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November 8, 2010

Commercial Energy Consumers Association of British Columbia
c/o Owen Bird Law Corporation
P.O. Box 49130
Three Bentall Centre
2900 – 595 Burrard Street
Vancouver, BC
V7X 1J5

Attention: Mr. Christopher P. Weafer

Dear Mr. Weafer:

Re: Terasen Utilities (comprised of Terasen Gas Inc., Terasen Gas (Vancouver Island) Inc. and Terasen Gas (Whistler) Inc.) 2010 Long Term Resource Plan

Response to the Commercial Energy Consumers Association of British Columbia ("CEC") Information Request ("IR") No. 2

On July 15, 2010, Terasen Gas filed the Application as referenced above. In accordance with Commission Order No. G-146-10 setting out the Amended Regulatory Timetable for the review of the Application, the Terasen Utilities respectfully submit the attached response to CEC IR No. 2.

If there are any questions regarding the attached, please contact the undersigned or Ken Ross at (604) 576-7343 or ken.ross@terasengas.com for further information.

Yours very truly,

on behalf of the TERASEN UTILITIES

Original signed:

Diane Roy

Attachment

cc (e-mail only): Erica Hamilton, Commission Secretary
Registered Parties

1. Reference: Exhibit B-6, CEC 1.1

With the oil and gas sector stimulating economic growth in the B.C., it will be a significant challenge to reduce GHG emissions from the fossil fuel production sector (21 percent) as this sectors omission is expected to grow with the recent Horn River and Montney resource plays being discovered. This leaves the transportation sector at 36 per cent, other industry at 14 percent, and the residential and commercial sector at 12 percent as the biggest areas for potential GHG reductions in the Province.

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Although the Terasen Utilities are facilitating more efficient use of energy and are advancing low carbon energy solutions, with the growth of the population in British Columbia more energy is expected to be consumed and therefore natural gas usage and throughput will not necessarily decline. However, the same of amount of natural gas may be serving more customers energy demands as their intensity of natural gas usage changes overtime. Moreover, as we switch from diesel to natural gas for transportation through our NGV service offerings, we are reducing overall emissions in the province but are also displacing the emissions from one sector to another. So from the Terasen Utilities customer's standpoint, we are still creating emissions from natural gas usage in vehicles, albeit these emissions are much lower than what would be produced from the consumption of diesel, propane, or gasoline.

Consequently, the Terasen Utilities are not necessarily reducing throughput levels to meet government's GHG emissions reduction targets. Instead we are actively helping the province reduce its overall emissions, particularly in the residential, commercial, and transportation sectors.

1.1 The CEC is concerned that planning for the next 20 years for the natural gas service may be significantly affected by provincial GHG emission reduction targets and policies. The potential for future Provincial Government policy to take a more prescriptive role in defining what may and may not be done could force Terasen to need entirely different policies and practices, depending upon what unfolds. The CEC believes that it would be prudent planning for the utility to anticipate scenarios in which the natural gas utility may be facing much more demanding legislative and regulatory environments. The CEC believes that some resource plan alternatives more responsive to the provincial GHG targets may provide the utility with insights into what strategies and policies it might follow. The CEC believes that it may be in the public interest for Terasen to be conducting scenario planning for alternative GHG futures.

1.1.1 Does Terasen believe there is any merit in the CEC views above and if not why not?

Response:

This response addresses CEC IRs 2.1.1.1 through 2.4.1.3.

The Terasen Utilities believe that the CEC concerns outlined in the preambles to CEC IRs 2.1.1, 2.2.1, 2.3.1 and 2.4.1 have merit and that the analysis of alternative future scenarios suggested there would be a valuable long term planning tool. We believe, however, that the Action Plan set out in Section 8 of the 2010 Long Term Resource Plan ("LTRP") is in the public interest because:

- The LTRP is based on current trends in public policy on energy and GHG emissions in B.C.;
- The Action Plan, being a four year action plan that will be revised again in two years when the next resource plan is submitted, has a short term implementation time frame and can be adjusted to address emerging policies and trends;
- The actions are aimed at helping to reach provincial GHG emissions reduction targets, helping customers reach their own GHG emissions reduction goals and providing safe, reliable and secure energy service for all of our customers;
- The actions that the Terasen Utilities will undertake during the next two to four years balance the development of new energy solutions for customers within today's economic and resource constraints; and
- The Action Plan includes ongoing work toward the development and analysis of a range of potential future scenarios as part of our long term resource planning process.

While long range planning and strategies may be impacted by the analysis of alternative future scenarios, the ongoing nature of integrated resource planning, together with the submission of a new LTRP on a two-year cycle allows the Terasen Utilities to adapt to the emerging new energy and/or carbon emission reduction policies. This adaptability may be the most important means for reducing long term risks that arise as the future unfolds. We do not believe that such future scenario analysis as is suggested by the CEC in these information requests would, at this time, cause the Terasen Utilities to alter their four year action plan.

The Terasen Utilities have, however, begun the process of examining alternative future scenarios by considering a number of 'what if' questions. Some 'what if' questions lead to easily identifiable consequences. For example, the question "What if a new policy or regulation required the electrification of all fossil fuel fired heating applications in the province" leads to the impractical conclusion that the capability of electricity resources in B.C. would need to be doubled over a short period of time (see the response to CEC IR 1.3.1). These easily identifiable outcomes have been considered in preparing the 2010 LTRP.

Other variations in future provincial policy and social trends require a better understanding of baseline provincial energy demand and the impacts of alternative future actions by government and customers. Some of the activities that the Terasen Utilities have initiated in order to acquire this information include working with other utilities to develop a base line thermal energy demand for the province, undertaking an end-use energy user / influencer preferences and intentions study and the development of new, end-use based demand forecasting methodologies that will allow the analysis of different end-use choices by customers. The Terasen Utilities will continue this work with the intention of analyzing a broader range of future scenarios and will include the outcomes in future Long Term Resource Plans. As we proceed, any additional research or resources required to complete this work and that have not already been identified by the Terasen Utilities within the current revenue requirement timeframe will be brought forward in future submissions to the Commission.

Consideration of a range of future energy prices, customer rates, fuel switching policies and technology advancements can also be included in future scenario analyses; however, there are a number of issues to consider. With regard to future energy prices, while the Terasen Utilities have included a discussion of long term natural gas price forecasts in the LTRP (exhibit B-1, pages 16 to 18), we also described the limitations of using electricity price forecasts for Long Term Resource Planning in the response to CEC IR 1.4.1. In this LTRP, the Terasen Utilities have not examined the impact of alternative future gas price scenarios on its Action Plan, but rather have used alternative future price forecast scenarios to ensure that the price forecast used in the resource planning process is reasonable. Comparing customer rates might provide better insights into the competitiveness of various energy types in B.C.; however, the uncertainty around future electricity rates, natural gas price and the price of carbon beyond the short term limits the value of any assumptions and observations that can be made. Further, customer's energy choices may not be simply based on economics. Other factors such as GHG targets and regulation can influence customer energy choices. The Terasen Utilities do not believe that further development and analysis of widely varying long term price forecasts and rate comparisons would alter the Action Plan put forth in this LTRP.

With regard to alternative fuel switching scenarios, the Terasen Utilities agree with the CEC concerns that using expensive, incremental electricity supply to meet new load from conversions to electric resistance heating will be cost ineffective. Although widely ranging fuel switching policy scenarios could impact the Terasen Utilities strategies and actions over the long term, we believe that the LTRP has responded to the potential for such variations and that the development and analysis of such alternative futures would not alter the four-year action plan contained in the 2010 LTRP. As stated above, we have initiated a number of activities that will assist with further analysis of alternative fuel switching analyses in future LTRPs.

With regard to analysing alternative technology development futures, the Terasen Utilities would agree that the potential exists for the development of technologies that could impact our strategies and plans over the longer term. However, the myriad of alternative scenarios for

emerging technology that could accelerate or delay the need for natural gas infrastructure or accelerate or delay the development of the Terasen Utilities alternative energy service offerings makes such an exercise both difficult and of limited value in developing a four-year action plan. As stated above, the short term nature of the action plan and the two-year resource planning cycle allow the Terasen Utilities to adapt to changes in technology and related trends.

In summary, the Terasen Utilities have initiated a number of activities that in the future will assist with the analysis of alternative scenarios. The importance of and reliance on such analysis, however, needs to be balanced against the flexibility to adapt to changes in the external planning environment as they occur. The inclusion of these and other factors in the development of an analysis framework of alternative future scenarios as part of the resource planning process will need to consider the sheer number of variations in potential futures and limit such analysis to a practical number of potential future conditions.

1.1.2 Does Terasen do any scenario planning with respect to alternative GHG futures beyond what is in the application?

Response:

Please refer to the response to CEC IR 2.1.1.1.

1.1.3 Does Terasen believe that its strategies and policies may be very different between one or another of potentially widely varying alternative GHG futures?

Response:

Please refer to the response to CEC IR 2.1.1.1.

2. Reference: Exhibit B-6, CEC 4.1 & Exhibit B-1, Page 25

The Terasen Utilities do not forecast energy prices. When needed, the Terasen Utilities will use independent, third party forecast sources for its analysis and planning purposes.

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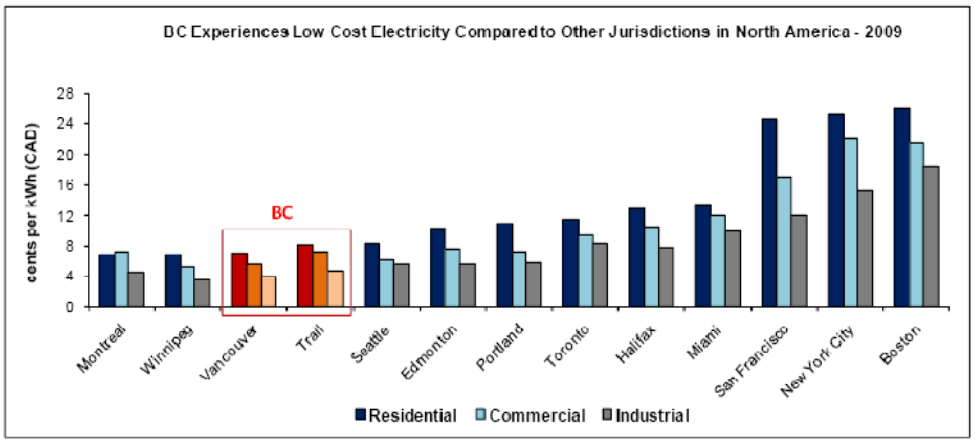
Hydro. For this reason, the inclusion of future electricity prices in B.C. within the Terasen Utilities' Long Term Resource Planning is limited to that discussed in Section 2.1.1.2, pages 21 to 27 of Exhibit B-1 of the LTRP.

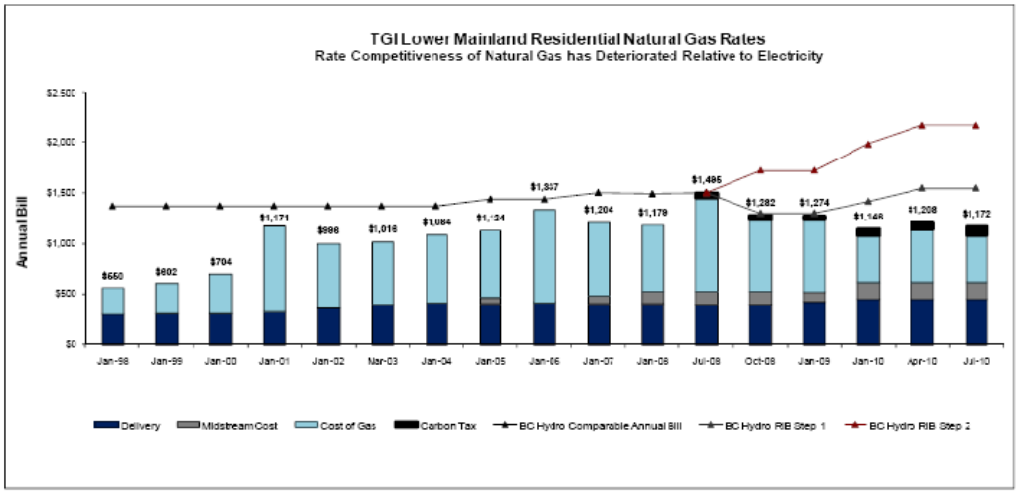
Figure 2-9: Electricity Rate Comparisons



Notes:

- Rates based on Hydro-Quebec's "Comparison of Electricity Prices in Major North American Cities" Effective April 2009
- Trail rates are based on FortisBC electric rates effective January 1, 2010

Figure 2-10: Residential Natural Gas and Electricity Bill Comparison



2.1 The CEC is concerned that much of the information used with respect to energy prices is either historical or short term in nature. The CEC is concerned that long-term resource planning may be being conducted with insufficient attention to the potential for future prices of competitive energy sources to play a significant role in the TUS future. The uncertainty for energy prices need not be an impediment to planning for the potential scenarios which could unfold. In seeking certainty the TUS resource plan appears to overly focus on the near term.

2.1.1 Does Terasen see any merit in the CEC concern and if not why not?

Response:

Please refer to the response to CEC IR 2.1.1.1.

2.1.2 Does Terasen do planning for alternative scenarios of the competitive future beyond what is shown in the application?

Response:

Please refer to the response to CEC IR 2.1.1.1.

2.1.3 Does Terasen believe that its strategies and plans might be very different in the event of one or the other of widely divergent scenarios emerging as reality in the future?

Response:

Please refer to the response to CEC IR 2.1.1.1.

3. Reference: Exhibit B-6, CEC 4.2

This response includes three examples of factors that can influence fuel switching and fuel choice. Quantifying these factors, however, remains a difficult challenge and the Terasen Utilities have limited their analysis of energy price differential to that contained in Section 2.1 of the LTRP.

3.1 The CEC is concerned about fuel switching, particularly as it may relate to BC Hydro getting into using expensive $140/MWh electrical power in resistance heating to displace natural gas, with its carbon tax included in its price, and having a much lower costs to individuals and society. This potentially makes this form of fuel switching very cost ineffective for GHG reduction, particularly relative to an array of other options. The CEC believes that Terasen needs to plan for scenarios of much more aggressive gas to electricity fuel switching. The CEC believes that strategies and policies focused on this issue are important for long-term planning. The CEC believes that Terasen's strategy of pursuing fuel switching from diesel to natural gas is critically important to the company and its customers. The CEC is concerned that Terasen's long term plans do not show scenarios of aggressive pursuit of fuel switching and is concerned that Terasen may not be doing enough in this area.

3.1.1 Does Terasen have different plans for the range of potential fuel shifting policy scenarios which could emerge?

Response:

Please refer to the response to CEC IR 2.1.1.1.

3.1.2 Does Terasen believe that its strategies and plans may be significantly different under different fuel switching scenarios?

Response:

Please refer to the response to CEC IR 2.1.1.1.

3.1.3 Does Terasen see any merit in the CEC concerns and if not why not?

Response:

Please refer to the response to CEC IR 2.1.1.1.

4. Reference: Exhibit B-6, CEC 5.1

The Terasen Utilities does not currently forecast or rely on external forecasts of the development of new technology. While the methodologies for forecasting growth in alternative energy customers and demand are still under development, the exercise is generally based on proven, commercial ready technologies. As discussed in Action Plan item 10 of the LTRP (Exhibit B-1), the Terasen Utilities will continue to monitor for new energy technologies emerging within the marketplace and assess their impact on both the growth of alternative and conventional energy and customers.

4.1 The CEC is concerned about the way in which technology development over the next 20 years can and will affect the Terasen resource plans. It would appear that Terasen may have both opportunity and significant challenges developing from the development of various forms of technology. The CEC is concerned that various technology scenarios are not modeled and projected over the Terasen resource plans as part of ensuring that the Terasen plans are sufficiently robust to handle the potential futures over 20 years.

4.1.1 Does Terasen find any merit in the CEC concerns and if not why not?

Response:

Please refer to the response to CEC IR 2.1.1.1.

4.1.2 Does Terasen believe that the development of certain technologies may have significant effect on the strategies and plans of the company over the next 20 years depending on which potential scenarios develop?

Response:

Please refer to the response to CEC IR 2.1.1.1.

4.1.3 Does Terasen believe that its response time to the development of various technology scenarios is such that it can wait for them to evolve before responding?

Response:

Please refer to the response to CEC IR 2.1.1.1.

5. Reference: Exhibit B-6, CEC 6.1 and Exhibit B-1, Page 111

> The low carbon fuel strategy is an example of an initiative that the Terasen Utilities are considering to help achieve government legislative targets. The anticipated load growth from the transportation sector would be an important offset to the levelling off of demand growth from residential and commercial customer segments and would help optimize the use of the existing natural gas infrastructure to the benefit of all of the Terasen Utilities' customers, while reducing province wide GHG emissions.
>
> ***4.3.3.4 Scenario Implications***
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> Figure 4-22 shows the load growth and total number of NGVs expected in each of the three NGV demand scenarios. The Utilities have estimated[104] that in the Favourable NGV Environment Scenario, 30 PJ of natural gas demand for transportation represents about 6.5% of the total target transportation market in 2030 (Figure 4-23). Capturing 6.5% of the transportation fuel market over the next 20 years is a reasonable expectation for this low carbon alternative to conventional fuel.

5.1 Given the existing economic advantage of natural gas over diesel and the GHG reduction environmental benefits of natural gas over diesel, why wouldn't Terasen examine scenarios involving the transformation of the trucking transportation market?

Response:

TGI believes that the scenarios used in the LTRP to examine potential future load growth are reasonable. The responses to CEC IRs 2.5.2 through 2.5.8 provide additional insight into how TGI developed its expected NGV growth scenario rather than a more aggressive market transformation scenario. If future events unfold such that a higher growth rate in the NGV market is possible and appears likely, TGI will adjust its forecast of demand growth for this sector accordingly.

The Terasen Utilities believe that there are no strong reasons why TGI should not develop the market for natural gas as a transportation fuel. The load generated by NGV is not subject to seasonal variations and, as shown in the response to BCUC IR 1.23.1, if the load can successfully be developed all customers will benefit from lower delivery rates. Pursuing NGV markets can deliver:

- Environmental benefits in the form of cleaner air and lower GHG emissions;
- Economic benefits from using a BC produced fuel;
- Operating cost reductions for NGV customers; and
- Lower delivery rates for all TGI system consumers.

On balance, the Terasen Utilities believe that pursuing the development of NGV markets in BC is in the best interests of ratepayers.

5.2 What does Terasen believe may be additionally required to see a market transformation?

Response:

The Terasen Utilities' NGV market development strategy involves stimulating early adopters to adopt NGV technology by providing incentives to offset the higher initial capital cost of the vehicles. TGI has a limited budget to support this incentive approach.[1] It would be very useful to have a larger incentive budget to support early adoption of NGVs within key market influencing customer operations.

Customers also face capital cost challenges with respect to investing in maintenance shop upgrades for gas safety. Programs to help address these costs would speed the uptake of NGVs.

Additional government policy drivers and or incentives would also lead to quicker and higher rates of adoption of NGV's. For example, the recently introduced accelerated capital cost allowance provisions introduced by the Quebec provincial government[2] would assist in market transformation.

5.3 What are the implications for the Provincial Government's GHG target reductions if only 6.5% of the trucking transportation market has shifted by 2030?

Response:

Based on TGI's NGV demand forecast, if 6.5% of the trucking transportation market shifted to natural gas by 2030 approximately 844,000 tonnes of CO_2e reductions would be achieved. TGI believes its GHG forecast is relatively conservative as the baseline comparison of GHG emissions is based on new gasoline and diesel vehicles rather than older, less efficient vehicles.

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1 Please refer to page 61 of the 2010 LTRP.

2 http://www.prnewswire.com/news-releases/westport-announces-robert-transport-order-for-180-peterbilt-lng-trucks-powered-by-westport-hd-systems-105996703.html

As discussed in CEC IR 1.6.2, the Province has set GHG emissions reduction targets of 33% below 2007 levels by 2020 and 80% below 2007 levels by 2050. Assuming a target of approximately 50% by 2030, the Province would need to achieve nearly 34 megatonnes (Mt)[3] of CO_2e reductions.[4] Assuming the transportation sector market would still represent 36% of total emissions, approximately a 12 Mt reduction by 2030 would be required. If favourable market conditions occur, TGI's NGV program could contribute reductions of 0.84 Mt, or 7%, to help achieve this goal. The development of biogas resources for use as transportation could have the potential to reduce GHG emissions even further.

5.4 Are there inherent impediments to transformation of the trucking transportation market that limit Terasen to achieving only 6.5% by 2030?

Response:

The Terasen Utilities discuss the market conditions which would need to occur under the Favourable NGV Environment Scenario to reach 6.5% by 2030 on page 108 of the 2010 LTRP. The absence of these factors would act as impediments to reaching a target of 6.5% or beyond.

In summary, impediments may include:

- A lack of incentive funding to reduce the incremental vehicle cost;
- An absence of favourable public policy to support the use of natural gas as a transportation fuel to meet climate action legislative targets;
- A narrow price advantage (or disadvantage) of natural gas over gasoline and diesel fuels overtime; and
- A limited number of Original Equipment Manufacturer ("OEM") vehicle options available within British Columbia.

Furthermore, if market transformation does not occur, economies of scale will not help to decrease the capital costs for NGV equipment. Similarly, a network of fuelling infrastructure may also fail to develop.

The degree, or severity, to which these impediments exist will ultimately impact the market penetration target over the long-term.

[3] One megatonne (1 Mt) is one million tonnes.

[4] Total GHG emissions in British Columbia in 2007 were 67.4 Mt of CO2e

Alternatively, if favourable conditions exist, it is possible that a tipping point in market transformation to NGVs could occur leading to much higher levels of market penetration. At the outset of development of the NGV market it is not possible to predict the timing or magnitude of this scenario.

5.5 What is the natural turnover rate for the trucking transportation fleet?

Response:

TGI believes the turnover rate for the trucking fleets in British Columbia is between 4 and 10 years.[5] Long-haul Class 8 tractors which operate an average of 300,000 kilometres per year may require replacement every 4 to 7 years. Short-haul vocational trucks such as refuse haulers which operate an average of 40,000 kilometres per year may require replacement every 8 to 10 years.

After fleet operators replace their trucks, vehicles can often be maintained and used in future service applications. Over the long-term, TGI believes a secondary market for NGVs could emerge as NGV adoption occurs under favourable market conditions.

5.6 What are the potential options for further GHG reduction beyond conversion to natural gas?

Response:

The Terasen Utilities foresee a few areas for further GHG emissions reductions. These include:

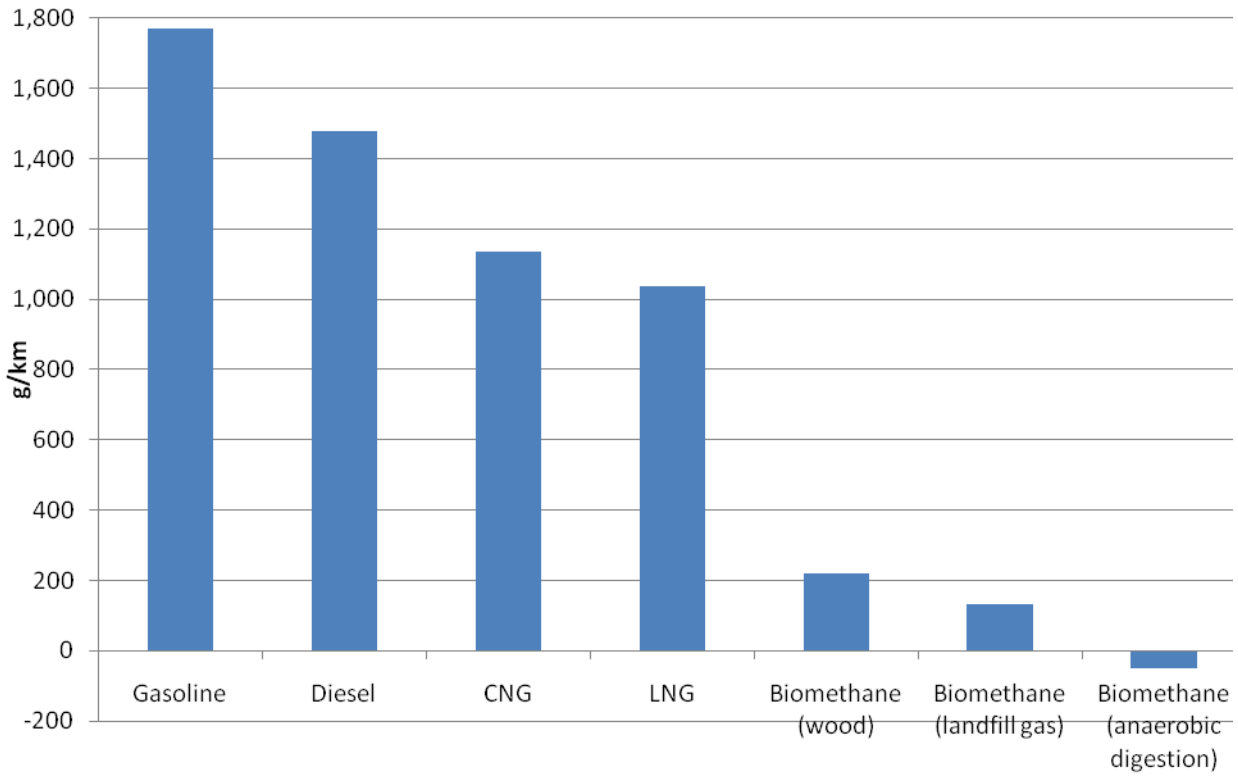
- **Addition vehicle uptake.** Beyond the Favourable NGV Environment Scenario in TGI's NGV demand forecast, the Plus Passenger scenario considers the momentum new NGV initiatives cause and the development of NGV solutions in the passenger vehicle market category. This scenario forecasts approximately 1.1 MtCO2e of GHG emission reductions by 2030.
- **Continued improvements in NGV engine technology.** NGV engine technology has already progressed significantly since the 1990s with respect to reliability and performance. Over the long-term, further efficiency improvements could result in greater GHG emissions reductions.

[5] Based on TGI conversations with large fleet operators in BC.

- **NGV Hybrids.** Greater opportunities within the transportation exist with the advancement of CNG-Electric Hybrid vehicles. These vehicles could provide further GHG emissions reductions when replacing diesel fuelled vehicles. Most recently, Tata Motors introduced CNG-Electric Hybrid Low-floor buses for service during the Commonwealth Games in October 2010.[6]

- **Increased use of biomethane as a transportation fuel.** Heavy duty vehicles operating on CNG result in 23% fewer lifecycle emissions than diesel, and LNG 27% fewer emissions than diesel equivalents.[7] Sourcing fuel from biomethane sources could achieve 85% - 103% fewer lifecycle emissions than diesel. In the short-term, anaerobic digestion and landfill gas sources are possible, and over the long-term gasification and methanation of syngas can provide biogas sources. The following chart summarizes these fuel types on a grams per kilometre basis.

Biomethane Advantage Relative to other CO2e Fuel Lifecycle Emissions



Source: GHGenius 3.18, BC

[6] NGV Global, September 21, 2010, http://www.ngvglobal.com/tata-delivers-cng-hybrid-buses-in-time-for-commonwealth-games-0921

[7] Based on data from Natural Resources Canada's GHGenius model 3.18, www.ghgenius.com

5.7 What are the resource plan implications of a more robust transformation of the trucking transformation market?

Response:

A more robust transformation of the trucking market to natural gas would lead to higher load additions which could potentially lead to the need for system improvements. The type and nature of system improvements will also depend on the changes in demand for natural gas in its traditional application such as space and water heating. The load additions from NGV markets are not seasonal in nature; hence they are attractive in that they will increase system utilization during the non-heating season.

CNG load additions can be expected to be broadly spread across the network as compression and dispensing stations would be added at the customer's fleet locations with some potential impact on system infrastructure.

LNG load additions will need to be serviced primarily through the Terasen Utilities' Tilbury LNG Facility. LNG production capability at Tilbury is 5,300 GJ/day and the Terasen Utilities are presently limited to 1,040 GJ per day of LNG sales for transportation markets. As LNG sales for transportation applications grow the Terasen Utilities will need to make applications to increase the allowed level of LNG sales under Rate Schedule 16. Incremental investments in LNG production, storage and shipping assets will need to be made at the Tilbury location to facilitate further growth.

The projected volumes for LNG sales in the Favourable NGV Environmental Scenario indicate that the supply chain will need to be expanded in the 2015-2020 timeframe. Such expansion depends on volume growth in LNG markets. The incremental costs of such expansions would be borne by LNG customers. The Terasen Utilities are exploring the cost-benefit of such expansions and would need to justify such investments through the CPCN process.

5.8 What more could Terasen do to remove barriers to a much more robust transformation of the trucking transportation market?

Response:

Additional activities that TGI might undertake to enable a more robust transformation of the trucking transportation market could include:

1. Providing assistance to customers with respect to their costs in establishing "gas safe" maintenance facilities. (This relates to safety modifications to address the possible release of natural gas in maintenance operation – methane detectors, increased ventilation etc.).

2. Establishing public access to the private fueling facilities being established under the LTRP.

3. On a limited basis, building out fuelling infrastructure in advance of load commitments to lessen the entry barrier for an operator considering adding only one or two vehicles to a fleet.

4. Actively promoting and communicating the benefits of NGVs to the trucking industry and the general public.

5. Developing a bio-LNG supply capability. For example by capturing and upgrading Landfill Gas.

6. Adding technical resource capability to assist customers in assessing and implementing NGVs for their operations.

7. More aggressive lobbying of provincial and federal governments for policy measures encouraging NGV adoption and incentives.

TGI's activities in support of NGV adoption reflect the resources available to the Terasen Utilities and recognition that there is inherent risk in development of any emerging market that needs to be managed. The activities contemplated in the LTRP minimize development risk to customers while providing the opportunity to achieve load additions that will provide substantial delivery rate benefits to our customers as discussed in BCUC IR 2.23.1. Please also see response to CEC IR 2.10.5.

5.9 Does Terasen find any merit in the concerns implied in the CEC questions above and if not why not?

Response:

The Terasen Utilities agree that certain market conditions could potentially lead to a future scenario with a higher market capture rate. However, given the responses to those IRs, the 4-year time frame of the LTRP Action Plan and the Terasen Utilities' 2 year resource planning cycle, we believe that basing our action plan with respect to NGV initiatives on a market capture rate of 6.5% is appropriate. We would not expect that analysis of a future scenario with a more

aggressive capture rate would change the Action Plan set out in the 2010 LTRP. Further details and analysis of the NGV market will be available in the upcoming submission to the Commission for TGI's new NGV initiative.

6. Reference: Exhibit B-1, Page 113

> **4.3.4 CONCLUSIONS FOR NEW FORECASTING ACTIVITIES**
>
> The Terasen Utilities' forecasting activities are evolving to capture the changes that are underway in our customers' energy demand patterns as a result of external forces such as changing energy policy and buildings codes and standards, as well as our own initiatives to better serve the needs of our customers. While these changes will not have a marked impact in the short term on natural gas demand, we need to be developing new methodologies in forecasting now to better understand the implications over the long run. The Utilities intend engage their stakeholders in the ongoing development of these new forecasting activities, and will continue to improve our methodologies as we gain further market experience and as new information becomes available.

6.1 Please describe the nature of the proposed engagement and the target date for the implementation of these new methodologies into the Terasen resource planning.

Response:

The Terasen Utilities plan to explore and test the new methodologies as additional information becomes available through ongoing research and analysis. At such time when the Terasen Utilities develop confidence in the data, we intend to bring forward the development of forecasting activities for an appropriate review by stakeholders. The consultation activities may include the Resource Planning Advisory Group (under development), resource planning related stakeholder workshops and/or potentially focused meetings with selected stakeholders to seek input and acceptance.

It is hoped that these initiatives will provide valuable input into future energy and emission reduction decision making, but at this time it remains too early to identify a date for completion and full implementation of the new methodologies.

6.2 Has Terasen mapped out and made cost estimates for the infrastructure investments required to service the transformation of the trucking transportation market?

Response:

TGI has made cost estimates on fuelling station infrastructure for each of its target vehicle categories based on conversations with fleet operators and preliminary quotations from engineering contractors. The approximate cost of each fuelling station is listed in the table below.

Estimated Cost of Fuelling Stations

Category	Station Capital Assumption
Passenger Cars	$ 250,000
Light Duty Trucks	$ 250,000
Medium Duty Trucks	$ 400,000
Heavy Vocational Trucks	$ 750,000
Heavy Duty Trucks	$ 750,000
Buses	$ 1,000,000
Marine	$ 1,500,000

These cost estimates will continue to be refined and updated when TGI starts its NGV program and once construction begins on fuelling station projects.

TGI has mapped out infrastructure costs for fuelling stations over the short-term. The following analysis is based on a scenario which will be submitted in the Transportation Fuelling Service Application in late 2010:

Under the Reference Case scenario, TGI expects a total of 23 fuelling station additions over the next five years. Multiplied by the assumptions in the following table, TGI anticipates it will require the following incremental capital investments to fund infrastructure projects.

Station Capital Requirement of $16 million Over Next Five Years

	2011	2012	2013	2014	2015
Number of Stations	3	3	4	4	9
Station Capital	$2,500,000	$1,400,000	$2,750,000	$2,750,000	$6,400,000

These capital investments will be recovered through a fuelling service tariff charged to the fleet operators who use the station.

6.3 Does Terasen expect only to include in its resource planning projections based on its specific market experience or would Terasen be prepared to examine scenarios with much broader strategic and policy context implications?

Response:

For planning purposes the Terasen Utilities have included projections based on historical analysis and future expected trends for its existing and new natural gas customers where historical data exists. This projection is based on specific market experiences across the different customer groups and current policy context.

However, the long range planning and strategies may be impacted by future provincial policy and alternative future scenarios. A range of alternate future scenarios are possible with variations in future energy prices, customer rates, fuel switching policies and technology advancements. At this point, limited data exists on the impact that such scenarios may have on natural gas demand and as such it is challenging at this time to estimate projections with any degree of accuracy. For this reason the Terasen Utilities have conceptually described the type of solutions under consideration and how we would examine their impact on demand. The use of new forecasting methodologies are not considered for planning purposes at this point in time. Going forward we will be monitoring the development of external changing market conditions and the policy environment on customer demand and preferences and include projections for planning purposes as meaningful data becomes available from ongoing research and market experience. Please see also the response to CEC IR 2.1.1.1.

7. Reference: Exhibit B-6, CEC 22.3

> The representative 100-unit condominium employed to develop Figure 4-19 would use 4,594 GJ/year of input energy (natural gas and electricity) if the building was configured with a conventional energy system. On the other hand the alternative energy system selected would only consume 1,891 GJ/year of input energy (mainly electricity to run the heat pumps with some natural gas use as backup in the colder winter conditions) to yield the same output. The particular AES example used in Figure 4-19 therefore results in a 58.8% efficiency improvement relative to a conventional system. The input assumptions for the representative 100 unit condominium example are described in detail in Appendix B-6 of the LTRP.

7.1 Is the 58.8% efficiency improvement relative to the conventional system a reference to a 90% or 95% high efficiency furnace standard, to lower efficiency furnaces which would be the target for replacement or to the existing average across Terasen's existing market?

Response:

The 58.8% efficiency improvement does not reference to any of the efficiencies of the furnaces. The representative 100-unit condominium assumes a conventional energy system of domestic water heating ("DWH") and space heating using a gas boiler with an efficiency of 75%.The details of energy usage assumptions are in appendix B-6.

7.2 Is this figure just the energy efficiency or is this the cost effectiveness efficiency?

Response:

The figure referenced in the question is just energy efficiency.

8. Reference: Exhibit B-6, CEC 22.4

> The Terasen Utilities has calculated an effective cost for GHG emission reductions using a present value of the cost differential between the conventional and alternative systems divided by the present value of the GHG emission reductions. The effective cost for GHG emission reductions varies considerably based on the evaluation period employed. Using the electric baseboard system as the basis for comparison, the effective cost of the GHG reductions for the geoexchange system is \$176/tCO_2 over a 20-yr evaluation period or \$42/tCO_2 based on a 35-year evaluation period. With the hydronic gas system as the basis for comparison, the effective cost of the GHG reductions is \$131/tCO_2 over a 20-yr evaluation period or \$71/tCO_2 based on a

8.1 Why is the comparison with the hydronic gas system showing a higher \$/tCO2 for a 35 year evaluation period than the comparison to the electric baseboard, which has higher 20 year evaluation \$/tCO2?

Response:

In the process of preparing this response an error was discovered in the calculations used to determine the GHG cost per tonne results for CEC IR 1.22.4. The original calculations had incorrectly failed to include the cost of replacement geoexchange equipment and gas boilers at the end of their useful life.

The corrected results for CEC IR 1.22.4 are as follows:

Comparison of Geoexchange to an Electric Baseboard / Gas boiler system:

20 yr term: \$112/tCO2
35 yr term: \$40/tCO2

Comparison of Geoexchange to a Hydronic Gas System:

20 yr term: \$137/tCO2
35 yr term: \$101/tCO2

With this correction, the cost per tonne results for the comparison of a geoexchange system to electric baseboard / gas boiler system are lower over both time periods than for the comparison to a gas hydronic system.

9. Reference: Exhibit B-6, CEC 25.1

> This initiative is part of the overall EEC program. Under the program TGI will offset up to 100% of the incremental cost of purchasing NGV's versus conventionally fuelled vehicles. The amount approved is subject to a business case assessment which includes a Total Resource Cost test.
>
> The amount of the support incentive will vary by the type of vehicle being proposed and the amount of diesel fuel displaced. A garbage truck for example may receive an incentive of $26 - $55,000. A heavy duty long haul LNG tractor may receive an incentive of up to $80,000.
>
> Funds available under this program are limited and it is TGI's intention to utilize the incentives on key customers that have an ability to influence market adoption. TGI is also seeking to leverage this incentive program with similar programs expected to be launched by federal and provincial governments in 2011. That may lead to lowering TGI's contribution from 100%.

9.1 Would it be fair to say that Terasen and potentially the federal and provincial governments may be working toward programs to incent the entire transformation of the trucking transportation market toward natural gas in LNG or CNG form, such that the capital investments required of trucking companies are similar to their costs for diesel trucking?

Response:

It is the Terasen Utilities' belief that TGI, provincial government, and federal government objectives are in alignment with respect to the goal of encouraging market transformation to natural gas in the heavy duty trucking segment. Higher initial capital cost has been identified as a major barrier in the NRCan NGV for Transportation Roadmap (included in Attachment 9.1). The Terasen Utilities' EEC incentive program addresses this issue for early adopters. As market transformation occurs, capital costs may well decrease toward that of the pre-program (diesel technology) level, thus reducing the barriers to technology adoption for late adopters with lower or no incentives offered. Government policy or regulation may also play a role in later stages of market transformation. Provincial policies such as the Low Carbon Fuel Requirements Regulation in BC[8] and accelerated capital cost allowance program in Quebec[9] indicate provincial government support for market transformation. As the use of natural gas for transportation creates demand for a BC produced product, market transformation will also generate natural gas production royalty revenues for the BC Government and increased economic activity in the northeast region of the province.

In summary, there is a strong alignment of interests to favour a coordinated development of NGV markets.

[8] http://www.empr.gov.bc.ca/RET/RLCFRR/Pages/default.aspx

9.2 In regard to the trucking transportation markets is Terasen in discussions with the Provincial Government with respect to whether or not the HST applicable to natural gas relative to no HST on diesel makes sense in regard to the desirability of transforming the tucking transportation markets?

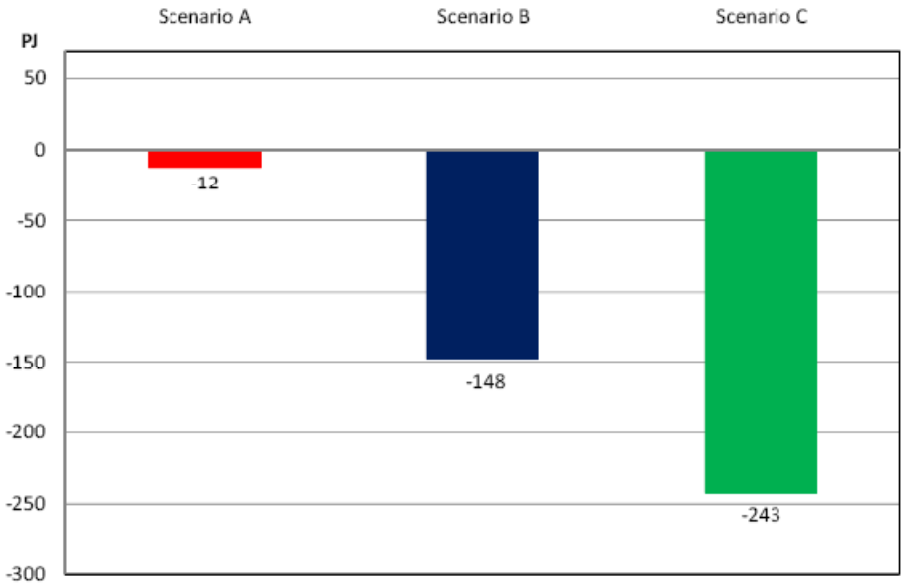
Response:

TGI has expressed its concern over the HST applicability on natural gas relative to diesel to the Provincial Government. The concern was recognized but is not likely to be addressed.

With respect to the impact of the HST, TGI does not believe this will be a significant barrier for most large trucking fleet operators. Since the HST is a "flow through" tax, HST paid on fuel can be recovered as a credit by the trucking operator when submitting HST collected on the value of the customers end product (for example the rate charged for collecting refuse).

10. Reference: Exhibit B-1, Page 122 and CEC 25.1

Figure 5-1: Year 2009 - 2030 Cumulative Natural Gas Savings from EEC Scenarios



Response:

The Terasen Utilities believe that approval of a five-year funding envelope would be appropriate. This would provide many of the benefits that come along with long-term funding. The primary benefit would be the certainty for the various actors in the marketplace that "efficiency is here to stay" and that investments made in advanced equipment and building development, training and the establishment of installation protocols and market transformation work in advance of regulations are worthwhile and will have lasting payoffs. A five-year funding envelope would also free up the EEC staff from the work associated with more frequent EEC funding applications. Oversight of the Terasen Utilities' EEC activity would be provided formally by the EEC Stakeholder group, which includes representation from the Commission and currently meets semi-annually, and through the EEC Annual Report to the Commission and stakeholders, as well as on an informal basis.

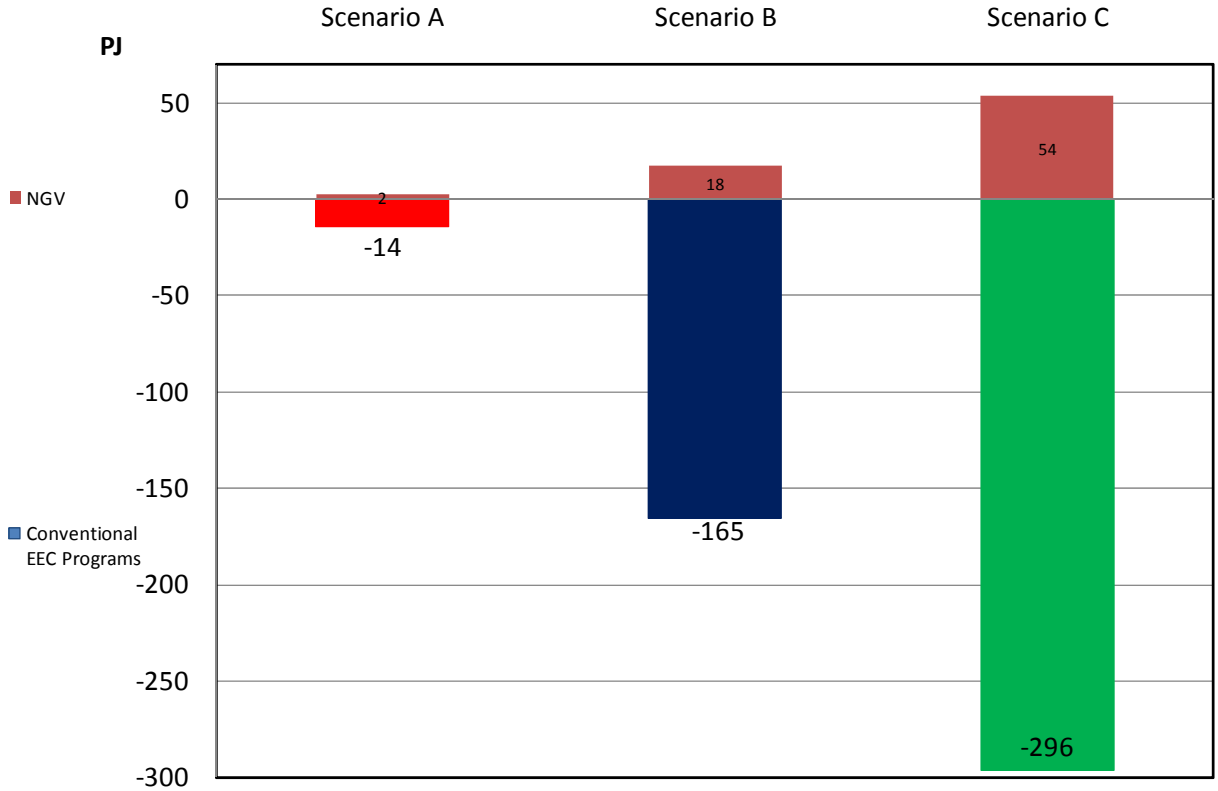
10.1 Does the metric used for the EEC savings make the trucking transportation investments awkward to reflect as savings or does Terasen have a methodology for reflecting the full benefit of transforming this market?

Response:

The figure referenced in the question illustrates net savings that include the sum of energy conserved from conventional EEC programs and efficient load building from the addition of natural gas vehicles. The figure 5-3 (page 123) of the 2010 LTRP illustrates the total reduction

in GHG emissions from conventional EEC programs and natural gas vehicles. The Information Request makes a valid point, however, and moving forward, it would probably be valuable to separate natural gas reduction initiatives from high-carbon fuel substitution initiatives in order to provide a more transparent view of the Terasen Utilities' EEC activity. This has been done in the figure below. In the case of NGV, the Terasen Utilities do not have a formal methodology for reflecting the full benefit of transforming this market as the development of natural gas as a transportation fuel is in the initial stages. At a high level the Terasen Utilities believe that the benefit of transforming this market will reduce province wide GHG emissions and utilize existing natural gas infrastructure to the benefit of all the Terasen Utilities' customers.

2009 - 2030 Gross Cumulative Savings and efficient load building from EEC Programs



10.2 Would longer term funding plans matching the full scope of plans to transform certain markets, including the trucking transportation markets, be a more effective and stable as a means of encouraging more effective results for Terasen and particularly for its customers?

Response:

Principle #12 as listed on page 48 of the TGI and TGVI's EEC Application states:

> *"Programs will have market transformation as their ultimate goal, and program plans will describe how a program will contribute to market transformation."*

Market Transformation was discussed in Chapter 8 of the TGI and TGVI's 2009 EEC Annual Report.

Timelines for market transformation efforts will vary by activity, depending on how far along the market transformation curve a particular technology might be. For example, in the case of water heaters, the Government of Canada is looking at implementing regulation requiring more efficient water heaters in the 2016 time frame, 6 years from now. In the case of trucking transportation, a full-scale market transformation effort to the point where there is sufficient penetration of the low-emission natural gas technology such that government can introduce regulation requiring that technology as the minimum standard would take longer. The certainty associated with laying out and fully funding market transformation efforts around each efficiency/emissions measure would be highly effective and stable in terms of encouraging effective results for the Companies and more importantly, for customers and for other market players. This would, however, be a departure from the usual Regulatory processes around DSM funding approvals. It would require that the Terasen Utilities file complete market transformation plans for the measures for which funding is being requested, and each plan would have a different funding level and length, depending on the technology. Market transformation plans would need to include activities to address each of the market barriers identified in the plan, such as ensuring that there is adequate supply of the efficiency measure, and that training of installers of the measure has been planned for and funding allocated for same. Such an approach could also address some of the limitations of the TRC, as the measure of effectiveness of market transformation plans and DSM funding for same could be market penetration, rather than just TRC.

10.3 What impediments does Terasen see to getting program approval for plans which envisage full market transformations in at least a few key strategically important sectors?

Response:

As noted in the response to CEC IR 2.10.2, approval of multi-year market transformation funding would constitute a departure from the status quo, which could be a potential impediment.

Another potential impediment would be capacity in developing, analyzing and approving market transformation strategies and plans, as this is not a skill that is readily available in the BC marketplace. This potential impediment could be addressed, with time and training.

A further potential impediment could be the availability of market penetration data in order to assess whether transformation efforts are working; there is some appliance shipment data for example that is difficult to obtain. This impediment could be addressed, however, through regulation requiring the disclosure of shipment data from all entities selling equipment in British Columbia.

Another potential impediment could be the extent of program costs. The Condensing Water Heater Initiative discussed in Chapter 8.3 of the TGI and TGVI's 2009 EEC Annual Report, and in Appendix I of the same document, has a conservative 7 year budget estimate of $26.1 million. Market transformation efforts for such program areas as the trucking transport market and multi-family and commercial new construction would have much higher costs, incentives and budgets associated with them.

10.4 Does Terasen find any merit in the CEC concerns reflected in the above questions and if not why not?

Response:

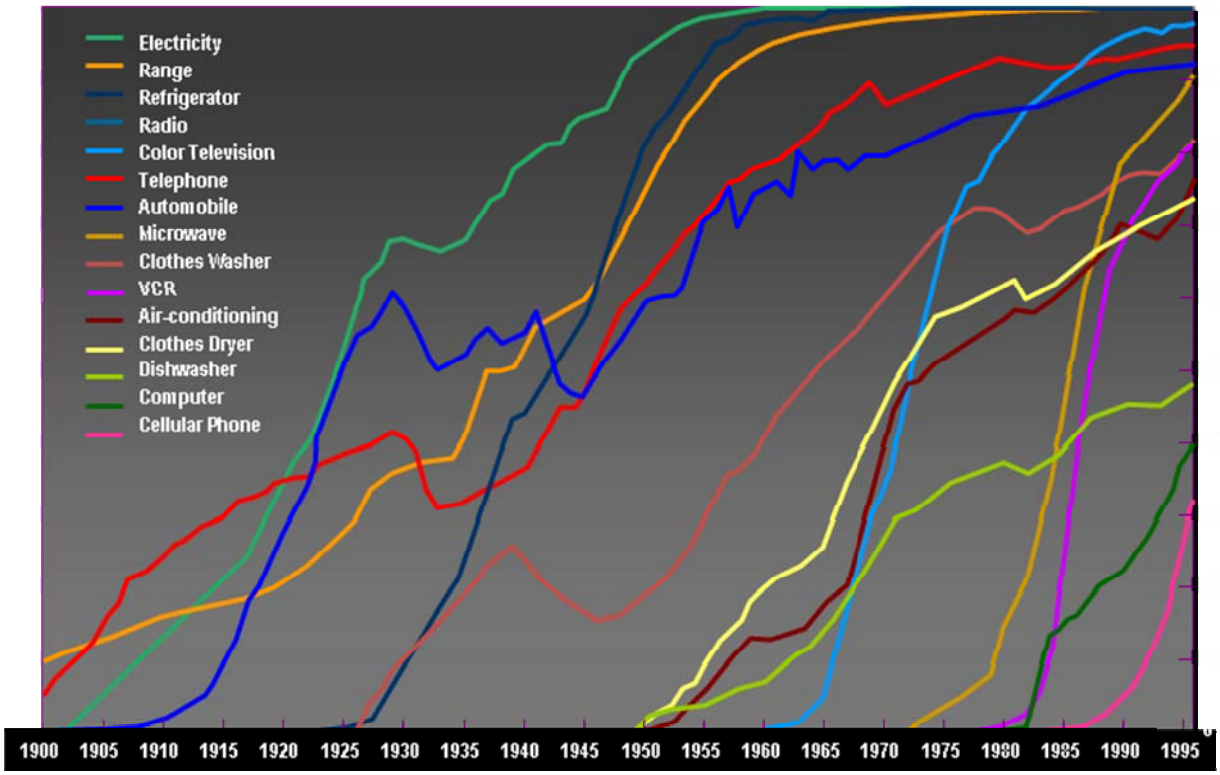
It is the view of the Terasen Utilities that taking a market transformation approach to at least some sectors, where a full market transformation plan is laid out and funding approval provided, would have great merit. It would provide the market actors in the sector with certainty so that they would have some confidence needed to make their investment in the transformation effort, would provide government with a clear path to the introduction of regulation, and would be a more efficient approach to funding approvals. Accountability could be provided through more frequent meetings of the stakeholder group, and through regularly scheduled reporting to stakeholders including the regulator.

10.5 Would Terasen's resource plans be more robust and reflect more cost-effective results for customers if they were to include scenarios for making full market transformations of the trucking transportation markets?

Response:

The three scenarios presented for NGV market development in the LTRP cover a range from 13 PJ to 35PJ of total demand. At present the NGV market in BC is only at 0.2 PJ of consumption. As shown in the figure below, emerging markets typically take many years to reach an inflection point in market adoption where rapid growth begins.

Adoption Rates for Emerging Markets - %of US Households with



Source: US Federal Reserve.

The Terasen Utilities believe there is little value to be gained at the outset of market development activities from planning for success rates greater than those contemplated in the LTRP. Rather, attention and detail should be concentrated on ensuring that initial development efforts are well executed to ensure that early adopters are successful and the market proceeds to the inflection point as rapidly as possible.

While the focus at this point in time needs to be on the more modest goals, the large potential for transforming the market need not be overlooked.

11. Reference: Exhibit B-6, CEC 27.1

Response:

Dependent upon the output capability, the development of a Cache Creek landfill operation as an alternative gas supply could possibly provide the following two benefits:

1. Defer or avoid the need to loop the Cache Creek/Ashcroft lateral.
2. Slightly reduce gas delivery from the Spectra T-south Mainline to Cache Creek/Ashcroft which could be diverted to the Lower Mainland.

However, the Terasen Utilities have not conducted analyses to determine whether the project is cost effective.

11.1 Would Terasen agree that its resource plan might be improved if potential projects such as the Cache Creek landfill alternatives were analyzed and included at some level of evaluation?

Response:

Note that the reference should be to Exhibit B-6, CEC IR 1.27.2.

As stated in Exhibit B-1, Page 143, the 17 km pipeline loop on the Cache Creek/Ashcroft lateral is required to provide capacity for firm transportation service if the industrial customer is prepared to underwrite the cost of the loop. The landfill operation as an alternative gas supply would need to be cost competitive to be a viable option.

The industrial customer has not expressed an interest for firm transportation service. Therefore, analysis of the landfill operation would not improve the resource plan at this time.

In general, analyses of potential alternatives to reinforce gas systems with capacity constraints would improve the resource plan. However, analyses could only be performed with the relevant information being available during the preparation of the resource plan.

12. Reference: Exhibit B-6, CEC 32.1

Response:

The Terasen Utilities believe that the development of renewable thermal energy solutions, increased energy efficiency programs and low carbon transportation fuel alternatives will not have a material impact for the near term based on information available at this point in time. The development and consideration of renewable thermal solutions became prominent only after the introduction of the 2007 BC Energy Plan. There is little historical data available to estimate trends. However, given British Columbia's energy objectives of reducing GHG emissions, the Terasen Utilities believe there will be impacts to our natural gas demand over the planning period of twenty years. The Terasen Utilities expect that in the 2012 LTRP, we will be able to provide more details on the nature, growth and impact that integrated energy solutions and our conservation efforts may have on demand in the near term as additional data becomes available.

12.1 Does this constraint effectively consign Terasen's resource planning to being (a) an historical trend projection process and not a long term resource plan (b) a near term planning process where every few years new developments are incorporated into the plans and not forecast in advance?

Response:

The Terasen Utilities do not believe that the constraints referenced in the preamble consign the resource planning process to include just the historical trends, or to only be a near term planning process. Rather, the integrated resource planning process needs to balance both a long term outlook and the ability to adapt to near term changes. At this time, the data available for examining long term growth of our alternative energy initiative is limited; however, over the near term this initiative will have limited impact on our natural gas infrastructure and planning than will the activities of our existing customer base of over 935,000 natural gas customers. Please see the response to CEC IR 2.1.1.1 for additional discussion in regard to balancing the need for a long range outlook with the need for adaptability to near term changes in the planning environment. The response to CEC IR 2.1.1.1 also discusses data gathering and analysis activities that the Terasen Utilities are undertaking to improve the long range forecasting for alternative energy services and their potential impact on our natural gas service.

13. Reference: Exhibit B-6, CEC 33.1

> However, expenditures for the development of natural gas as a transport fuel in the forms of CNG and LNG (as discussed in Exhibit B-1, Section 6.1.4, Page 150-153) and a portfolio of capital investments in a long term sustainment plan (as discussed in Exhibit E-1, Section 6.1.5, Page 153-159) have not been fully developed and therefore have not been included in the LTRP.

13.1 Would the Terasen resource plan be more reflective of anticipated reality if it were to include some approximation estimates for these issues?

Response:

As stated in the 2010 LTRP, the Terasen Utilities are not requesting approval of any capital plans with its submission. At the time of submission, TGI had not fully developed capital investments in a long term sustainment plan with respect to its NGV infrastructure, and therefore did not consider it prudent to include approximations. In its upcoming Transportation Fuelling Service Application, TGI will submit a capital plan as described in the response to CEC IR 2.9.2.

13.2 Is Terasen constrained in putting forward such plans primarily by the fact that it is too uncertain about these issues to have developed a full scale plan or is it constrained by timing and resources such that it was not able to develop such plans for this resource plan?

Response:

In regards to its NGV initiatives, the Terasen Utilities have been constrained by both of these factors.

Firstly, since TGI's demand scenarios are forecasts of possible developments in an emerging market, they are subject to inherent levels of uncertainty. TGI does not believe it would be prudent to release a full scale plan before sufficiently scoping the market demand for NGVs in BC and engaging with its various stakeholders. TGI expects to submit a more complete plan in its Transportation Fuelling Service Application in late 2010.

Secondly, timing and resource constraints have also impacted the planning process due to the fact that dedicated NGV resources have not yet been defined. TGI has not yet sought Commission approval of additional resources toward the development its NGV programs. Again, TGI intends to submit such a request in its Transportation Fuelling Service Application in late 2010.

Attachment 9.1

Natural Gas Use in Transportation Deployment Roadmap

DRAFT FOR DISCUSSION

Forward by Cassie Doyle

In Canada, we are blessed with an abundance of clean energy resources—including natural gas—which provides us with an opportunity to achieve significant benefits for our businesses and citizens. However, with this opportunity comes a significant responsibility to optimize the use of our resources so that they can provide maximum benefit to today's Canadians as well as future generations. The "Natural Gas Use in Transportation Roadmap" achieves this goal by defining the optimal use of natural gas for medium- and heavy-duty vehicles in Canada while recommending a process to increase this fuel's use in other vehicle applications in the coming years.

Optimizing the use of natural gas in the transportation sector has a number of important benefits, such as stimulating demand for this resource and accelerating new market opportunities for its use via the deployment of 'made-in-Canada' infrastructure and vehicle technologies. As a relatively inexpensive fuel, natural gas also has important economic benefits for fleets. Given projections of abundant natural gas supplies at affordable prices as well as numerous Canada-based natural gas vehicles and infrastructure suppliers, we are well positioned to take advantage of the NGV value proposition.

Recognizing this opportunity, governments at all levels, natural gas suppliers, vehicle and equipment manufacturers, end-users, as well as academic and non-governmental organizations have spent the past six months working diligently to achieve a common goal. The result is a roadmap that is truly groundbreaking in nature due to its unique emphasis on business modelling and consultation with end-users, which helped identify opportunities and challenges associated with NGV deployment. It is my hope that this roadmap will educate, guide, and coordinate future public and private sector actions that will make the deployment of NGVs a reality. The roadmap could also serve as a model to those who are working to enhance deployment of other alternative fuel vehicles.

I would like to thank those involved in this process for their dedication to ensure that this effort was a success. As this work was conducted, key stakeholders worked together in an unprecedented manner and at an unprecedented pace. Consensus-building played an essential role during the development of the roadmap's analyses and recommendations. Moving forward, similar stakeholder collaboration and dedication will be needed since our work is not complete. Other jurisdictions around the globe have embraced NGVs, and implementing the recommendations is the next phase of our work.

I look forward to continuing to work with Canada's natural gas community as we ensure that natural gas use in our nation's transportation sector is optimized.

[insert signature]

Table of Contents

Executive Summary 3

Introduction 7

Natural Gas Market Fundamentals 10

Natural Gas Use in Transportation (State of Play) 16

End-User Needs 23

The Value Proposition 28

Business Case Analysis 34

Natural Gas Education and Outreach 38

Technology Research and Development Needs 44

Recommendations 48

Roles and Responsibilities 50

Next Steps 51

Executive Summary

The Purpose

The Natural Gas Use in Transportation Deployment Roadmap was launched to define the optimal use of natural gas across the transportation sector in Canada. This initiative has been helpful in developing recommendations to governments, industry, and other stakeholders regarding best uses for natural gas in Canada's transportation sector. A number of factors have recently focused attention on the opportunity for natural gas in transportation, including a strengthened supply outlook for natural gas which underpins a price forecast that is relatively low compared to forecasted oil and electricity prices; increased availability of factory-built natural gas trucks and buses incorporating Canadian engine technologies, and the need to reduce carbon emissions from the transportation sector.

Why a deployment roadmap?

This deployment roadmap is groundbreaking in nature and distinguishes itself from technology roadmaps in two fundamental ways: 1) the detailed business modeling work that was performed to assess, analyze, and rank potential end-use applications in the medium- and heavy-duty portion of the transportation sector; and 2) the consultations that were undertaken that focused on various end-users that might adopt this technology. In addition, this roadmap's framework for assessing the true potential of natural gas vehicle adoption could also be used by those considering other fuel or technology pathways.

Process

The Roadmap was launched by the Deputy Minister of Natural Resources Canada at a March 12, 2010, roundtable meeting that included federal and provincial officials, industry representatives such as gas producers, distributors, truck and equipment manufacturers, and transportation end-users, as well as representatives from environmental non-government organizations and academia. During this meeting, working groups – consisting of industry representatives, energy and transportation experts as well as officials from Natural Resources Canada and provincial governments - were formed to focus on the following issues:

- Natural gas markets;
- Vehicle readiness and research and development (R&D);
- Infrastructure readiness and R&D;
- End–user needs;
- Codes and standards; and
- Market transformation and policy analysis.

Scope

As an initial step to develop the roadmap, working groups assessed opportunities for new natural gas markets in the on-road transportation sector (including light-, medium, and heavy-duty vehicles) as well as marine and rail applications. In the near-term, medium- and heavy-duty vehicles were found to offer the greatest opportunities for increased natural gas use in this sector. The prospects for natural gas use in other applications, including light-duty vehicles, marine vessels, and locomotives, were also found to be promising. However, due to more substantial technological and market barriers, these vehicle applications will likely require a longer timeframe to achieve wide-spread natural gas use. Because of this finding, working groups' subsequent work—which included conducting business case modeling, developing an education and outreach strategy, and examining RD&D requirements—focused primarily on medium- and heavy-duty applications.

The resulting roadmap aims to:

- Address fundamental knowledge gaps regarding stakeholder interest, capacity, and economic and environmental impacts;
- Inform public and private sector decision-making;
- Assist in determining long-term investment requirements by stakeholders;
- Outline key steps for implementation and define future government programming needs and industry's role.

The roadmap process has brought together a broad range of representatives from industry and government to develop a comprehensive strategy for expanded use of gas in selected transportation markets. The input of the participants has been most valuable in identifying key market and technology challenges, and potential governments and industry responses to these challenges.

Recommendations

The following set of recommendations was developed in consultation with stakeholders representing all working groups under this roadmap process. These recommendations have also been developed as a result of analysis related to business modeling work, capacity building needs and an assessment of research, development and demonstration requirements. Recommendations have been proposed in four key areas: (1) Capital Investments, (2) Research, development and demonstration, (3) Capacity Building, and (4) Overall Coordination.

Capital Investments:

1. Medium- and heavy-duty natural gas vehicles provide environmental and over-vehicle-life economic benefits, but the upfront capital vehicle premium is a barrier to adoption. Financial support is needed on a temporary basis to address the barrier to adoption and reduce the incremental cost of natural gas vehicles for fleet owners.

2. Significant financial investments are needed to ensure that the development of key corridor infrastructure, which may span across multiple jurisdictions, proceeds in a timely manner. L-CNG stations capable of dispensing both LNG

and CNG are recommended in key corridors.

3. Industry business models for financing stations for return-to-base operations should be able to support the development of individual stations on fleet owners' sites without the need for external support and such infrastructure can be shared with other fleets, thus improving the overall business case.

Research, development and demonstration:

4. The natural gas vehicle industry funds R&D activities at present. Further investment has the potential to enhance the competitive position of the industry through targeted investment in R&D. Priorities for future R&D include: eliminating the cost differential between natural gas and diesel vehicles over the long-term and maximizing the operational and environmental benefits of natural gas vehicles.

5. Demonstration of the use of natural gas is needed to address technical barriers, develop standards, as well as to conduct feasibility studies and business cases. In particular, demonstrations of renewable natural gas in targeted applications such as refuse trucks are needed to provide tangible displays of this technology to potential end-users.

Capacity Building:

6. A holistic education and outreach strategy is needed to target end users as well as market influencers and other key stakeholders. This strategy should be comprised of both a 'top-down' and 'bottom-up' approach. A 'top-down' approach would include a central website or all target audiences with local content tailored to specific jurisdictions. A 'bottom-up' approach would feature a local support network for end-users and access to resources including workshops and case studies of local fleets.

7. A 'safety - codes and standards' working group needs to be established to develop mitigation strategies to address gaps and issues in existing codes and standards identified during this roadmap process. Separate committees for LNG and for CNG should be formed to develop new codes and standards based on these strategies.

8. Appropriate training materials for station and vehicle repair and operation as well as for cylinder inspection need to be developed and delivered.

Overall Coordination:

9. An NGV implementation body—consisting of select roundtable members and other key stakeholders—should be established to:

   - Support and advance the implementation of the roadmap's recommendations and assess progress versus key milestones;

- Provide recommendations to stakeholders regarding how the natural gas community could respond to future developments, such as changes in market conditions and technological innovations;
- Act as an umbrella organization for the local support network for end-users;
- Serve as a forum for stakeholders who participated in the roadmap process to continue discussing issues pertinent to the natural gas community.

10. The timely development of inter-jurisdictional corridor infrastructure development will require a coordinated approach to ensure that infrastructure build-up matches demand and is strategically located to support end-users.

11. Continue to explore potential for natural gas use in other transportation and non-transportation applications.

Roles and Responsibilities

The following stakeholders have been identified as parties who would take on roles and responsibilities as they relate to moving the recommendations of this roadmap forward.

Natural Gas Use in Transportation: Roles and Responsibilities

		Governments	NG Producers and Distributers	Infrastructure and Vehicle Supply Stream	End-Users
Capital Investments	Vehicle Premium	√			√
	Corridor Infrastructure	√	√		
	Return-to-Base Infrastructure		√	√	√
RD&D	R&D	√		√	
	Demonstrations	√		√	√
Capacity Building	Education and outreach	√	√	√	
	Codes and Standards	√	√	√	
	Training	√	√	√	
Overall Coordination	Implementation Committee	√	√	√	√
	Corridor Infrastructure	√	√	√	
	Use of NG in Other Applications	√	√	√	

Introduction

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This deployment roadmap is groundbreaking in nature and distinguishes itself from technology roadmaps in two fundamental ways: 1) the detailed business modeling work that was performed to assess, analyze, and rank potential end-use applications in the medium- and heavy-duty portion of the transportation sector; and 2) the consultations that were undertaken that focused on various end-users that might adopt this technology. In addition, this roadmap's framework for assessing the true potential of natural gas vehicle adoption could also be used by those considering other fuel and technology pathways.

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- Market transformation and policy analysis.

Scope

As an initial step to develop the roadmap, working groups assessed opportunities for new natural gas markets in the on-road transportation sector (including light-, medium, and heavy-duty vehicles) as well as marine and rail applications. In the near-term, medium- and heavy-duty vehicles were found to offer the greatest opportunities for increased natural gas use in this sector. The prospects for natural gas use in other applications, including light-duty vehicles, marine vessels, and locomotives, were also found to be promising. However, due to more substantial technological and market barriers, these vehicle applications will likely require a longer timeframe to achieve wide-spread natural gas use. Because of this finding, working groups' subsequent work—which included conducting business case modeling, developing an education and outreach strategy, and examining RD&D requirements—focused primarily on medium- and heavy-duty applications.

The resulting roadmap aims to:

- Address fundamental knowledge gaps regarding stakeholder interest, capacity, and economic and environmental impacts;
- Inform public and private sector decision-making;
- Assist in determining long-term investment requirements by stakeholders;
- Outline key steps for implementation and define future government programming needs and industry's role.

Natural Gas Supply Projections

This information will help governments and industry respond to the current North American outlook for natural gas, which has changed significantly within the past two years as advanced drilling technology has enabled the extraction of gas from unconventional reserves. The size of these newly accessible reserves, and the rapid rate and relatively low cost at which they can be developed, is causing earlier outlooks for steadily declining North American gas production to be rewritten. The new and more optimistic natural gas outlooks present opportunities for expanded and new uses in the transportation and other sectors.

Challenges

Despite this opportunity, there are some fundamental, historical challenges associated with natural gas vehicle deployment in Canada. In particular, the cost effectiveness hurdle is an issue for the development of an economically viable natural gas vehicle industry. Historically, significant mileage was required for natural gas vehicles to be cost effective due to the high capital costs associated with original equipment manufacturers' (OEM) offerings. Other significant barriers include the lack of and high cost of infrastructure, lack of OEM natural gas vehicles (there are no light-duty vehicles available in Canada), and uncertainty of payback due to high and volatile energy prices.

Historical Context

Canada had significant experience with natural gas in transportation in the 1980s and 1990s. During those years, backed by strong policies and incentives, natural gas was used mainly in light vehicles and transit buses as part of Canada's efforts to reduce oil dependency in transportation and to provide an alternative to the high prices of gasoline and diesel fuel. Several Canadian companies, often aided by research assistance from governments, became technology leaders in supplying gaseous fuel injection equipment for vehicles, gas compressors and dispensers to refuel vehicles, and lightweight tanks to store gas.

With the collapse of world oil prices in the late 1980s and again in the 1990s, the price advantage of natural gas as a transport fuel in Canada was eroded and its use declined rapidly. Other factors that contributed to the declining market were increases in vehicle costs as vehicle modifiers added technology to meet tighter vehicle exhaust emission requirements; the high cost of expanding refueling infrastructure; relatively long new vehicle delivery times for fleet markets; limited model range for new light duty vehicles; and the deregulation of the natural gas distribution industry who had, until this point, been at the forefront in developing the natural gas vehicle market in Canada.

Moving foreword

The sustained higher oil prices of the past several years, combined with concerns about the need to reduce greenhouse gas and criteria air contaminants, has renewed interest in natural gas for transportation. Fortunately, some companies with leading natural gas technologies are still based in Canada, so that there is an excellent technology capacity, as well as a sound base of codes and standards, for quickly expanding natural gas usage in transportation now that market conditions are more favourable.

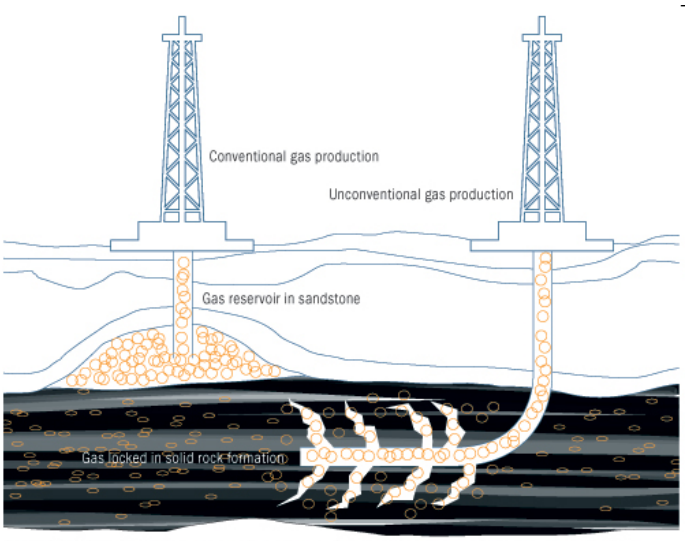
The roadmap process has brought together a broad range of representatives from industry and government to develop a comprehensive strategy for expanded use of gas in selected transportation markets. The input of the participants has been most valuable in identifying key market and technology challenges, and potential governments and industry responses to these challenges.

Natural Gas Market Fundamentals

The North American natural gas supply portfolio is shifting from one dominated by conventional reservoirs in sandstone or carbonate rock, to one dominated by unconventional resources, particularly natural gas from shale, or shale gas. Shale deposits holding significant amounts of gas are widely spread across North America. Until recently this gas was difficult to extract since the gas does not readily flow into wells drilled by conventional methods. Technological advancements in areas such as horizontal drilling and multi-stage hydraulic fracturing are now permitting economic extraction of this resource in many areas.

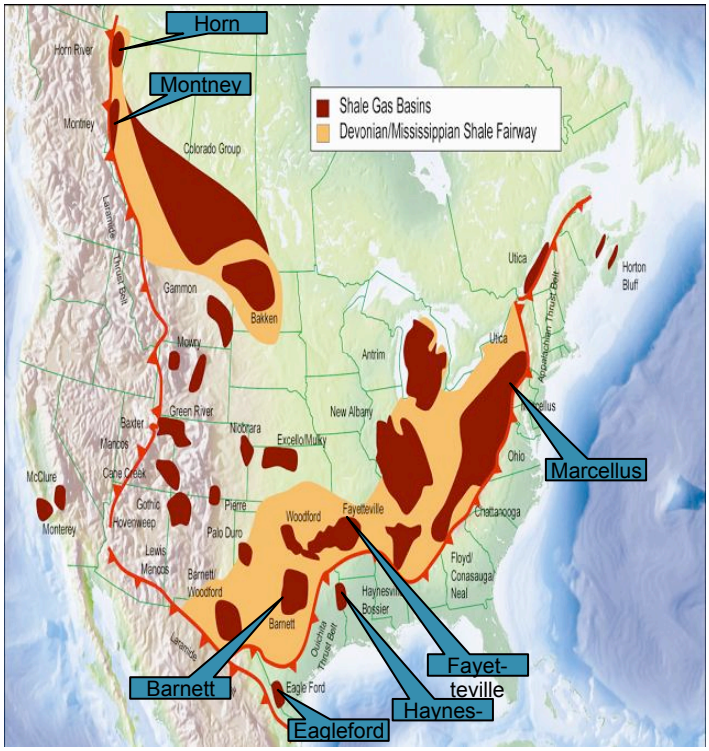
Shale gas extraction technology:

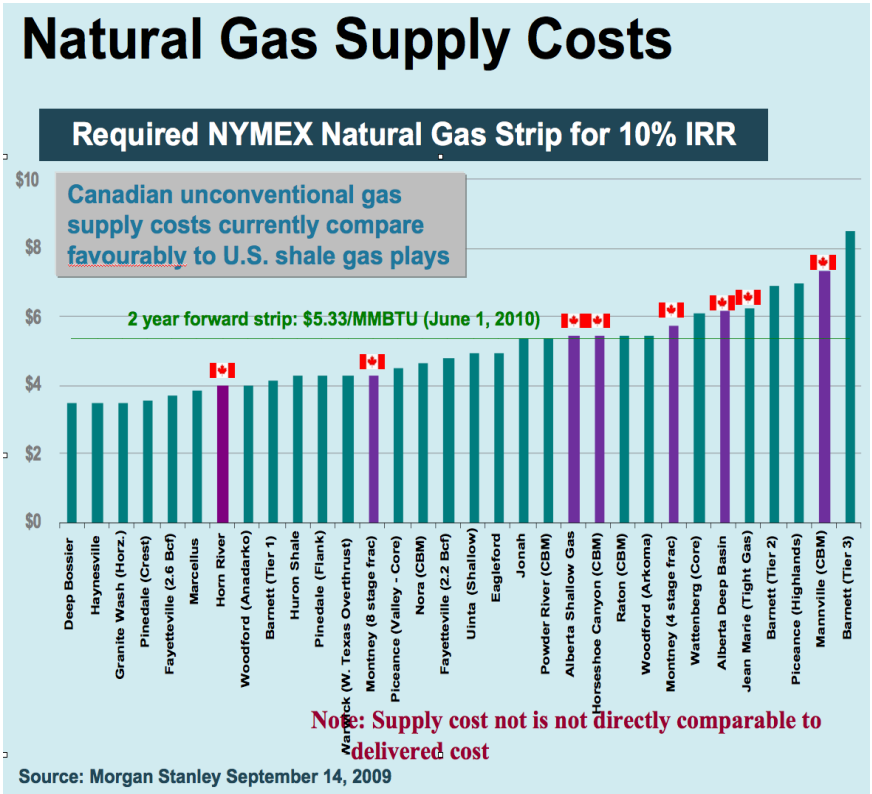
several horizontal wells are drilled from one platform and then "slick water" (fresh water with friction-reducing chemicals added) mixed with sand is injected into the formation at high pressure. This fluid shatters the shale into numerous fractured pieces underground. The sand props open the fractures so gas can flow into the well bore.



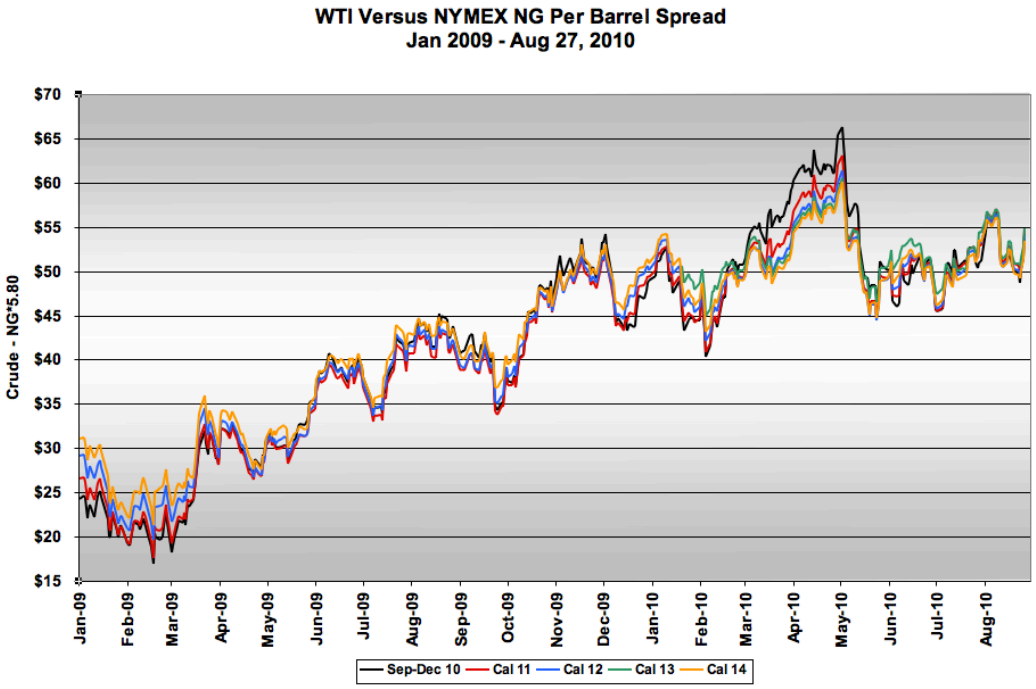
GAME CHANGER: The development of multi-stage fracture stimulation this decade has unlocked a motherlode of natural gas trapped in solid rock formations such as shale

Only a few years ago gas production in North America was forecast to decline steadily as conventional reservoirs were being depleted. More recent forecasts, taking into account shale gas and coalbed methane, have changed the outlook to increasing North American natural gas production for the foreseeable future. Shale gas development began in Texas with the Barnett shale and quickly spread throughout the United States. In Canada, shale gas development is in its early stages and is mainly focused in Northeast British Columbia. Other shale deposits are spread across the continent (see map); each area has unique geological and geographical characteristics that affect the cost of gas extraction. Even at today's low gas prices, production is already economic in many locations. Incremental improvements in drilling techniques, such as longer horizontal wells and increases in the number of fracturing stages, should bring other fields into the economic range in the future. The following chart shows that there is a large amount of supply available at today's gas prices.



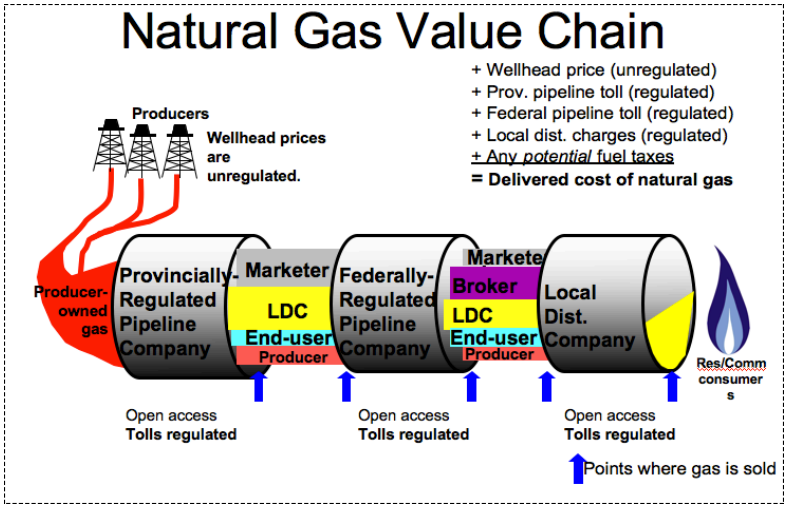


The amount and rate at which natural gas is developed depends not only on extraction technology and cost, but also the anticipated market prices for natural gas. Higher market prices encourage more gas development, but if they rise too high they dampen demand by industrial and commercial gas users that have fuel-switching capability. Current gas prices are attractive to users given the relatively higher prices of oil products and electricity. The chart below highlights the substantial price differential (gas at $50/bbl equivalent) to date. The differential in price between natural gas and crude oil is expected to increase according to industry estimates based on go-forward natural gas pricing contracts through 2014. This trend should go a long way in satisfying end-user concerns about the future price of natural gas versus diesel fuel. Increases in gas demand in the transportation sector could have some inflationary effect on gas prices; however, this effect is likely to be minor, since gas volumes going into transportation will be relatively small in comparison to the main markets for natural gas in the industrial, commercial and residential sectors.



End users are also concerned about price volatility, but past pump price history indicates that diesel fuel prices have been much more volatile than natural gas prices. The final price of gas to consumers is the sum of the unregulated producer price, regulated pipeline tariffs, plus certain taxes (in Canada either GST/HST or QST depending on the province),and local distribution charges. These are summarized in the following chart. For transportation users, the charges for storage and dispensing of compressed and liquefied gas at transport terminals and fleet yards can be a significant component of the final gas price. The respective roles of producers, brokers and marketers in serving large road transport fleets, as well as rail or marine markets, is yet to be determined and may differ by province. Depending on the availability of services, the end-user may pay a price for natural gas that includes certain services, such as rental of compression and dispensing equipment, and amortized conversion cost of vehicles. Smaller fleets may purchase natural gas at a cardlot facility shared by other users, while larger fleets may negotiate a unique contract price. Whatever the arrangement, it appears that there is scope for attractive prices for fleets and other bulk users.

Using gas is an advantage for companies that are investing in greenhouse gas (GHG) emission reductions; as conventional gas has about 27% lower GHG emissions on an energy equivalent basis compared to diesel or fuel oil for example.[1] However, unconventional gas production and processing can result in the release of CO2 that occurs naturally with the gas. The CO2 content of shale gas varies considerably by deposit. In Canada, the approximate range of CO2 content of shale gas is anywhere from 1 percent or less to 12 percent. Since some shale gas contains more CO2 than conventional gas, mitigation methods will need to be developed for high CO2 shales.



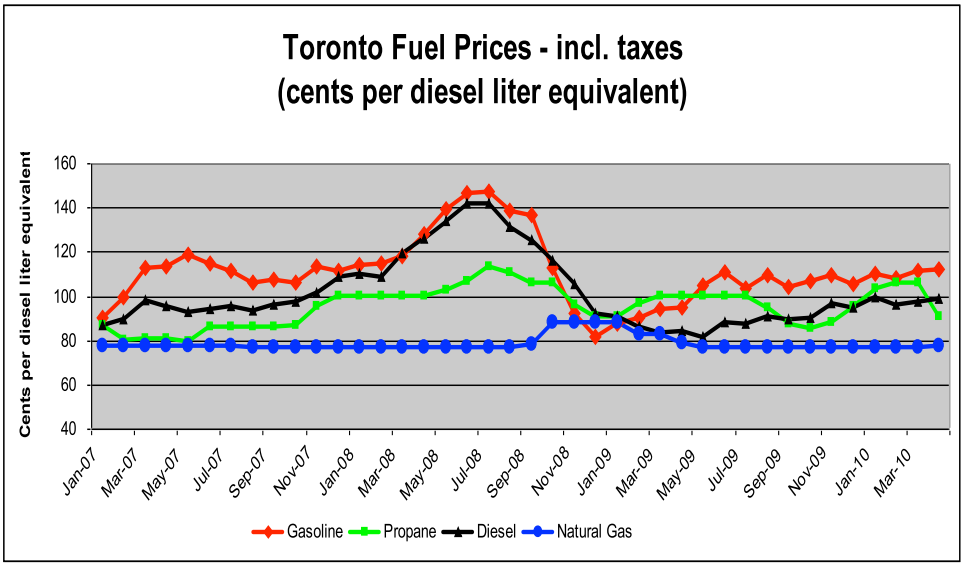
When considered along with the GHG impact of the final combustion of natural gas, the upstream contributions are relatively small and the differences between conventional and unconventional natural gas represent, at most, 3% of the total GHG footprint. Furthermore, there are upstream emissions associated with diesel fuel as well, and these could be higher than those associated with shale gas in some cases. Further analysis in this area is warranted.

Concerns have been raised surrounding the environmental impact of shale gas development, particularly with respect to the impact on water quality, as well as water usage. Such issues have received more attention in the United States than in Canada, as shale gas development is further advanced and takes place on a larger scale than in Canada. In Canada, most aspects of shale gas development fall under provincial jurisdiction. Evolving drilling technology improvements and water treatment and recycling can help reduce the overall impacts.

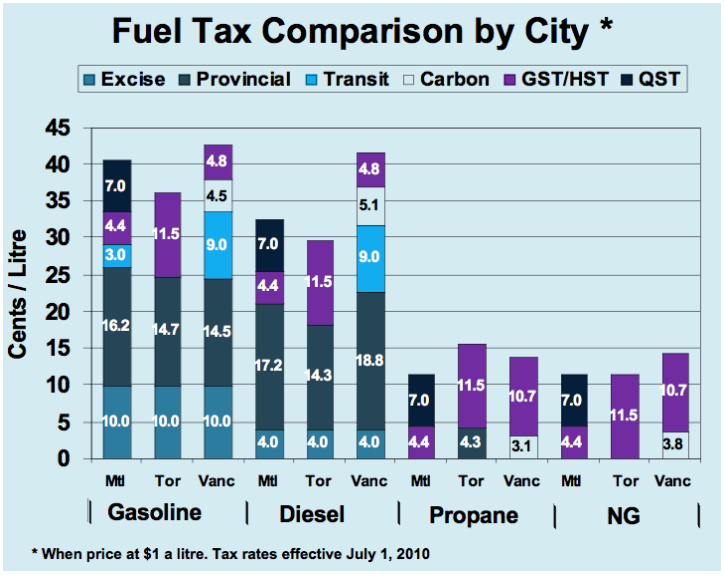
For transportation users, particularly truck fleets, the cost of fuel is a major concern, and the prospect of a significant, and even growing, gas to diesel fuel price differential is very attractive. To justify initial investments in new equipment, transport users would like some assurance that compressed or liquefied gas prices will be predictable and stable.

[1] However they operate at different efficiency levels

The history of gas and diesel prices in Canada is that, only on rare occasions, has diesel fuel fallen below gas prices (see chart showing Toronto pump prices). Part of the price advantage of gas for transportation is that it is taxed at a lower rate than diesel and gasoline. While this tax treatment gives an advantage to gas in the short term, if gas usage grows to the point that it significantly constrains fuel tax revenues there could eventually be pressure for natural gas to be taxed by provinces at similar rates to diesel fuel.



The prices for compressed gas in the chart are based on a survey of sales at retail stations. Contract gas prices for in-yard fleet fuel deliveries can be lower than those in the chart. Since truck fleet and other large transport users are used to delivery and storage prices for diesel of only a few cents per litre, there is likely to be pressure on gas suppliers to reduce the gap between wholesale and delivered compressed and liquefied gas. While there are good reasons for higher prices for delivered gas based on the different fueling equipment, storage tanks and code requirements, there should be some room for cost and margin reductions as gas volumes grow.



Biogas and Biomethane

Biogas is a readily available supply of renewable gas from landfills, sewage treatment and anaerobic digestion of waste from agricultural operations. Established technology exists that can be used to upgrade biogas to biomethane, which has characteristics that make biomethane a reliable and safe substitute for, as well as interchangeable with, natural gas.

Moreover, biomethane is a renewable fuel that is considered carbon neutral[2]. The displacement of a carbon positive fuel such as natural gas through the use of this carbon neutral fuel results in a net reduction of GHG emissions. Biogas is substantially composed of methane that is produced by the bacterial digestion of organic matter (biomass) in the absence of oxygen. Biomethane is already being used in vehicles in North America, such as in fleets of garbage compactors that can conveniently refuel with biomethane produced at landfill sites. In locations close to natural gas pipelines, biomethane can be added to pipeline gas for distribution.

Conclusion

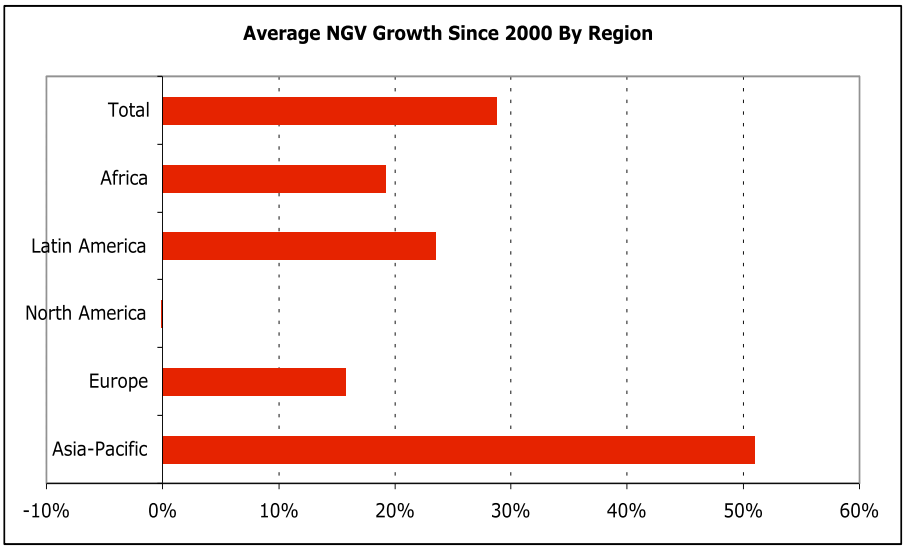
The outlook for natural gas has changed significantly, from gradually declining conventional gas production to rapidly growing gas production enabled by advances in drilling technology that is allowing producers to tap into the huge unconventional gas reserves distributed across the continent. The production of much of this gas is economic at prevailing natural gas prices, so that the outlook is for fairly stable or slow growth in prices. It is anticipated that the price differential between natural gas and petroleum fuels will grow in future years, allowing natural gas to enter new markets. Biomethane is becoming increasingly available and can be used directly in stationary and transportation applications with significant GHG benefits.

2 Life cycle GHG emissions from the production and use in heavy-duty vehicles of biomethane from landfills or anaerobic digestion is approximately 90% lower than GHG emissions from the use of diesel fuel Source: “The Addition of Biomethane to GHGenius” (S&T2) Consultants Inc, March, 2009.

Natural Gas Use in Transportation (State of Play)

Global Market for NGV

As of December 2009, there were more than 11 million NGVs in operation globally[3]. Globally, the use of natural gas as a road transport fuel currently accounts for only one percent of total gas consumption. The average growth rate in the number of NG vehicles between 2000 and 2009 has been 28.7% with Asia-Pacific and North America ranking the highest and lowest, with +50.9% and -0.1% growth rate respectively. This trend is expected to continue at an average rate of 3.7% per year to 2030, with most of the growth coming from non-OECD countries, which already account for most gas use for road Transport.



Source: International Association of Natural Gas Vehicles (IANGV)

Canadian Market for NGVs

With assistance from federal and provincial research, demonstrations and market deployment programs for natural gas in transportation during the 1980s and 1990s, the population of light-duty natural gas vehicles grew to over 35,000 by the early 1990s, and there was significant use of natural gas by transit buses and medium duty trucks. The market started to decline after 1995, reaching a vehicle population today of about 12,000. This number includes 300 heavy-duty vehicles, 150 urban transit buses, 45 school buses, 9,450 light duty cars and trucks and 2,400 forklifts and ice-resurfacers[4]. The total fuel use in all NGV markets in Canada was 1.9 PJ in 2007 (or 54.6 million liters of gasoline equivalent), down from 2.6 PJ in 1997. Public refuelling stations have declined from 134 in 1997 to 72 today; there are 22 in BC, 12 in Alberta, 10 in Saskatchewan, 27 in Ontario and 1 in Quebec. There are only 12 private fleet stations.

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3 International Association of Natural Gas Vehicles

4 Source, Canadian Natural Gas Vehicle Alliance (CNGVA)

Several factors led to the decline in the Canadian NGV market since the 1990s:

- the price advantage of natural gas over gasoline and diesel in Canada was eroded after world oil prices collapsed in the late 1980s and again in the 1990s;
- vehicle costs increased in the early 1990s as vehicle modifiers added technology to meet tighter vehicle exhaust emission requirements;
- R&D support to NGV diminished in the 1990s;
- the high cost of expanding refueling infrastructure;
- there was a limited choice of NGV models available; and
- the deregulation of the natural gas distribution industry which limited non-core business activities including natural gas vehicle business development activities.

US Market for NGVs

Like Canada, the US has implemented various NGV initiatives and programs since 1980, but has had limited success in sustaining the market. In the US, there were 105,000 NGVs in operation in 2000; this figure peaked in 2004 at 121,000, and decreased to 110,000 in 2009[5]. LNG and CNG use in heavy-duty trucks and buses has grown in California in response to the state's aggressive clean air policies. At the federal level, vehicle tax credit and fuel incentive policies have provided an assist over the past five years and the natural gas vehicle industry is currently working to secure extensions of these measures.

The current US market is served by several small and medium size companies that convert a limited number of models of light and medium duty gasoline and diesel vehicles to natural gas. Natural gas transit buses are supplied by Canadian and US bus manufacturers that use CumminsWestport engines. In addition, there are a growing number of truck manufacturers offering natural gas products such as Freightliner, Peterbilt, Mack, and Navistar. NGV is promoted by the US Department of Energy's Clean Cities Program.

Support for NGVs in Canada

Early SupportIn 1983, the federal government launched the Natural Gas Vehicle Grant Program and the Natural Gas Station Program, which respectively gave $500 for each light duty natural gas vehicle conversion, and up to $50,000 to offset the cost of a private or public natural gas fueling station. Some provinces and gas utilities provided their own incentives in addition to these programs. When the initial federal program funding was terminated in 1986, an additional source of funds was found for continuation of NGV incentives, as well as some research and demonstration activities[6].

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5 IANGV

6 This source, known as Market Development Incentive Payments (MDIP), was established in 1980 to partially offset the cost of building lateral gas pipelines in Central Canada – these pipelines provided new markets for Alberta gas and they reduced the heavy dependency on oil in the industrial, commercial and residential sectors. When the pipeline extension program was terminated, the Alberta and federal governments agreed that the remaining $35 million in the MDIP fund should be used to help expand natural gas use in transportation.

The initial grant programs were targeted to conversion of light and medium duty gasoline vehicles, as well as transit buses and the high-rate fueling infrastructure to serve them. At the time, these markets were the only viable choices since robust technologies for heavy-duty trucks, marine and rail were not yet available. Research and demonstrations were successful in assisting the development of improved and new technologies, particularly gaseous fuel injection for light and medium vehicles, lightweight gas storage tanks and engines for heavy-duty trucks.

Current Support

There is little remaining federal support for natural gas in transportation apart from the continuing exemption from the excise tax on fuels (10c/L on gasoline and 4c/L on diesel). However, as the fuel tax chart in Chapter 2 shows, the combination of the exemptions from excise and provincial fuel taxes for natural gas remains as a substantial subsidy.

Provincial sales tax relief of $1000 was offered for natural gas vehicles in BC and Ontario, but this ended in July 2010 with the transition to the harmonized sales tax. Ontario's Green Commercial Vehicle Program provides an incentive of one third of the premium for a natural gas Class 3-7 commercial vehicle, to maximum of $15,000, but this program is currently unfunded and is scheduled to end in 2012. Quebec's 2010 Budget increased the capital cost allowance rate for freight hauling trucks and tractors, with additional deductions for LNG fuelled trucks. BC's Clean Energy Act, introduced in May 2010, includes a provision that could be used to support NGV.

Support for NGVs in the United States

The US federal and some state governments continue to support NGV through vehicle and station incentives and tax credits. An important policy driver in the US has been the need to reduce dependency on oil imports. The recent expansion in domestic natural gas production is one of the reasons that Congress is currently considering renewal and strengthening of NGV incentives.

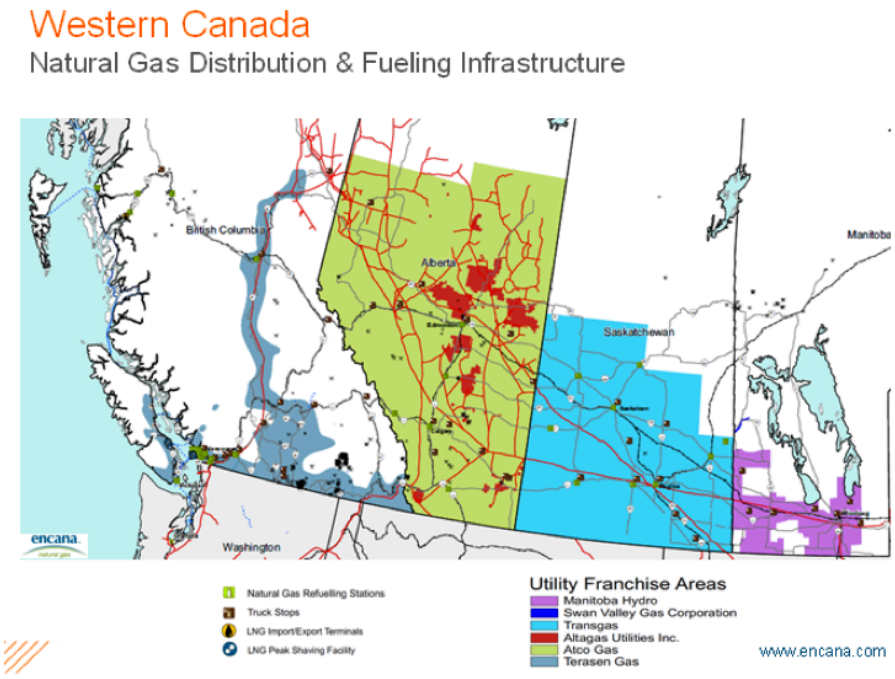
At the federal level, several key incentives have either recently expired or are about to expire.

- An excise tax credit of $0.50 per gasoline equivalent of CNG or liquid gallon of LNG for use as a motor vehicle fuel expired December 31, 2009.
- A tax credit for the purchase of a new, dedicated, repowered or converted alternative fuel vehicle expires December 31, 2010. The credit is for 50% of the incremental cost of the vehicle (if the vehicle meets EPA or CARB emission standards) plus an additional 30% if the vehicle meets certain tighter emission standards.
- An income tax credit equal to 50% of the cost of natural gas refuelling equipment and up to $30,000 for large stations will expire December 31, 2010.
- Although there are bills in both the House and Senate that would prolong and expand these incentives, the status of these bills is unclear.
- Additional programs at the federal level include:

- The Department of Energy's Clean Cities Program, which is a government-industry partnership, announced 23 cost share grants (10 related to natural gas), which totalled $13.6 million in 2009.
- The US National Renewable Energy Laboratory's April 2010 request for proposals regarding the development of natural gas engines and vehicles. The solicitation includes the potential for $14.5 million in funding for engine development, chassis integration, and demonstration of on-road products.

Infrastructure Technology Readiness

Canada has one of the most extensive natural gas pipeline distribution networks in the world, delivering gas from Western Canada and the East Coast off-shore to residential, commercial, industrial and power sector markets in the US and across Canada. The expansion of this pipeline network over the past 30 years has led to the backing out of petroleum in these sectors. The reach of this natural gas network, the attractive price of natural gas, and its emission reduction benefits provides an opportunity for transportation to increase its use of the fuel.



Transportation remains about 97% dependent on petroleum fuels. In some major transportation corridors, natural gas trunk pipelines are coincident with major highways, rail lines and even waterways. Natural gas refuelling stations can be located along these corridors to serve the trucking industry, and in some cases could use high-pressure pipeline gas to reduce the cost of providing CNG at stations. In urban areas such as Metro Toronto and Vancouver, there are already some 50 CNG public stations serving light and medium duty vehicles, as well as a smaller number of private fleet refuelling facilities.

Currently there are no fuelling facilities that provide LNG to vehicles on a regular basis. LNG is available at three locations in Canada where there are peak-shaving plants operated by natural gas utilities. It appears that these facilities may have

some excess LNG capacity that can be diverted to transportation markets; two of the utilities[7] are in the process of securing approvals from regulators to allow this use. LNG is also being imported into Canada at the Canaport facility in New Brunswick, although all of this gas is, at present, being re-gasified for transmission via pipeline to markets in the Northeast U.S. If the demand for LNG in trucking, marine or rail develops as envisaged in this Roadmap, LNG can be manufactured from pipeline gas and be transported in tank trucks, rail cars and marine vessels to be distributed to refuelling facilities. LNG can also be vapourized at a refuelling facility to provide CNG.

Natural gas, as either CNG or LNG, is typically sold to the end-user in one of three ways:

- 'Do-it-yourself' – end-user would purchase natural gas from a utility or gas marketer (delivered by utility) and source remaining equipment separately
- 'Utility Package' – all utilities deliver and sell fuel and some provide infrastructure
- 'Clean Energy' model – Clean energy builds, operates and maintains end-user fueling stations and facilitates the purchase of natural gas on a long-term contract basis

Vehicle Technology Readiness

There are two types of NGVs available to end-users: retrofitted vehicles (also called conversions), and those developed specifically by vehicle manufacturers and delivered to customers as factory-built vehicles (OEM).

Aftermarket vehicle conversion is a provincial jurisdiction in Canada and industry must take care to ensure that only high quality and low polluting retrofit technologies are offered to the market. OEM vehicles must comply with Transport Canada regulations.

What is CNG and LNG

In transportation applications, natural gas is used either as compressed natural gas (CNG) or liquefied natural gas (LNG).

- CNG is made by compressing natural gas to less than 1% of its volume at normal temperature and pressure. It is stored in steel or fibre-wound cylinders at high pressures (3000 to 3600psi). The gas is passed through a pressure regulator and into a spark-ignited or compression ignition engine.

- LNG is made by condensing natural gas at temperatures of approximately -162°C. The liquefaction reduces the volume by a factor of more than 2 compared to CNG and eliminates the need for high pressures. The LNG is stored on vehicles in a double-walled stainless steel tanks and vaporized before injection into the engine.

7 Terasen Gas has obtained approval to sell LNG into the transportation market from its plant in the port area of Vancouver. Gaz Metro is in the process of obtaining similar approvals for its Montreal peak shaving LNG plant. A third peak-shaving LNG facility in Northern Ontario is owned by Union Gas. LNG may also be available in future from LNG plants built to export natural gas to overseas markets.

Dedicated NGVs are designed to run only on natural gas, while bi-fuel NGVs have two separate fueling systems that enable the vehicle to use either natural gas or a conventional fuel (gasoline or diesel). In general, dedicated NGVs demonstrate better performance and have lower emissions than bi-fuel vehicles because their engines are optimized to run on natural gas. In addition, the vehicle does not have to carry two types of fuel, thus reducing weight and allowing increased cargo capacity.

There are two engine technologies that can be used to power natural gas vehicles: Spark Ignited (SI) engines use the same combustion cycle as gasoline engines, while Compression Ignition (CI) engines are based on the diesel cycle. While CI engines tend to have a higher overall efficiency than SI engines, their higher acquisition costs tend to make them more suited for large fuel consumption applications.

For cars and light duty trucks, there are no factory produced (OEM) products available in Canada, although GM is now offering two cargo vans with dedicated natural gas fuel systems installed by a third party converter. Ford has announced that it will make at least one natural gas "prepped" engine available to upfitters in the near future. A number of small and medium capacity vehicle upfitters serve the US market by converting mostly new gasoline light duty vehicles to natural gas at an incremental price in the range of $12,000 to $15,000.

Medium and heavy-duty natural gas engines are available as options from an estimated 15 North American truck and transit bus manufacturers at price increments of $35,000 to upwards of $60,000. These engines are of two types:

I. spark-ignited engines are fueled purely by natural gas and can serve the medium and heavy-duty engine market, including those used in transit buses;
II. higher horsepower heavy-duty engines use dual-fuel injectors to initiate combustion with a small amount of diesel fuel, followed by the main injection of natural gas – these engines typically use 95% or more natural gas.

Leading world manufacturers of advanced medium and heavy-duty natural gas truck and bus engines with the lowest emission engines in their class are located in Vancouver:

- Westport Innovations supplies high horsepower engine systems that operate on natural gas, with pilot injection of a small amount of diesel fuel to initiate compression ignition.
- Cummins Westport supplies spark ignition natural gas engines to several bus and truck manufacturers.
- Other key Canadian manufacturers with world-wide distribution are:
- Dynetek (light fibre-wound CNG tanks);
- IMW (oil-free compressors);
- Kraus Global (natural gas dispensers and control systems)
- Xebec Adsorption (natural gas dryers and biogas upgrading equipment)

To provide sufficient driving range for heavy-duty trucks, the preferred way to store natural gas is in its denser liquid form (LNG) in cryogenic stainless steel tanks. These tanks are costly to manufacture and account for a significant share of the incremental cost of natural gas trucks. Transit buses mostly use several roof-mounted fibre-wound tanks to store

compressed gas, while medium-duty trucks use one or more chassis mounted tanks. The main reason for using gas in its compressed form is that it is widely available by compressing gas from Canada's extensive pipeline system.

LNG has been used successfully in two trucking demonstrations in Canada, but general commercial uptake has not yet occurred even though the main suppliers of the engine technologies are based here. Significant use of LNG by trucking would require expansion of existing facilities and construction of new LNG plants specifically to serve this market. The same is true for marine and rail applications where the LNG volumes required per vehicle are large. A recent study by Marbek[8] found that, in addition to transit and heavy-duty trucks, marine and rail applications appear to be among the most attractive future markets for natural gas in transportation.

Codes and Standards

As new technologies are developed, there is also a need for concurrent development of related safety codes and standards. During the 1990's there was a significant amount of work done to develop codes, standards and regulations for compressed natural gas (CNG) storage for use on-board vehicles, as well as those pertaining to dispensing and refuelling infrastructure[9]. Over the last decade, however, due to a decrease in demand for natural gas vehicles, the relevant codes and standards committees have lapsed. There are currently no codes, standards or regulations in place in Canada that specifically address the installation of LNG vehicles, refuelling stations, and fuel supply. The lack of harmonization of codes and standards across Canadian jurisdiction as well as with those which are developed and implemented in the United States is also an important barrier to full market penetration of natural gas vehicles into the transportation sector.

Summary

Excellent natural gas technologies are available from Canadian suppliers for fuel delivery, compression, storage, dispensing and medium and heavy-duty engines. These technologies are exported to many countries, but sales in Canada have been limited in recent years. Natural gas refuelling infrastructure is available in some major urban markets, but overall is very limited. LNG supply for vehicles is very limited and will need to be expanded if the market potential in HDVs is to grow beyond a few demonstrations. While a number of codes and standards are available to cover CNG and vehicle conversions, LNG codes and standards for transportation applications remain to be fully developed.

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8 Study of Opportunities for Natural Gas in the Transportation Sector, Marbek, March 2010, for NRCan.

9 As part of this Roadmap a complete listing of codes and standards was assembled.

End-User Needs

Introduction - Why Focus on End Users?

Understanding and addressing end user needs is fundamental to increasing the use of natural gas in transportation and ensuring successful deployment. Trucking fleets tend to be conservative in adopting new technology, and natural gas (particularly LNG) is unfamiliar and unavailable to most fleets. The uncertainty about fuel availability and prices, combined with the high incremental vehicle prices, limited marketing and lack of financial incentives for natural gas trucks, explains the low level of uptake. The potential for market growth for natural gas vehicles will not be realized unless the attitudes, knowledge and key concerns of end users are understood and addressed.

Which End Users Involved

As part of the Roadmap project, consultations were conducted with five end-user groups that operate medium- and heavy-duty fleet vehicles. The overall objective for this Group was identify the operating environment and circumstances of the end user community, and to engage and consult with them so as to determine opportunities and challenges related to increasing the use of natural gas as a transportation fuel in Canada. The following five end user groups were consulted: (1) highway trucking; (2) municipal; (3) transit; (4) vocational truck; and (5) school bus.

Consultation Processes

While there were differences in how the engagement and consultation process was carried out, in each case the focus was to develop a clearer view of end user needs in regards to operating a fleet of medium- and/or heavy-duty vehicles. Information regarding fleet use of natural gas vehicles was also gathered from the three groups (municipal, transit, school bus) with experience in this area.

Key Findings

1. Vehicle incremental cost must be addressed. Payback requirements varied considerably, but end users were unanimous in identifying incremental vehicle cost as a barrier to adoption. Some public sector fleets also noted fixed budget constraints.

2. Existing fuel tax exemptions need to be maintained. This was most clearly articulated by highway trucking end users who also had the most aggressive payback requirements. Environmental benefits related to GHG reduction were cited as a rationale.

3. Credit for using a lower carbon fuel needs to accrue to fleets. Natural gas use should benefit fleets through carbon credit generation and compliance with regulations. Mandates requiring lower GHG fuels for public contracts were also suggested.

4. Aligned federal and provincial measures are needed. Suggestions ranged from support for vehicle trials, programs that are accessible to both public and private sector fleets, and aligned measures that help to ensure that GHG reductions are achieved.

5. Assistance is needed related to regulations and approval processes. End users noted that refuelling facilities represent a challenge in terms of approvals. It was suggested that government could play a role to facilitate refuelling station approvals.

6. Past problems were not insignificant and must be addressed. Inadequate support for stations, parts, and vehicles was noted. Also highlighted were slower refuelling times than liquid fuels, and unreliable, maintenance-intensive early generation engines.

7. Available natural gas vehicle models may not suit all end users' needs. School bus end users noted the lack of natural gas Class C type school buses as a barrier. If the "correct model" is not available in natural gas, this poses a challenge.

8. Natural gas use must mesh with fleet operational practices. Transit and vocational truck users both noted that other vehicle maintenance tasks are carried out in conjunction with refuelling. Maintaining operational efficiencies is a key driver for end users.

Results from Each of Five End Use Areas

It was evident from the consultations that there are significant differences in end-user awareness regarding the current availability, capabilities, and benefits of medium- and heavy-duty natural gas vehicles. In addition, while the consultation process was not intended to gauge intent, it was clear that natural gas has the potential to be a viable option for medium- and heavy-duty vehicles in Canada, provided end-user needs can be addressed. The following charts summarize the findings by each-end user group.

Highway Trucking

Overall Business Case	It is critical that the trucking industry can take advantage of a carbon credit system and get credits if truckers use natural gas as a fuel. The cost of premium green technology cannot be passed on, so truckers need other direct benefits to support investment.
Fuel Costs	There will eventually be a tax on natural gas, but the soial good of lower GHG should relate to the level of tax on NG. Government needs to take advantage of our huge domestic NG reserves.
Vehicle Capital Costs & Financing	Quebec offers incentives…now you can depreciate lower emission trucks much more rapidly at 60% plus and 85% multiplier for LNG, but this is only for the Quebec portion of corporate income taxes. Need the federal and other provincial governments to get on board. Need more than just road tax exemptions. Industry is making investments and needs governments to open doors and take away roadblocks.
Operational Issues	With the size of the fuel tanks, changes in technology using more "real estate" on the frames, need to give consideration to weight allowances or increased wheel bases – running out of room.

Refuelling Requirements	Refuelling facilities and infrastructure are one of the biggest challenges. Government needs to take the initiative in development of refuelling facilities. Need a facilitator to get through all the permits and legislation.
Training	It takes training to get technicians up to speed, but it's not a huge issue. It is part of doing business.
	Municipal
Overall Business Case	There is a generally held belief that new technologies are so clean (100 new vehicles = 1 old vehicle) that there is no clear sense of what the advantage of NG or other alternative fuels might be. Diesel tends to beat out LNG or CNG on a strict business case basis.
Fuel Costs	With some station financing models, the end user must commit to buying a minimum amount of gas. This creates an unacceptable risk – especially if a) the government support shifts, b) the technology is inadequate, or c) the business case otherwise changes.
Operational Issues	Perception that downtime is still an issue, as it is not that durable of a system. Fuelling infrastructure does not exist in large quantities.
Training	Training for mechanics is an issue.
Facilities & Refuelling Stations	Maintenance and safety infrastructure need to be upgraded when introducing CNG/LNG to a garage. Maintenance infrastructure upgrades were costly - $80,000 for methane detectors in garages. Hamilton found CNG quite costly to maintain, specifically the fuelling stations
Perspective on Roles	Mandates and incentives must be realistic, long term, and helpful. In 1980s, vehicles had to be OEM which is good, but very limiting. The business case changes dramatically when new fuel taxes are imposed and when incentives are withdrawn. Need a solid, long term commitment that at least matches vehicle life (10 years).
	Transit
Vehicle Refuelling	Estimated fill times ranged from 3 to 9 minutes, with an average of 4.4 minutes. The single reported fuelling time of 9 minutes was specifically attributed to CNG, and that Transit System also reported a fill time of 3 minutes for diesel.
Experience with Natural Gas Refuelling Stations	Fuelling station reliability was reported to be good for one current operator and below expectations for the other current operator. The third operator reported problems with winter use: adjusting compressor regulators to compensate for fuel flow. Support from the fuelling station operator was rated as poor but improving by one current operator. The former operator indicated that service was helpful but not timely. Parts availability was rated as poor but improving by one current operator and good by the other. The third indicated that they carried additional stock, and that it was very expensive.
Operational Issues	Several Isues were reported: that the infrastructure to fuel and park buses inside was expensive; TSSA required numerous inspections; and that pressure relief valves required annual testing at a cost of $500 each.
Training	Specialized training was required for fuelling. One indicated that a licensed TSSA Compressor Operator needed to be on duty even when the station was not running.

Experience with Natural Gas Transit Buses	One current opertor reported average reliability. The other two were not so positive: *"Nowhere near as reliable as diesel. Runs very hot and multiple problems during the summer months. Required increasing bus spare ration due to multiple problems and long lead times for parts."* Warranty issues were cited a significant by all three operators: *"Huge problems historically." "Yes, poor engine life." "Numerous meetings with manufacturer to attempt to resolve issues."*

Vocational

Acceptable Payback Period	Due to the increased risk associated with new fuel efficient technologies, a payback period of 12 years (average life of a vehicle) is not practical as the durability of the technology is unknown. Three years is the preferred payback period for new technology. The (Ontario) government got rid of an incentive program that offered up to 33% of the price difference between a NGV and a diesel. With the rebate, the payback period is 4 years. Without the rebate, the implementation of NGV would be considered risky.
Vehicle Performance and Refuelling	Has driven new trucks and the technology is much better. After driving, knew they had to have these trucks However, there is difficulty finding the appropriate model.
Implementation Challenges	Fuel capacity. Will the vehicle be able to conduct a full day's work without refueling? Will it be able to make longer journeys? Related to this is the issue of refueling, currently the infrastrucutre is not widespread to ensure easy access. Pricing, availability, refueling infrastructure, no crash test information, and the question of who does maintenance and repair work on NGVs. Costs, competitive nature of the industry, must bid against other firms for contracts. The only way to get NGVs regularly used is to mandate their use for residential (collection) contracts.
Government Role	There is a lingering sentiment that NGVs are 'pieces of junk'. The government needs to help educate people about the improvement in the technology to get past this stigma. Follow the lead of the US. They offer many incentives, rebates, and tax breaks.
Additional Comments	There is a green initiative throughout the economy and NGV are a good way to market a company to companies and municipalities that are interested in being more environmentally friendly.

School Bus

Acceptable Payback Period	They have a fixed purchasing allowance. They replace 6% of their fleet per year, but have a fixed budget to purchase new vehicles that is dictated by the province. There is little leeway to purchase higher cost vehicles.
Implementation Challenges	Lack of a Class C NGV school bus is the biggest hurdle. NGV not made in a model that they use and available model (Class D) has higher operating costs by 37%. CNG vehicles are only available in pusher buses and these are unpopular with drivers. There needs to be more variety in vehicle options. If conversion to NG was more accessible and easier, it would facilitate increased NGV use.
Experience with Natural Gas	They have had a CNG bus for 2-3 years and may be buying 11 more. It is slower to refuel, by roughly 6 minutes and drivers don't like that. Performance and power are good and operators enjoy driving the 84 seaters.
Government Role	Incentives, tax breaks & grants. They are bothered that federal government incentive programs generally seem to not be accessible to school bus operators. Pay for trial adoption of the vehicles. The school board is currently working with Nova Scotia on driver monitoring and training to reduce fuel consumption. They are willing to experiement but it is not in their budget to do so.
Operational Issues	Vehicle cleaning and light maintenance tasks are performed in conjunction with refuelling including vehicle washing, light service, fluids, sticky door repairs, etc.
Information Needs	There is not sufficient information or knowledge (on natural gas school buses) available to them.

Implications for Successful Deployment

It was evident from the consultation process that an extensive amount of information is needed to support end users who are considering deploying medium- and heavy-duty natural gas vehicles. Of the information needs identified, some information requirements are common to all end users, while other information requirements are unique and applicable only to certain end user groups. In addition, end users with past experience with natural gas in their fleets require additional information that identifies what has changed in regard to natural gas vehicle and station technologies.

Regardless of the type of fleet they operate, end users will typically follow a similar process to consider and decide upon natural gas as an alternative fuel for their fleet. This process involves: (1) research, (2) decision-making, and (3) deployment. Successfully moving through these three stages requires access to information, ideally from as few points as possible so as to ensure a reasonable degree of simplicity for the end user. The following diagram is intended as a guide only. The specific process undertaken by an end-user will be iterative rather than linear and will vary depending on their own fleet needs, unique circumstances, and jurisdiction of operation.

RESEARCH	Gather information
	Consult with other end users
	Verify and confirm validity of information
DECISION-MAKING	Assess business case and fit for fleet
	Get government program and incentive information
	Drive a vehicle and talk to fleet adopters
	Determine options to refuel including station design options
	Determine fuel pricing and contract options
	Develop a natural-gas based vehicle specification
	Get a vehicle quotation from a truck or bus dealer
DEPLOYMENT	Ensure compliance and order vehicle(s)
	Secure approvals for refueling station
	Train personnel – maintenance and operators
	Make facilities gas-ready
	Determine how to service vehicle(s) and maintain station
	Take delivery of vehicle(s)
	Perform periodic inspections as required
	Access information updates and support for in-use issues

The Value Proposition

Participants involved in the Roadmap's development focused on addressing two fundamental questions pertaining to the scope of this study. The first question was "Recognizing that natural gas use could be expanded in several key sectors, why should governments and industry consider natural gas in transportation sector at this time?" In other words, what factors are driving interest among stakeholders to increase natural gas use in the transportation sector? The second question was, "Within the transportation sector, which vehicle applications have the greatest potential for natural gas use?"

Why Should Governments and Industry Consider Natural Gas Use in the Transportation Sector?

As Table 1 indicates, many economic factors are driving interest among stakeholders to increase natural gas use in the transportation sector. Gas producers and suppliers will gain new and diversified markets, realize economies from greater utilization of their natural gas supply infrastructure, and increase their attractiveness for investment. Vehicle and equipment suppliers will sell greater numbers of their product and realize scale economies; they should be able to offer a broader range of products and generate stronger networks of suppliers and service companies. Increased profitability will encourage more investment in research. Vehicle users will be able to use a lower emission fuel that is lower in cost than petroleum fuels which are likely to see upward pressure on prices as oil becomes more difficult to find and develop in the quantities needed to meet increasing global demand. Governments are interested in using natural gas in transportation to achieve goals related to enhanced economic activity, competitiveness of the transportation system, reduced emissions, job creation, energy sector diversification and increased exports.

Table 1: Drivers for Key Stakeholders

Stakeholder	Drivers
Governments	• Develop clean energy solutions; • Build a low-carbon economy/ encourage growth of green industries; • Foster strong markets for Canada's energy resources; • Support economic recovery and sustainable growth; • Support economic competitiveness of Canadian industries and technology; • Enhance energy diversification.
Fuel Supply Stream (Natural Gas Producers)	• Abundant low-cost natural gas resources; • Stimulate demand and expand markets; • Retain and attract investment in Canada; • Anticipation of climate change regulations.
Fuel Supply Stream (Natural Gas Transmission and Distribu-tion)	• Significant infrastructure already in place; • Increased throughput improves competitiveness; • Diversification of markets.

Vehicle and Equipment Suppliers	• Opportunity to supply consumers with "green" transportation options; • Build on the competitiveness of Canada's world-leading industry: ○ Develop strong technology and manufacturing base in Canada; • Encourage wider use of technologies to achieve economies of scale in production.

End-Users	• Expectations of heavy-duty GHG emissions regulations;
	• Demonstrate commitment to customers/shareholders:
	  ○ Renewable NG produces close to zero GHG emissions;
	  ○ Ability to measure and quantify GHG reductions;
	  ○ Opportunity to reduce noise in urban settings;
	• Expectation that NG will remain competitively priced:
	  ○ NG use may reduce fuel price volatility risks;
	• Increasing cost and complexity of 2010 diesel engine emission control technology.

In addition to economic drivers, many stakeholders value the potential environmental benefits associated with natural gas use in the transportation sector. In 2007, Canada's transportation sector accounted for approximately 29 percent of total energy demand—the second largest energy consumer in the nation. As a result of such significant energy demand, this sector accounted for 36 percent Canada's GHG emissions, which is the second largest source of emissions in the country.[10] Moreover, total energy demand in the transportation sector is expected to grow by 31 percent between the period of 2004 and 2020.[11] The major source of energy use and emissions is on-road vehicles, which consist mainly of light-duty gasoline passenger vehicles and heavy duty freight vehicles (see Figure 1 for transportation energy use by mode).

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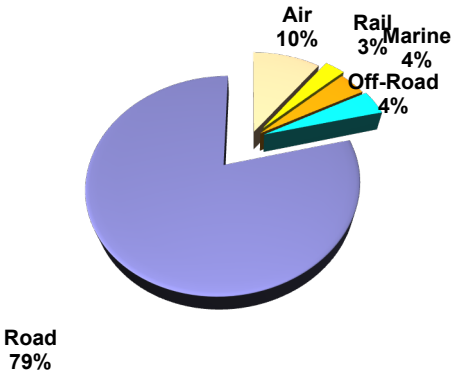
10 Natural Resources Canada (2010), "Canada's Secondary Energy Use by Sector, End-Use and Sub-Sector."

11 Natural Resources Canada (2006), Canada's Energy Outlook: Reference Case 2006.

12 Natural Resources Canada (2010), "Canada's Secondary Energy Use by Sector, End-Use and Sub-Sector."

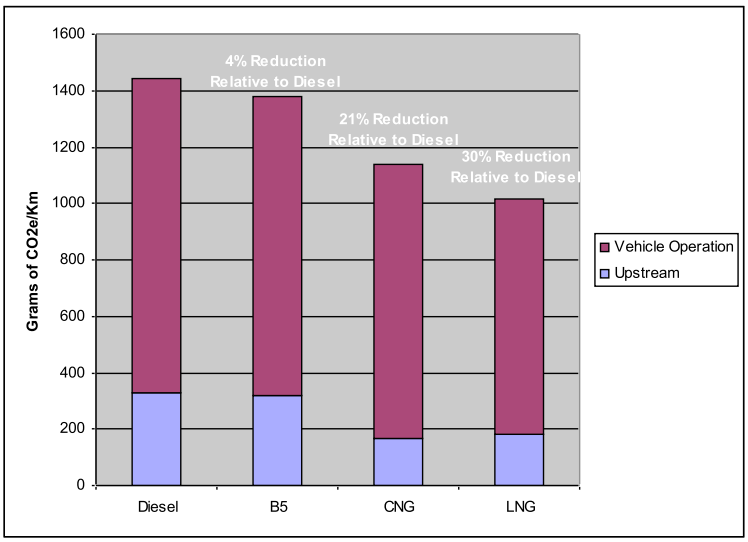
13 Natural Resources Canada (2006), Canada's Energy Outlook: Reference Case 2006.

Figure 1: Transportation Energy Use by Mode (2007)



To reduce emissions from the on-road sector, the Government of Canada has issued aggressive GHG fleet average standards that new light duty vehicles (LDVs) must meet over the coming decade. Similarly, the Government has announced its intentions to regulate GHG emissions from medium- and heavy-duty vehicles, although there appear to only be two main strategies for doing so: 1) using less carbon intensive fuels; and 2) burning less fuel. In some cases, these options can be combined to maximize GHG reduction benefits. With regard to the first option, Figure 2 compares diesel fuel emissions with emissions produced by biodiesel (5 percent blend), compressed natural gas (CNG), and liquefied natural gas (LNG). For each fuel, the graph includes upstream emissions (i.e., emissions produced during resource recovery, refining, and shipping) and vehicle operation emissions (i.e., emissions produced at the tailpipe). As the graph indicates, diesel fuel produces 1,444 grams of CO2e per kilometer relative to LNG, which produces 1,017 grams of CO2e per kilometer (a 30 percent reduction).

Figure 2: Alternative Fuel Options to Reduce GHG Emissions from Heavy Duty Trucks



Source: GHGenius version 3.16b (2010)

Therefore, the inclusion of natural gas vehicles in their fleets could prove attractive for manufacturers working to meet fleet average GHG standards. In addition to the incoming GHG vehicle standards, there are other environmental regulations for which natural gas could receive favourable treatment.

For instance, natural gas use in vehicle fleets could provide an important contribution at reasonable cost to climate change policies in Canada and the United States. However, this extent of this benefit (if any) is difficult to estimate at this time due to the uncertainty regarding the nature and timing of these policies. Similarly, fuel providers are already preparing to meet new regulations for low carbon fuel in British Columbia, and forthcoming regulations in some other provinces. The inclusion of natural gas for transport in the mix of fuels sold by fuel suppliers, could help them meet standards where the regulations permit.

In addition to using alternative fuels, additional GHG emission benefits can be achieved through the use of supplemental options that burn less fuel, such as aerodynamic design, fuel efficient tires, and driver training. The US Environmental Protection Agency has estimated the benefits of these options. For example, aerodynamic technologies, such as trailer end fairings, can provide an estimated 5 percent or greater reduction in fuel use. Low rolling resistance tires can lead to fuel savings of approximately 3 percent or greater. The application of these technologies coupled with driver training can lead to additional fuel saving benefits.[14]

In addition to GHG reduction benefits, potential air quality benefits associated with natural gas use was another important driver for some stakeholders, especially some end-users operating in urban areas. The past 15 years has seen steady improvement in heavy-duty vehicle emissions of CACs as a result of successive rounds of regulation of nitrogen oxides (NOx) and particulate matter (PM) and diesel fuel sulphur content. Vehicle standards tightened again in 2010 and engine manufacturers are investing in sophisticated technologies to meet the new standards. All this will add cost to heavy-duty engines. Since natural gas engines already have very low engine-out[15] NOx and PM emissions, they may be able to use lower cost emission control systems than diesel systems, although this will depend on market volumes. Natural gas engine manufacturers expect that some emission control components, such as particulate filters and catalysts, may have a longer service life on their engines because of their inherently lower emissions.

The list of positive drivers is compelling. Individual stakeholders can realize benefits, but only if the other stakeholders agree to participate in developing the market. The likely extent and strength of such cooperation will depend on the

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14 US Environmental Protection Agency (2010). "Verified Technologies." Available online: http://epa.gov/smartway/transport/what-smartway/verified-technologies.htm

15 "Engine out emissions" refers to emissions measured before any aftertreatment of exhaust gases. SCR, oxidation catalysts and particulate filters are used to clean up engine-out emissions. With lower the engine-out emissions, less aftertreatment is required and the lower the cost of meeting emission standards. Eventually, low temperature combustion techniques will be developed for diesel engines to the point where they can reduce both NOx and PM simultaneously, possibly lowering the cost of emission control systems.

investments, risks and economic returns; these are summarized in the following chapter which outlines the business case for natural gas in transportation.

Within the transportation sector, which vehicle applications have the greatest potential for natural gas use?

To address this question, working groups assessed the potential for increased natural gas use in various vehicle segments based on the following criteria: technology availability, market potential, environmental benefits, energy use, and economics.

The vehicle segments included heavy-duty, medium-duty and light-duty vehicles, marine vessels and rail locomotives. The principal findings were:

- **HDVs:** Emissions certified natural gas engines are available in a variety of power ratings, and these engines are being offered as optional equipment by a growing number of truck OEMs. Because HDVs use a lot of fuel, the potential savings from choosing natural gas are significant (about $27,000 per year). The internal rate of return on investment is high, but the initial investment cost could be a deterrent to trucking fleets that tend to be conservative in their investment decisions. Natural gas fuel tanks are heavier than diesel tanks and for some trucks that travel close to the weight limit, some tradeoff in cargo weight may be required[16]. The significant volumes of trucks along the Windsor-Quebec corridor, and the coincident natural gas pipeline network, provide a very favourable opportunity for natural gas as a vehicle fuel. Transit buses are also a large potential market for natural gas, since buses have high fuel use, are centrally fueled, and have longer lifetimes for amortization of the initial investment.

- **MDVs:** Engines are available for buses and trucks, and in some cities (Vancouver, Metro Toronto) a CNG refueling network is available. Many MDVs operate primarily in urban areas, where the low emissions of natural gas vehicles are of most benefit. MDVs can realize significant fuel savings, particularly when they are operated over longer distances (e.g. airporter buses and some package delivery fleets). Return-to-base fleets can take advantage of central refueling and low natural gas prices.

- **LDVs:** Privately owned vehicles would need to be converted to natural gas as there are no OEM vehicles sold in Canada. Public refueling infrastructure is available in Vancouver and Metro Toronto but is very limited elsewhere. Because private vehicles use relatively little fuel, additional refueling infrastructure investment for them would not be justified unless large numbers of vehicles were converted or manufactured to use natural gas. Consumers have a choice of other technologies to reduce their GHG emissions by their new vehicle purchase decision: hybrid-electric, advanced diesel, and in the near future, plug-in and pure battery vehicles. If OEM natural gas vehicles are brought to market in future at a price that is competitive with other choices, there could be some market interest.

16 Some provinces and states are examining this issue and whether to allow some overweight margin for LNG trucks.

- **Marine – Short-Sea Shipping:** Natural gas propulsion technology is commercially available for large marine engines. One ship can use as much fuel as 50 heavy-duty trucks. The fuel savings potential for shipping using natural gas is very significant, since marine diesel and heavy fuel oils are becoming more expensive under pressure from new emission regulations. While some expensive emission control equipment can be avoided, this saving must be balanced by additional investment cost in LNG tanks and dual fuel injection systems. There are good opportunities for LNG in shipping on the Great Lakes with the proximity of natural gas pipelines and the possibility of shared LNG infrastructure with HD trucks. Ships have very long lifetimes (25-40 years) to amortize the high investment costs ($40-$50 million). While LNG is best fitted during ship construction, retrofits are feasible when a major refit is scheduled. The additional LNG tank volume could force cargo reductions in some cases.

- **Rail Applications:** The technology for natural gas in locomotives is at a prototype stage. For the market to develop, there is a need to interest OEM locomotive manufacturers in providing integrated technology solutions to storing and using LNG on trains. Fuel injection and metering technologies are similar, but of a larger size, to those used in HD vehicles. Potentially the market for LNG use in locomotive is attractive since one locomotive uses as much fuel as 20 HD trucks, and there are significant CAC reductions compared to diesel fuel. Rail routes parallel to major trucking corridors could share LNG infrastructure to assist the economics. Even with high investment costs (yet to be determined) long locomotive service life and high fuel use should yield attractive rates of return.

In summary, the most attractive and earliest applications appear to be in heavy-duty and medium-duty vehicles. Marine is also very attractive, but the market uptake will depend on vessel acquisitions and refits, as well as the availability of shared LNG infrastructure. LDVs may become attractive in the longer term if attractively priced OEM products become available in North America. Rail applications may also be attractive, but the technology is yet to be commercialized so that market entry dates are uncertain.

The next chapter will outline the business case for natural gas in medium- and heavy-duty applications in more detail.

Business Case Analysis

Objective

The objective of the business case analysis task was to examine the value proposition of natural gas as a fuel in various vehicle applications with the goal of identifying those applications which have the strongest value propositions and the greatest likelihood of being developed in an economically sustainable fashion. The analysis focused on medium and heavy-duty vehicles as these were identified as promising by the Working Group and by the Marbek report, based on the maturity of the technologies, the availability of factory-produced vehicles and the possibility of early implementation.

Description of the model and inputs

The analysis was conducted by Change Energy Incorporated using its proprietary lifecycle costing model. A steering group, with broad representation from industry and government, was formed to develop the statement of work, advise the consultant on inputs and assumptions to the model and to review the results. The model was used to calculate costs over a ten-year period for natural gas fueled vehicles, with diesel vehicles as a baseline. The results of the analysis are summarized by a measure known as a Fuel Value Index (FVI). The FVI combines all incremental operating and capital costs associated with using one fuel in place of another.

An FVI of one means that the alternative fuel offers an equivalent value proposition for the end user as the base line fuel, on a purely economic basis. The degree to which the FVI is greater than one indicates the degree that the natural gas option will be a compelling value proposition for the end user[17]. Sensitivity of the FVI to key factors and assumptions was tested; factors included possible government measures, carbon pricing and varying fuel costs. Since costs of inputs can vary over the forecast period of ten years, the FVI changes in value over time. Thus, if the price differential between natural gas and diesel fuel increases over ten years, the FVI will also increase. This change in the FVI over time is shown in the chart on the next page.

It was assumed that all LNG applications used the Westport system and all CNG applications used the Cummins Westport engine. This arbitrary distinction was made to simplify the number of modelling scenarios. In addition, the lower mileage applications were assumed to be CNG applications. In the real world, a fleet's choice of CNG or LNG vehicles will depend on a number of factors.

[17] There are other non-economic factors, such as environmental or social goals, that may encourage a fleet to use natural gas even if the FVI is one or less.

Four provinces were chosen for the analysis based on the likelihood that they could support market launch and early development. The selection was based on a weighted evaluation of the following parameters:

- Existence of natural gas distribution infrastructure (local, transmission)
- Existence of LNG infrastructure and proximity to potential market
- Existence of natural gas refuelling stations (public, private)
- Transportation fuel demand characterization in local area
- Identification of supportive policies and programs

The model is based on Excel spreadsheets so that it can readily be used by end-users and other groups to examine specific situations.

Results

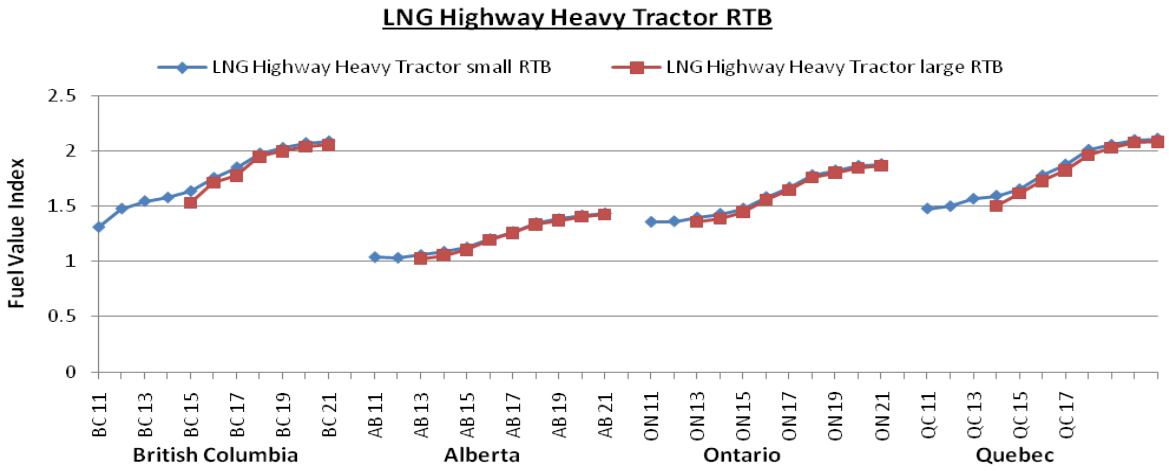
Of the thirteen vehicle applications analysed in the study, natural gas fuel provides a compelling value proposition for several commercial applications:

- Compressed natural gas (CNG) Transit buses;
- Liquefied natural gas (LNG) heavy highway tractor-trailers, refuelling at a central facility (referred to as Return to Base or RTB);
- LNG heavy urban tractor trailers, operating in RTB mode;
- LNG heavy highway tractor trailers, filling at publicly accessible stations on highway corridors;
- CNG heavy urban tractor trailers, operating in RTB mode; and
- CNG Refuse haulers, privately operated in RTB mode.

Other applications were less attractive on the basis of economics alone. These are shown in the lower half of the results table. The results broadly reflect the amount of fuel used by the vehicles in the particular duty cycles; port drayage trucks and school buses, for example, do not accumulate many kilometers, and so use much less fuel than a highway tractor trailer or a transit bus – the rankings (based on FVI) in the table show this. While the study included a broad range of applications, each individual application must be judged on its own merits. For instance vocational vehicles with higher annual mileage that those examined in this study will have a more attractive value proposition.

Application	*Mileage*	*Rank*	*Comments*
CNG Transit Bus RTB	80,000	1	Very Good
LNG Highway Heavy Tractor RTB	200,000	2	Very Good
LNG Urban Heavy Tractor RTB	140,000	3	Very Good
LNG Highway Heavy Tractor COR	200,000	4	Very Good
CNG Urban Heavy Tractor RTB	60,000	5	Good
CNG Refuse - private RTB	30,000	6	Good
CNG Vocational - high use RTB	50,000	7	Fair
LNG Port Drayage RTB	60,000	8	Fair
CNG Refuse - public RTB	20,000	9	Weak
CNG Vocational - medium use RTB	30,000	10	Weak
CNG School Bus RTB	15,000	11	Very Weak
CNG Port Drayage RTB	20,000	12	Very Weak
CNG Vocational - low use RTB	15,000	13	Very Weak

The FVI differs over time as the input costs change, and it also differs between provinces as it is affected significantly by different factors such as diesel fuel prices and the cost of electricity. For example, Alberta has lower diesel fuel prices than the other three provinces. The impact of this difference on the FVI is shown in the following chart.



CNG in transit buses had the strongest FVI. Although the economic case for buses is very good, the adverse experience of some transit properties with an earlier generation of CNG buses must be overcome for this application to succeed. Provincial government assistance for natural gas transit vehicles and refueling infrastructure has been discontinued, in contrast with the generous transit capital programs in the US. Even though the business case for transit is the most attractive, the consultants point out that some form of government assistance will almost certainly be needed for natural gas to re-enter the Canadian transit market.

LNG in heavy trucks is a particularly interesting opportunity since the amount of fuel used by trucks in the busy Windsor-Quebec corridor is so large. Over the past decade, the structure of the trucking industry has swung increasingly towards return to base operations as opposed to long distance hauling. This means that the majority of trucks can be filled from one or two facilities and this means that the capacity of fuel infrastructure should be well utilized.

Other important results on the FVI from sensitivity tests were:

- A carbon credit based on BC's carbon tax had little benefit for low fuel use vehicles, but in high-use applications yielded a 6% benefit by the end of the 10 year period;
- Measures that reduced the capital cost premium of a truck or bus by 50% had a significant impact of from 6 to 20%;
- Assuming that the price differential between natural gas and diesel fuel could be fixed, then a 20% differential would be needed for high-use vehicles to be economic, while low-use vehicles would need a 30-40% fuel price differential.

Conclusions

The results of the business case analysis, along with its detailed notes on the barriers and opportunities that exist for each of the vehicle applications, are valuable in confirming the best applications and locations for natural gas as a vehicle

fuel. The barriers in the transit industry have already been mentioned, but there are other equally important issues that must be resolved for other markets to succeed:

- Of key importance to trucking operators is the residual value of a natural gas vehicle at the end of its cycle – typically 5-7 years. Will the vehicle need to be repowered to diesel before it is sold, or will there be a valuable used market for natural gas trucks?
- Can economies be realized by transferring high value components such as dual fuel injectors and cryogenic storage tanks from trucks being retired to new trucks?
- How quickly will the prices of natural gas components decrease as production volumes increase?
- Can the significant capital cost of new LNG trucks and buses be easily accommodated within the existing financial structure of fleets?
- Can GHG emission reductions from the use of natural gas in vehicles be translated into monetary value for end-users?

These issues have technical and economic aspects that will need to be addressed through comprehensive information and education initiatives for markets to develop successfully – the important subject of education and outreach is covered in the next chapter.

Other issues that were not quantified in the economic analysis can be important to end-users. Examples are the low noise of natural gas engines compared to diesel; this is important in the transit, port drayage and refuse hauling markets. Also, some urban fleets may be able to use very low GHG biogas that is generated locally. The consultants suggest that a triple bottom line analysis be conducted to account for such environmental and social factors.

Natural Gas Education and Outreach

Medium- and heavy-duty natural gas vehicles have been shown to have economic and environmental benefits to users and society. However, to enable the market for these vehicles to develop in Canada, various stakeholders have important information and knowledge requirements that need to be met, and these stakeholders influence vehicle purchase decisions in direct or indirect ways. This chapter reviews what information needs to be provided to stakeholders, or target audiences as they are called here, to inform their decisions, and how best to provide it.

Following a background section that provides the rationale for natural gas vehicle education and outreach, this chapter highlights the key components of this strategy, including the objective, target audiences, and approach. To obtain the information for this section, a teleconference involving all working groups took place in July 2010. The purpose of this call was to identify key target audiences, key messages, and potential dissemination strategies. This information was consolidated in a matrix (see Appendix XX)

Background

Past efforts to encourage natural gas vehicle adoption have included education and outreach elements with the federal government partnering with industry to implement programs targeting fleet owners. For example, in the past, information brochures were developed and distributed at trade shows targeting municipal fleet contacts. While activities of this nature were undoubtedly helpful, on their own they are insufficient to effect meaningful change.

In addition, several aspects of the natural gas vehicle story have changed recently and these changes need to be communicated:

- The turnaround in the outlook for natural gas supply has been described in Chapter 2 and supply is no longer a barrier to considering natural gas use in transportation;
- Technologies for medium- and heavy-duty natural gas vehicles have improved significantly in terms of reliability, power, fuel efficiency, and availability from original equipment manufacturers (OEMs). Canadian suppliers have developed leading engine, storage and compression and dispensing technologies that are sold around the world;
- There is renewed interest from industry in the potential for natural gas as a transportation fuel. This interest is aligned with government priorities in terms of carbon reduction as a public policy priority;
- The full natural gas value chain is interested and engaged, with producers (e.g. Encana), transmission companies (e.g. TransCanada), and local distribution companies (Gaz Métro, Terasen Gas, ATCO Gas, Enbridge) all actively involved in the deployment roadmap process.

In particular, the changes in natural gas supply and vehicle technology are not necessarily well-known to end users or to the wide range of stakeholders that influence the market. Similarly, natural gas as a fuel is not as well understood as conventional liquid fuels in terms of its properties, differences compared to other fuels, delivered cost, lower carbon nature, and renewable form.

Key Components of a Natural Gas Vehicle Education and Outreach Strategy

To address these knowledge gaps, a comprehensive and sustained education and outreach strategy focused on key target audiences is essential in order to effect change and begin to transform the vehicle market.

Objective

The objective of this strategy would be to:

"Educate and inform stakeholders to ensure that they have the necessary information and tools at their disposal to make informed decisions that will support the deployment of natural gas vehicles in Canada."

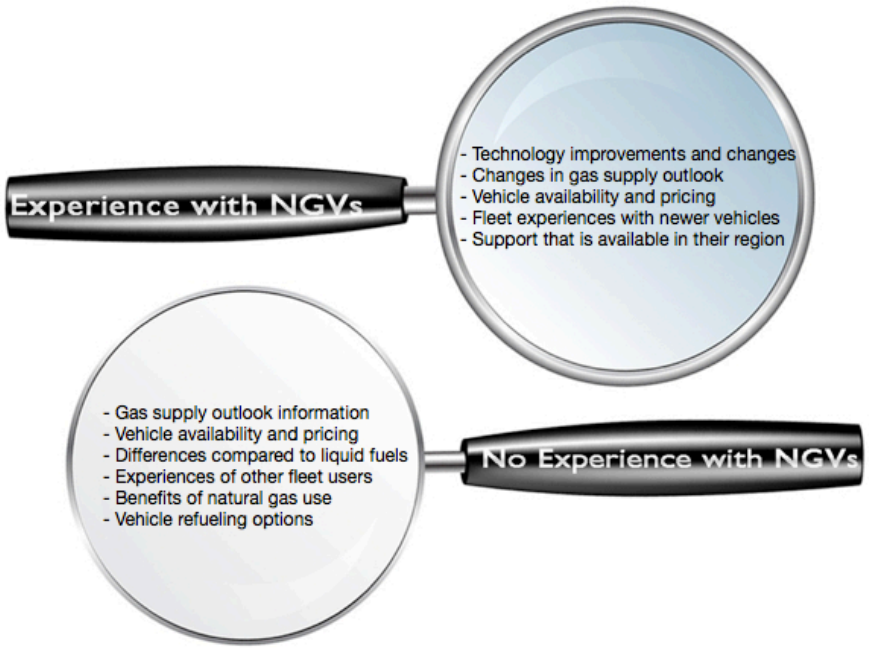
Target Audiences

The education and outreach matrix identifies 14 key target audiences that can be organized into the following five categories: 1) end-users; 2) vehicle supply chain; 3) authorities and regulatory bodies; 4) industry; and 5) general interest.

1) End-Users: This category includes public and private sector fleets such as municipal including transit, short-distance delivery, long distance delivery, industrial, school bus, and vocational. Education and outreach efforts for this category would need to focus on basic education and outreach needs in the context of both knowledge gaps as well as past experiences with natural gas vehicles. The former group would include those fleet managers who have little, or out of date, information about natural gas vehicles. These individuals need information to assist them with investment decisions related to natural gas to fuel their vehicles, including information about natural gas resources and prices, vehicle technology availability and price, operating experiences of other users, applicable codes and standards in their region, equipment and fuel suppliers, and environmental and other benefits of natural gas as a vehicle fuel.

The latter group includes those who have had previous negative experiences with natural gas vehicles and remain skeptical about the potential benefits associated with using this fuel. These individuals would likely require information regarding the experience of contemporary fleets that use natural gas as well as details about technological advancements, current vehicle and infrastructure offerings, and opportunities to receive support for transition in their region.

Experience Dictates How End Users Perceive NGVs



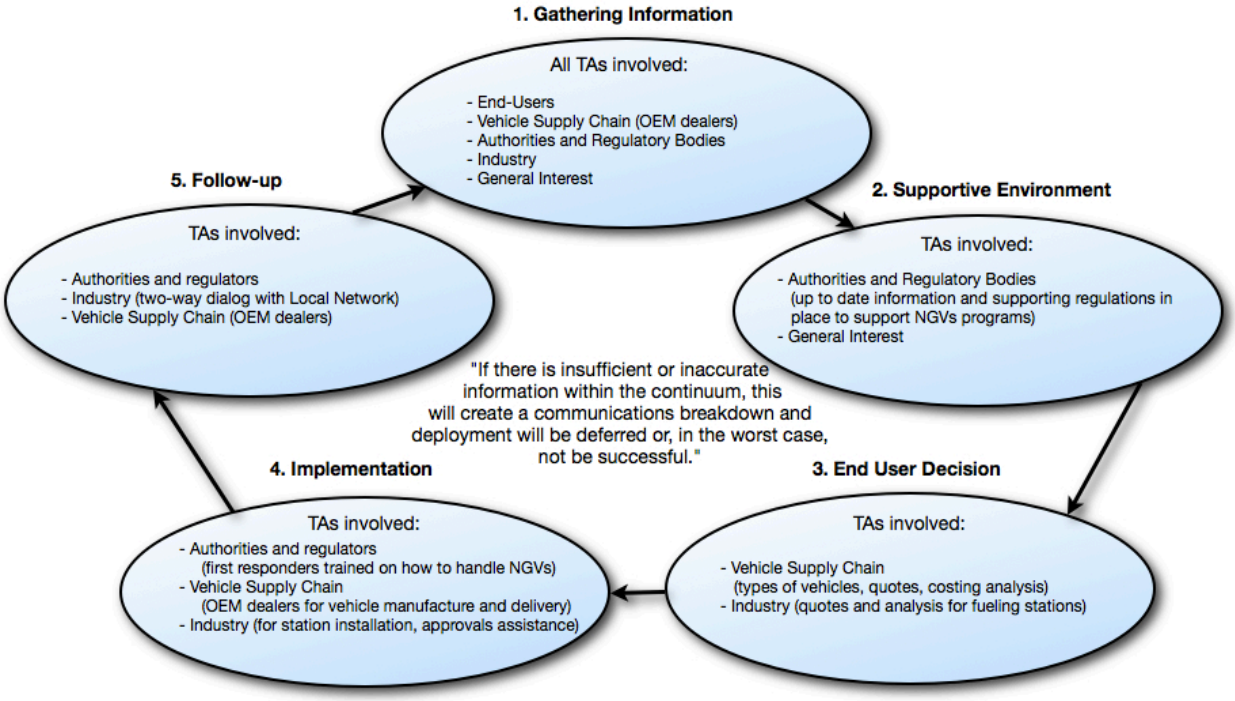
2) Vehicle Supply Chain: This category includes OEM dealers, many of whom have limited experience with natural gas vehicles. Therefore, these target audiences require information that would enable them to address the needs and concerns of potential purchasers of natural gas vehicles. Examples include information about the potential environmental and economic benefits associated with natural gas vehicle use, impact on vehicle range, weight and dimensions as well as other details that would help individuals make informed decisions about vehicle purchases.

3) Authorities and Regulatory Bodies: This category includes Authorities Having Jurisdiction, regulators, governments, and emergency response providers. These target audiences may not have a major role in the market for natural gas for vehicles once the market has been developed. However, they are important target audiences as their involvement in the initial stages of market development is crucial; the standards for which they are responsible must be met during the approval, construction and operational phases of a project such a refueling station.

4) Industry: This category includes companies active in the upstream, midstream and downstream portions of the natural gas industry. This category also includes equipment manufacturers, consultants and research organizations. This target audience works with end users to assess and deploy natural gas vehicles, so they need to understand their role in the decision –making and deployment process, working to ensure that implementation is coordinated and that it effectively meets end user needs.

5) General Interest: This category includes the public, media, and environmental groups. The target audiences in this category, especially the media, play roles in forming the opinions of others, so they need to have accurate information at their disposal.

Process Continuum for Deploying a Medium-Heavy-Duty NGV in Canada



- Step 1: The first step in the continuum is for the End-User to gather information. All TAs are involved at this stage because each channel is a possible source of information that can be used to inform and influence the End-User.
- Step 2: There must be a supportive environment for the use of the NGVs. Regulations need to be in place and the possible incentives or programs are identified. Positive references to natural gas vehicle use in the media help to generate awareness and interest
- Step 3: End-users need to have costing and analysis done that incorporates vehicles, fuel, and possibly a refueling station. Payback scenarios must be developed. Benefits must be weighed against costs and perceived risks in order to make a decision.
- Step 4: Dealers must deliver vehicles and industry needs to work with the end users to ensure required approvals are secured for vehicles and station. Proper support for emergencies must be in place. First responders need to be trained to recognize and handle an emergency involving a NGV.
- Step 5: There needs to be continued follow-up involving industry, the vehicle supply chain and end users with respect to vehicle and station performance, maintenance, warranty issues and product updates. There will also be follow-up involving authorities and regulators depending on inspection and certification requirements in local regulations.

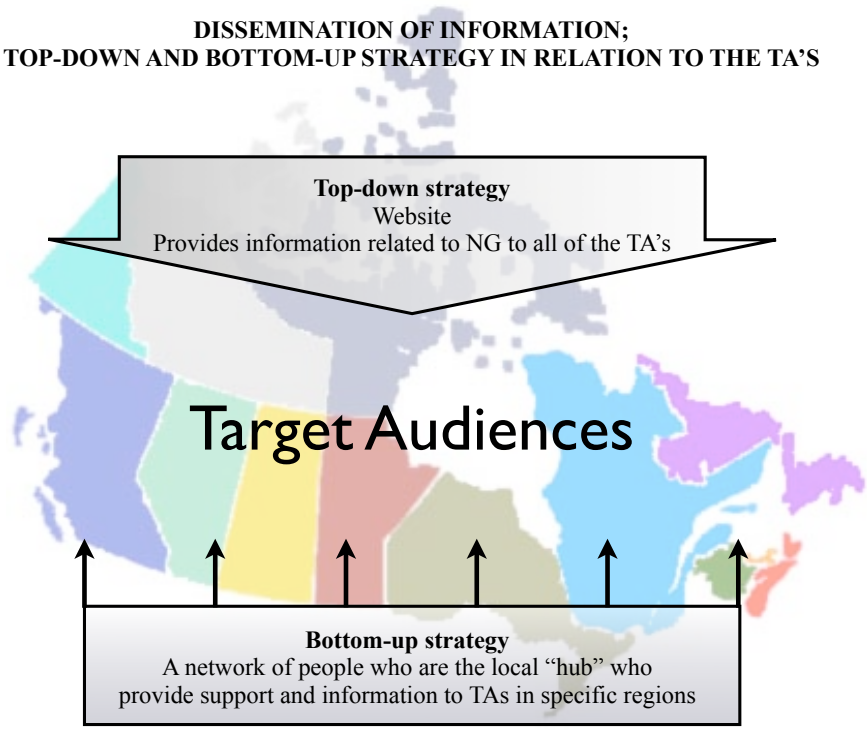
Approach

It is recommended that a holistic education and outreach strategy be developed that targets end-users as well as market influencers and other key stakeholders. The strategy should have two main elements:

- A “top-down” approach that includes a central website for all target audiences with local content tailored to specific jurisdictions. This website should focus on basic education and outreach needs in the context of both knowledge gaps and past experiences with natural gas vehicles. The website would serve as a central access point for all information related to natural gas vehicles (properties, benefits, suppliers, case studies, reports, news, refuelling stations, etc.) and provide real-time information on events such as announcements or upcoming workshops. The website could house brief videos (5-6 minute) which are educational and focused on "101" type of topics and

- A “bottom-up” approach, which features a national support network that will provide access to resources at the local level for end-users, including workshops and meetings. This network—which would be similar to that of the Clean Cities Program in the US—would be overseen by an umbrella organization. The network would have provincial coordinators that would provide customized support to users of natural gas vehicles. The coordinators would pool information and collect data that would be relevant for end-users, host workshops and meetings, disseminate education and outreach information and provide technical assistance and other resources. See the figure below.

DISSEMINATION OF INFORMATION;
TOP-DOWN AND BOTTOM-UP STRATEGY IN RELATION TO THE TA’S



In order to avoid competing messaging there should be a branding exercise to ensure all elements and tools have a common and unique look and feel. Branding would help the target audiences to differentiate the new information from outdated information. Delivery of the education and outreach programs, including website hosting, will ideally involve an objective third party, with resources and overall management provided by industry and government on a collaborative basis.

Technology Research and Development Needs

During the 1970s, governments in Canada began funding research and development (R&D) on alternative fuels—such as propane, hydrogen, and natural gas—to reduce dependency on petroleum resources. Since that time, governments in Canada and the United States have funded R&D on natural gas vehicles (NGVs) to achieve environmental benefits, as this technology was viewed as a means to improve air quality in urban areas.

Initial R&D on gaseous fuels focussed on developing codes and standards that would govern vehicle conversions, station design, and siting. These efforts also focused on addressing several short-comings for natural gas as a vehicle fuel, including:

- Power loss;
- Incomplete combustion of methane;
- Limitations associated with natural gas conversions of diesel engines;
- Heavy gas storage tanks.

Other R&D work funded by federal and provincial governments, in some cases with participation from the US agencies, engine manufacturers, and universities resulted in large natural gas-diesel bi-fuel engines; lightweight fiber-wound CNG tanks; high capacity fuelling facilities for transit buses; and other important innovations. Despite this progress, NGV R&D in Canada and the US declined to very low levels beginning in 2000 due to the declining outlook for natural gas resources. With the turnaround in the gas resource outlook over the past two years, US governments have begun to increase funding support for NGV R&D. Although public sector support in this area in Canada remains minimal, Canadian companies are world-leading producers of NGV technology because of past R&D investments.

Current Status of NGV Technology and Codes and Standards

Natural Gas Engines and Infrastructure

Current NGV refuelling station as well as light- medium-, and heavy-duty vehicle technologies are available, reliable and economical. NGV refuelling station technology is mature and is in use for both CNG and LNG applications. Similarly, natural gas vehicle technology has reached maturity. Vehicles with modern NGV technology have horsepower, acceleration, and cruise speeds that are equivalent to conventional fuel vehicles. Natural gas engines have been certified to exhaust emission standards established by the US Environmental Protection Agency and Environment Canada, which are among the most stringent in the world. And recent innovations, such as Westport Innovation's High Pressure Direct Injection (HPDI) have addressed fuel efficiency limitations associated with older natural gas engines.

Moreover, original equipment manufacturers have increased the number of NGV options that are currently on the market. Examples include highway tractors from Freightliner, Kenworth, and Peterbilt; refuse trucks from Autocar and Mack; school buses from Thomas Built and Bluebird, and speciality vehicles from Capacity. Westport Innovations has also

recently entered into an agreement with Volvo to develop natural gas injection systems for Volvo's engines. Details regarding current medium- and heavy-duty vehicles that are certified to meet EPA 2010 emissions standards can be found in Appendix XX.

Natural gas engines and LNG technologies are also available for LNG short-sea shipping through multi-fuel compression-ignition engines (Diesel-HFO-Gas) and dedicated lean burn spark-ignited engines and for rail applications through diesel dual fuel and gas turbines. However, these technologies still need to be integrated into platforms that are primarily custom-built.

Codes and Standards

Due to the significant efforts undertaken by NRCan and other stakeholders in the early 1990's, a number of codes and standards for natural gas vehicles, and CNG refuelling stations were developed. A list of existing codes, standards, and regulations for CNG vehicles, CNG refuelling infrastructure, and fuel quality, has been compiled as part of this roadmap process (Appendix XX). These codes represent a mature state of development; however, limited market adoption for natural gas vehicles in Canada in the past 5-7 years has led to a decline in committee activity for natural gas vehicle, refuelling station, and fuel codes and standards. In some instances, formerly active codes and standards committees have become dormant. In other instances, there are no existing committees whose scope of work explicitly includes emerging areas of interest such as codes and standards for LNG vehicles and refuelling stations. In addition, known issue areas, such as impact loading requirements, have gone unaddressed in the absence of committee activity.

The Need for Ongoing Technology Support

Engines and Infrastructure

There is a clear rationale for ongoing NGV R&D. As evidenced by the forthcoming GHG standards for model year 2016 heavy-duty vehicles, environmental standards pertaining to the transportation sector continue to evolve. As a result, natural gas technologies must continue to improve for them to be competitive with conventional fuel vehicles. In addition, there are ongoing advances in diesel and gasoline combustion research, and natural gas vehicle technology must keep pace. Even as NGV technology closes the efficiency gap with its diesel competition, the diesel engine is benefiting from substantial R&D dollars that were allocated to improve its performance. In order to remain competitive, NGVs will have to improve at a similar pace, while emphasizing their clean-burning advantages. Much of the required NGV R&D is highly sophisticated, involving the use of specialized diagnostic equipment and numerical modelling capacity that is not normally found within medium-sized companies. Government support for R&D in this area, is therefore, an imperative.

These issues were taken into account by the California Energy Commission (CEC), as this organization developed its "Natural Gas Vehicle Research Roadmap"[18] in 2009. The CEC roadmap describes the strategic research, development,

18 Prepared for the California Energy Commission, Public Interest Energy Research Program, August 2009 CEC-500-2008-044-F

demonstration, and deployment (RDD&D) needed to enhance the viability of the NGV market in California. Results from the CEC roadmap's research suggests that there exists a lack of heavy-duty and off-road engines sizes or capacity, and that vehicle integration of new engines is a significant hurdle to greater natural gas vehicle availability and market penetration. Specific research topics include engine development and vehicle integration; fuelling infrastructure; as well as storage, technical and strategic studies.

Although the Canadian market opportunities for NGVs are different than those in the US, many of the findings of the CEC roadmap are applicable to Canada's efforts to increase the use of natural gas in its transportation sector (see Table 1).

Table 1: Canada's NGV-Related RD&D Needs

	Short-Term (0-5 Years)	Longer-Term (5-10 Years)
Engine Development and Vehicle Integration	• Develop engines & NGVs with improved economics, efficiency, and emissions; • Integrate available natural gas technologies (e.g. Westport HPDI, Cummins Westsport ISL G, Emission Solutions technologies) into a broader range of NGV engine sizes and applications of original equipment manufacturers (OEMs); • Develop NGV high efficiency clean combustion (HECC) engine technology.	• Develop NGV versions for off–road applications, particularly large engine solutions for the rail and marine sectors; • Develop a variety of hybrid natural gas HDVs.
Fuelling Infrastructure and Storage	• Develop Fuelling infrastructure upgrades to accommodate fuel variability; • Develop improved CNG storage designs that integrate superior safety features and improved handling (with concurrent cost reduction); • Develop higher efficiency NG compression technology, with recovery of energy in compression; • Develop improved efficiency, handling, reliability, and durability of liquefied natural gas (LNG) dispensing and onboard storage.	• Develop small scale liquefaction technology that uses the waste energy from the pressure differential in natural gas transmission pipelines to liquefy pipeline gas; • Commercialize low energy station technologies that minimize energy inputs for CNG and LNG refuelling stations.

These RDD&D opportunities are of great interest to the Canadian NGV industry, which has historically shown leadership in this area, but is now experiencing pressure to export much of its expertise abroad since the market for Canadian NGV companies are located in China, India, the United States and Europe. The US and Europe have well-developed RD&D programs that Canadian companies may be able to access, however, continued access to them often involves relocating (in at least some capacity) to the country funding the work.

Codes and Standards

There is a strong link between codes and standards committee activity and research and development efforts. Research and development generates the necessary data, on issues like safe distances, and component failure, from which the committee members can adapt existing codes, and develop new ones. As new technologies are developed, there is also a need for concurrent development of related safety codes and standards, to ensure that possible gaps in regulations do not impede new products coming to market. The symbiotic and iterative relationship between the R&D community and the codes and standards committees is essential for the creation of pertinent regulations.

Next Steps

Moving forward, it will be important for industry, government, and universities to collaborate to achieve the RDD&D priorities that were described in this chapter. One way to achieve such collaboration would be through the formation of a technical advisory group, which is a proven vehicle to help establish priorities and provide guidance to a federal R&D effort on the needs of industry[19].

With regard to codes and standards, focused effort at the committee level will be required to address and resolve codes and standards issues and gaps related to natural gas vehicles and refueling stations. Having an active and appropriate committee structure that is properly resourced will be an important prerequisite to achieving progress.

19 Examples in the transportation and energy field are the Rail Research Advisory Board and the Hydrogen Technical Advisory Group (HYTAG).

Recommendations

The following set of recommendations was developed in consultation with stakeholders representing all working groups under this roadmap process. These recommendations have also been developed as a result of analysis related to business modeling work, capacity building needs and an assessment of research, development and demonstration requirements. Recommendations have been proposed in four key areas: (1) Capital Investments, (2) Research, development and demonstration, (3) Capacity Building, and (4) Overall Coordination.

Capital Investments:

1. Medium- and heavy-duty natural gas vehicles provide environmental and over-vehicle-life economic benefits, but the upfront capital vehicle premium is a barrier to adoption. Financial support is needed on a temporary basis to address the barrier to adoption and reduce the incremental cost of natural gas vehicles for fleet owners.

2. Significant financial investments are needed to ensure that the development of key corridor infrastructure, which may span across multiple jurisdictions, proceeds in a timely manner. L-CNG stations capable of dispensing both LNG and CNG are recommended in key corridors.

3. Industry business models for financing stations for return-to-base operations should be able to support the development of individual stations on fleet owners' sites without the need for external support and such infrastructure can be shared with other fleets, thus improving the overall business case.

Research, development and demonstration:

4. The natural gas vehicle industry funds R&D activities at present. Further investment has the potential to enhance the competitive position of the industry through targeted investment in R&D. Priorities for future R&D include: eliminating the cost differential between natural gas and diesel vehicles over the long-term and maximizing the operational and environmental benefits of natural gas vehicles.

5. Demonstration of the use of natural gas is needed to address technical barriers, develop standards, as well as to conduct feasibility studies and business cases. In particular, demonstrations of renewable natural gas in targeted applications such as refuse trucks are needed to provide tangible displays of this technology to potential end-users.

Capacity Building:

6. A holistic education and outreach strategy is needed to target end users as well as market influencers and other key stakeholders. This strategy should be comprised of both a 'top-down' and 'bottom-up' approach. A 'top-down' approach would include a central website or all target audiences with local content tailored to specific jurisdictions. A 'bottom-up' approach would feature a local support network for end-users and access to resources including workshops and case studies of local fleets.

7. A 'safety - codes and standards' working group needs to be established to develop mitigation strategies to address gaps and issues in existing codes and standards identified during this roadmap process. Separate committees for LNG and for CNG should be formed to develop new codes and standards based on these strategies.

8. Appropriate training materials for station and vehicle repair and operation as well as for cylinder inspection need to be developed and delivered.

Overall Coordination:

9. An NGV implementation body—consisting of select roundtable members and other key stakeholders—should be established to:

    A. Support and advance the implementation of the roadmap's recommendations and assess progress versus key milestones;
    B. Provide recommendations to stakeholders regarding how the natural gas community could respond to future developments, such as changes in market conditions and technological innovations;
    C. Act as an umbrella organization for the local support network for end-users;
    D. Serve as a forum for stakeholders who participated in the roadmap process to continue discussing issues pertinent to the natural gas community.

10. The timely development of corridor infrastructure will require a coordinated approach to ensure that infrastructure build-up matches demand and is strategically located to support end-users.

11. Continue to explore potential for natural gas use in other transportation and non-transportation applications.

Roles and Responsibilities

The following stakeholders have been identified as parties who would take on roles and responsibilities as they relate to moving the recommendations of this roadmap forward.

Natural Gas Use in Transportation: Roles and Responsibilities

		Governments	NG Producers and Distributers	Infrastructure and Vehicle Supply Stream	End-Users
Capital Investments	Vehicle Premium	√			√
	Corridor Infrastructure	√	√		
	Return-to-Base Infrastructure		√	√	√
RD&D	R&D	√		√	
	Demonstrations	√		√	√
Capacity Building	Education and outreach	√	√	√	
	Codes and Standards	√	√	√	
	Training	√	√	√	
Overall Coordination	Implementation Committee	√	√	√	√
	Corridor Infrastructure	√	√	√	
	Use of NG in Other Applications	√	√	√	

Next Steps

This *Roadmap for the Use of Natural Gas in Transportation* is largely the result of the generous contributions of effort and time by Working Group members. Much has been learned during the project by the different industry, non-government stakeholders and government representatives since the Roadmap inception.

The Road map has succeeded in its mission to:

- Address fundamental knowledge gaps regarding stakeholder interest, capacity, and economic and environmental impacts;
- Inform public and private sector decision-making;
- Assist in determining long-term investment requirements by stakeholders;
- Outline key steps for implementation and defining future government programming needs and industry's role.

The Roadmap contributes greatly to a broader understanding of what is needed for natural gas to succeed in the transportation market. The detailed inputs from the gas producers, technology providers and end-users allow a much richer understanding of the issues and potential solutions to market barriers than was available before.

Clearly there is much to do to put in place the structures for a successful market for natural gas in the heavy duty vehicle sector – the sector with the most compelling business case opportunities. Canada has the technologies at all stages of the supply chain to build this market; the combined efforts of industry and government will be need to realize these opportunities.

The steps that need to be taken include detailed discussion and follow-up on each of the recommendations in the previous chapter. There are a number of recommendations that are in the domains of federal and provincial governments, and these need to be followed up through the normal process of assessments and approvals.

There is a significant task in education and outreach that is a precondition to establishing new markets. This Roadmap has contributed substantially to the knowledge needed to design effective education and outreach programs.

The Roadmap has been useful in shining a light on the excellent products of Canadian companies that have built export markets in the natural gas for vehicles area. The task ahead is to apply these products and Canadian expertise towards using natural gas in our own transportation markets for the further benefit of Canadians.