corn grown in the U.S. is used to produce ethanol. The United Nations has projected a 70% increase in the demand for food by 2050, and the continued use of corn for ethanol may put additional pressure on food prices.

A number of cost barriers have been identified to introducing CNG and RNG into the transportation sector. A compressed natural gas/liquefied natural gas (CNG/LNG) vehicle price premium, which amounts to roughly $65,000 for Class A vehicles, as well as the lack of refueling station infrastructure, are major issues. It was noted that there may be opportunities in Ontario to use the proceeds from cap and trade to overcome these barriers by supporting 50% of vehicle price premiums and installing public refueling stations.

**Regulatory barriers**

Existing regulations can hinder efficiency. For example, the fact that the 6x2 axle configuration with load transfer is prohibited for heavy-duty vehicles in Canada means that drivers cannot switch to a single drive axle at times when this would be sufficient, leading to the loss of roughly 3% in fuel efficiency.

**Infrastructure gaps**
The reason Ontario is trailing Quebec and British Columbia in terms of percentage of EVs on the road is the province’s lack of a widespread DC fast charging network — a critical enabler of widespread EV adoption as it would facilitate more convenient long distance EV travel.

Other potential low-carbon infrastructure needs include: rail electrification, bus electrification, hydrogen fueling stations, natural gas fueling stations, RNG production facilities, utility-managed home EV chargers, dedicated bike lanes, and pedestrian-friendly corridors.

The lack of supporting infrastructure for alternative fuels is another barrier. Moreover, intelligent communications systems are needed to enable communication between vehicles, as well as between highways and vehicles.

Environmental impacts

There are many alternative biofuels for heavy-duty vehicles, including biodiesel, synthetic diesel, methanol/ethanol, biogas, and dimethyl ether (DME). While some of these options have significant GHG emissions reduction potential, there are many issues surrounding their use and widespread production, including impacts on water, soil and land use, high costs, limited feedstocks, and impacts on food supply. For example, it has been estimated that the production of corn ethanol requires 200-400 times more water than is required to produce petroleum fuels. Fertilizer runoff and soil erosion in the corn belt are land use concerns that have emerged in the U.S. Advanced biofuels, which are now becoming commercially available, may help to address these challenges.

Diesel, which is increasingly being produced from biomass resources, will likely remain the dominant fuel for heavy-duty vehicles, with renewable DME being an attractive candidate as a longer term future fuel.

Lack of large-scale demonstration projects

Visions of completely electrified transportation systems are being tested in some countries. For example, electrified conductors could be built into major highways that would provide power on an ongoing basis to electric heavy-duty vehicles, and these vehicles could draw power from on-board batteries for relatively short periods of off-highway use. In Sweden, researchers are already testing the feasibility of such systems. Four German states have signed a Letter of Intent to purchase 40 fuel cell-powered regional commuter trains. Canada should consider comparable and appropriate large-scale studies and demonstration projects.

Need for comprehensive policy approaches

Significant potential improvements in heavy-duty vehicle efficiency are possible, but the freight transportation market is complex and has multiple players, requiring a coordinated approach. A comprehensive freight transportation vision and policy framework is needed that provides clear
direction and coordination among stakeholders to ensure that more effective efficiency improvements occur in the sector.

The development of certain new technologies, such as autonomous vehicles, is occurring faster than the regulatory development required to get these technologies to market. New policy frameworks may be needed to incent and guide these technologies in support of GHG emissions reduction targets and timelines.
4.0 Conclusion: Opportunities for Decarbonization

Among the information and ideas presented and discussed at the workshop, a number of opportunities were identified for the reduction of transportation-related GHG emissions in Ontario. In this concluding section, Pollution Probe puts forward an aggregation of issues and topics that were identified as having the potential to significantly impact transportation-related GHG emissions, and identifies broad areas of opportunity as frameworks within which specific opportunities could be pursued. A number of specific technological opportunities are identified that have significant potential to reduce the largest sources of transportation-related GHG emissions.

The Pathways Initiative workshop provided stakeholders with a high-level look at the latest research and development efforts that are underway in different transportation sectors in the pursuit of decarbonization. With regard to GHG emissions reduction potential, it was made clear that while the challenge of achieving an 80% net reduction from 1990 levels by 2050 is daunting, a suite of emerging technology and fuel options are increasingly showing promise, and their adoption will complement ongoing efforts related to increasing the efficiency of internal combustion engines. Within the domain of health and social benefits, it was stated that while low-carbon transportation policies adopted in the near term are unlikely to yield any appreciable health and social benefits in the first 10 to 15 years after adoption, such policies will foster significantly greater savings in the long term than they will cost to implement in the near term.

With this in mind, broad opportunity areas for decarbonization that were identified during the workshop included:

- The development of densified, mixed-use cities and communities that are amenable to active transportation. This would represent a shift away from planning communities around cars, towards a planning philosophy that promotes healthy lifestyles and efficient and accessible transportation options for all citizens. Wherever possible, citizens must at least be given the option to choose low-carbon modes of transportation that are safe, reliable and efficient.
- Developing more closely integrated multi-modal freight movement supply chains that prioritize and maximize the use of modes of transport that have the smallest carbon footprints.
- Implementing large-scale demonstration projects for low-carbon technologies, especially for freight movement and public transit.
- Developing new financing mechanisms, regulations and institutions that reduce innovation risk and address barriers to the deployment of low-carbon technologies.
- Creating comprehensive and effective approaches to public and stakeholder engagement on societal transformation.
- Offering near term support to multiple platforms for personal transportation that have the potential to be game-changers for the sector. This will allow market forces and consumer behaviour to dictate which low-carbon forms of transportation are the most feasible in the long run.

Technology pathways that were suggested to have substantial potential to reduce GHG emissions from transportation included:

- Aggressive efficiency enhancements in conventional light- and heavy-duty vehicles – in terms of both how vehicles are designed and how they are used. These could include improved
powertrain efficiency, vehicle lightweighting, enhanced aerodynamics, route and cargo optimization, operator training programs and low-carbon fuel usage.

- The deployment of electric vehicles and the development of hydrogen fuel cell vehicles.
- The use of autonomous vehicles for both human and freight movement. Research is needed to better quantify the likely costs and benefits of CAV technologies and to explore policy approaches that could shape the direction of CAV development and deployment to ensure that they offer net environmental benefits in addition to social benefits.
- The development and use of low-carbon advanced biofuels (based on life cycle analysis).
- The development and use of renewable natural gas.
- Emissions reduction opportunities in the rail sector including improvements to operational efficiencies and the adoption of low-carbon technologies such as electrification.

The broad opportunity areas and specific technology applications should work together as integrated systems to ensure that maximum environmental, economic, and social benefits are obtained.

General considerations that should inform the development of strategic frameworks and guide government policies and expenditures in support of low-carbon transportation include:

**Infrastructure (new and renewed)**

Infrastructure investments for roads, rail, energy, telecommunications, urban development, and public transit tend to be long term, in some cases spanning many decades. As new transportation-related infrastructure is built and aging infrastructure is renewed, it should support the GHG emissions reduction targets set by Ontario and help address the ‘chicken and egg’ problem associated with many emerging low-carbon technologies. Wherever possible, long-lived public infrastructure should be versatile, amenable to serving a variety of functions, and adaptable to accommodate the deployment of future technological innovations at minimal costs.

**Technology**

Technology innovation and deployment should support and leverage existing infrastructure to whatever extent possible while catalyzing a shift towards more sustainable infrastructure in the future. Technologies that make the realization of GHG reduction targets unlikely should be phased out over a reasonable timeframe and replaced by newer, more sustainable, technologies. Due to the inherent uncertainties associated with emerging innovative technologies, taking a ‘silver buckshot’ approach to supporting low-carbon technologies will help to mitigate risks, ensure that the best technologies are used in their ideal applications, and allow the market to ultimately pick the winners.

**Financing and Incentives**

Financing mechanisms should be modified and new ones developed that remove barriers to building and deploying new and renewed infrastructure and low-carbon transportation technologies. A portion of revenues from the province’s cap and trade program could be put towards funding low-carbon transportation infrastructure, smart grid technology development and incentives to advance deployment. Industries require incentives to make low-carbon transportation technologies and processes viable business cases within the next decade, and consumers need incentives to accelerate the retirement of older technologies and the deployment of new low-carbon technologies.
Stakeholder Engagement and Transparency

Sound, science-based information should be provided for use by all sectors of society, with concerted efforts made to ensure that the information is unbiased and trusted. Educational materials should be targeted to specific stakeholder groups, including the general public, as consumers require information that is relevant to the decisions they will make. Engagement with key stakeholder groups will be critical to the successful deployment of low-carbon transportation technologies and practices.

The enhanced exchange of data based on real-time energy consumption will facilitate greater efficiencies at both the individual vehicle and system level. Vehicles need to exchange data with each other and with supporting infrastructure providers to maximize the value of system assets and streamline net energy usage.

Leadership

Leaders in all sectors should support the societal transformation that a low-carbon world will entail. Federal-provincial cooperation will be fundamental to sustained leadership. Private sector leadership on low-carbon initiatives must also be cultivated and supported through low-carbon regulatory frameworks based on viable business cases for emerging technologies. Clear and consistently-enforced regulations related to each of the above-mentioned considerations are needed to drive continuous improvement in transportation-related emissions. Such regulations must consider what is achievable from industry and consumer standpoints, setting realistic targets and timelines while maintaining a clear focus on meeting GHG reduction targets in the transportation sector.
5.0 Addendum

Upon the completion of a draft version of this report, workshop participants were given the opportunity to review it for accuracy and to provide the authors with relevant supplementary ideas that were not mentioned at the workshop, but which the reviewers believed warranted inclusion in the final report. A number of comments were received which were factual in nature, and were incorporated into the body of the final report. In addition, the following supplementary comments were contributed by reviewers of the draft report:

“There has been debate over the impacts of first-generation biofuels on food prices, water usage, and land use, but these concerns have been countered by scientific research from the U.S. Department of Energy and others.”

“LCFSs are a market-based mechanism which allow all low-carbon fuel technologies to compete, thereby allowing the lowest-cost solutions to come forward. [It was asserted that Ontario’s cap and trade program will set emissions certainty and will allow reaching GHG emissions reduction targets with the use of lowest-cost technologies.] However, without complementary measures to provide a price signal for the use of different types of alternative fuels based on carbon content, the policy will be less effective at achieving GHG reductions in the transportation sector.”

“Policy uncertainty created by debates over first-generation biofuels has greatly dampened investment in next-generation biofuels and slowed their commercial deployment. Clear policy support for next-generation biofuels is necessary to scale up technologies and reduce costs.”

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1 Oak Ridge National Laboratory. 2012. “Global economic effects of U.S. biofuel policy and the potential contribution from advanced biofuels.”
APPENDIX 1.0: Record of Workshop Proceedings

1.1 Opening Plenary: Presentations

Mr. Alex Wood  
Executive Director, Ontario Ministry of Environment and Climate Change, Climate Change Directorate

Mr. Wood provided a high-level overview of Ontario’s key policy initiatives on climate, their implications for the transportation sector and the province’s actions to reduce transportation emissions. Ontario has set targets to cut greenhouse gas (GHG) emissions by 15% of 1990 levels by 2020, 37% by 2030 and 80% by 2050. In November 2015, the province released its Climate Change Strategy, which sets out the government’s vision for Ontario to 2050, charting a course to secure a healthy, clean and prosperous low-carbon future by transforming the way Ontarians live, move, work and adapt to the environment. The Climate Change Strategy contains a commitment to release a detailed five-year action plan in 2016, focused on specific commitments to help meet the 2020 target as well as initiatives aimed at laying the foundation for medium and long term emission reductions.

Mr. Wood provided an overview of Ontario’s GHG emission trends, noting that transportation was the single-largest source of emissions in the province, accounting for 35% (60 Mt) of the total, in 2013. He observed that while the electricity generation and industry share of emissions has diminished over the last 10 years, emissions in the transportation and building sectors continue to grow. Mr. Wood stated that there is a need to decouple emissions growth from economic growth, and observed that the shrinking share of emissions from industry and electricity generation reflects such a decoupling. The new challenge is understanding the relationship between emissions growth and population growth. Ontario is a growing province and there is a need to consider the population drivers of emissions within the transportation and building sectors.

Ontario’s Climate Change Strategy highlights five areas of transformation, consisting of: a prosperous low-carbon economy with world-leading innovation, science and technology; adaptation and risk awareness; reducing GHG emissions across key sectors, including transportation; a resource efficient, high-productivity society; and government collaboration and leadership. In addition, Ontario’s Climate Change Strategy outlines key areas in which actions are needed to move towards a low-carbon economy, including: innovation, science and technology; government leadership; resource-efficient high-productivity society; reducing emissions in key sectors; and adaptation and risk awareness. The Strategy outlines a series of measures to guide the development of actions. A relevant example is the reduction of emissions from transportation by promoting zero emission and plug-in hybrid vehicles, low-carbon goods movement, renewable fuels, and improved land use planning.

Mr. Wood provided an overview of the Bill 172 – the Climate Change Mitigation & Low-carbon Economy Act, which establishes a long-term framework for climate action and provides a foundation for the cap and trade program. In particular, the Act enshrines into law Ontario’s GHG emission reduction targets and establishes progress reporting and action plan review requirements for the government. The Act provides the legislative authority for a cap and trade program and sets out key criteria for the spending of program proceeds, stating that all initiatives to be funded through the program should support the reduction of GHG emissions. Potential transportation initiatives that could be funded include support for the increasing demand for zero emission and plug-in hybrid vehicles, active transportation infrastructure, and public transit vehicles and infrastructure.
Mr. Wood discussed the implications of Ontario’s climate initiatives for the transportation sector. Based on the forecast for the price of carbon, which will initially be roughly $15 to 17, the pump price of a litre of gasoline would increase by 4.3 cents, and by 4.7 cents per litre of diesel, as a result of cap and trade. He stated that this increase is very small compared to the larger decreases that have recently occurred as a result of lower global prices for oil. Ontario gasoline prices in January 2016 were, on average, 34.4 cents per litre lower than in the same period of 2014. This means that the price increase of 4.3 cents resulting from the cap and trade will be more than offset by historically low prices, raising the question of how much impact that price signal is going to have.

Mr. Wood stated that a wide range of incentives are available for Ontario households to help reduce their energy consumption and manage costs. For example, the $325 million Green Investment Fund supports energy retrofits in homes and energy efficiency investments in small and medium-sized enterprises, as well as providing support to Aboriginal communities. Specific to the transportation sector, the Fund committed $20 million in new investments for electric vehicle (EV) infrastructure. According to Mr. Wood, demand for this funding has outstripped the supply and the province is currently looking at options to address this issue.

Mr. Wood discussed opportunities for reducing emissions from Ontario’s transportation sector, emphasizing that the sector accounted for 35% of Ontario’s GHG emissions in 2013, with major contributions coming from on-road gasoline and diesel vehicles. These trends reflect years of land use planning decisions around the use of automobiles which resulted in a built-form pattern that does not support low-carbon mobility options such as walking and cycling. He stated that reducing emissions from transportation requires a transformation in the way we live and move, including the creation of complete communities to reduce travel demand; mode-shifts towards transit, cycling, and walking; and the replacement of the use of all gasoline and diesel vehicles with low/zero emission vehicles powered by low/zero-carbon fuels.

Mr. Wood concluded by stating that the province will be releasing a Climate Change Action Plan in 2016 with specific actions to help meet the 2020 target while also laying the foundation to achieve long-term targets and reduce emissions across key sectors including transportation.

**Mr. Peter Boag**  
*President, Canadian Fuels Association*

Mr. Boag opened by highlighting that transportation is an essential underpinning of our society, being a major enabler of economic activity and citizens’ standard of living. Canadian industries, including manufacturing, agriculture, fishing, forestry, energy, retail and tourism, rely heavily on transportation. Transportation also helps us meet our needs for travel to and from work, school, recreational activities, shopping and social events. There has generally been a strong correlation between GDP growth and transport energy demand growth although in recent decades this link has been reduced through gains in transportation energy intensity.

Mr. Boag stated that petroleum fuels power 95% of transportation today, enabling individual mobility and independence, and the large scale, long-distance transportation of goods. At the same time, transportation is a significant element of Canada’s GHG challenge. On a national basis, emissions from
this sector account for 28% of total emissions. Road transportation is the biggest contributor, accounting for 19% of total emissions in Canada. Importantly, transportation emissions have grown by 40% since 1990. According to Mr. Boag, an 80% reduction in road transportation emissions by 2050 (below 1990 levels) would thus require an 86% decrease (118 Mt CO\textsubscript{2}e) from 2013 levels, or close to a 90% reduction from 2016 levels to achieve the aspirational 2050 target.

Mr. Boag discussed the study “A Long Hard Road” which was developed by the Conference Board of Canada (CBOC) to examine Canada’s road transport sector in the context of the 80% reduction by 2050 target. The study identified significant practical and economic barriers to achieving the target and highlighted the need to make very significant adjustments in the attitudes and behaviours of Canadians. The study looked at a number of options for GHG abatement from economic and cost perspectives. It found that at a minimum, the abatements costs of various opportunities started at $100 per tonne and went as high as $600 to 1000 per tonne.

Mr. Boag stated that for personal transport and light-duty vehicles, population growth is the key driver of GHG emissions, while in the freight sector, the key driver is GDP growth. The CBOC study suggests that consumer behavior and preferences are major factors in light-duty vehicle (LDV) emission trends. Of late, there has been significant growth in SUV sales and reduction in the number of traditional passenger cars sold, with implications for emissions growth. Freight traffic has grown very rapidly over the last 20 to 30 years and emissions from this sector have grown faster than those of any other transportation sector.

Mr. Boag discussed the three scenarios put forward by the CBOC study for GHG abatement. The reference case uses existing vehicle patterns, fuel choices, and regulations. While emission levels in this scenario decline slightly through 2025, road transportation emission levels decline by 12% of current levels, but are still nearly 25% above 1990 levels.

The continuous improvement scenario makes the same assumptions as the reference case for population and GDP levels, but reflects two additional trends: declining distances travelled per vehicle, and continued fuel efficiency improvements in internal combustion engines. In this scenario, the combined impact is a steady 1% per year improvement in the emissions intensities of all vehicles. The near term outcome is very similar to the reference case – emissions decline steadily through to 2025. Beyond that, the rate of decline flattens, with total road transport emissions declining to 86 million tonnes in 2050, which is 12% below the 1990 level.

The third scenario included a variety of mitigation options – such as alternative fuel/vehicle technologies, mode switching, land use changes, and behavioural change – for both passenger and freight transportation. This scenario delivered a further 10 to 15 Mt reduction by 2050, bringing emission levels in Canada down to between 22 and 27% below 1990 levels by 2050. Mr. Boag highlighted that the implementation of alternative technology solutions would not accomplish more than compensating for the increases in emissions that would result from increased population and economic growth. He also noted that for some key mitigation technologies, the CBOC study documented high or very high abatement costs per tonne of CO\textsubscript{2}. He stated that these costs should be compared with the carbon price of $15 to 17 per tonne in Ontario’s cap and trade program.

In addition, Mr. Boag looked at how we could reasonably expect emerging technologies to penetrate the market. He highlighted that there were only 15,000 plug-in EVs registered in Canada as of mid-2015, out of the 23 million registered worldwide. The CBOC study suggests that even at a rate of 10% of new
vehicle sales by 2050, EVs would only constitute 7% of all vehicles on the road, highlighting how slow it will take for EV technology to penetrate the market. An important factor to consider is fleet turnover rates. The average age of vehicles in Canada today is approaching 10 years. Vehicle turnover rates and the speed with which new technologies penetrate the market to comprise a meaningful share is part of the decarbonization challenge.

Mr. Boag discussed six areas of focus identified by the CBOC study for moving towards a low-carbon future in the transportation sector. First, a continued focus on improving vehicle performance is needed, including the fuel efficiency of conventional internal combustion engines. Second, we need to look more carefully at alternative vehicles and understand the abatement costs of various technologies and the speed with which they can realistically penetrate the market. More effort is needed to get people out of cars and address the demand for transport. A focus on freight is also increasingly important because it is the fastest growth area in the transportation sector. Finally, we need to find the right balance and ensure that policy actions to reduce emissions do not constrain our ability to move people and things around.

Mr. Boag concluded with three fundamental questions for workshop participants: how much can we legitimately rely on the technology to accomplish? What is it going to cost? How much are we going to change behaviour?

Mr. Bob Oliver
Chief Technology Advisor, Pollution Probe

Mr. Oliver offered some perspective on a strategic approach to confronting the challenge of decarbonizing transportation. On the one hand, Ontario has introduced a policy to dramatically cut GHG emissions in a very short period of time and help Canada to achieve its international commitment on climate change. On the other hand, he observed that Ontario’s economic and social structure is deeply reliant on advanced and energy-intensive transportation systems, powered almost exclusively by liquid fossil fuels such as gasoline, diesel and kerosene. These are very convenient and rich forms of dense, portable energy – and it does take a lot of energy to move massive objects like vehicles.

Mr. Oliver stated that a sustained effort is needed to progressively decarbonize transportation energy use. While there are no simple solutions, largely because the alternatives are costly, the revenue generated from carbon pricing may be available to invest in less energy- and carbon-intense technology and infrastructure. He stated that we have confronted the challenge of decarbonizing transportation before numerous times. A recent paper produced by Navius Research, Simon Fraser University and the University of California, Davis, published in Nature Energy (“Moving beyond alternative fuel hype to decarbonize transportation”), refers to a ‘fuel du jour’ mentality which government, industry and other stakeholders find themselves repeatedly swept up into. Their analysis shows a strong alignment between positive media attention, government funding and new automotive product introductions relating to a variety of alternative transportation fuel types in the U.S. which were popular at times between 1980 and 2013, including methanol, natural gas, plug-in electric, hybrid electric, hydrogen and various forms of biofuels. The authors claim that little success in displacing gasoline or diesel has followed any of these periods of popularity and attention. Their results do not attempt to determine whether this ‘fuel du jour’ hype has had a net positive or negative impact on alternative vehicle innovation. It is also unclear whether this pattern should be perceived as ‘failure’ or whether it is simply part of a natural process of testing alternatives.
Mr. Oliver highlighted the primary recommendation of the study, which is the need for policy-makers to improve their institutional capacity to conduct balanced, science-based technology assessments. If such assessments are designed to be cross-disciplinary, participatory, ongoing and grounded in scientific evidence, they can contribute to the creation of reasonable shared expectations, effective coordination among key stakeholders, and the design of adaptive policy. Although such a process cannot eliminate uncertainty, efforts to draw on the best possible knowledge in the present can help to develop more plausible expectations about the future.

Mr. Oliver stated that while we realize the need to address the challenge of decarbonizing transportation, predicting the future of such a complex and multivariate system is futile. He believes that if we can create credible scenarios of decarbonized futures, and within these understand the conditions for success, then we should be able to develop technically credible and economically practicable strategies – or pathways – towards these outcomes, involving investments in technology and infrastructure, as well as changes in our approach to urban planning and design. Mr. Oliver highlighted the need to balance the choice of a broad scope of possible pathways with a focus on options that not only deliver deep reductions in GHG emissions, but also build Ontario’s capacity for valued exports, economic growth, job creation and other social, human health and well-being objectives.

He looked at Ontario as a lens through which the challenge of decarbonizing transportation can be interpreted, as its different regions have different transportation needs. For example, north of the City of Sudbury, which calls itself the gateway to northern Ontario, resides about 5% of Ontario’s population. The northern economy is centred around resource development, mainly mining and forestry. South of Sudbury live the other 95% of Ontarians (about 13 million), who mainly work in the services sector, but also in manufacturing. Ontario’s automotive assembly and vehicle parts plants directly employ around 110,000 people. Although this sector generally exhibits a pattern of decline in employment and production levels, some facilities are expanding. In 2014, a region stretching along the Highway 401 corridor between Toronto and Waterloo was recognized as being second only to California’s Silicon Valley as the world’s leading high-tech industry region, employing nearly 280,000 high-tech workers (which is more than 60% of Canada’s total).

On the freight movement side, three of North America’s largest border crossings are along Ontario’s border with the U.S. at Windsor/Detroit, Sarnia/Port Huron and Niagara Falls/Buffalo. These crossings are part of a network of over-the-road freight corridors running north-south through Canada, the U.S. and Mexico, which connect manufacturing hubs to major seaports of international trade, including the ports of Montreal, Houston and Veracruz.

Mr. Oliver stated that both the movement of goods to markets and the ability of individuals to travel, work and engage in commerce relies on efficient, reliable and sustainable transportation systems. Part of Ontario’s Climate Change Plan is based on the goal of becoming a more “resource-efficient, high-productivity society.” These are some of the socioeconomic characteristics of the province that need to be considered when looking at the transportation needs of its future.
In conclusion, Mr. Oliver stated that decarbonizing transportation is as much a regional challenge as it is an international opportunity, and that it is important to decarbonize the entire system – not simply to press for the adoption of one or two technology platforms. This will require a strategic approach with a long term vision of success. The Pathways Initiative is not about picking winners, it is about understanding the success factors for numerous decarbonization options, and taking action in the near term to support those options in which Ontario and Canada have economic, social and environmental interests in making successful – not just at home but around the world.

Opening Plenary: Discussion

A participant asked Mr. Wood what the total figure was for Ontario’s emissions in 1990, a base year for Ontario’s GHG reduction targets, and how 1990 emissions ratios compare with 2013 ratios for different sectors. Mr. Wood stated that in 1990, electricity and industry accounted for a large share of total emissions. The electricity sector’s share was decreasing in absolute terms while for industry the relative share of emissions was shrinking in the 1990s. Mr. Wood stated that national reporting on emissions has changed over the years as new data is acquired and new standards are adopted, but the latest figure for 1990 emissions is 182 Mt.

Another participant asked Mr. Wood to comment on the provincial government’s work to model the impacts of its GHG reduction measures. Mr. Wood responded that the province produced the “Ontario Climate Change Update,” which is a forecast of emissions based on current policy (BAU or no policy action) as well as on actions that have been announced and, in some cases, funded. He also stated that while the province does some of the back end modelling and an analysis of what potential reductions would be to inform decision-making, little modelling work is done until a package of actions is approved and a sufficient level of detail is provided for the model.

Mr. Wood was asked to comment on what the Government of Ontario’s expectations are in terms of specific contributions from the transportation sector towards meeting the province’s GHG reduction targets. Mr. Wood stated that the province looked at reductions from the transportation sector in an exercise which assumed that Ontario’s emissions would be roughly proportional to what they are now by 2050. However, he stated that caution is needed when looking at this exercise because the implementation of Ontario’s cap and trade program means that carbon pricing will become a key driver of change in the economy and the market will determine which sectors can make the most cost-effective GHG reductions. He stated that after a few years of experience with cap and trade, the province will be better informed on the sectors in which carbon pricing is having an impact, and where continued application of government policy and investment is needed.

One participant asked Mr. Boag if there were studies looking at how recent fluctuations in the prices of gasoline have impacted behaviour and the elasticity of demand for gasoline. Mr. Boag stated that since the financial crisis of 2008/9, there has been a decrease in fuel consumption; however, with a stronger U.S. economy and a significant decrease in the price of gasoline, the demand for gasoline has gone up significantly over the last year or so. Mr. Boag also noted that studies over the past years have indicated that the price of gasoline is fairly inelastic when it comes to human behaviour so the impact has been relatively small.

Another participant asked Mr. Boag to comment on concerns around methane leaks and fugitive emissions from compressed natural gas (CNG) and liquefied natural gas (LNG), noting that while the potential for CNG is increasingly recognized, there are also concerns about a “Volkswagen moment” in the industry. Mr. Boag responded that the main CNG applications are return-to-base fleets, while
challenges have been around cost and refueling infrastructure. He also stated that the science of life cycle analysis is saddled with a huge degree of uncertainty. While LNG and CNG have been promoted as having a 25 to 27% emissions advantage over diesel, some new research suggests that CNG and LNG may actually perform worse than diesel. Mr. Boag also said that within the trucking community, which is conservative and very risk averse, the uptake of CNG was very modest even in the face of high prices for diesel.

One participant asked Mr. Oliver to provide specifics around the future transportation services for the Toronto-Waterloo innovation corridor considering that workers in the knowledge sector do not travel a lot. Mr. Oliver felt that Ontario would want to support the diverse high-tech and knowledge sector as a cornerstone of our jobs and exports and that transportation decarbonization strategies that result in solutions that make it more productive and more internationally connected are needed for the region.

1.2  Breakout Session A (Morning): Presentations

Fuel-saving light-duty vehicle technology
Mr. John German  
Senior Fellow, U.S. Co-Lead, The International Council on Clean Transportation

Mr. German began his presentation by reminding those present that “all technology forecasts are conservative” as they typically only assess current technologies and do not account for emerging technologies and innovation in general. Over the last four years, the biggest, unanticipated breakthrough in vehicle components has been computers – computer design, computer simulations and on-board computer controls – which are revolutionizing every aspect of light-duty vehicles.

Technologies like gasoline direct injection (GDI), turbo-charging, hybridization and continuously variable transmissions (CVTs), have defied projections for 2025 made only several years ago, achieving projected performance and cost levels by 2015 in most cases due to innovations on the part of automakers. The single biggest advancement over the last several years has been in the field of vehicle lightweighting. In 2011, the U.S. EPA projected that by 2025 there would be an average reduction in vehicle weight of 7%, but almost all production vehicles from the 2016 model year have already achieved 5 to 7% weight reductions. The Ford F-150, for example, doubled its lightweighting projection over ten years early.

On the topic of engine turbo-charging, Mr. German stated that the use of turbo-chargers to boost exhaust gas recirculation (EGR) was considered leading-edge technology in 2011, and U.S. federal agencies like the EPA and NHTSA projected that only 6% of light-duty vehicle engines would be using this technology by 2025. This type of turbo-charged engine, however, is already obsolete, and automakers are now working on dedicated EGR engines in which all of the exhaust from each cylinder is circulated back into the air intake. Yet even dedicated EGR engines are expected to become obsolete before ever entering into production. Manufacturers are now experimenting with Miller-cycle turbo-charged engines, which can increase engine fuel efficiency by roughly 5% when combined with EGR. Altering the length of piston connecting rods, in conjunction with hydraulics, can lead to 3 to 6% fuel efficiency improvements. Coupling turbo-chargers with small electric motors can enhance the performance of the turbo-chargers while allowing for decreases in engine size. Engine manufacturer Eaton released test
results showing that turbo-chargers coupled with 4 kW electric motors and 0.25 kWh battery packs yielded a 21% improvement in fuel economy relative to a baseline turbo-charged engine.

Improvements in vehicle lightweighting over the last several years have been greatly facilitated by computer simulations, which allow automakers to perform a rigorous array of tests on lightweight materials, showing the impacts of the materials on other vehicle components without actually having to build these vehicles and test them manually.

Most of the above-mentioned technologies serve to improve the performance of modern gasoline-powered vehicles while enhancing fuel efficiency and reducing engine size. Mr. German’s research has indicated that by 2050, internal combustion engines without hybridization should be able to achieve fuel economies of 3.1 L/100 km (75 mpg), while hybrid engines should achieve 2.5 to 2.0 L/100 km (95 to 120 mpg). This would amount to fuel economy improvements of over 100% from today’s averages. Emerging alternative vehicle technologies will have to be able to compete with the reduced GHG footprint of increasingly fuel efficient gasoline-powered vehicles.

In terms of savings on fuel costs from a consumer perspective, Mr. German reminded workshop participants that there is a great deal of uncertainty in regard to calculating fuel costs over the lifetime of a new vehicle. Due to this uncertainty, the average consumer will only calculate fuel costs two or three years into the future when considering the purchase of a new vehicle. While fuel producers are the ones who ultimately pay for reduced fuel consumption, society as a whole benefits financially, as consumer savings on fuel tend to be spent elsewhere in the economy. Like consumers, auto manufacturers are inherently risk-averse, and tend to be hesitant to adopt new technologies due to the risk that they may not be accepted by consumers. As a rule, manufacturers thus tend to push for more time before the introduction of new fuel efficiency standards to study and implement efficiency enhancements in their vehicles and ensure that such enhancements will not negatively affect vehicle performance.

**Hydrogen fuel cell technology**

**Dr. David Greene**

*Research Professor, Department of Civil and Environmental Engineering, University of Tennessee, Knoxville*

Dr. Greene began by stating that the premises of the arguments he would be presenting were:

1. Society is unlikely to meet the GHG reduction targets for light-duty vehicles without a transition to low-carbon forms of energy;
2. Although energy efficiency improvements are, and should be, the primary strategy for reducing GHG emissions from transportation, they will not be sufficient to reach emissions reduction goals in the order of 80% below 1990 levels by 2050;
3. If there are low-carbon biofuels available at reasonable costs, quantities will be limited and will most likely be reserved for transportation applications like aviation and heavy-duty road vehicles;
4. This leaves society with electrons and protons to power light-duty vehicle transport, and so we have to find ways to make such technologies work;
5. Despite the urgency of implementing new low-carbon technologies, the current status of such technologies is not currently good enough to achieve a cost-effective, eventually self-sustaining transition of sufficient magnitude to meet reduction targets;

6. The challenges related to the implementation of hydrogen fuel cell vehicles and electric vehicles are quite different, as the two modes use distinct technologies and have independent probabilities for successful implementation.

Dr. Greene expressed that the probability of society successfully implementing a low-carbon transportation option for light-duty vehicles increases by 50% when investments are made in both hydrogen fuel cell and electric vehicles. To date, technological improvements in both hydrogen fuel cell and electric vehicles has been impressive, with fuel cell cars becoming viable for personal transportation over the last two decades, and lithium-ion battery costs falling by roughly 14% per year. Modern hydrogen fuel cell vehicles are expected to operate well for 240,000 km, can start in temperatures as low as -37 °C, they can re-fuel in three minutes, and have ranges in excess of 480 km. Hydrogen fuel cell vehicle costs have been decreasing at rates comparable to electric vehicles in recent years. Hydrogen storage tanks are a big expense, with 5 kg tanks costing roughly $2,500 each, at high-volume production levels. While access to electricity is widespread, hydrogen gas refueling stations are almost non-existent, suffering from high capital costs and low utilization rates. As a result, hydrogen gas in California currently sells for about $13/kg, with station dispensing costs alone being between $6.5 and 8 per kg. With high utilization rates, however, these dispensing costs could drop to as low as 25 cents per kg.

Based on a study completed for the National Research Council, Dr. Greene stated that by 2050, the cost of producing and operating hydrogen fuel cell and electric vehicles will be less than those of internal combustion engine vehicles. Findings like this support Toyota's assertion that by 2050 it will no longer be manufacturing gasoline-powered vehicles.

In order to achieve transportation-related GHG emissions reductions of 80% by 2050, the following points should be considered:

1. Subsidies for low-carbon fuels and technologies need to be provided for 10 to 20 years;
2. Governments must accept that no net social benefits associated with the implementation of policies that are favourable to low-carbon transportation technologies will be realized for 10 to 15 years after the introduction of such policies;
3. When the net benefits of low-carbon, energy efficient vehicles are calculated in the 2050 timeframe, they end up being an order of magnitude greater than the costs associated with the transition.

In order to achieve consumer acceptance, electric vehicles need reduced battery costs, extended vehicle range, reduced recharging time, and expanded recharging infrastructure. Hydrogen fuel cell vehicles need reduced fuel cell system and hydrogen storage costs, reduced costs of dispensed hydrogen, and the deployment of an adequate refueling infrastructure. Both modes require upstream low-carbon energy production. Pursuing the development of both modes of transportation is a better strategy than pursuing just one of them, and will increase the odds of developing a viable alternative to gas-powered personal transportation.
**Breakout Session A (Morning): Discussion**

One participant mentioned that there are no odorants light enough to travel with hydrogen gas to facilitate leak detection, so leaks may be hard to identify and thus pose a safety risk. Dr. Greene and Mr. German responded by saying that safety considerations for hydrogen are different from those of natural gas, as hydrogen disperses more rapidly and the extremely small size of hydrogen gas molecules means that the gas can pass directly through roofs and other materials that would typically help to contain leakages.

Another participant questioned the speakers about whether or not region-specific applications for hydrogen fuel cell and electric vehicles would make sense, based on differences in fuel and support infrastructure availability in different regions. Dr. Greene responded by saying that because hydrogen fuel cell vehicles are best-suited to drivers who want the freedom to travel long distances, they would want hydrogen refueling infrastructure to be available in all regions. The same does not apply to electric vehicles, as Dr. Greene feels they will always have a limited range and long recharging times, so a regional strategy would make more sense for them.

Another participant asked how emerging approaches to transportation like autonomous vehicles and car sharing would impact the value propositions of hydrogen fuel cell and electric vehicles. Mr. German stated that he is highly uncertain in regard to the future of autonomous vehicles, as they will catalyze fundamental changes in society’s approach to transportation, comparable to the transition from the horse and buggy to the automobile. People would be likely to drive more, the efficiency of travel could improve, and autonomous vehicles could facilitate the use of electrified transportation. Autonomous vehicles could facilitate lower-emissions travel if they are used in conjunction with low-carbon mass-transit systems. However, autonomous vehicles could lead to increased net energy use if they provide an incentive for people to live further away from where they work, due to the fact that they could sleep or work while they travel; and if commuting distances are beyond the ranges of electric vehicles, autonomous vehicles could increase the demand for gasoline-powered travel. Dr. Greene stated that the impact of autonomous vehicles on net energy usage could be +200% or -90%. One determining factor in this equation will be whether or not people will be willing to share rides and vehicles. The more vehicle sharing that takes place, the greater the energy savings will likely be. Autonomous vehicles will likely reduce traffic congestion, but these efficiency enhancements could be offset by increases in total distance travelled per person.

One participant asked about one of the premises shared in Dr. Greene’s presentation, which stated that the limited availability of renewable biofuels will likely limit their possible applications to transportation modes like aviation and on-road heavy-duty vehicles (modes that require light weight, energy-dense fuels), but that light-duty vehicles are relatively well-suited to technologies like hydrogen fuel cells and battery electric drives. The participant wondered why fuel cell and electric vehicles were poorly suited to other applications. Dr. Greene responded by stating that the relatively low energy density of batteries and hydrogen gas would require a lot of additional size and/or weight to vehicles used in aviation and on-road transport, which would eat into cargo capacities leading to lowered efficiencies. Mr. German stated that the durability of current hydrogen fuel cell stacks was sufficient for light-duty vehicles but insufficient for heavy-duty vehicles, which tend to travel greater distances over vehicle lifetimes. A participant noted that hydrogen was not a climate-friendly fuel for use in aviation considering the high altitudes at which planes fly, as exhaust from hydrogen gas contains more water vapour than jet fuel, and would thus increase cloud cover.
Active transportation and urban form

Mr. Ryan O’Connor  
*Project Manager, 8 80 Cities*

Mr. O’Connor began his presentation by reminding participants that active transportation represents a low-tech, traditional approach to getting around that nonetheless has great potential for reducing transportation-related emissions in the modern age. As he put it: “Through active transportation we can create more sustainability in months instead of years, with thousands instead of millions.”

To illustrate the general attitude towards active transportation among Canada’s general public, Mr. O’Connor provided a case study from the remote northern town of Cochrane, Ontario. Several years ago, the township began examining barriers to walking and cycling, and found that residents simply felt that active transportation was not a part of the local culture. The township pressed ahead, and worked with the local police department and a high school to collect and refurbish over 100 donated bicycles. The bike share program took a mere two weeks and about $1,000 to establish, and the bikes were made openly available for use by all residents, who started using them almost immediately. Participation in the program has grown over the last two years, and it helped to catalyze a cultural shift that would have been difficult to anticipate. The township is now investing in its first dedicated bike lane as part of a broader strategy to encourage active transportation.

8 80 Cities studies and applies global best practices in active transportation to provide advice tailored to the needs and form of individual cities, with the aim of making them more accessible and healthier for all citizens, from 8 year old children to 80 year old seniors. Mr. O’Connor stated that despite having to serve a broad array of functions, cities and their streets are designed, first and foremost, for cars. This creates a dependency on cars and forces people to view personal vehicles as the most viable mobility option available. “When we define our cities around cars, we get more cars. When we define our cities around people, we get healthier and happier people” stated Mr. O’Connor. Expanding personal vehicle infrastructure simply encourages the broader usage of personal vehicles through the laws of induced demand, which can lead to social impacts like higher obesity rates and increased traffic congestion. Jurisdictions in which active transportation is embedded into the daily routines of citizens have been shown to have far lower obesity rates than jurisdictions that discourage the use of walking and cycling.

Cities and infrastructure that force citizens to drive also serve to alienate and limit the mobility of certain demographics, like children, seniors, and the 20% of Canadian households that do not own a car. So what is a walkable city? Urban planner Jeff Speck argues that walkable cities tend to share four key characteristics:

1. **Safety.** If walking routes are deemed unsafe, people simply will not use them. For example, pedestrians who are struck by cars travelling 60 km/h or faster have a one in ten chance of survival, whereas those struck by cars travelling at less than 30 km/h have a nine in ten chance of survival. Speed limit reductions in residential and downtown areas can thus serve to make
walking safer and more inviting. Such reductions can be achieved not only through laws, but through changes to the built environment that discourage high speed vehicular travel.

2. **Convenience.** If people feel that their time and energy is not being expended in an efficient way, then they will not choose to walk over other mobility options. Walking corridors need to connect residences to local amenities in a straightforward way to encourage broader usage.

3. **Comfort.** Walking routes need to provide adequate space to move around freely, rather than being added as an afterthought and squeezed into vehicle-prioritized corridors. Walking corridors should also be well-lit and have places to sit down and relax.

4. **Stimulation.** Walking corridors should be as interesting as possible so they stimulate the senses of walkers with sites to see and amenities to visit.

On the subject of cycling infrastructure, Mr. O’Connor noted that cities like Copenhagen and Amsterdam are well-known for being bicycle-friendly, but that this status has only been achieved through decades of effort and investment to continuously improve their cycling infrastructure. Roughly 50% of all trips taken within these cities are conducted via bicycles. The City of Calgary recently built several separated bike lanes as part of a pilot project, and after just three months, bicycle usage on those streets increased by 95%. This illustrates that there may be an under-estimated latent demand for dedicated bicycling infrastructure in major North American cities, and if cities build them, the bikers will come.

80 Cities follows four key criteria whenever they work with cities to establish cycling infrastructure:

1. **Separation.** In order to feel safe, cyclists must be separated from vehicular traffic via some type of physical barrier, such as simple plastic bollards, parking spaces, curbs, or raised paths.

2. **Connectivity.** To optimize usage, bike lanes should be connected to one another via a grid that covers as much of a city as possible.

3. **Accessibility.** Bike lanes should be planned in such a way as to get people to where they want to go in as efficient a manner as possible.

4. **Safety.** Bike lanes should be safe for people of all ages and abilities.

A survey completed by 40,000 residents of Portland, Oregon showed that only about 10% of people have a high degree of confidence on bikes, and will use them in almost any condition or on any type of street. Roughly 37% of the population was found to have little-to-no interest in using a bike for personal mobility. The majority of people, however, were found to be “interested but concerned” bikers, who would bike more if dedicated infrastructure was available to them.

These figures hold true in Ontario, where the average citizen makes over 2,000 trips under 3 km in length each year. Surveys have shown that if adequate active transportation infrastructure was provided, people would make a great deal more of their trips by walking or biking. In Toronto, 70% of people would cycle more if dedicated biking infrastructure was more widespread.

A participant asked how average active transportation levels in Canada compare to other parts of the world. Mr. O’Connor responded that about 12% of all trips in Canada are made using active transport, as opposed to levels upwards of 50% in parts of Europe.

Another question for Mr. O’Connor was on the topic of biking in the winter, with the questioner wondering if ridership levels would decrease significantly in winter conditions. Mr. O’Connor responded
that as long as bicycling infrastructure is well-maintained and cleared of snow in the winter, ridership levels only tend to decrease by 10 or 15%.

A workshop participant stated that many people always wear helmets when biking, yet bike share programs have failed to address this need. They wondered how bike share programs could provide users with helmets. Mr. O’Connor replied that British Columbia, with its mandatory helmet law, is a good place to look for solutions to this problem. They will be introducing a bike share program shortly, and are considering options like bike helmet vending machines or having local stores have helmets available for rent.

**Transforming public transit**

**Dr. Josipa Petrunic**

*Executive Director and Chief Executive Officer, Canadian Urban Transit Research and Innovation Consortium (CUTRIC)*

Dr. Petrunic explained that the Canadian Urban Transit Association (CUTA) established CUTRIC to address issues with public transit including GHG emissions, inefficiency, a lack of route optimization and a lack of data usage to inform efficiency improvements, and the integration of next-generation technologies. CUTRIC’s area of activity includes electric bussing, alternative propulsion systems, sensors, signals and controls for rail systems, cyber-security, connected vehicle communications technologies and light-weight materials, as well as emerging personal transportation technologies (due to the lack of a dedicated innovation consortium in Canada for the automotive sector).

Dr. Petrunic provided participants with an overview of an ongoing project called the Pan-Ontario Electric Bus Demonstration and Integration Trial Study. Most electric bus trials are limited in scope, and generally only test one to three buses in a given service area. Recently there has been a big push on the part of governments to reduce emissions from transportation, and this has created a situation in which bus manufacturers, which primarily build diesel-powered buses, are coming under increasing pressure to innovate yet have very limited budgets with which to do so. The typically small scale of demonstration projects means that the costs of producing buses using alternative propulsion technologies are inordinately high. Very few transit systems in Canada have any research and development budgets at all. The goal of CUTRIC’s e-bus demonstration project is to get 25 electrified buses onto Ontario’s roads over the next two years. The project will include two bus manufacturers and seven transit systems spread across five local distribution company service areas. This regional focus will help bus manufacturers sell Canadian products globally, as they will have to develop ways to integrate vehicle systems and plug and play models across multiple electrical jurisdictions. Different e-bus manufacturers are being used in the study in order to reinforce the need for harmonized charging platforms, as fleet operators will want the opportunity to switch vendors without having to overhaul their entire charging and data management network. The trial will use in-route as well as end-point charging systems. The buses will be equipped with artificial intelligence that will allow them to communicate with local smart electrical grids and self-charge based on the type and capacity of electricity being generated at any given point in time.

Key research questions that the trial is seeking to answer include:
1. To what extent do transit systems in Ontario benefit from GHG reductions, cost reductions, and service improvements due to electrification?

2. What technical challenges need to be overcome in vehicle-to-grid communications to achieve mass electrification of buses over the next 10 years?

3. To what extent should transit systems and local distribution companies use grid-scale energy storage devices to power electric buses with green, low-cost or free electricity?

A key problem associated with the electrification of mass transit is the higher up-front costs that transit authorities will have to pay when making a bulk purchase of e-buses. While a typical diesel bus costs roughly $600,000, a typical e-bus and its charging equipment costs upwards of $2 million. These high costs may necessitate a new business model for transit operators and bus manufacturers. Rather than buying buses outright, transit operators could pay bus manufacturers a monthly or annual subscription fee for the provision of e-buses, and another fee for the vehicle-to-grid communications service provider.

An audience member asked if e-buses charging during peak hours of electricity usage in Ontario would still offer GHG benefits over diesel buses. Dr. Petrunic answered that yes, they would still offer GHG benefits, but the risk would be power outages or transformers catching fire if the bulk of e-bus charging occurred during peak hours.

**Optimizing infrastructure for electric vehicles**

**Dr. Matthew Stevens**  
*Chief Executive Officer, FleetCarma*

Dr. Stevens began his presentation by telling workshop participants that electric vehicles (EVs) are actually just the back-up to the back-up plan for an idealized transportation system. In an ideal system, most people would use active transportation for the majority of personal mobility. In a slightly less ideal system, people would use public transit to get around. The third best case would be people using EVs for personal mobility.

On the current state of EVs in Canada and Ontario, Dr. Stevens stated that there were a total of 18,500 EVs on Canada’s roads as of the end of 2015, spanning 23 available models. Over 10,000 of these EVs were battery electric vehicles, as opposed to hybrids. Quebec is the leading province in terms of EV adoption, followed by Ontario and British Columbia. The EV fraction of Canada’s total light-duty vehicle fleet is roughly 0.09%, while this number stands at 0.17% for Quebec and 0.08% for Ontario. The three top selling EVs in the country, the Chevrolet Volt, Nissan LEAF, and Tesla Model S, made up roughly 75% of all EVs sold. In Ontario, sales of the Tesla Model S surpassed those of all other EVs in 2015. In terms of new vehicle sales, EVs made up 0.3% of the light-duty vehicle market in Canada in 2015, or 0.7% if light trucks, minivans and SUVs were excluded from the numbers.

On the outlook for EVs in Ontario, Dr. Stevens expressed his excitement at the Government of Ontario’s recent announcement to allocate $20 million to public EV charging infrastructure. He feels that the reason Ontario is trailing Quebec and British Columbia in terms of the light-duty vehicle market share for EVs is the province’s lack of a widespread DC fast charging network – a critical enabler of widespread EV
adoption as it would facilitate more convenient long distance EV travel. Ontario also increased its maximum purchase incentives for EVs this year, which Dr. Stevens indicated was a promising sign.

In contrast to what Dr. Greene stated in terms of current battery costs, Dr. Stevens stated that for its soon-to-be-released Bolt EV, Chevrolet is paying less than $200 per kWh for its lithium-ion battery packs. Battery costs, he said, are falling much faster than anticipated, and this could be a game-changer for the EV market.

Dr. Stevens felt that there are two fairly basic steps that could be taken in Canada to facilitate increased EV adoption. The first would be to amend vehicle fuel economy labels, which are overly complex as a single format for labelling must be applied to vehicles of all types, resulting in a cluster of numbers and metrics that are difficult for consumers to make sense of. The second step would be to decouple EVs with climate change in public ad campaigns. EVs, he contends, should stand on their own technical and performance merits, rather than their indirect corollary benefits, as purchasing decisions are most often made on the basis of performance, costs and risks rather than on other considerations. The GHG reduction argument will not significantly increase EV sales, argued Dr. Stevens. Rather, it will simply come down to the ability of EVs to outperform other vehicles in terms of performance and price.

Dr. Stevens closed his presentation by overviewing a major new project being undertaken by FleetCarma – ChargeTO. The project is intended to address the concern that the increasing power at which EVs charge could stress electricity systems at the neighbourhood scale. This concern arises from the fact that EVs charge at anywhere between 3.3 kW and 19 kW, yet most households in Ontario have electrical feeders sized at only 5 kW. ChargeTO, Canada’s first residential smart charging pilot, provided 30 EV owners with a free smart charging station. While EV owners typically charge their vehicles whenever they prefer (usually overnight), in this project they were only given autonomy over their home charging patterns in two ways: they were allowed to specify the time in the morning when they wanted their EVs to be fully charged by, and they were also able to prevent charging from being slowed down if they were below a specified state of charge. As long as the EV owners were above the minimum state of charge they specified, and as long as their cars were fully charged by the time they specified in the morning, the rate and timing of charging was in the hands of FleetCarma and the local utility company. The utility company was told to, whenever possible, keep the total charging load of all the cars participating in the program below 10 kW.

Dr. Stevens walked participants through the different types of EV charging:

1. **Dumb Charging.** Charging begins as soon as an EV user plugs in.

2. **Scheduled Charging.** Charging is delayed until a preset start time or to finish at a specific end time. Delaying charging to a preset start time allows EV users to reap the benefits of time-of-use pricing in jurisdictions like Ontario which offer cheaper electricity rates during off-peak hours. Delaying charging to finish at a preset departure time (e.g., when a driver typically leaves for work in the morning) can still allow EV users to charge with cheap electricity rates while extending their battery range in cold conditions, as charging heats EV batteries slightly, making them more efficient.

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**IN AN IDEAL SYSTEM, MOST PEOPLE WOULD USE ACTIVE TRANSPORTATION FOR THE MAJORITY OF PERSONAL MOBILITY. IN A SLIGHTLY LESS IDEAL SYSTEM, PEOPLE WOULD USE PUBLIC TRANSIT TO GET AROUND. THE THIRD BEST CASE WOULD BE PEOPLE USING EVS FOR PERSONAL MOBILITY.**
3. **Smart Charging.** Charging can begin immediately yet can be reduced and/or delayed based on external factors. Partial control over charging may be given to a third party (i.e., a utility or building manager). If an EV is equipped to provide what’s known as “side data” to that third party, its needs (e.g., state of charge, time of departure) can be viewed by that party. If an EV does not provide side data, the system will be blind to its needs.

For roughly six months, the project monitored how participants normally charged. Half of the participants used dumb charging most of the time, plugging in to charge as soon as they arrived home. When charging became managed by utilities over three months, significant reductions in net power demand were achieved. Charging was curtailed for most EV owners on a nightly basis, and researchers found that it was possible to reduce the charging load by 85% during periods in which the grid was experiencing issues. This was possible while still meeting all the charging parameters set by the EV users. The project managed to reduce the peak load of the participating EVs by 50 to 55% every night. The EV users did not really care how or when their cars were charged overnight, as long as they were good to go first thing in the morning. This type of charging management can also synchronize the charging of EVs with electricity generation from intermittent renewable sources, allowing utilities to maximize the value and efficiency of their grid assets.

**Breakout Session A (Afternoon): Discussion**

A workshop participant asked the speakers if Canada should develop strategies for the decarbonization of transportation at the federal level or on a provincial basis. Dr. Petrunic responded that, in regard to electrified transportation, the federal government can lay out a set of best practices to guide provinces and municipalities in planning for the deployment of EVs. The federal government can also play a leading role in large-scale demonstration and modelling projects that strive to implement and test the business cases of emerging technologies. At the provincial level, Dr. Petrunic said that some provincial energy regulators and managers have strong R&D mandates and capabilities that make them well-suited to conducting research on emerging technologies and practices, but other provinces lack such resources. Therefore the likelihood of having 13 unique provincial/territorial strategies or technical specifications in the future is low, but there may well be 13 different ways of deploying such policies. Dr. Stevens stated that from his perspective there are three major barriers to EV adoption. The first is how to market EVs, the second is federal fuel economy labelling, which is under the purview of the federal government and should communicate to people the fuel costs associated with particular vehicles rather than fuel consumption in litres, and the third is the role utilities should play in vehicle charging. This third area would be well-suited to provincial oversight, as provinces use different modes of electricity generation, have different electricity markets, and different operating protocols for grids.

An audience member asked Dr. Stevens if he offered participants in FleetCarma’s ChargeTO study any financial incentives to hand over a portion of their control over vehicle charging to their utility companies. He replied that his team was also curious about this issue and divided the study participants into three groups, two of which received financial incentives based on the frequency with which they allowed their utility to control their charging rate and timing, and one which received a blanket incentive simply for participating. He said that there was a significant uptick in participation levels from the two groups that received the dynamic financial incentives over the group that received the static incentive.
This shows that incentives based on level of participation are effective at eliciting broader public support for sharing EV charging responsibilities with utilities.

Dr. Petrunic asked Dr. Stevens if he thought there was a role utilities should be playing in the sale or leasing of EV charging equipment. Dr. Stevens stated that he strongly feels that the role of utilities should extend “beyond the meter” into the hardware and software that governs EV charging rates and times while communicating with the grid. He said that utilities have a lot of experience and expertise related to the sale and management of such infrastructure. The major debate is whether or not utilities should own home EV charging stations, and there are solid arguments on both sides of the debate. Some argue that if utilities owned the EV charging stations in people’s homes, innovation would not happen fast enough. On the other hand, there are big benefits associated with smart charging and incorporating its impacts into the management of local feeders, and if utilities do not own the charging stations, it will be difficult for them to engage in smart charging.

1.4 Breakout Session B (Morning): Presentations

Fuel-saving heavy-duty vehicle technology
Mr. Anthony Greszler
Engine and Vehicle Engineering and Emissions Control Consulting

Mr. Greszler focused on the challenges and opportunities for decarbonization within the on-road commercial transportation sector. Led by heavy-duty trucking, commercial transportation fuel demand has been rising steadily and is projected to become the largest energy-consuming segment of the transportation sector globally by 2040. Mr. Greszler noted that commercial vehicles vary greatly in terms of shape, size, and duty cycle. This variety means that there is no one solution to GHG emissions reduction in the sector.

Mr. Greszler stated that until recently, approaches to reducing GHG emissions from commercial transportation focused primarily on improving the energy efficiency of the front (tractor) half of the combination truck, while attention to other areas for improvement has been limited. He claimed that freight emissions reduction efforts should focus on the following three areas: improving fuel efficiency, reducing vehicle kilometres traveled, and developing new low-carbon fuels for heavy-duty vehicles.

According to Mr. Greszler, the U.S. projections for fuel use in heavy trucks through to 2050 show that the bulk of fuel will be consumed by class 7-8 vehicles, with 80% of this use coming from long-haul vehicles. He highlighted key technology areas for improvement in long-haul truck freight efficiency. On the engine side, improved efficiency can be achieved by utilizing technologies that enable waste heat recovery, improvements in NO\(_x\), after-treatment, engine friction reduction, and more efficient diesel combustion. Mr. Greszler noted, however, that there is a theoretical upper limit for diesel engine efficiency – likely in the 55% range. As this efficiency limit is approached, the costs of improvements will increase dramatically. On the truck side, efficiency gains can be achieved via the application of smart transmissions, powertrain integration, cooling optimization, smart navigation and idle reduction devices. Fleet operations was highlighted as another important area for improving efficiency, for example by ensuring that trucks do not travel with low freight density, by training drivers on fuel-efficient operating
practices and by expanding the use of intermodal freight transport. Mr. Greszler stressed that these strategies can only contribute to the extent they are integrated into the complete vehicle and system. Mr. Greszler discussed the U.S. Department of Energy’s SuperTruck program, which sought to achieve and demonstrate on highways a 50% increase in overall tractor-trailer freight efficiency and a 20% increase in engine efficiency by 2015. He praised the program’s integrated approach, noting that efforts to improve freight efficiency often focus on individual component technologies. While effective in a lab, these component improvements may not have a significant impact on the overall efficiency when integrated into a complete vehicle.

Mr. Greszler observed that a range of fuel-efficient technologies are already available on the market, and that many drivers are already trained in careful driver practice, helping to minimize fuel consumption. He also identified a number of emerging technologies and approaches that could help achieve further gains. In particular, predictive cruise control systems offer new opportunities in energy management for heavy-duty vehicles. Cruise control enables a truck to obtain information about highway road grades and measure the load. Data can be recorded and stored, and strategies to optimize truck speed can then be calculated. As trucks become more aerodynamic, they climb and descend hills more quickly, meaning they can better capture downhill energy. Packaging density is another important consideration for vehicle efficiency. Efforts are underway to optimize consumer goods packaging and load more goods onto trucks. Enabling longer combination trucks (those pulling multiple trailers) is another opportunity for improvement as more cargo capacity makes trucks more efficient in terms of tonne-kilometres per litre of freight delivered. Combination trucks present a major potential for efficiency gains, with studies suggesting fuel savings in the range of 17 to 28% could be achieved. Mr. Greszler noted that Sweden and Finland permit 25.25 metre truck rigs, which use 20% less fuel per tonne-kilometre than the 18.75 metre rigs used in other European nations. The increased utilization of intermodal transport options, most notably trains, could be a viable solution for longer hauls, particularly for deliveries that are not time-sensitive. Improved intermodal usage could potentially result in freight transport fuel savings of 50%, but more studies are needed to better understand the logistics, costs, timing and fuel consumption levels.

IMPROVED INTERMODAL USAGE COULD POTENTIALLY RESULT IN FREIGHT TRANSPORT FUEL SAVINGS OF 50%, BUT MORE STUDIES ARE NEEDED TO BETTER UNDERSTAND THE LOGISTICS, COSTS, TIMING AND FUEL CONSUMPTION LEVELS.

Mr. Greszler discussed the viability of biofuels for heavy-duty vehicles, noting that there are many alternatives, including biodiesel, synthetic diesel, methanol/ethanol, biogas, and dimethyl ether (DME). While some of these options have significant GHG reduction potential, there are many issues surrounding the use of biofuels, including high costs, limited feedstocks, and impacts on food supply. Mr. Greszler believes that diesel fuel, increasingly from biomass resources, will remain the dominant fuel for heavy-duty vehicles. He also identified renewable DME as an attractive candidate for a more long term future fuel. Mr. Greszler highlighted the need for a long term vision and a planning process that takes an integrated approach, considering autonomous operation, loading speeds, warehouse distribution, and other aspects of heavy-duty vehicles.

Mr. Greszler discussed some of the health and social benefits of reducing GHGs from freight transport, pointing to climate change mitigation, reduced fossil fuel use, improved air quality (reduced NOx and particulate matter), reduced transport costs and reduced urban congestion. On the economic growth potential for the sector, he stated that freight transport growth has traditionally been proportional to economic growth and that changes in economic activities will affect freight. For example, the shift
towards a service and software economy may reduce that linkage while increases in online purchasing and delivery might increase total freight transport.

Mr. Greszler identified a range of barriers to the improvement of on-road freight efficiency. Firstly, fuel efficiency technologies and practices are complex and expensive, therefore an economic case for efficiency is needed to encourage business investment. Alternatively, technologies and practices could be forced through regulation, but he suggested that slow acceptance by fleets should be expected in this case. The lack of supporting infrastructure is another key barrier. Mr. Greszler stated that intelligent systems are needed to facilitate highways communicating with trucks and trucks communicating with each other and other vehicles. In addition, he stated that existing regulations can hinder efficiency. For example, the fact that the 6x2 axle configuration with load transfer is prohibited in Canada means that drivers cannot switch to a single drive axle at times when this would be sufficient, leading to the loss of roughly 3% in fuel efficiency.

Mr. Greszler concluded by stating that while engine and vehicle technologies in the sector are already quite advanced, many available efficiency features are only slowly gaining acceptance, especially for trailers. A comprehensive freight policy with clear direction and coordination between multiple stakeholders is needed to realize further potential improvements in heavy-duty vehicle efficiency.

Decarbonizing railway operations and prime movers

Mr. Peter Eggleton
Principal Consultant, Telligence Group

Mr. Eggleton discussed the opportunities and challenges of decarbonizing railway operations and prime movers. He opened with an overview of the sector, stating that the Canadian locomotive fleet totalled 3,070 units in 2013, of which mainland freight locomotives represented 65%; yard and road switchers were 27%; and the rest were passenger locomotives. Railway operations consumed around 2 billion litres of diesel fuel in 2013, with freight accounting for 95% of that. Total annual GHG emissions produced by locomotives in operation in Canada amounted to 6 million tonnes while criteria air contaminant (CAC) emissions were 102,000 tonnes.

Mr. Eggleton emphasized recent improvements in the Canadian railway sector’s fuel economy and emission levels. Between 1990 and 2013, the GHG emissions intensity (kg of CO₂e/1000 revenue tonne-km) for total freight operations decreased by 39.5%. Modern freight trains with the latest fuel-efficient locomotives can haul one tonne of freight 200 km on one litre of fuel. Mr. Eggleton also stated that trains are five times more fuel efficient than trucks and that moving more freight by rail instead of truck could potentially lower freight-related GHGs by 75%. He identified a number of initiatives implemented by the Railway Association of Canada to improve fuel efficiency in the railway sector. These include crew education and training targeted on efficient operations, fleet upgrades, the use of emerging technologies, and investments in infrastructure, operational related initiatives, and research and development programs.

Mr. Eggleton went on to discuss railway electrification options, noting that the conventional overhead catenary connected to the grid continues to be the most common application in Canada. However, novel disruptive technologies, such as inductive power transfer and hydrogen fuel cells (HFCs), are
attracting increasing attention in the rail sector. Mr. Eggleton highlighted the potential multiple benefits of using HFCs in combination with buffer batteries as motive power for railway applications. In particular, this option avoids the visual pollution and high capital costs of overhead catenary infrastructure, which range up to $40 million/km within cities to $10 million/km in rural areas. Other major benefits of HFC motive power include reduced emissions, noise and vibration. In addition, HFCs allow rail operators to avoid the complexity of the diesel power pack, the extensive idling associated with most diesel trains, and the use of fossil fuels while maintaining the operational flexibility of diesel locomotion. HFCs with buffer battery power packs have the potential to capture and store energy through regenerative braking, which can provide a significant amount of power in frequent stop-and-go commuter train operations. HFCs can also contribute to grid peak load reduction by using electrical energy generated during off-peak hours to produce hydrogen gas, which could then be compressed and stored for delivery to rail refueling points. However, Mr. Eggleton cautioned that this will only be an economically viable option when sufficient HFC infrastructure is in place, and highlighted the need for more site-specific application studies to determine comparative overall costs per kWh of a hydrogen energy infrastructure.

Mr. Eggleton discussed a number of studies exploring the viability of HFCs for railway applications as well as projects currently implementing the technology. Telligence Group undertook, with Hydrogenics Corporation, an HFC application study for the Toronto Union-Pearson Express rail line, and has also looked at options for retrofitting other industrial switcher and commuter locomotives with HFC technologies. Internationally, a notable development in commercial-scale HFC technology is a program in Germany to deploy 40 HFC-powered commuter trains for regional lines by 2020. The hydrogen gas that will fuel the HFCs is to be produced by the electrolysis of water using excess wind farm electrical energy. For this program, Hydrogenics, an Ontario-based fuel cell and electrolyzer manufacturer, was awarded a 10-year €50 million contract in 2015 by train manufacturer Alstom France to supply 200 HFC units for self-propelled hydrogen-fueled commuter railcars. Their powertrains will use HFCs, buffer batteries and energy storage systems as alternatives to diesel engines, and will deliver performance equivalent to catenary-powered electric trains. Two prototype trainsets are planned to be in operation by the end of 2018 for revenue service trials. The railcars are structurally similar to the Coradia diesel-powered units Alstom supplied for the Ottawa O-Train. According to Mr. Eggleton, these initiatives demonstrate the viability of HFCs for railway applications. A key remaining question is the safety aspect of hydrogen, but the European project might help to resolve some of these concerns.

**Breakout Session B (Morning): Discussion**

During the discussion session, Mr. Greszler was asked to comment on the use of auxiliary power units (APUs) in heavy trucks, U.S. tailpipe emissions testing and the effectiveness of the U.S. EPA’s SmartWay program in reducing GHG emissions in the commercial freight transport sector. On the topic of APUs, Mr. Greszler stated that the overnight idling of truck engines is an area where APU use could help reduce fuel consumption and emissions by enabling truck engines to shut down while allowing the driver to maintain a supply of power to the cab for heating, cooling and other needs. There are different technologies currently on the market, such as diesel-fired heaters and diesel APUs. Mr. Greszler claimed that APU technologies should be tailored to the environmental conditions that a given truck is operating in. For example, in Canada where heating represents the biggest draw on cab power, diesel-fired heaters with a battery system to power the electronics would be the most suitable option, but in the
southern U.S., where air conditioning is needed all year round, a battery system or a diesel APU would be more appropriate.

On the topic of tailpipe emissions testing and glider kits, Mr. Greszler noted that emissions are regulated in the U.S. based on the age of the engine that is installed in a vehicle, not the vehicle year. Thus, emissions tests for re-built trucks are based on the performance requirements of older engines, most often the lighter engines built before 2002, when emissions regulations mandated the use of exhaust gas recirculation and after-treatment control devices. The glider kit issue essentially represents a glitch in the U.S. system, which the EPA is trying to address in new emissions regulations.

With regard to the SmartWay program, Mr. Greszler stated that it is a good program that has brought emerging technologies to the attention of fleets, and that there are groups that are starting to aggregate real-world data across fleets to better understand the impacts of efficiency-enhancing technologies.

A participant asked Mr. Eggleton about the costs and range of HFC locomotives relative to other options like electrification or the continued use of diesel engines. Mr. Eggleton responded that certainly diesel trains have cheaper operating and fuel costs, but the point of HFC locomotives would be to reduce CO$_2$ emissions, not necessarily costs. A fairer comparison would be between HFC trains and those electrified by overhead catenary lines, which would also cost more than diesel-powered trains. This comparison could only be made through a detailed analysis of costs per kWh in the specific applications for which the trains would be used.

Another participant asked Mr. Greszler to comment on whether road pricing has been effective in the U.S. in terms of improving on-road freight efficiency. Mr. Greszler believes that road pricing has had little impact on fuel efficiency because freight needs to move where it needs to move, and added costs from road pricing will be buried in the rates that carriers charge. If the pricing is set too high, it diverts freight off the highway to less effective and efficient roads.

Mr. Eggleton was asked if natural gas could be a stop-gap technology to increase the acceptance of different fuels in the rail industry. He responded that natural gas should be viewed more as a step in the evolution of energy – which has gone from wood, to coal, to oil, to natural gas, to hydrogen – than as a stop-gap measure. To effectively eliminate carbon emissions from rail, the key solutions to consider are overhead catenaries (electrification) or fuel cells. Mr. Eggleton noted that while HFC systems may be too bulky for trucks, the technology could be used in locomotives. Mr. Greszler then referenced a slide from his presentation that showed the cooling system of the Toyota Mirai, a commercial HFC car. He pointed out that the entire front end of the Mirai is covered with cooling radiators. Fuel cells, he continued, are 50 to 55% efficient, and all of the remaining energy produced must be exhausted at relatively low temperatures, at around 70 °C or less. So there is a huge cooling issue, as 45-50% of the energy produced must be removed at relatively low temperatures. He wondered how that could be done for a locomotive used in freight transport, and where the extensive cooling systems required would go. He acknowledged that this is being done for commuter trains which are relatively lightly loaded, but freight locomotives would require extensive cooling systems, especially when going up-hill. Mr. Eggleton responded that there are weight and bulk issues with fuel cell systems for freight, but that catenary-electrified trains with on-board batteries would also have weight issues.
One participant asked the speakers whether a major reduction in GHGs could be achieved by implementing the vision of a decarbonized electricity system powering an electrified rail system, including the use of fuel cells, with bus and truck-dedicated lanes for electrified modal distribution in urban centres, or whether a significant component of our freight transportation system will continue to be based on the internal combustion engine by 2050 and beyond. Mr. Greszler replied that with improved efficiencies in conventional technologies used in the on-road freight transport sector, GHG emissions could be reduced by roughly 40%, but to go beyond that, electrification will likely be needed in all freight and personal transport modes, including rail. He stated that there are certainly possibilities that could be explored and visions of completely electrified systems are currently being tested. For example, electrified rails could be built into major highways that would provide power on an ongoing basis to electric heavy-duty vehicles, and these vehicles could draw power from on-board batteries for relatively short periods of off-highway use. In Sweden, researchers are already testing the feasibility of such systems.

Mr. Greszler was invited to comment on the opportunities for light-weighting vehicles in the commercial sector. He stated that light-weighting vehicles for freight haulage is very difficult and not particularly productive. In the case of cars, light-weighting efforts are more productive because the primary weight being hauled is that of the vehicle, not its cargo/passengers. In the case of heavy-duty vehicles, the weight of the vehicle might only be 30% of the total weight being hauled when a truck is fully loaded, so efforts to reduce the weight of heavy-duty vehicles tend to offer small returns in terms of GHG reductions. Mr. Eggleton added that a great deal of work has already been done on commuter trains to make them lighter, for example by using aluminum rather than steel.

1.5 Breakout Session B (Afternoon): Presentations

Renewably-sourced fuels
Ms. Carolyn Tester
Senior Regulatory Affairs and Planning Advisor, Imperial Oil

Ms. Tester opened by stating that there are multiple solutions to reducing emissions in the transportation sector and addressed the question of how to determine which solution is best for society. She put forth four policy principles as a framework for approaching the question. First, solutions should be market-driven, they should meet consumer needs and be compatible with transportation fuel infrastructure. Second, solutions should be based on sound science, which necessitates a full life-cycle analysis of different fuel options, looking at vehicles and fuels as a system and considering wider environmental implications in terms of GHG emissions as well as land use, air quality, water, soil, and waste impacts. Third, solutions should be evaluated in terms of both their costs and their benefits to society, and options with net benefits should be prioritized. Ms. Tester emphasized that solutions should be judged on a dollar per tonne basis, and that the solution with the lowest cost should be utilized first in order to maximize benefits to society. Lastly, an appropriate, clear, and consistently enforced regulatory framework is needed to promote the adoption of the desirable solutions in the sector.

Ms. Tester provided an overview of renewable fuels, stating that their benefits depend on how biomass is grown and converted into fuel. First-generation biofuels, such as ethanol and biodiesel, are produced from food crops. While these fuels are commercially available today, there are a number of concerns around their impacts on food prices, water usage and land use. For example, about 40% of corn grown
in the U.S. is used to produce ethanol. The UN projects a 70% increase in the demand for food by 2050, which means the continued use of corn for ethanol may put additional pressures on it. Furthermore, the production of corn ethanol requires 200 to 400 times more water than is needed for petroleum fuel production. Fertilizer runoff and soil erosion in the U.S. corn belt are examples of land use issues that have emerged.

Next generation, or advanced, biofuels are produced from non-food feedstocks, such as various types of waste, algae and lignocellulosic residues (from woody plants). Ms. Tester noted that the commercial-scale production of advanced biofuels has been limited due to technical hurdles, high costs and other challenges. She illustrated some of the issues around biofuels using the example of cellulosic ethanol. In 2012, the U.S. Energy Information Administration (EIA) projected significant growth in the amount of cellulosic biofuels produced. However, the anticipated commercial production levels did not materialize. In 2015, only 100 million gallons of cellulosic ethanol were produced in the U.S., far below the 3 billion gallon target envisioned in the Energy Independence and Security Act of 2007, which set the production requirements for biofuels in the U.S. The National Academy of Sciences has indicated significant challenges with cellulosic ethanol, including high costs in the order of $5/gallon of gasoline equivalent, significant land use requirements, and implications for cropland. Ms. Tester stated that significant technological advances and scientific breakthroughs are necessary in both biomass optimization and processing to make large-scale production of advanced biofuels economical.

Ms. Tester provided an overview of how the biofuels industry has evolved over the last decade. The U.S. and Brazil are the world’s largest producers of biofuels, together accounting for two-thirds of global supply, with ethanol representing roughly two-thirds of this. About 50% of biofuels are consumed in the Americas. Global investment in biofuels stood at $1.6 billion in 2015. The majority of investment in first generation biofuels occurred in the 2006 to 2008 timeframe, under the U.S. EPA’s Renewable Fuel Standard, and has been declining since then due to concerns over impacts on food prices, land and water use. Europe has also been moving away from first generation biofuels, placing a cap on their use. Ms. Tester highlighted that next-generation biofuels captured the majority of global investment (81%, or $1.3 billion) in biofuels for the first time in 2015, suggesting that first generation biofuels are no longer viewed as a long term solution to GHG reduction.

Ms. Tester discussed the need for life cycle analysis (LCA) in assessing the net GHG emissions of biofuels, which would encompass crop cultivation, the processing and transport of feedstocks, as well as emissions associated with any co-products. Ms. Tester noted that indirect land use change is an important impact of biofuels production; however it is not accounted for in Canada, unlike other jurisdictions such as California and the EU. She highlighted the importance of including indirect land use change (iLUC) in Canadian LCAs, stating that it can significantly increase the carbon intensity of a biofuel, depending on the crop and the scope of the analysis. She noted that biofuels impact commodity markets, as the agricultural sector responds to the demand for more biofuels by clearing more land, which can result in the significant release of GHGs – either through a loss of biomass or through soil disturbance. When iLUC is considered, the carbon intensity of biofuels could become comparable to that of gasoline.
Ms. Tester also stated that LCA methods should be transparent, and subject to a peer review and validation processes. She noted that Canada’s life cycle modeling tool for transportation fuels, GHGenius, is currently under review, and that settling on the process for administering the tool is key to ensuring its effectiveness.

In addition, Ms. Tester stated that ExxonMobil is currently conducting research on non-food feedstocks for second generation biofuels, as well as fuels and products made from advanced biofuels, with a specific focus on lignite cellulose and algae. She noted that algae is a particularly promising area of research due to the fact that it does not require the use of arable land or fresh water.

**Autonomous vehicle technology**

**Mr. Karl Simon**  
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*Director, Transportation and Climate Division, U.S. Environmental Protection Agency*

Mr. Simon discussed the opportunities and challenges related to connected and autonomous vehicles (CAVs). He observed that many companies are interested in the CAV space and the sector is innovating rapidly. There are, however, many challenges that companies face in bringing CAVs to market, not just on the technology side, but also from legal and regulatory perspectives. He stressed the need to be thoughtful in the policy space to keep pace with the rapidly changing technology.

Mr. Simon discussed the factors driving CAV technology development. Firstly, CAVs could help reduce road fatalities and congestion, especially in growing urban areas. In the U.S., an estimated 33,000 people were killed in car accidents in 2015. He observed that the world is becoming more urbanized and that traffic congestion is becoming an increasingly common problem in many megacities. An equivalent of one new city of one million people will be created every five days between now and 2050.

Mr. Simon stated that there are a number of economic incentives for CAVs. Personal vehicle ownership comes with high costs. For example, figures from the U.S. suggest that the average price of a new car is $33,340 (USD), while annual ownership costs stand at roughly $9,000 (USD). Despite these costs, vehicles are parked 96% of the time. The auto sector is increasingly perceived by many as the next big area for innovation and disruption.

Mr. Simon discussed the different levels of automation identified by the U.S. National Highway Traffic Safety Administration (NHTSA): 1. No Automation; 2. Function Specific; 3. Combined Function; 4. Limited Self Driving; and 5. Full Self Driving. He stated that most vehicles on the market today have automated features, such as automatic transmissions and stability control. Some limited self-driving features such as Tesla’s Autopilot function are already available today, and a number of companies are currently involved in demonstration projects related to full self-driving CAVs. Mr. Simon emphasized that the technology is developing faster than the regulatory system and that many questions about the potential implications of the technology need to be addressed.
From an environmental perspective, Mr. Simon identified five clusters of potential benefits from CAVs: vehicle efficiency, connectivity, fuels, the built environment, and shared mobility. With regard to efficiency, CAVs could be much more efficient than conventional vehicles through reductions in “stop and start,” disjoint activities and smoother acceleration/deceleration. Studies suggest a 6 to 14% improvement in efficiency could be achieved with CAVs. The U.S. EPA is currently participating in a research project that aims to quantify the potential fuel economy improvements of CAVs. Connectivity, or communication between vehicles and infrastructure, is currently a challenge due to the lack of sufficient supporting infrastructure. The potential benefits of greater connectivity include platooning, improved aerodynamics and better operations. On fuels, Mr. Simon noted that many questions around CAVs are currently fuel neutral. While there are benefits to having CAV technologies integrated into EVs, CAVs do not have to be electric as their technology can also work with internal combustion engine vehicles. Mr. Simon stated that there is potential to create more livable cities through better infrastructure and transportation planning in conjunction with CAVs, as they will not put the same demands on public parking spaces, which will free up space for other types of development like parks and green spaces.

With regard to the impacts of shared mobility, Mr. Simon raised a number of questions, such as how will CAVs change human behaviour; will changes in infrastructure encourage car sharing; and will technology (e.g., Uber) allow for the right-sizing of transportation systems? According to Mr. Simon, recent studies suggest greater shared mobility leads to reductions in GHG emissions, vehicle ownership, and vehicle kilometres traveled. How society interacts with the new technologies and how public policy will influence different options will be an increasingly interesting policy challenge.

Mr. Simon discussed the potential for CAVs to decarbonize the transportation system. A recent study found that automation can affect the travel and energy demands and the resulting GHG emissions of vehicles in many ways, both positive and negative. The benefits could include platooning, improved safety, more feasible eco-driving, smaller cars and alternative mobility services. The risks include the potential for CAVs to increase emissions due to the ease of travelling and the opportunity to integrate more features in autonomous vehicles, which could potentially increase total travel time. Mr. Simon emphasized that the fuels used for CAVs must not be overlooked, as CAVs could utilize internal combustion engines. Mr. Simon discussed four future scenarios for CAVs, emphasizing that they could have large impacts in either direction. He hopes that the market will drive the development of CAVs in a direction that supports GHG reduction initiatives. CAVs are projected to have significant impacts on the marketplace within the next 5 to 20 years. Researchers are currently collecting data on how CAV systems are developed and what the environmental impacts of different configurations are. Mr. Simon also mentioned that CAV technology is not tied to cars and is transferable to other transportation sectors, including commercial trucks and off-road vehicles.

Mr. Simon concluded by posing several questions that need to be addressed: What does CAV technology mean for us? What should we be paying attention to as a regulatory body and as a society? How can we help achieve the vision of zero-emission CAV mobility in major cities?
Natural gas and natural gas infrastructure in transportation

Mr. Wayne Passmore
Economic Development Manager, Union Gas

Mr. Passmore discussed the role that natural gas can play in helping to decarbonize transportation in Ontario, particularly within the heavy-duty vehicle sector. Worldwide, there are currently over 16 million natural gas vehicles on the road, growing at a compound annual rate of 20%. Mr. Passmore believes there are opportunities to achieve similar growth rates in Ontario.

He shared the results of an aspirational forecast conducted in collaboration with Enbridge, Union Gas and ICF Canada which looked at what could be achieved by displacing fuels used in medium- and heavy-duty vehicles with natural gas. More specifically, the study investigated the GHG savings resulting from natural gas taking over 90% of Ontario’s on-road diesel market, 10% of its on-road gasoline market, as well as its rail and marine sectors. The study predicted potential savings amounting to 6.7 billion litres of diesel equivalent (DLE), which would reduce GHG emissions by 2.7 Mt CO₂e (using the 17% well-to-wheels GHG emissions reduction potential identified by a Delphi Group report) and $3 billion in savings per year by 2035. Mr. Passmore also noted that the theoretical limit of emissions reductions from natural gas relative to diesel (roughly 32%) must be considered in light of factors such as inefficiencies from spark-ignited engines and upstream natural gas leakage, which are currently eroding the GHG reduction potential of natural gas. Efforts are underway to address these issues.

In terms of cost savings, Mr. Passmore said forecasts suggested savings in the range of 10 cents/litre. He stated that the energy in a litre of diesel is roughly equivalent to the energy in 1 m³ of natural gas; however, diesel is roughly five times more expensive than natural gas, which costs roughly 17 cents for 1 m³ versus 90 cents or more for 1 litre of diesel.

Mr. Passmore stated that economies of scale are critical to the success of decarbonizing Ontario’s transportation sector with natural gas, but also pose a major challenge. A major issue is the size of the compressors used to produce compressed natural gas (CNG) and getting the throughput commitment to the compressors.

Mr. Passmore highlighted that renewable natural gas (RNG) represents an important opportunity to help decarbonize not just the transportation sector but the entire natural gas system. In 2011, Union Gas and Enbridge commissioned a report which identified the potential for Ontario’s generation of RNG at an energy value of 52 petajoules (PJs) per year in the near term, which represents 5% of the province’s natural gas consumption today. In the longer-term, as gasification capacity increases, there could be an opportunity for additional RNG production amounting to 115 PJ of energy per year. Ultimately, RNG can displace 16% of the conventional natural gas consumed in the province, with each unit of RNG providing GHG reductions in the range of 80 to 170% over conventional natural gas.

In addition, the study looked at the costs of various pathways for RNG. It found that the price ranges from $7 to 40 per GJ, depending on the type of project, but averages between $15 and 20 per GJ. Blending RNG into CNG would result in a higher but still compelling pump price, while offering the potential for significant GHG reductions. Reductions up to 8 Mt CO₂e/year could be achieved in Ontario’s medium and heavy-duty transportation sector by 2035 in a scenario with 50% RNG blending.

Mr. Passmore identified a number of barriers to the mainstream introduction of CNG and RNG, but also proposed solutions. A CNG/liquefied natural gas (LNG) vehicle price premium, which amounts to roughly
$65,000 for Class A vehicles, as well as the lack of refueling station infrastructure, are some of the major barriers. Mr. Passmore sees opportunities in Ontario for using the proceeds from the cap and trade program to overcome these barriers by supporting 50% of vehicle price premiums and installing public refueling stations.

CNG tank weight and cost is another problem, but tank efficiency can be increased by targeting the development of adsorbed CNG, which uses abrasion technology to store the same volume of natural gas but at lower pressures, thus reducing the compression requirements. Promoting the local manufacturing of these technologies could help to reduce costs. Reducing or eliminating inefficiencies through research and development is another opportunity and there are efforts to reduce the roughly 15% lower efficiencies of spark ignition engines versus compression ignition diesel engines. Work is also underway in Ontario to address the challenges around RNG supply and cost by establishing a program to enable utilities to acquire RNG and blend it with CNG.

Mr. Passmore stated that the penetration of natural gas into Ontario’s transportation market has started but it needs to reach a tipping point in acceptance before it can take off. He concluded by stating that Ontario’s cap and trade program is an exciting opportunity for the natural gas sector. Natural gas can play a role in GHG reduction and RNG can help decarbonize the natural gas system and save billions of dollars. Funding from cap and trade revenues will be needed to mitigate some of the barriers to introducing CNG and RNG into the transportation sector, and as the market develops, a tipping point will be reached, leading to a better functioning market.

Breakout Session B (Afternoon): Discussion

During the discussion session, one participant made a comment on biofuels and internal combustion engines, noting that for both technologies, there is great potential for improved efficiencies and environmental performance and a need for better regulations to achieve these improvements. The participant also highlighted the need to move beyond the polarizing debate on biofuels towards a state where regulation drives continuous improvement in GHG performance and accounts for land use changes and other impacts. This will help us achieve better performance from the fuels that are on the market today.

Participants also discussed how a CAV future might look in the commercial transport sector, especially with respect to heavy-duty vehicles. Mr. Simon noted that there are many interesting factors at play in the commercial sector that will drive how CAV technology is adopted. The need for a human driver is one example. Driver training has become an important factor for larger commercial fleets in the U.S. Another relevant consideration is how freight and goods could be moved in and out of cities at off-peak times, particularly considering that cities are growing and freight movement is projected to increase significantly.

One participant asked Mr. Passmore about the opportunities for Ontario in terms of storage systems for CNG as well as for addressing the adsorption challenge. Mr. Passmore stated that storage tanks represent a large part of the costs for CNG vehicles, with the next biggest cost coming from pressurizing the gas. So optimization exercises need to be undertaken that look at vehicle range, the number of storage tanks that are carried on-board, and the level of gas compression. Chemical adsorption can allow CNG to be produced at lower rates of compression, but the technology around it is still in the
research and development stage. There may be opportunities for Ontario, which imports the technology from other jurisdictions, to get more involved in the sector.

One participant raised a question about the reporting methodologies for GHG emissions from transportation in Canada, noting that they are reported based on tailpipe emissions and not on LCA. The participant observed that incorporating LCA into the calculations may result in double-counting and asked the speakers about reporting styles that could include LCA. Ms. Tester responded that in Canada, Alberta has a requirement for renewable fuels that are used for fuel blending to be 25% less carbon intensive than conventional fossil fuels. Mr. Passmore responded that the method that considers emissions per GJ of fuel consumed in respect to natural gas is attractive. While some segments of society favour the ‘well-to-wheels’ approach, Mr. Passmore believes it is important to look at both measures to get a more comprehensive picture of impacts. Mr. Simon observed that the programs currently used in California, Canada and the EU, could lead to three different numbers for the same fuel. When determining where investments should go, having the life cycle numbers and knowing where they are coming from is important. Mr. Simon also stated that while there are many uncertainties around iLUC, it is an important factor that should be considered in order to more fully understand GHG emissions. From a regulatory perspective, different tools could be useful for GHG emission calculations.

One workshop participant observed that a theme of the workshop seemed to be that different fuel types are best-suited to different transportation applications, and asked if certain inherent attributes are going to be necessary as value added for certain segments of transportation, how does this contrast and compare with a relatively open market which does not force the use of specific technologies for specific applications? Ms. Tester replied that on the biofuels side, Ontario is moving to put a price on carbon through a program that considers biofuels to have zero emissions. She believes that as long as the fuel is compatible with the equipment, and as long as biofuel is second generation, a price on carbon will drive the use of renewable fuels in the market, and that is the most cost-effective way to put biofuels to use.

Participants discussed the benefits and drawbacks of low-carbon fuel standards (LCFSs). Ms. Tester believes that LCFSs create an additional cost for consumers, are administratively difficult to manage and are ineffective in driving additional reductions in GHG emissions. By adding another cost to transportation, LCFSs prevent the lowest cost solutions from coming forward in a timely manner. Ms. Tester also noted that Ontario’s cap and trade program sets emissions certainties and will allow it to reach reduction targets with the use of the lowest cost technologies. Mr. Simon responded that LCFSs provide a broader platform for innovation; however, he agreed that the LCFS program in the U.S. is very difficult to implement. Mr. Passmore stated that while LCFS programs help to increase the share of RNG in the market, which is important, he is not in favour of implementing such a program in Canada because it is important to target emissions across different sectors.

1.6 Closing Plenary Discussion
During this plenary session, speakers and participants convened to discuss the key learnings, themes and questions emerging from the expert presentations.
One workshop participant stated that free markets can help find the most sustainable and cost-effective solutions to the challenge of decarbonization with the limited resources available, and that Ontario’s cap and trade program is the right approach to take in this regard. The program will help reduce emissions in the province’s transportation sector by driving lowest cost solutions and innovations. However, another participant felt that putting a price on carbon will not be a sufficient measure to incent advanced biofuels in Ontario because carbon pricing systems do not provide enough detail to look at different GHG emission impacts from different types of renewable fuels. Ontario’s cap and trade program considers both first and second generation biofuels as carbon neutral, which means these types of fuels are competing directly against each other. For second generation biofuels, which are a newer development, this is a challenge. The participant pointed out that LCFSs were recognized as one of most important drivers of GHG reductions in the province of British Columbia. The lesson for Ontario is that there are policies that are technology neutral and which let the market pick winners while driving carbon reductions in the transportation system.

Another participant highlighted that there is a need for a complex policy response to address the different sides of the issues we face, including institutional, consumer and educational, as well as the costs and the infrastructure to support different solutions. We need to accept that initially, costs will likely exceed the social value of reducing GHG emissions, but what we are aiming at is the future, which is uncertain with regard to what technology or markets will look like in 2050. In this context of uncertainty, feedbacks and tipping points, there is a need to be persistent, adaptable to the changes and to pursue a multiplicity of options.

Another participant stated that in order to effectively support the adoption of cleaner vehicles and tackle transportation-related GHG emissions, policies that address both the demand and supply side are needed. In addition to cap and trade and standards, feebate programs can be very useful in promoting the adoption of alternative fuel vehicles while providing funding for research and development on emerging technologies. That participant believed that electric batteries will be a tough sell in Canada due to cold winters and their impacts on cabin heating and range, however HFC vehicles offer great potential which should be explored. There are opportunities for Ontario, and more specifically Toronto, to become the Canadian hub for HFC vehicles and to learn from southern California, Germany and Japan, which have already established clusters of infrastructure for HFCs, working to break the ‘chicken and egg problem’ associated with the technology.

The participants discussed the experience of the City of Hamilton which successfully went through a process of implementing CNG buses. In the mid-1980s, Hamilton was one of first Ontario municipalities to implement CNG as a fuel for bus fleets, but got out of the business due to high technology and maintenance costs. The city looked at the industry again in 2013 and found that CNG technology had matured, that the cost differential for CNG and diesel buses had become more comparable, and that the two technologies have about 85% of parts in common, putting maintenance costs on par with each other. In addition to more favourable economics, the city’s decision to switch to a CNG-powered bus fleet was influenced by an opportunity to achieve a 25% reduction in emissions. The city partnered with Union Gas to help it overcome challenges related to a lack of knowledge about CNG technology.

Hamilton’s experience suggests that when looking at a specific technology, it is important to consider...
the system that supports it and the associated costs; for example, compressor stations in the case of CNG vehicles and recharging infrastructure in the case of EVs. The city is working to convert half of its bus fleet to CNG by 2020. It was highlighted that committing significant funds to a specific transportation technology, when technological change is very rapid, is challenging. In such a context, it is important to have an open mind, recognizing that many technology options might emerge over time. It is important to bring in talented experts to evaluate new technologies as well as develop business cases for new technologies and approaches.

Another point of discussion was around the question of Ontario’s decarbonization strategy and whether it should be viewed first and foremost as an economic development strategy or an environmental strategy. One participant observed that there is no silver bullet solution, but perhaps there is a ‘silver buckshot’ solution to emissions and energy challenges in the transportation sector. Different solutions offer different benefits for different applications and it is important to understand what fuels work best at the technology, application, and regional level. From this perspective, it is a matter of both decarbonizing and improving the economy at the same time. One participant stated that costs are paramount to fleet operators and without viable business cases, technologies will fail. While reducing carbon is usually associated with excess costs, this is not necessarily the case. By using the right fuel in the right application, both the economy and environment can be improved. Another participant noted that while Ontario’s Climate Change Strategy comes from a commitment to decarbonization, the buy-in for the strategy can only be secured if it makes economic sense. According to this participant, Ontario should take its strategy beyond the language of greening the earth and create more of an economic narrative. The province should make sure that it shapes a system that will reduce emissions while delivering economic benefits, such as industrial growth, high quality jobs, intellectual property and the ecosystem around it. Another participant provided a commentary on the potential for Ontario to achieve these economic benefits, noting that while the province’s cleantech industry has great access to talent and research and development funding, the domestic market for certain technologies is small. In contrast, companies in other jurisdictions, such as the U.S. and Norway, are benefiting from a very high demand in their local markets, driven by very strong mandates and/or high energy prices, which support high levels of technology adoption and drive innovation. The international companies who succeed in their local markets have an early-mover advantage and can export their experience and expertise elsewhere. The participant noted, however, that changes are currently underway in Ontario to make it easier for local cleantech companies to sell technology on the local market. Setting up a technology hub in Ontario would further increase opportunities for the industry to grow, while driving innovation and creating jobs. The participant also expressed optimism that Ontario’s auto sector will continue to be vibrant, however it will not be focused on sheet metal fabrication, as it is today.

One workshop participant challenged the room to think about transportation less narrowly and consider what the underlying services and amenities we want from transportation are, and if there is the potential to reduce emissions by avoiding some aspects of transportation. He observed that while there has been much discussion on innovation, the focus has been on technologies that in some cases are 50 or 100 years old. He highlighted the need to think outside the box and re-envision the future of transportation. He suggested that we might need to expand the stakeholders in the Pathways Initiative dialogue and look at modes of transportation that do not require energy, for example with the help of information and communications technology (ICT). In addition, he suggested that we might need to consider how to build local economies without expanding the transportation system. In response, one
participant stated that while we do need to think differently, it is also important to use a robust analytical framework to populate new ideas, data and technologies and take a disciplined approach to moving forward into the future. The participant mentioned the Trottier Energy Futures Project launched by McGill University which modelled what low-carbon pathways might look like by 2050. The project found that cost curves for some pathways could be very high, in the $200 to 400 per tonne range. Modelling is key to understanding what the pathways might look like and what the associated costs are. A disciplined approach to the implementation will help ensure that targets are met.

One participant elaborated on the question of when to let a technology fail in the process of innovation. He observed that there is no certainty in long term forecasting and formal criteria are needed to make decisions regarding when to stop funding technologies. Such thresholds could include price, emissions and timelines. The participant noted, however, that even very innovative companies experience challenges and some great technologies may not make profits for a long period of time. One solution could be to set gates at stages where things can progress, but implementing this idea is challenging as people who have to make those decisions will have biases. Another option is to incent economically without selecting specific technologies. That participant held that it is important to keep an open mind because the end solutions are uncertain and technologies might surprise us in the long term.

The discussion concluded with a commentary on the Government of Ontario’s approach to the challenge of decarbonization. A participant stated that the government is committed to renewing the Climate Change Action Plan every five years and strives to shape the best policies for Ontario that support the triple win for society, the economy and the environment. Ontario’s approach to the challenge is based on being open to technology trends and taking a ‘silver buckshot’ approach to the solutions, continuing dialogue with stakeholders and seeking the expertise of Ontarians as well as outsiders.