

North America Transportation Energy Futures Study

- Long-Term Scenarios to 2050 -

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This paper outlines three long-term scenarios and a base case for the evolution of the North American transportation sector through the period 2000 - 2050. They cover Canada and the United States and examine the technologies and fuels that combine to meet the demand for energy services in the sector for mainly on-road mobility.

1.0 Purpose

The scenarios form part of a joint Canada – USA Department of Energy (DOE) study designed to estimate the energy, oil, carbon, and economic impacts of introducing alternative technology/fuels into the North American market over the next 50 years. The study will also identify the critical and most robust technologies and help outline the best policies and programs that can facilitate the evolution to a more sustainable transportation sector.

The scenarios will provide supply and demand profiles that will be used by both the Champagne model and the World Energy Supply model. There will also be a base case projection to 2050 against which the three scenarios developed and compared. The sensitivities of adding pathways or changing individual variables throughout each the scenarios and base case will also be investigated.

2.0 The NRCan Scenarios

The purpose of the scenarios is to establish a range of plausible futures for the evolution of the transportation sector and to estimate their impacts on energy use and the transportation system. They are not based on past historical trends or relationships but are intended to challenge current thinking and shift our current frame of reference. In doing this, we can assess the potential role and limits of transportation technologies, fuels and approaches. Three scenarios are established as well as a base case to 2050. The base case is derived from current trends and contains no revolutionary technology. Some variables such as population and vehicles per household remain constant across the base case and the scenarios.

2.1 The Drivers

The scenarios are developed using three drivers of future change. The drivers selected had to have the potential to lead to significant changes in the future; had to be independent of the other drivers, and had to be beyond the direct control of the client group but still also had to have a degree of reactivity to government or industry intervention.

The drivers establish the boundaries for the identification and development of the scenarios and allow for comparisons and contrasts to be highlighted. The definitions of these drivers and their dimensions or poles are outlined below.

2.1.1 Energy Interdependence

The vector reflects the degree of energy interdependence of North American (Canada, U.S., and Mexico) energy markets. **Limited** energy interdependence means that there is little in the way of accessibility to shared NA energy resources. NA energy markets operate somewhat independently with sporadic and uneven co-ordination of standards, regulations and approaches to energy use and supply. **Full** energy interdependence allows for more co-ordinated energy standards, regulations and approaches as well as easier accessibility to the energy resources available through out NA. Sufficient energy supplies are available and full to flow from North/South and East/West. This also includes, on a broader scale, common and well-established systems for undertaking and completing transactions regardless of their nature and new channels and infrastructure for product delivery, and market and sales support.

2.1.2 Environment Responsiveness

This vector reflects how business and the public regard environmental issues, and build them into their decision-making processes. It represents a behavioural response to environmental issues, and encompasses environmental ethics and environmental consciousness. Its polarities range from **Low** where business and the public are slow to react to environmental concerns, to **High** where business and public demonstrate high levels of awareness and are proactive, incorporating environmental concerns into decisions affecting their day-to-day operations.

2.1.3 The Pace of Innovation¹

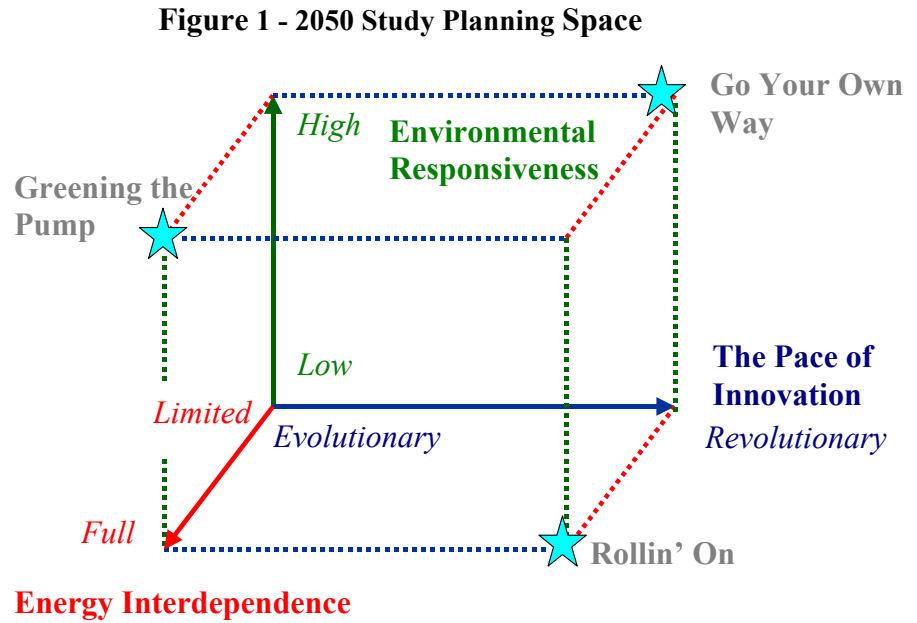
This vector reflects the speed at which the North American the innovation system functions. It reflects the speed at which we conceive ideas, nurture them through the R&D cycle and ultimately commercialize the technologies or products developed. The low end of this vector reflects an **Evolutionary** or slow pace of innovation. This involves incremental improvements to existing technologies with new technologies slow to arrive and penetrate the market. Research is less networked with cross-disciplinary expertise and technologies applications unable to reach wider audiences. The other dimension of this vector is a **Revolutionary** or rapid pace of innovation that sees exponential growth in new technologies leading to rapid capital stock turnover and greater application of technologies developed for one area applied to others. Increased innovation and increased GDP go hand in hand with positive feedback for both factors.

2.2 The Planning Space

By placing the “low end” of the drivers at the origin, a three-dimensional planning space is created. The eight corners of the box establish the extremes of the planning space and points within the box represent the full range of possible worlds given these drivers.

¹ This definition of the innovation system is clearly distinct from either product innovations that are made by firms in response to competitive forces or from the ability of a firm or economy to employ a technology. The ability of firms to adjust their product design in response to enhanced competition is market dependant, and the use of this definition of product innovation could be linked to market access, and thus these vectors would not be independent.

Figure 1 outlines the scenarios and their placement within the planning space. The formulation of the scenarios is built on the interaction of the drivers and their polarities. The world illustrated by each scenario represents the drivers' combined effect from now to the year 2050. Each scenario is distinct, internally consistent, and provides a coherent story line outlined by cause and effect relationships.



The range the scenarios covered is illustrated in the following chart. The three scenarios were chosen such that they would represent the widest range of possibilities for policies and technologies.

| Chart 1 – Driver Interaction | | | |
|-------------------------------------|-------------------------------|---------------------------|-------------------------------------|
| | Energy Interdependence | Pace of Innovation | Environmental Responsiveness |
| Greening The Pump | ON | OFF | ON |
| Rollin' On | ON | ON | OFF |
| Go Your Own Way | OFF | ON | ON |

2.3 *Greening the Pump*

This is a world with a slow pace of innovation, full energy interdependence and high environmental responsiveness. Fuels such as natural gas are preferred for the North American market while conventional, offshore and oil sands resources are extracted, processed and used in incrementally cleaner and more efficient ways. Technology investment is mainly for the demonstration and deployment of off-the-shelf technologies. This focus on deployment and nearer term activities resulted in a very uneven pattern of investment along the innovation chain. The lack of commitment to longer-term planning and R&D in transportation left North America with limited pools of technologies from which to draw on.

2.4 *Rollin' On*

Full energy interdependence and a revolutionary pace of innovation with low environmental responsiveness have led to a North American transportation sector with a

high reliance on fossil fuels. North Americans growing demand for passenger and freight transportation are met by a concerted effort of governments and industry. Rapid growth and capital stock turnover result in the new technologies being developed and deployed as rapidly as possible and North American energy sources tapped and delivered to market.

2.5 Go Your Own Way

Rapid innovation, limited energy interdependence and high environmental responsiveness have led to regions in North America seeking their own solutions to the development of a sustainable energy system. Rapid innovation has produced a variety of fuel and vehicle choices, however, many of the individual country solutions are constrained by the slate of vehicles and drive trains produced in the U.S. who continues to be one on the major vehicle suppliers. This world sees the greatest strides in renewable energies, fuel cell technology and biofuels.

3.0 The IIASA World Scenarios

The International Institute for Applied Systems Analysis outlined several scenarios of the future in their Global Energy Perspectives. These world scenarios are being used to provide the world background for the supply and demand of oil. These IIASA scenarios do not provide the demand and supply criteria for North America in this study but do provide information of GDP growth. The following sections explaining the scenarios are adapted from IIASA documentation.

3.1 Case A: High Growth

Case A is characterised by great increases in productivity and wealth. They are both technology and resource intensive and have rapid capital stock turnover and improvement in energy intensity and efficiencies. Technological change also provides greater access to energy resources.

Case A includes three high-growth scenarios that address key developments in energy supply. In Scenario A1, there is high future availability of oil and gas resources. Technological change enables the vast potential of conventional and non-conventional oil and gas resources to be used at competitive cost without significant efficiency or environmental penalties. Fossil energy sources only become phased out toward the end of the 21st century. There is no need to resort to exotic or speculative oil and gas occurrences or other “backstop” resources such as shales and low quality coals.

Scenario A2 provide a more conservative strategy with respect to both technological change and resource availability. Technological progress is more gradual, evolving along the lines of current supply technologies and the most abundant energy resources. The scenario assumes oil and gas resources to be scarce, i.e., limited to known reserves, resulting in a massive return to coal. Improved technology is needed to resolve the increasing costs of coal production and to introduce advanced conversion of coal to methanol and other synliquids.

Scenario A3 is also “technology intensive” but with a different direction compared to the other variants. New renewables and new nuclear technologies combine into a “bio-nuc” technology cluster that permits the transition to a post fossil fuel age along market penetration dynamics similar to those by which fossil fuels phased out traditional energy forms over the course of the 19th century. Natural gas provides the transitional fossil fuel of choice for a phase out of fossil fuels for economic reasons rather than due to resource scarcity. This strategy leads to a significant degree of decarbonisation of the global energy system. Scenario A3 is an illustration of a case in which “rich and clean” energy future resolves some of the challenges of global warming without the recourse to stringent environmental policy measures.

3.2 *Case B: Middle Course*

Case B has a single “middle course” scenario that is based on a more cautious approach regarding economic growth prospects, rates of technological change and energy availability. In short, the scenario is best characterised by modest dynamics and derives its appeal primarily because of its pragmatic attitude. It might also have a higher probability of occurrence than the more challenging technology and resource intensive Case A scenarios or the policy intensive Case C scenarios. Overall, Case B is reachable without relying on drastic changes in current institutions, technologies, and perceptions of the availability of fossil fuel resources.

Case B’s lower energy demand implies that it can rely on fossil fuel resources to the extent that is commensurate with current estimates of ultimately recoverable oil and gas reserves. Energy supply and end use patterns are also closer to the current situation for a longer period in Case B than in Cases A and C. Resource constraints do not materialize because of geological scarcity of oil and gas but rather arise due to the financing and environmental constraints of moving into progressively more remote, deeper and dirtier fossil resources. Eventually, nuclear and renewable energy replace fossil fuels, but these more dramatic shifts are post 2050.

3.3 *Case C: Ecologically Driven*

The two Case C scenarios present challenging global perspectives. Ambitious policy measures accelerate energy efficiency improvements and develop and promote environmentally benign, decentralized energy technologies. In addition to vigorous control of local and regional pollutants, a global regime to control the emission levels of greenhouse gases is established. The goal is to reduce GHG emission to stabilise atmospheric CO₂ concentrations by 2100 and mitigate against undesirable climate change impacts. It assumes unprecedented progressive international cooperation focused explicitly on environmental protection and international equity. It includes substantial resource transfers from industrialized to developing countries, spurring growth in the South. These resource transfers, which recycle funds from the OECD to developing countries, reflect stringent international environmental taxes and incentives to reduce carbon emissions.

Case C describes a challenging pathway of transition away from the current dominance of fossil fuels to a dominance of renewable energy flows. By 2050, renewables account

for 40% of global energy consumption, a share that increases to close to 80% by the end of the 21st century. The quality of the energy carriers delivered to the end users is high in order to meet the environmental constraints at the local level as well as the requirements of high efficiency end use devices. This means that renewable energy sources are transformed into electricity, liquid and gaseous energy carriers. Fossil fuels continue to be used as transitional fuels. Nuclear energy is at a crossroads in Case C and which direction it takes constitutes the main difference between the two Case C scenarios.

In Scenario C1, nuclear power proves a transient technology that is eventually phased out entirely by the end of the 21st century along with most fossil fuels. This assumes the nuclear industry is unable to adapt to public concerns or to pressures for downsizing and decentralising the energy system. In Scenario C2, a new generation of nuclear reactors is developed that is inherently safe and small scale (100 to 300 MWe) and finds widespread social acceptability, particularly in areas of scarce land resources and high population densities. Its expansion limits the contribution from renewables.

| Chart 2 - Summary of IIASA Case characteristics | | | |
|--|--------------------|----------------------|----------------------------|
| | A | B | C |
| | High growth | Middle course | Ecologically driven |
| Population, billion | | | |
| 1990 | 5.3 | 5.3 | 5.3 |
| 2050 | 10.1 | 10.1 | 10.1 |
| Global primary energy intensity improvement, percent per year | | | |
| | Medium | Low | High |
| 1990 to 2050 | 0.9 | 0.8 | 1.4 |
| Primary energy demand, Gtoe | | | |
| 1990 | 9 | 9 | 9 |
| 2050 | 25 | 20 | 14 |
| Resource availability | | | |
| Fossil | High | Medium | Low |
| Non-fossil | High | Medium | High |
| Technology costs | | | |
| Fossil | Low | Medium | High |
| Non-fossil | Low | Medium | Low |
| Technology dynamics | | | |
| Fossil | High | Medium | Medium |
| Non-fossil | High | Medium | High |
| Environmental taxes | | | |
| | No | No | Yes |
| CO2 emission constraint | | | |
| | No | No | Yes |
| Net carbon emissions, GtC | | | |
| 1990 | 6 | 6 | 6 |
| 2050 | 9-15 | 10 | 5 |
| Number of variants | | | |
| | 3 | 1 | 2 |

4.0 Matching IIASA World Scenarios to NRCan North American Scenarios

For the purposes of this study, there are four scenarios and a base case. All of the scenarios and the base case need to be matched to a IIASA world scenarios to provide the context for modellers who will examine North America's energy relationship with the rest of the world.

The following section outlines the “best fit” IIASA scenarios for each NATET scenario by identifying their similarities and differences. One significant difference between the NATET and IIASA scenarios is IIASA's consideration of resources constraints either by scarcity or financing. The NATET scenarios do not make any assumptions or considerations about resource constraints but instead, focus on technology, behaviour and markets. The NATET scenarios make the tacit assumption that the supply for any given fuel will be met by any means necessary with the increased environmental and financing costs considered qualitatively within the scenario. This difference in approach does not pose a problem as long as the resource scarcity assumptions of IIASA do not limit the ability of North America to balance its demand for energy with supply.

4.1 Base Case Scenario

The NATET base case has obvious connections to the IIASA Case B scenario. Both are middle course scenarios that are neither technology, policy nor resource intensive. The base case for NATET will be derived from incremental improvements to technology and medium projections of energy demands. There are no significant changes in its energy supply and demand profiles in this scenario. Similarly, the IIASA Case B scenario does not rely on any drastic changes in institutions, technologies or perceptions. Case B has the lowest level of energy intensity improvement per year that is consistent with the incremental improvements of the base case scenario.

4.2 Greening the Pump Scenario

The NATET “Greening of the Pump” scenario is a low growth ecologically based scenario. There is a move away from fossil fuel use towards renewable energy. In North America, this results in a greater amount of natural gas use in lieu of coal and, to a lesser extent, petroleum. Renewable energy grows in North America but has greater success in the developing world where there is little in the way of existing fossil fuel based infrastructure. This world does introduce new technologies but relies mainly on behaviour and government policy to decrease GHG emissions.

Case C has the lowest GDP growth of all of the IIASA scenarios for North America but sees the developing world growing well and adopting new renewable technologies. Since nuclear energy is not considered an acceptable energy source in “Greening the Pump”, Case C-1 in which nuclear power is phased out seems to be the most appropriate fit. In the IIASA Case C scenario, energy intensity improvements are the highest than all other IIASA scenarios. This is inconsistent with the “Greening the Pump” scenario and its lower rate of innovation. These values should be adjusted in the modelling of the ROW with the IIASA C model. An annual intensity improvement that is slightly more than the base case scenario is recommended. Therefore, the NATET “Greening the Pump”

scenario has the most in common with a modified IIASA Case C-1 with a lower rate of energy intensity improvements.

4.3 Rollin’ On Scenario

The NATET “Rollin’ On” scenario is a highly innovative and high growth scenario. In NA, the fuels of choice are fossil fuels, with petroleum and natural gas the preferred choices. Through innovation, energy supplies are more readily available and more useful energy is extracted per unit of fuel. The environment is not a concern to people and governments and NA is very energy interdependent to secure long-term fuel supplies for all countries.

Similarly, Case A is also characterized by large increases in productivity and wealth. Case A is both technology and resource intensive and each of its three variants has different emphasis on certain fuels. Case A-1 assumes a high availability of natural gas and petroleum resources from conventional and unconventional sources. Case A also assumes a medium level of energy intensity improvements, which is consistent with the NATET scenario. Though Rollin’ On is very innovative and has a lot of capital stock turnover, many of the advances go towards more appliances, electronics or to increase the power of previous models, not to decrease their energy demand. Therefore, the NATET “Rollin’ On” scenario has the most in common with the IIASA Case A-1.

4.4 Go Your Own Way Scenario

The NATET “Go Your Own Way” scenario is a highly innovative scenario that has a high degree of environmental responsiveness. Market interdependence is limited in this scenario so there is a greater emphasis on regional energy sources and a desire for countries like the US to lessen their dependence on imported fossil fuels. Through innovation and high economic growth, renewable energy’s portion of energy supply expands and energy intensity rapidly declines.

The IIASA Case A scenario reflects this NATET scenario very well for its high rate of growth and innovation. The variant A-3 scenario relies on strong growth in renewables and nuclear at the expense of coal and petroleum products. However, the IIASA Case A scenarios have a medium rate of energy intensity improvements in them while the NATET “Go Your Own Way” scenario would have a rapidly improving energy intensity as most new innovation would go towards improving energy and fuel efficiency. Therefore, the NATET “Go Your Own Way” scenario has the most in common with the modified IIASA Case A-3 with a higher rate of energy intensity improvements.

| Matching NRCan Scenarios to IIASA Scenarios | |
|--|---|
| | |
| Base Case | Case B |
| Greening the Pump | Case C-1 (with lowered Energy Intensity improvements) |
| Rollin’ On | Case A-1 |
| Go Your Own Way | Case A-3 (with higher Energy Intensity improvements) |