The Evolving Canadian Energy System

Clement Bowman, Fellow, Canadian Academy of Engineering
CAETS 2009 Calgary – July 14, 2009

Abstract

Canada is blessed with an enormous endowment of energy resources. At the ends of the spectrum are non-renewable resources such as the Alberta oil sands, with established reserves of 175 billion barrels and an in-place resource base of over 1600 billion barrels, and renewable resources such as hydroelectric power, with a current generating capacity of 73 Gigawatts and the potential to double this figure. These two resources represent the bookends of environmental issues: the oil sands currently have GHG emissions significantly higher than conventional oil production, whereas hydroelectric power, while blemish free with respect to GHG emissions, faces its own environmental challenges in bringing new resources on line.

It is now recognized that to meet these challenges and achieve its full potential, Canada's energy industry must be developed as an integrated system. It is not the resources themselves that define the energy system, but the ability to upgrade and transfer large flows of energy products among producers and users.

Canada is now evolving new approaches in the management of its energy system to reduce GHG emissions, increase flows of renewable energy, release stranded electrical power, and produce value-added energy products. Canada has well-established gas and oil pipelines and has plans for major new interprovincial electrical interconnections, which in total represent the backbone of the energy system. Energy corridors are emerging as important nodes in the backbone that will help establish Canada as a world leader in sustainable energy development. Examples of current and future options for integration of the energy system will be described in this paper.

The Evolving Canadian Energy System

June 21 Draft

Clement Bowman, Fellow, Canadian Academy of Engineering

CAETS 2009 Calgary – July 14, 2009

(Slide 1) Canada has abundant energy resources and a long history of successful development. But Canada's energy system, involving an integrated flow of energy products and currencies is just now evolving and that is the subject of this presentation.

(Slide 2) Canada is blessed with ample supplies of both non-renewable and renewable resources. The oil sands of Alberta and the extensive hydroelectric potential across Canada represent bookends of high and low GHG emitters. In total Canada only produces 64 megatonnes of GHG per exajoule of energy, less than other developed countries. But it is not the energy resources themselves that create value- it is the production of upgraded products from these resources – petroleum fuel and chemical products, hydrogen, and electricity. Carbon dioxide is a by-product which in the short term must be captured, transported and stored, but in the long term should be seen as a valuable raw material. Dr. Steven Chu, the U.S. Energy Secretary has spoken about the latter potential. The transactions among these products and by-products can be considered as taking place in a virtual energy corridor.

These various energy products and currencies have strengths and weaknesses which represent on-going challenges.

(Slide 3) Petroleum fuel and chemical products in Canada are produced from both conventional oil and gas and oil sands and heavy oil. The former have had a long and successful history in Canada, dating back to the digging of the first oil well in Canada in Lambton County, Ontario in 1857. Later large discoveries in Alberta launched the oil industry we know today. But the conventional oil wells are now depleting and replacements are in difficult reservoirs and/or in remote locations. On the other hand, the oil sands are massive in size with 175 billion barrels of established reserves with a potential in-place resource of over 1600 billion barrels. Three decades of successful development by two pioneering companies have proven the technology that was developed in the early 1930s. But the oil sands, as they have done in the past, have hit a wall and new technologies are now needed to overcome serious environmental issues and rising production costs. Canada is also seeking to upgrade the bitumen into higher valued fuel and chemical products, and reverse our long held reputation of hewers of wood and drawers of water.

(Slide4) Hydrogen is an extremely important currency for Canada and our long experience in producing it from natural gas has resulted in being a low-cost producer. We have some limited experience in producing it from alternative sources such as by electrolysis of water and

gasification of coal or biomass. We have an on-going market for hydrogen for both fertilizer manufacture and for upgrading oil sand bitumen, the latter representing an essentially 'perpetual' market. It is clear, however, that meeting the future hydrogen requirement for the oil sands will require new sustainable sources from water, either electrolytic or thermal.

(Slide 5) Canada has reliable and well established provincial-based electrical generation and transmission infrastructure, which provides 74% of the demand from low GHG emitting sources, mainly hydro and nuclear. Hydro alone provides 59% of the demand. But there are problems. Coal combustion is a major generator for base loads and is being phased out in some regions of the country. There is considerable stranded and unrealized low GHG power potential, and the capacity for energy storage is limited. One of the impediments is the limited and low capacity for interprovincial transfers; the strongest interconnections are North-South to the U.S.

(Slide 6) Carbon dioxide is an increasing challenge with pervasive and low concentration emissions from many utilities and industrial processes. Canada is attacking part of the problem through the demonstration of coal and biomass gasification, which produces hydrogen as a co-product with a concentrated stream of carbon dioxide. Fortunately, Canada has a market for a modest level of CO_2 in enhanced oil recovery, and extensive saline reservoirs to store CO_2. But the infrastructure for capture, transportation and storage remains to be developed, with only a few demonstration projects underway.

(Slide 7) With this discussion of the characteristics of these energy products and by-products, what is needed to create an integrated energy system? Basically it will require a market driven system for managing the flows and transactions involved in the interplay of many energy sources.

(Slide 8) Here is an example of the kind of interactions that are expected to occur. The spine of the system would be an electrical grid supplying power without interruption to all industrial and residential users. This grid would be fed by a combination of low GHG base load generators and a distributed supply from renewable sources. Storage of electrical energy will be needed to overcome the intermittency of renewable sources without requiring full back-up. For coal to continue to be a component of the Canadian electrical system, it will require a shift to the coal gasification process. This has the advantage of co-generation of hydrogen for the oil sands. With regards to a long term sustainable source of hydrogen, it is highly likely that this will be derived from water using nuclear or coal generated electricity, or by a thermal process in conjunction with nuclear power. A management system will be needed to capture, transport and store carbon dioxide, and hopefully its potential as a future raw material will be realized.

(Slide 9) Let's now look at the state of the transportation system that can move raw materials and products. Canada has extensive oil pipelines which connect East and West and link deep into the U.S.

(Slide 10) Natural Gas pipelines are also well developed and transverse through the U.S. on route to Eastern Canada.

(Slide 11) As mentioned earlier, the electrical connections between provinces are limited and are more robust in the North-South direction.

(Slide 12) However, there are a number of new electrical interconnections in the planning stage that would increase the capacity for both East-West and North-South directions.

(Slide 13) These enhancements would eventually lead to a robust ability to wheel power in all directions though a Canadian/U.S. continental grid network.

The benefits of a Canadian national grid are subjects of considerable debate with proponents on both sides. The con argument is that the economics of new enhancements favour North-South connections to the U.S. However, the U.S. Annual Energy Reference Case Outlook for 2009 does not show any increase in imports from Canada and Mexico over the next 20 years. (Slide 14) The proponents for a national grid identify a number of benefits that should be quantifiable, such as access to markets in four time zones, improved business case for intermittent renewables, expansion of carbon-free generation, balancing peak loads and facilitating continental connectivity.

(Slide 15) But pipelines and electrical grids are not the end game. It is not the movement of energy materials along transportation corridors that adds value. It is the value-added processing that occurs in industrial nodes that are imbedded in the transportation system that generate wealth and employment.

(Slide 16) Two examples of energy nodes are the Alberta Industrial Heartland in Alberta where much of the upgrading of oil sand bitumen will take place, and the Sarnia-Lambton Petrochemical and Refining Complex with 80 years of experience in upgrading petroleum products.

(Slide 17) Canada is in the process of planning the next stage in the evolution of its energy system. The increasing complexity of product transfers among companies, and the need for the development of new technologies that are likely to be beyond the ability of individual companies, indicate that a long term infrastructure investment plan will be needed. Several advisory panels have recommended that a cross-sectoral planning board be established. Canada

has a model for this in the establishment of the Alberta Oil Sands Technology and Research Authority in 1975 to undertake public/private sector demonstration of new technology for the deeply buried oil sands. This was presented as a model for consideration at the recent Fifth Summit of the Americas in Trinidad.

(Slide 18) Where does Canada expect to be with regard to future development of its energy sources over this century? Canada now produces 75% of its total energy from carbon sources, significantly less than other countries. This is expected to decrease as hydro, nuclear and renewables expand, perhaps decreasing to 50% before midcentury (Future 1) and 33% at an unknown Future 2. Hydro, nuclear and renewables will be fighting for positions in that diminishing carbon world. But carbon will still be needed as an important raw material for any foreseeable future.

The Evolving Canadian Energy System

Clement Bowman
Chair, Canadian Academy of Engineering
Energy Pathways Task Force

CAETS 2009 Calgary, July 14, 2009

Canada's Energy System

Non-Renewable Energy

- Conventional Oil
- Oil Sands
- Bituminous Carbonates
- Conventional Gas
- Non-conventional Gas
  - Tight Gas
  - Coal Bed Methane
  - Gas Hydrates
- Coal

National Energy Corridor

Petroleum Products
(Fuels, Chemicals)

Hydrogen
(Production, Transportation, Use)

Electrical Infrastructure
(Generation, Transmission Distribution, Storage)

Carbon Dioxide
(Capture, transportation, storage and use)

Renewable Energy

- Biomass
- Geothermal
- Hydro
- Solar
- Wind
- Tidal/Wave

Nuclear

- Uranium Resource
- Candu Power Reactor

Petroleum Products

(Fuels, Chemicals)

Conventional Oil and Gas

Strength
- Long and successful history of exploration, development, refining

Weakness
- Reserves declining and replacements are more difficult to find and develop

Oil Sands and Heavy Oil

Strength
- Massive resource, three decades of successful development

Weakness
- Serious environmental issues and rising production costs
- Limited capacity to upgrade to value-added products.

Hydrogen

(Production, Transportation and Use)

Production

Strength
- Extensive experience in production from natural gas

Weakness
- Limited commercial experience in production from alternative sources

Transportation and Use

Strength
- Massive ‘perpetual’ market in upgrading oil sands bitumen

Weakness
- Must soon find sustainable renewable source

Electrical Infrastructure

(Generation and Transmission)

Generation

Strength
- 74% from low GHG emission sources (nuclear and hydro)
- Unrealized low GHG potential

Weakness
- Coal combustion (high GHG emitter), for base load to be partially phased out
- Stranded low GHG power
- Limited capacity for storage

Transmission

Strength
- Well established provincial grid networks with a few profitable links to the U.S.

Weakness
- Limited and low capacity interprovincial connections

Carbon Dioxide

(Capture, Transportation, Storage and Use)

Capture

Strength
- Several coal and biomass gasification projects underway with CO2 capture potential

Weakness
- CO2 emissions are pervasive and generally in dilute concentrations

Transporation Storage and Use

Strength
- Moderate market for use in enhanced oil recovery
- Enormous capacity for storage in saline reservoirs

Weakness
- Only a few demonstration projects underway

An Energy System

One of the major conclusions from several recent energy sector evaluations is that energy must be seen as a 'System'

Non-Renewable Energy

- Conventional Oil
- Oil Sands
- Bituminous Carbonates
- Conventional Gas
- Non-conventional Gas
  - Tight Gas
  - Coal Bed Methane
  - Gas Hydrates
- Coal

The System is comprised of the flows and transactions that take place among the products and byproducts generated from the energy sources

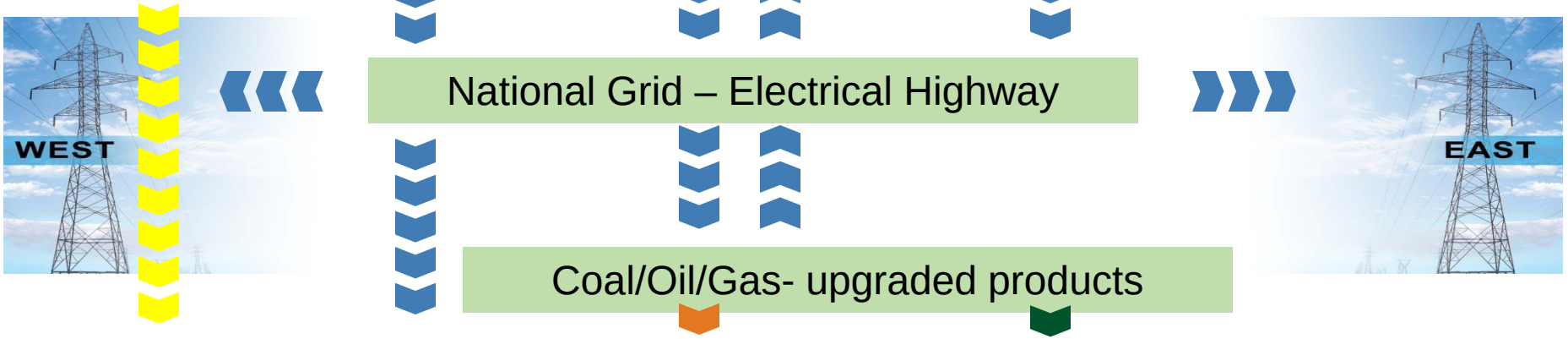
Renewable Energy

- Biomass
- Geothermal
- Hydro
- Solar
- Wind
- Tidal/Wave

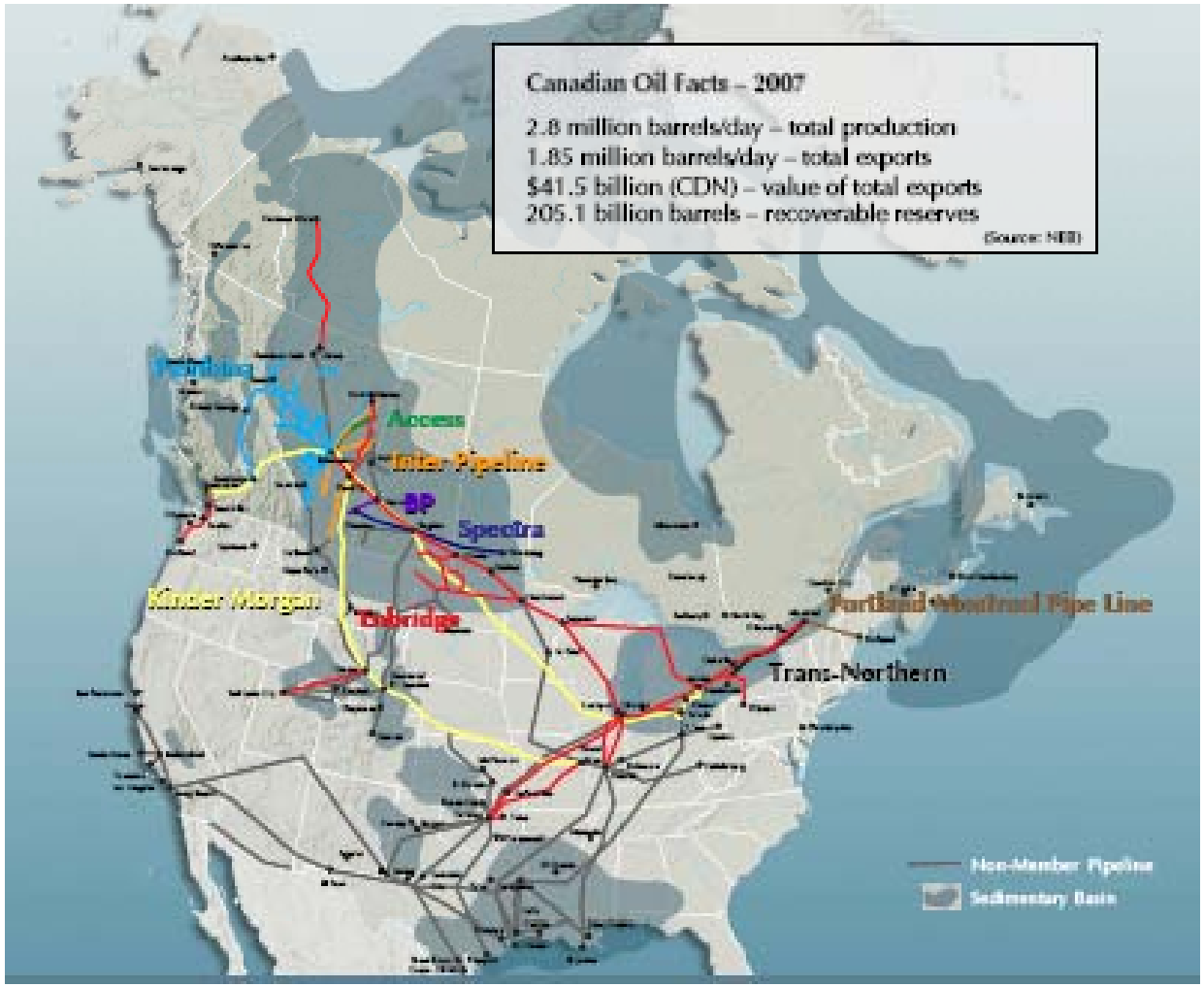
Nuclear

- Uranium Resource
- Candu Power Reactor

The Evolution of an Energy System

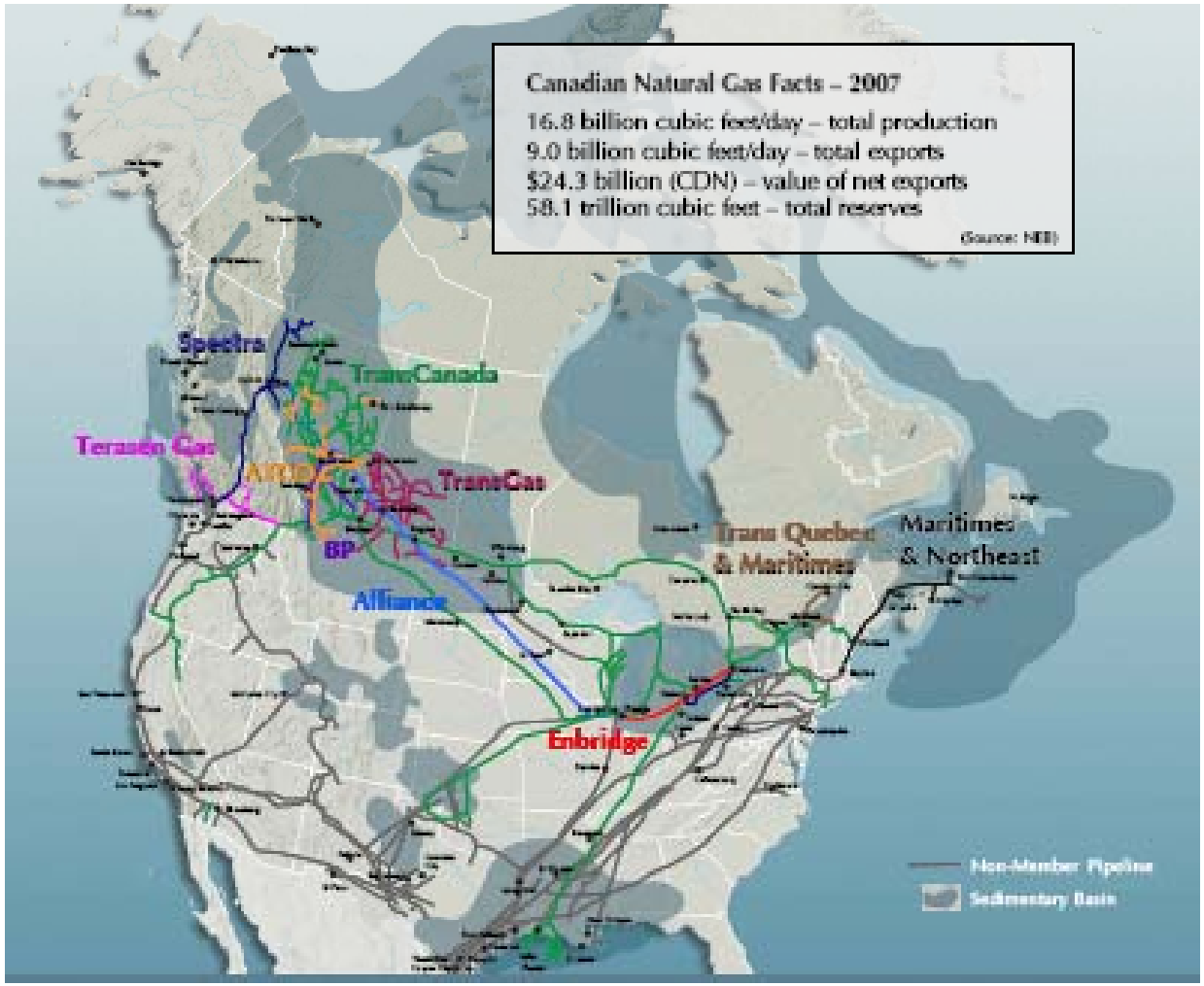


Oil Pipelines – CEPA data



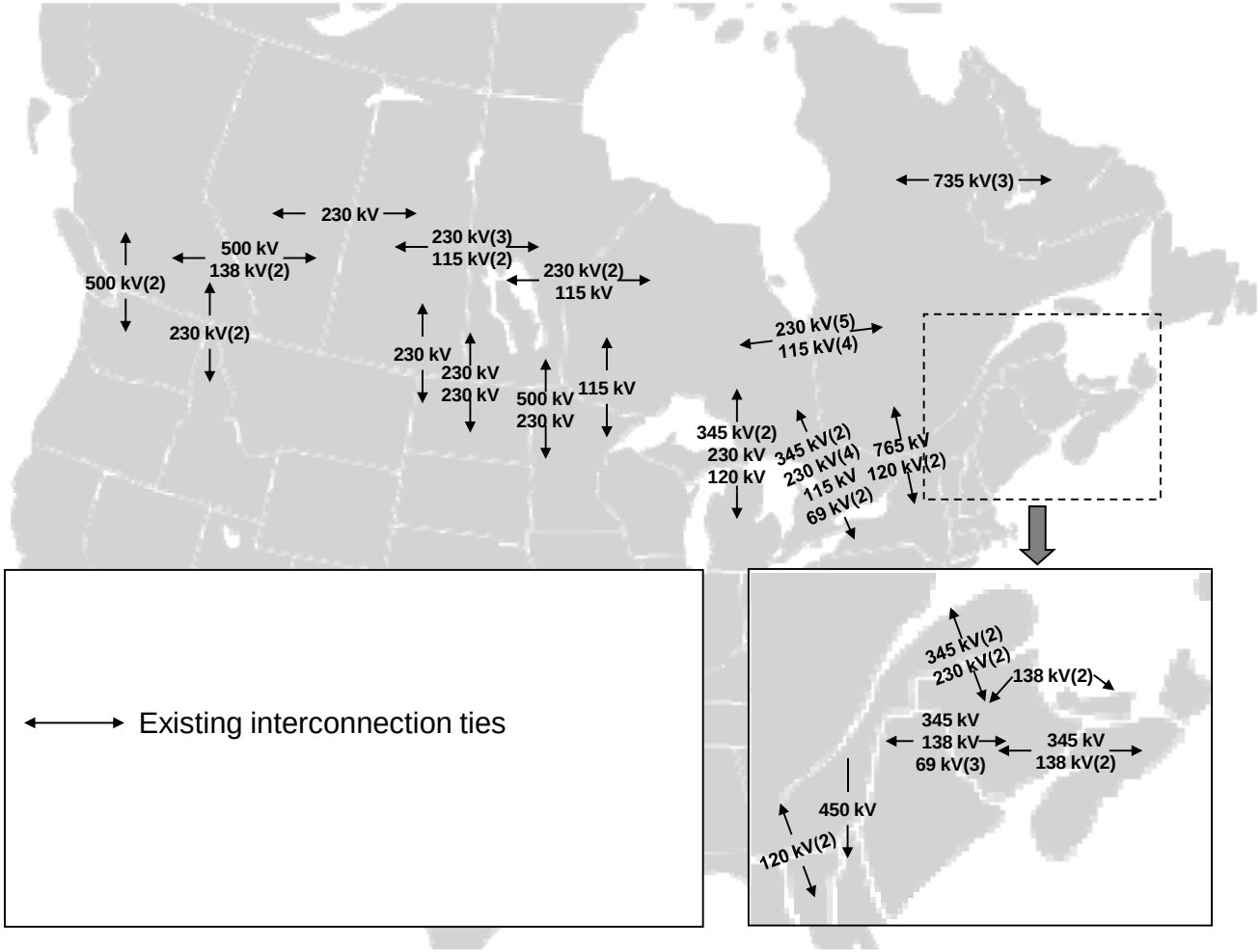
CAETS 2009 Calgary, July 14, 2009

Natural Gas Pipelines – CEPA data

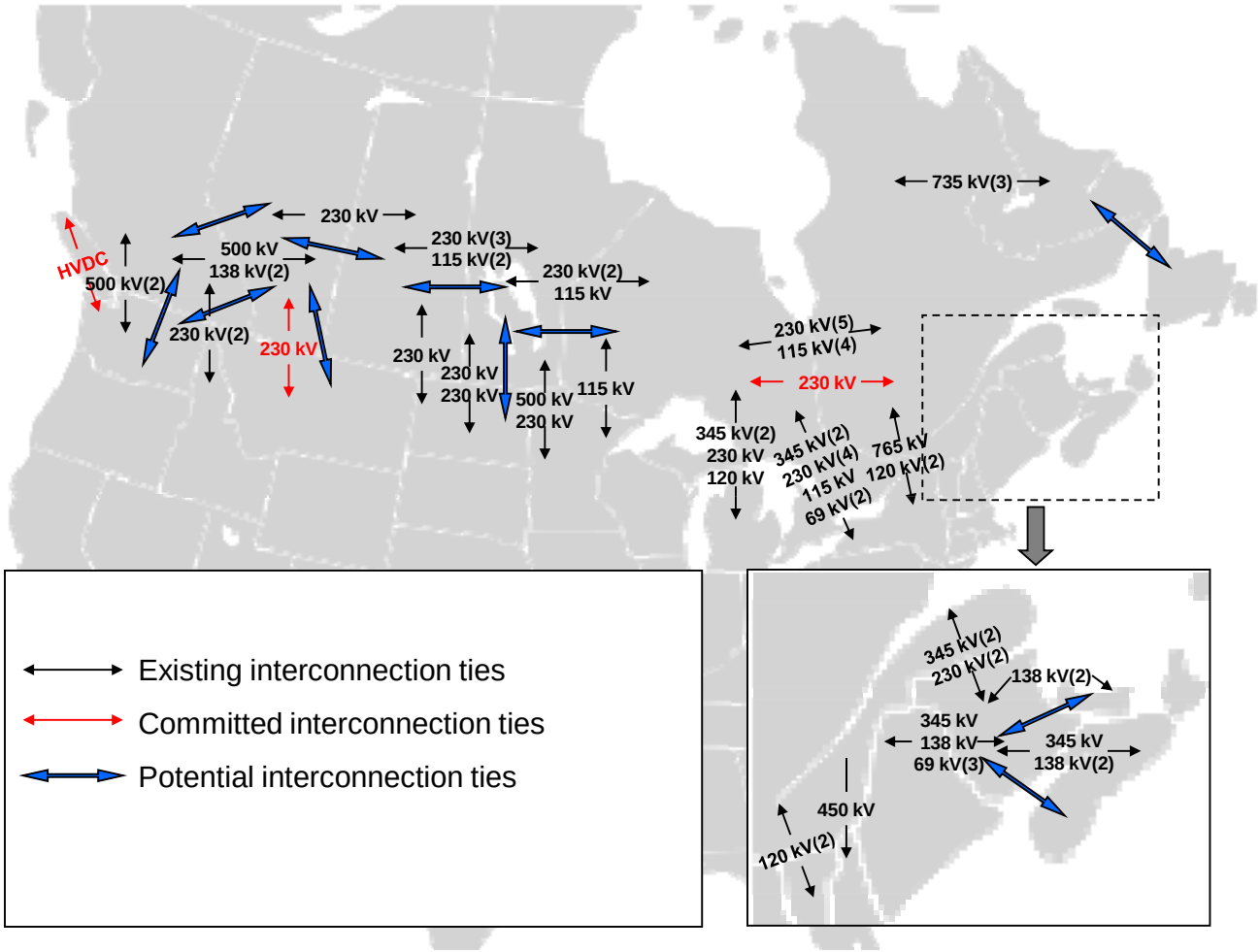


CAETS 2009 Calgary, July 14, 2009

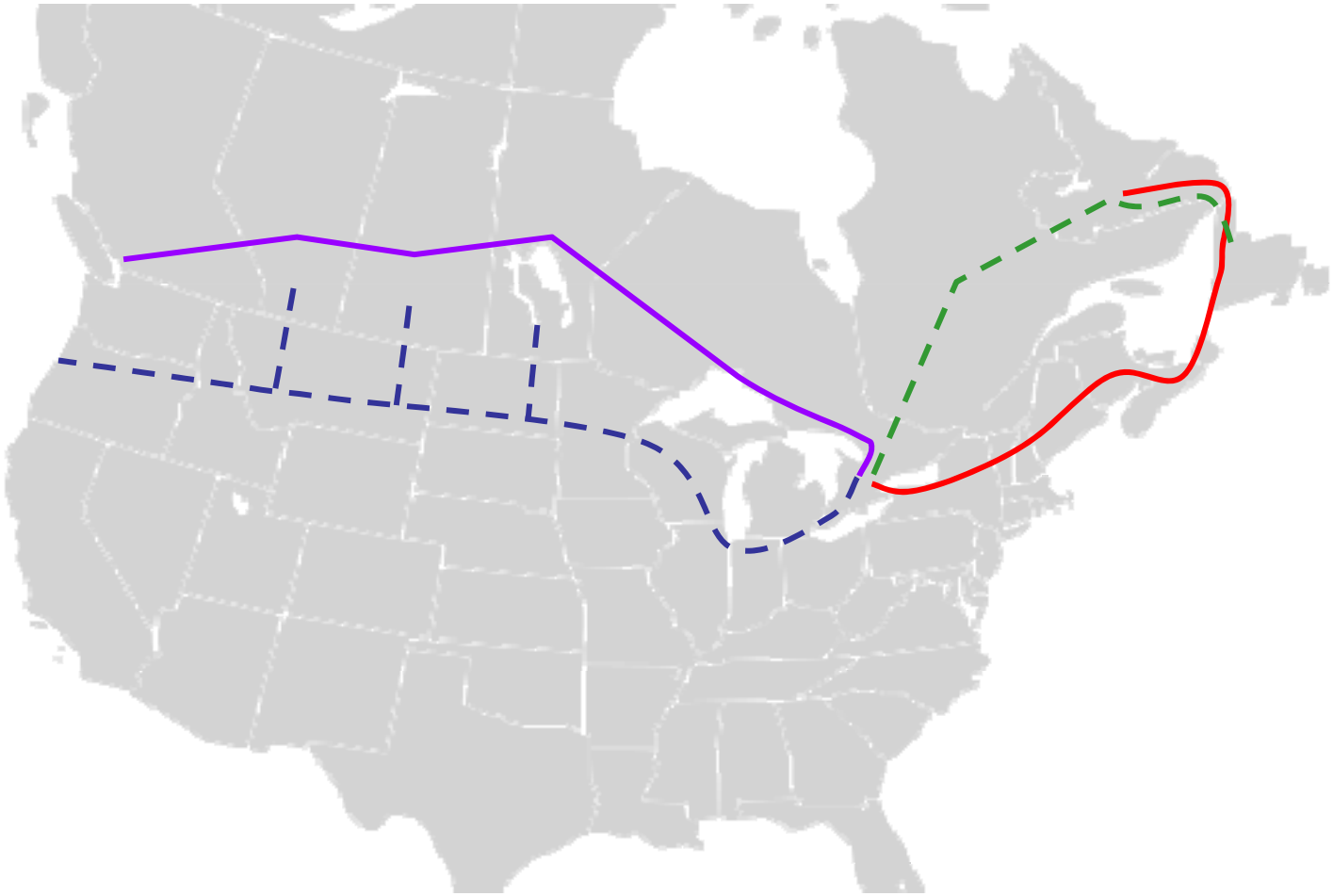
Existing Electrical Interconnections



Existing, Proposed and Potential Electrical Interconnections



Evolution to a Continental Energy Grid



Benefits of a Canada East-West Grid

- **Access to markets:** Market access in four time zones
- **Renewables:** Improves business case for new renewables-based generation,
- **Carbon-free generation:** Stimulates expansion of traditional carbon-free generation
- **Peak load:** Improves ability to deal with local peak loada
- **Continental connectivity:** Facilitates connection to expected U.S. East-West grids

Pipelines and Grids are not the End Game

- **Moving energy and materials along transportation corridors does not create a value-added Energy System**

- **It is value-added nodes in the corridors that create wealth and employment through product upgrading.**

Two Examples of Energy Nodes

Alberta Industrial Heartland

- A cluster of petrochemical, chemical and oil and gas companies, North East of Edmonton
- An integral part of the North American pipeline network
- Electrical system upgrades will assist the planned expansion

Sarnia-Lambton Petrochemical and Refining Complex

- Integrated petroleum and petrochemical industries, lying along the St. Clair River, near the location of the first oil discovery in Canada
- A brilliant history of private/public sector developments dating back to WW2

Completing the Energy System

- Develop the long term vision
- Establish an infrastructure investment fund
- Create a cross-sectoral management board[1]

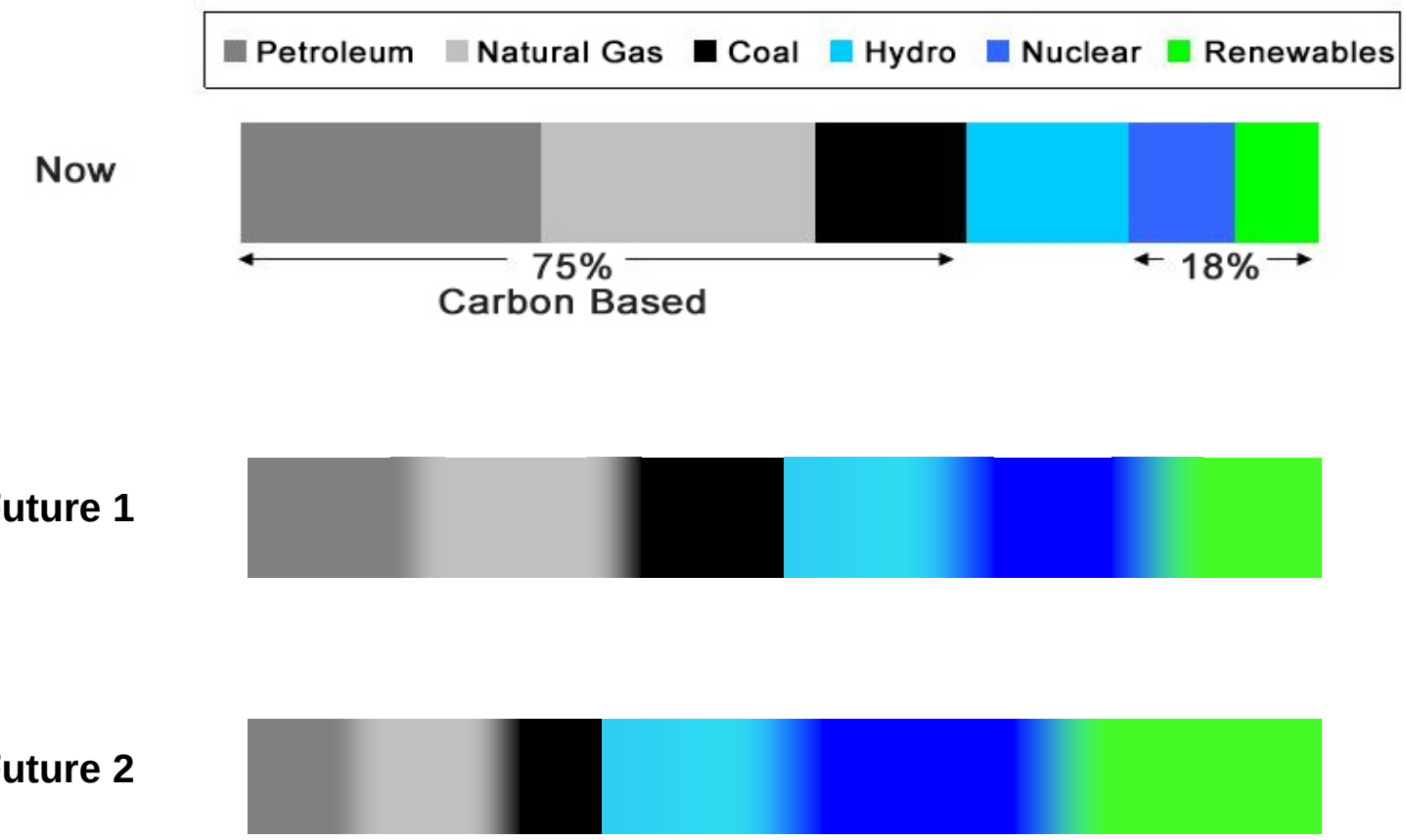
Canada has a model for this:
Alberta Oil Sands Technology and Research Authority

- A National Project launched by a $100 million seed fund, that grew to $1 billion (1970s dollars). Projects funded 50/50 by the private/public sector
- The Purpose – to get the private sector back working on the 90% of the oil sands too deeply buried to be mined.
- Presented as model for consideration by the Fifth Summit of the Americas [2]

[1] – as recommended in "Powerful Connections- Priorities and Directions in Energy Science and Technology" and in "CAE Energy Pathways Task Force Phase 1 Final Report"

[2] – Blueprint for a Sustainable Energy Partnership of the Americas, April 17-19, 2009

The Renewable/Non-Renewable Balance



CAETS 2009 Calgary, July 14, 2009