

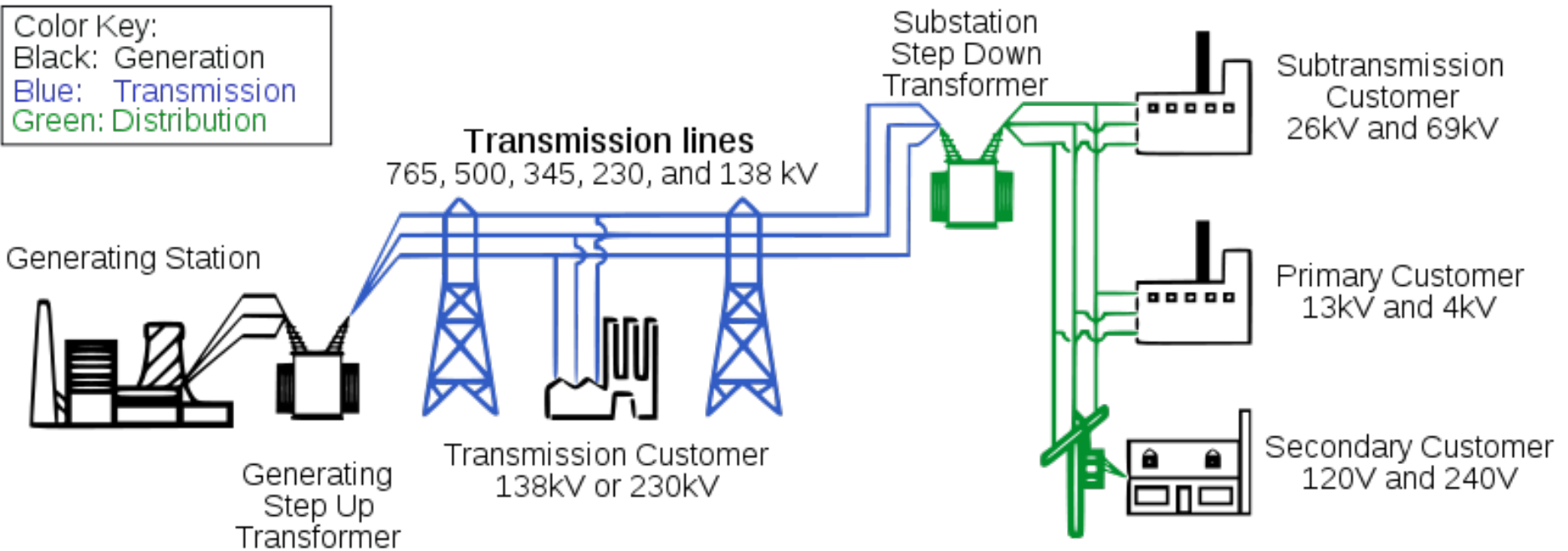
Introdcution to North American Power System



Outline

- Basic Power System
- North American Power System
- Canada Power System
- Ontario Power System

Basic Power System



North American Power System

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North American Transmission Grid

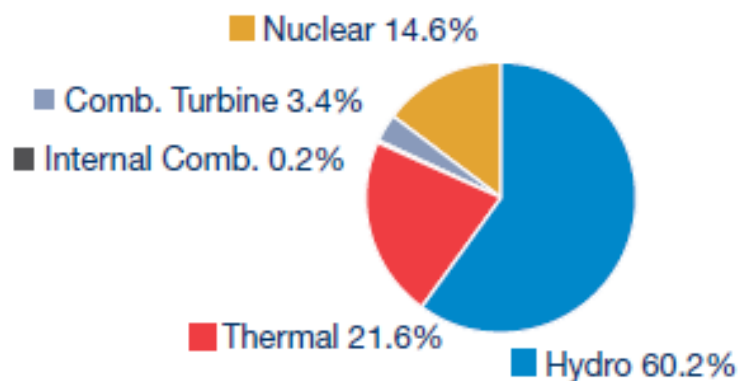
Interconnections of Transmission Grid above 345kV, as of March 2007



Source: Canadian Electricity Association, CEA

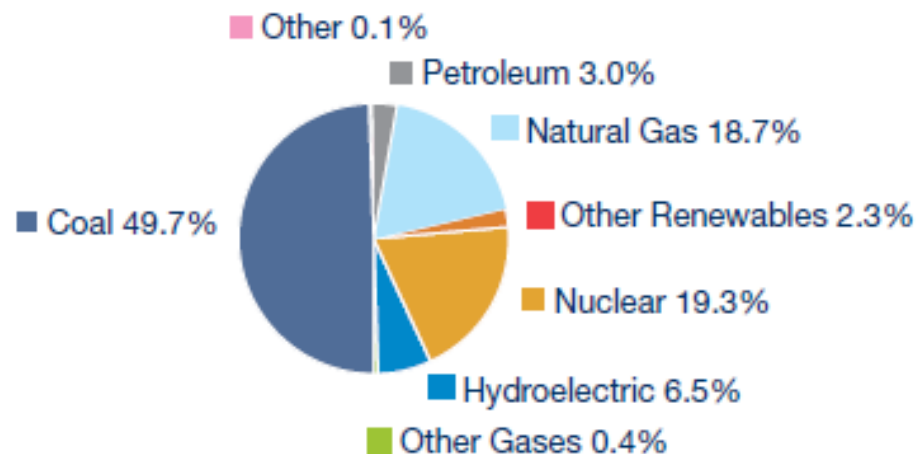
North American Generation

CANADA



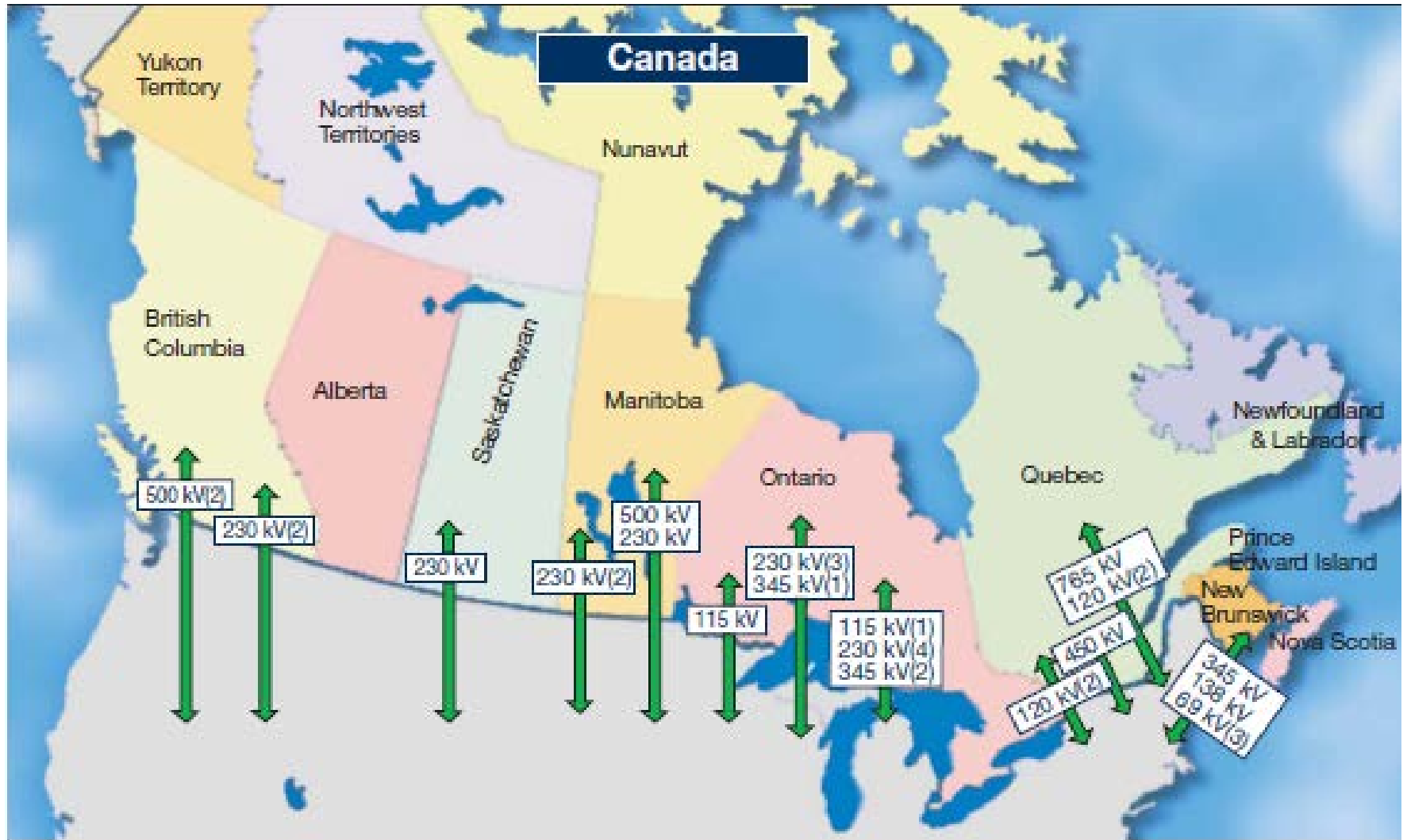
Total = 593.6 TWh

USA

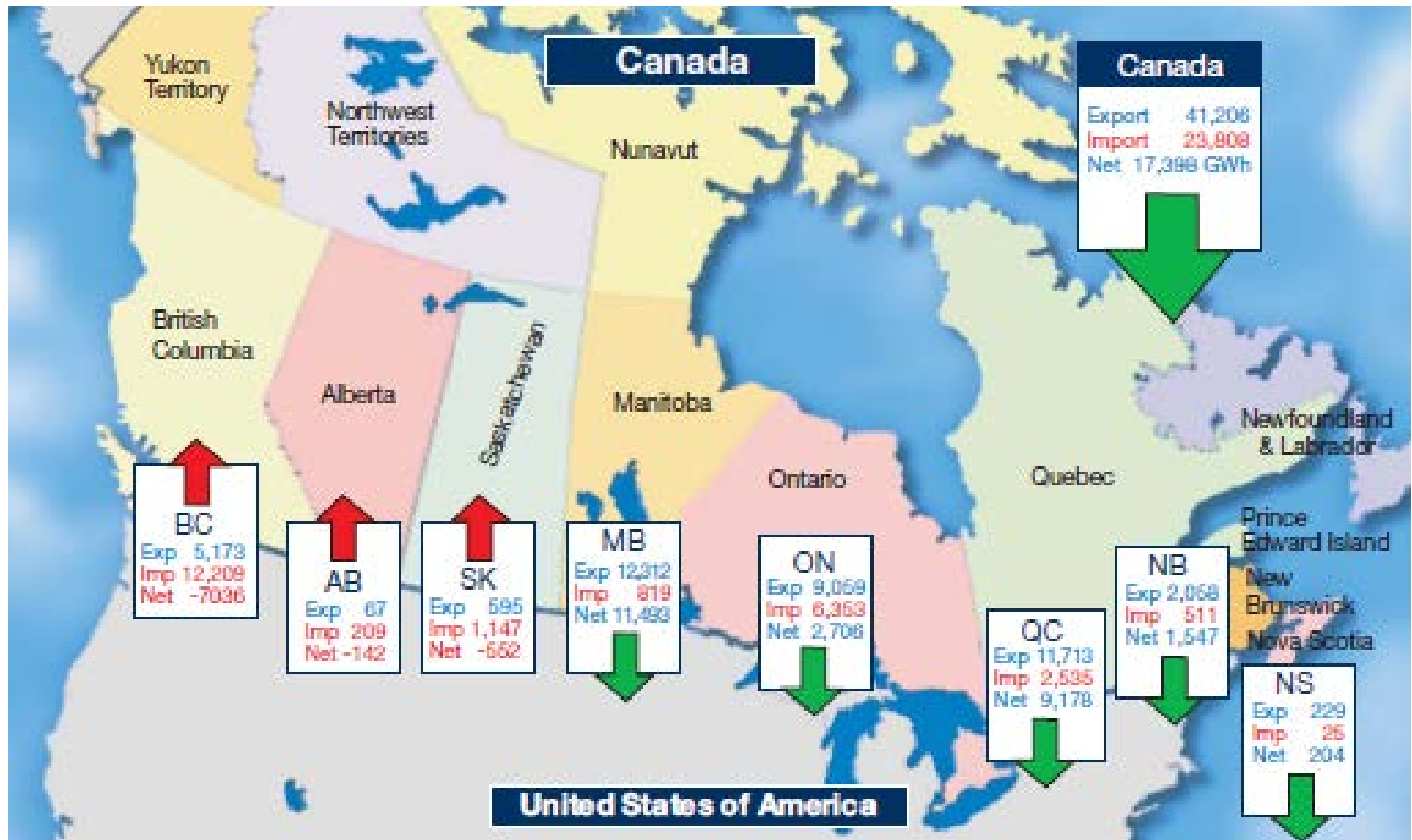


Total = 4,055 TWh

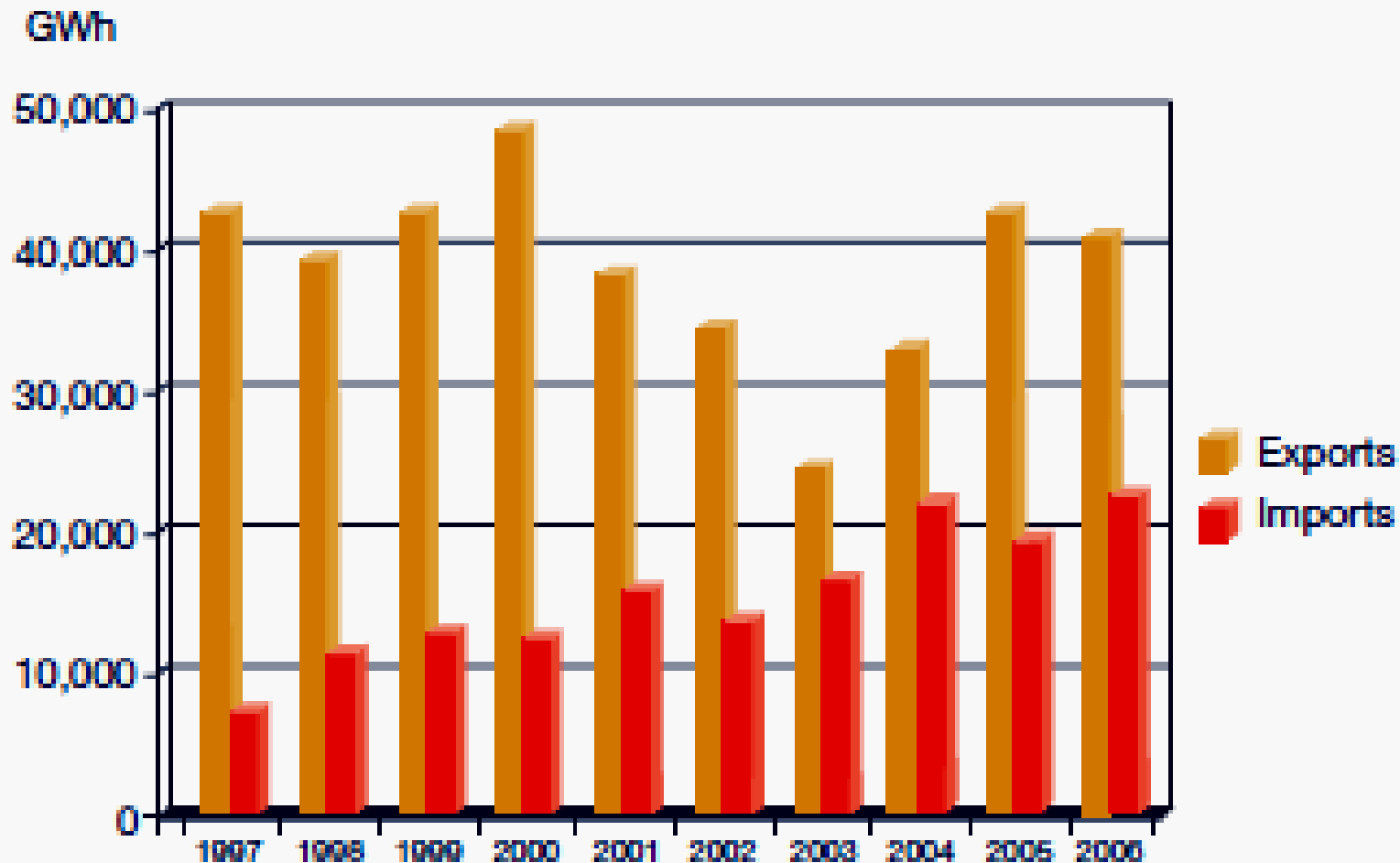
U.S./Canada Interconnections



North American Transmission Grid



North American Transmission Grid



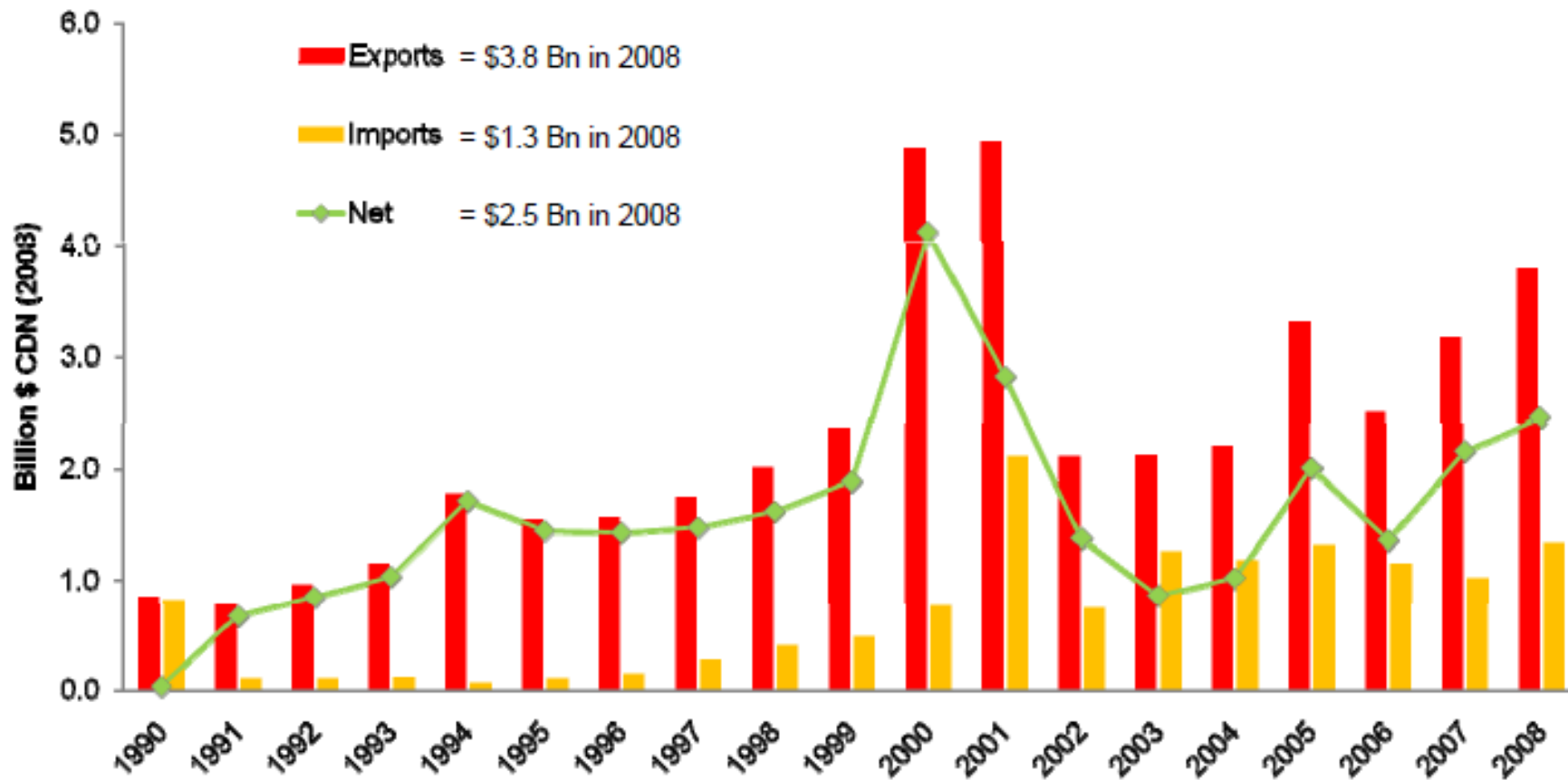
Canada-US Electricity Trade

As of 2008

	Exports (TWh)	Imports (TWh)	Net (TWh)
British Columbia	8,081.43	11,514.05	-3,432.62
Alberta	227.85	761.35	-533.50
Saskatchewan	137.20	431.65	-294.45
Manitoba	9,880.37	87.88	9,792.49
Ontario	18,570.88	7,997.88	10,573.00
Quebec	17,454.74	1,352.46	16,102.28
Nova Scotia	1,367.25	1,081.48	285.76
New Brunswick	12.69	272.69	-260.00
Total	55,732.40	23,499.44	32,232.96

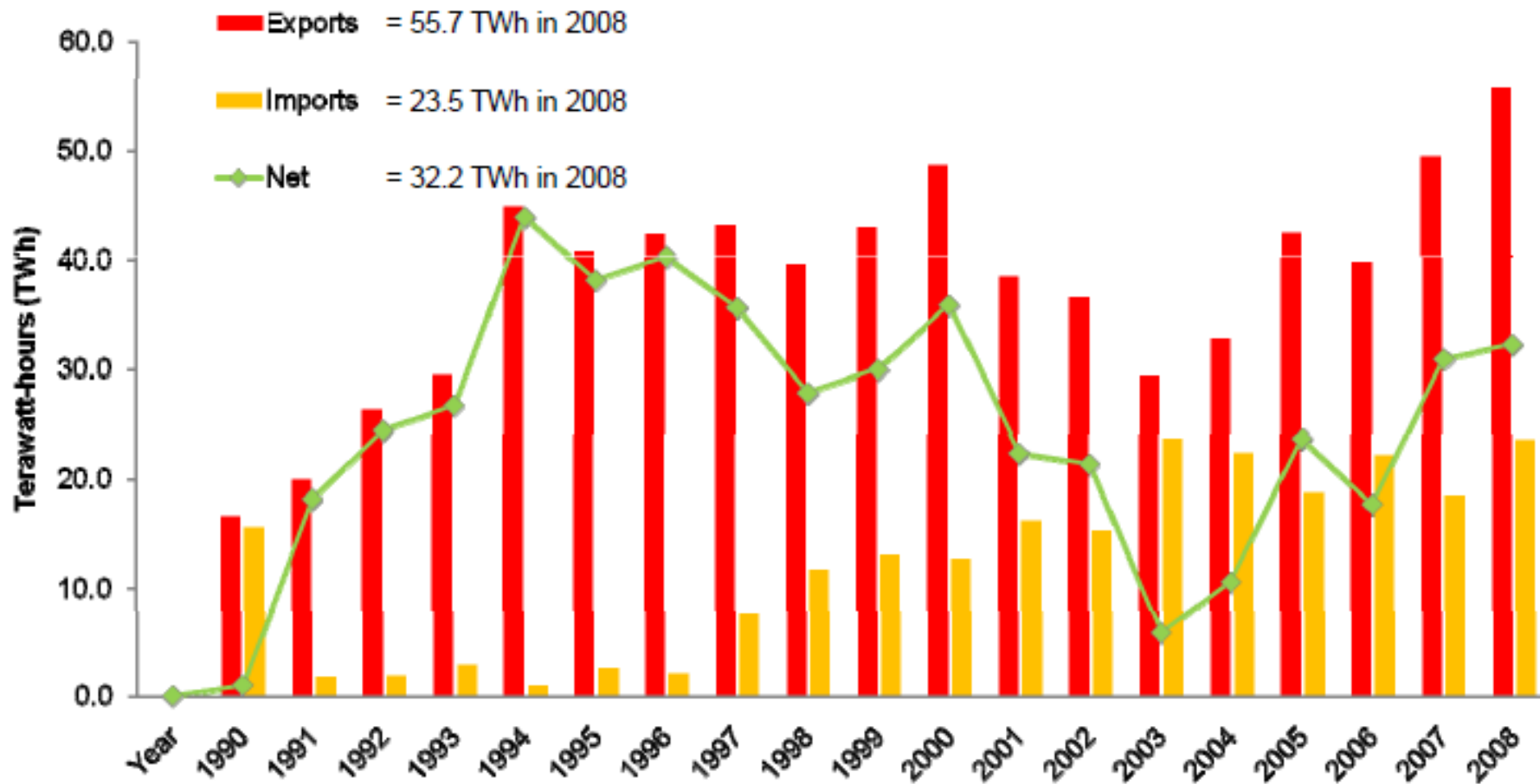
Canada-US Electricity Trade

Between 1990 to 2008



Canada-US Electricity Trade

Between 1990 to 2008

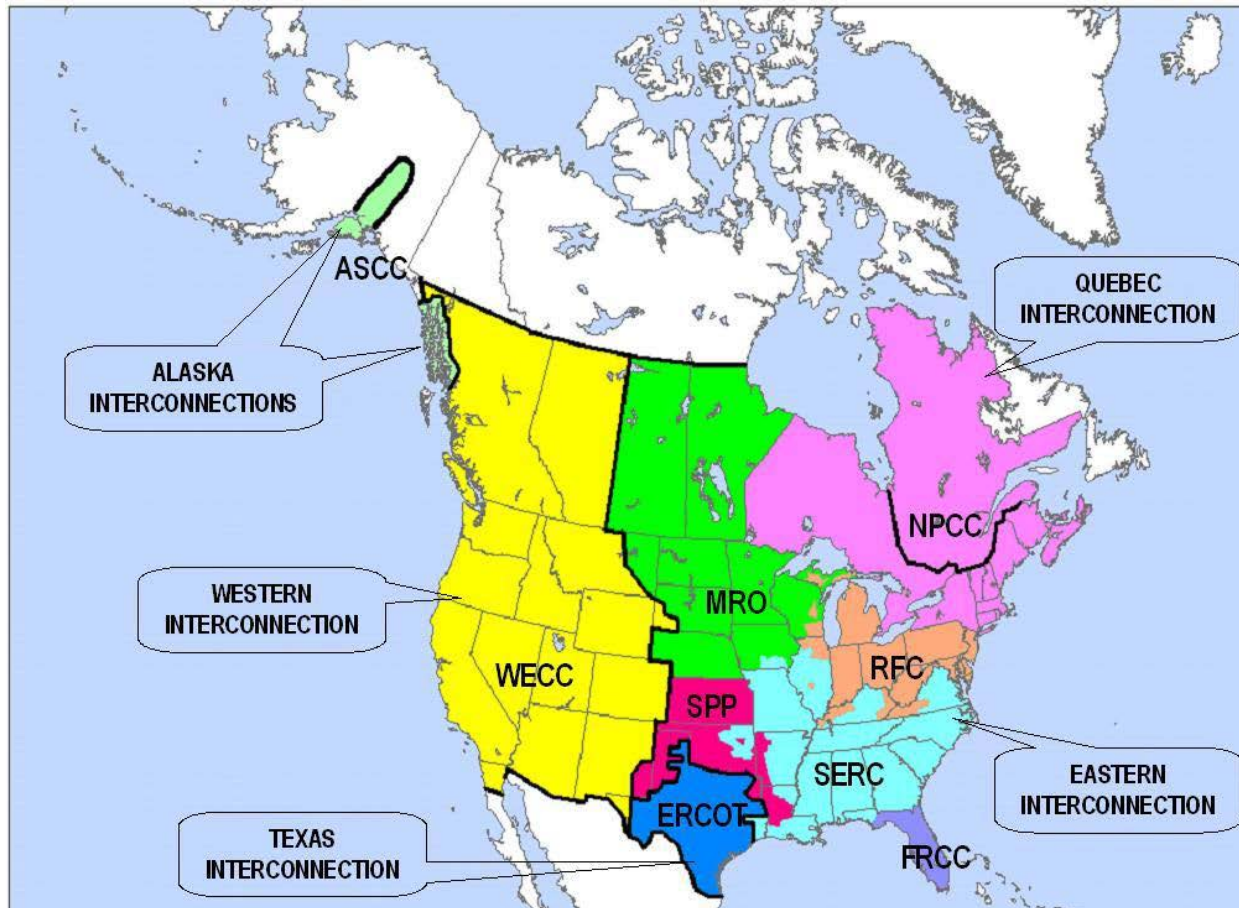


North American Reliability Council (NERC)

- The original NERC was formed on June 1, 1968 by the electric utility industry to promote the reliability and adequacy of bulk power transmission in the electric utility systems of North America.
- The Electric Reliability Act of 1967, passed due to the political pressure and fallout from the 1965 blackout, was a significant turning point in the arena of electric reliability in North America.
- NERC's mission states that it is to "ensure that the bulk power system in North America is reliable."
- NERC oversees eight regional reliability entities and encompasses all of the interconnected power systems of the contiguous United States, Canada and a portion of Baja California in Mexico.

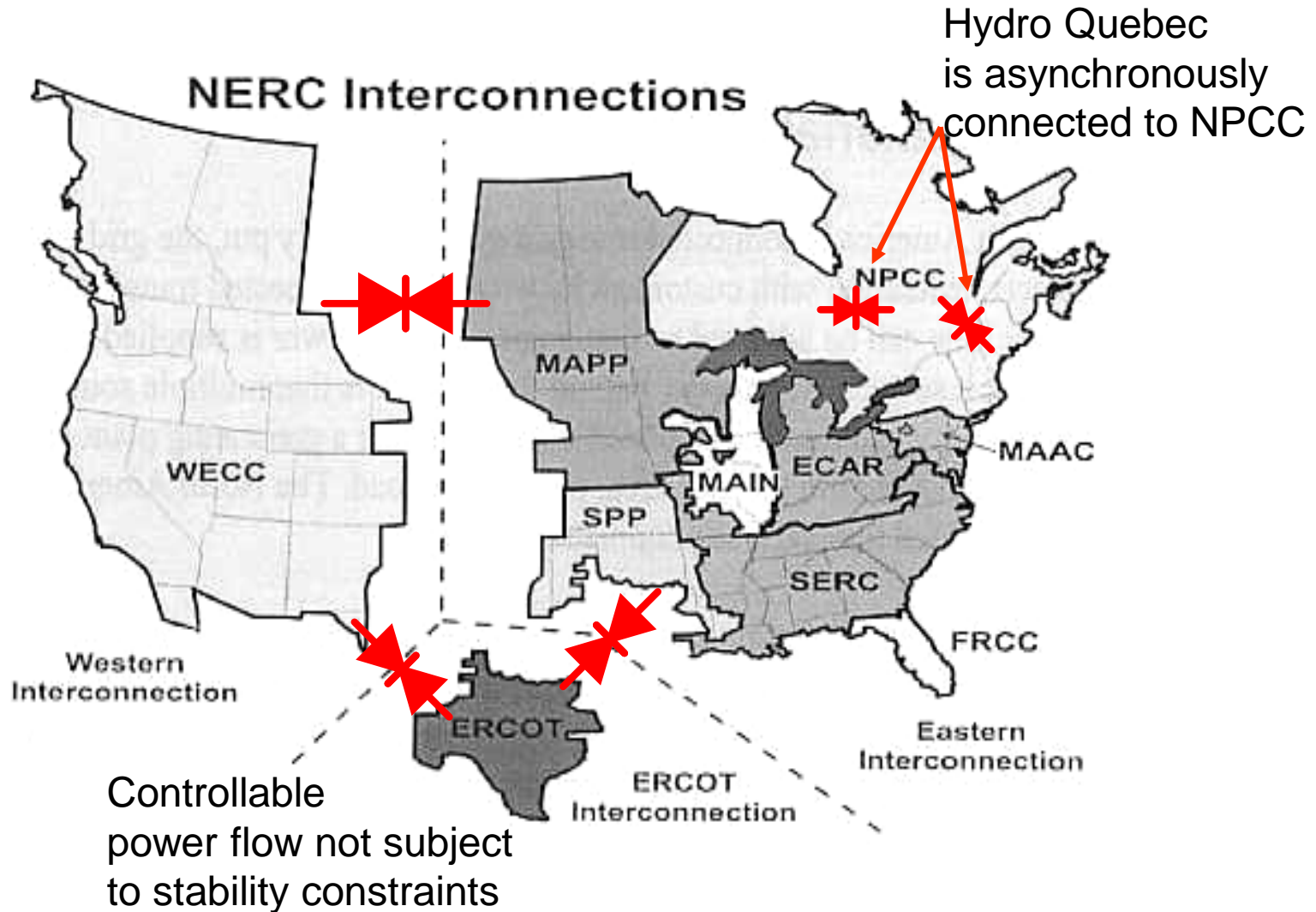
NERC Interconnections

North American Regional Reliability Councils



- **NPCC:** Northeast Power Coordinating Council
- **FRCC:** Florida Reliability Coordinating Council
- **ERCOT:** Electric Reliability Council of Texas
- **RFC:** Reliability First Corporation
- **MRO:** Midwest Reliability Organization
- **WECC:** Western Electricity Coordinating Council
- **SERC:** Southeast Electric Reliability Council
- **SPP:** Southwest Power Pool
- **ASCC:** Alaska Systems Coordinating Council

NERC HVDC Interconnections



NERC Interconnections

North American Regional Reliability Councils

- **NPCC:** Northeast Power Coordinating Council
 - **NPCC** was formed January 19, 1966, as a successor to the Canada-United States Eastern Interconnection (CANUSE).
 - The NPCC occupies the Provinces of Ontario, Québec, New Brunswick, Nova Scotia and Prince Edward Island, and the greater New England region of North America, covering all of the States of Maine, Vermont, New Hampshire, Massachusetts, New York, Connecticut, Rhode Island.
 - NPCC covers 20% of the Eastern interconnection's total load demand, and 70% of Canada's entire demand.
 - The Hydro-Québec system, which encompasses all of Québec, is commonly considered as part of the Eastern Interconnection even though it technically is its own interconnection. It is tied to rest of the NPCC and Eastern Interconnection through four HVDC ties.

NERC Interconnections

North American Regional Reliability Councils

- **FRCC:** Florida Reliability Coordinating Council
 - The area served by FRCC was previously served by SERC Reliability Corporation (SERC).
 - The FRCC serves almost all of Florida, with the exception of a portion of the Florida Panhandle below Alabama.
 - It is one of eight Independent System Operators in North American.
- **ERCOT:** Electric Reliability Council of Texas
 - The ERCOT region occupies the entire Texas Interconnection, which occupies nearly all of the state of Texas.
 - It is one of eight Independent System Operators in North American.
- **RFC:** Reliability First Corporation
 - The RFC covers territory stretching from the Eastern United States to the lower Great Lakes, covering all of the states of Pennsylvania, New Jersey, Delaware, Maryland, West Virginia, Ohio, Indiana, and portions of the states of Wisconsin, Michigan, Illinois, Kentucky and Virginia.
 - RFC began operations on January 1, 2006, as the successor to three other reliability organizations:
 - Mid-Atlantic Area Council (MAAC) which originally formed in 1967,
 - East Central Area Coordination Agreement (ECAR) which also formed in 1967,
 - Mid-American Interconnected Network (MAIN)

NERC Interconnections

North American Regional Reliability Councils

- **MRO:** Midwest Reliability Organization
 - The **Midwest Reliability Organization (MRO)** began operations on January 1, 2005, as the successor to the Mid-continent Area Power Pool (MAPP), which was formed in 1965.
 - MRO covers all of the states of Minnesota, North Dakota and Nebraska, portions of the states of Montana, South Dakota, Iowa, Wisconsin and the Upper Peninsula of Michigan, and the Provinces of Saskatchewan and Manitoba in Canada.
 - MRO has four of the six HVDC ties which connect the Eastern interconnection to the Western Interconnection, and also has ties to non-NERC systems in Northern Canada.
- **WECC:** Western Electricity Coordinating Council
 - was formed on April 18, 2002, from the merger of the Western Systems Coordinating Council (WSCC) which itself was formed on August 14, 1967, the Southwest Regional Transmission Association (SWRTA), and Western Regional Transmission Association (WRTA).
 - The WECC region encompasses the Provinces of British Columbia and Alberta in Canada, and the entire Western Interconnection, which comprises the states of Washington, Oregon, California, Idaho, Nevada, Utah, Arizona, Colorado, Wyoming, portions of Montana, South Dakota, New Mexico and Texas in the United States,.

NERC Interconnections

North American Regional Reliability Councils

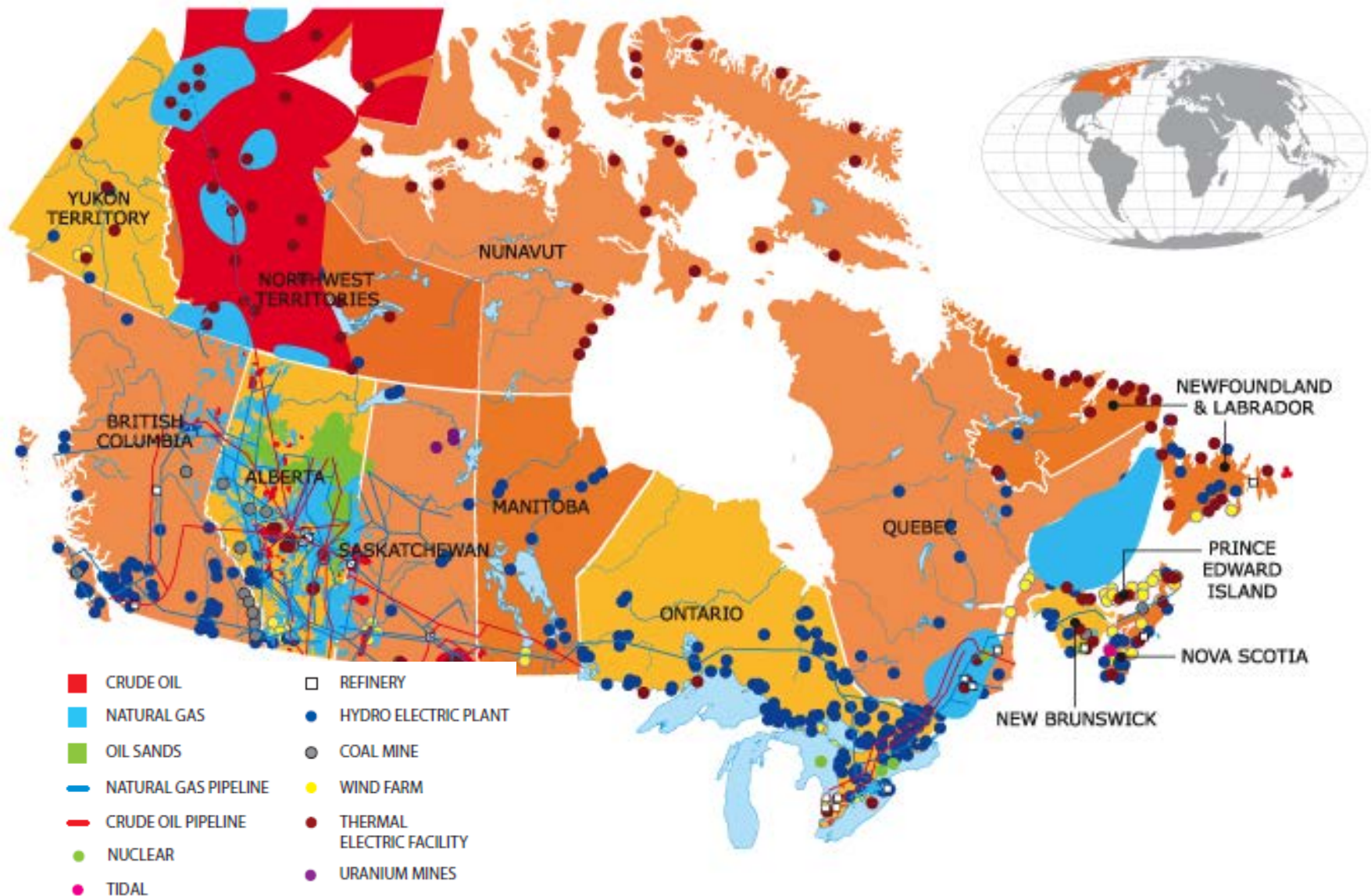
- **SERC:** Southeast Electric Reliability Council
 - The SERC occupying most of Southeast North America, serving all of the States of Missouri, Alabama, Tennessee, North Carolina, South Carolina, Georgia, Mississippi, and portions of Iowa, Illinois, Kentucky, Virginia, Oklahoma, Arkansas, Louisiana, Texas and Florida.
- **SPP:** Southwest Power Pool
 - SPP was incorporated as a nonprofit corporation in 1994, and was approved as a Regional Transmission Operator (RTO)
 - The SPP serving all of the State of Kansas, and portions of New Mexico, Texas, Oklahoma, Arkansas, and Louisiana, Missouri and Nebraska.
- **ASCC:** Alaska Systems Coordinating Council
 - The ASCC region covers the two grids in the Alaska Interconnection, one of which is in South Central Alaska and the other in the Alaska Panhandle.
 - Neither of the small grids in ASCC has interties to any other interconnection.

Questions ?

Canadian Power System

A decorative graphic consisting of several horizontal stripes in various shades of blue and white, located at the bottom of the slide.

Canada: Energy Facts



Source: Centre for Energy, CANADA

Electricity in Canada: A Brief History

Between 1880 to 1900

- Toronto's first generator is built for T. Eaton Co.
- In 1883, the Parliament Buildings in Ottawa are lighted by lamps, powered by a steam-driven plant on the Ottawa River.
- In the same year, Hamilton installs Canada's first incandescent street lights.
- The first electric utility company, the Pembroke Electric Lighting Company, is formed in 1884. It is still in operation.
- In 1885, Ottawa becomes the world's first city to install electric lighting on all its streets.
- The first single-phase AC generators in Canada are put into operation at Bow River Lumber Company in Calgary, and at Chaudière Electric's generating plant in Ottawa.

Electricity in Canada: A Brief History

Between 1880 to 1900

- In 1890, the first electric streetcar service begins operation in Victoria.
- In 1891, the Canadian Electrical Association is formed to represent the industry.
- In 1893, Niagara Falls boasts the world's largest generating station, with three 5,000 hp generators.
- In 1897, the British Empire's first long-distance high-tension transmission (11 kV) of electric power travels 27 km from St-Narcisse on Batiscan River to Trois-Rivières, Québec.
- The Canadian National Electrical Code is first published in 1897.

Electricity in Canada: A Brief History

Between 1900 to 1919

- Electricity trade between Canada and the U.S. begins in 1901, with a transmission line built at Niagara Falls.
- The same Niagara generating station, built to supply southern Ontario communities, stimulates Canada's world expertise in long-distance transmission.
- In 1903, the world's longest transmission line (136 km) is built to transmit 50 kV from Shawinigan Electric Company to Montreal.
- Calgary Power is formed in 1909, and develops into the largest investor-owned utility in Canada
- In 1912, the world's first completely electric steel mill is built for the Steel Company of Canada. This event is followed a year later by Canada's first reversible mine hoist.

Electricity in Canada: A Brief History

Between 1920 to 1939

- By 1920, hydro accounts for more than 97 per cent of the electricity generated in Canada.
- The first electric range, a Canadian invention, is built in 1921.
- In that same year, Ontario Hydro opens Sir Adam Beck No. 1, the world's largest power plant.
- With the introduction of refrigerators and washing machines in the 1920's, electric appliances for the home begin to multiply.
- In 1928, the first 220kV transmission travels more than 440 km from Pagan Falls, Québec to Toronto.
- In the same year, Edmonton Power installs one of the world's first 10 MW turbo-generator, running at 3,600 rpm, at its Rosedale Plant.

Electricity in Canada: A Brief History

Between 1940 to 1959

- Edmonton's 330 MW Rosedale Generating Station, with six coal-fired steam turbine sets, becomes Canada's largest thermal power plant.
- The Québec Hydro-Electric Commission (later Hydro-Québec) is formed in 1944 by expropriating investor-owned utilities. Today, it is one of North America's largest utilities.
- In 1951, Canada's first 100 MW steam turbo-generator set goes into service at the Richard L. Hearn plant in Toronto.
- Atomic Energy Canada Limited is formed in 1952.
- Preliminary studies begin on Canada's first nuclear power plant in 1953. Construction begins the following year, with electricity fed into Ontario Hydro's grid on June 4, 1962.
- In 1957, B.C. Electric is Canada's first utility to build a 360 kV transmission line.

Electricity in Canada: A Brief History

Between 1960 to 1969

- The first 300 MW generating begins at Lakeview station.
- Canada's first prototype nuclear power station, at 25-MW, begins production in 1962.
- In 1965, Hydro-Québec inaugurated the world's first 735-kV commercial transmission line.
- The first commercial nuclear plant, the 200 MW Douglas Point NGS, delivers power to Ontario Hydro's grid in 1967.

Electricity in Canada: A Brief History

Between 1970 to 1979

- The first four units of the Pickering nuclear power station are completed between 1971-1973. Ontario adds its four Bruce units by 1980.
- The first two units of Churchill Falls Hydro-Electric Generating Station achieve full power in 1971. When all 11 units (475,000 kW each) are completed by 1974, Churchill Falls becomes the largest hydroelectric installation of its kind in the world.
- Nuclear production increases throughout the seventies, accounting for more than 4 per cent by mid-decade, and about 10 per cent by the end of the decade.

Electricity in Canada: A Brief History

Between 1980 to 1989

- Nova Scotia Tidal Power Corp. commissions North America's first tidal generating station in 1984.
- In 1986, Hydro-Québec builds the Kuujuaq Wind Turbine demonstration project in Québec's Far North.
- Also in 1986, Hydro-Québec completes phase 1 of the La Grande complex; at that time, it accounted for 40 per cent of installed capacity.
- As a result of spiraling thermal production costs in the U.S., Canada's electricity exports peak at 45TWh, worth \$1.2 billion in 1987.

Electricity in Canada: A Brief History

Between 1990 to 1999

- By 1992, nuclear generation's share of total electricity production rises to 15 per cent.
- Hydroelectricity's share of production stands at about 62 per cent. The percentage fluctuates throughout the seventies and eighties, as fossil-fuel prices rise and fall.
- In 1995 new legislation is introduced in the Alberta legislature to support and hasten the corporate "unbundling" of the aggregation of electrical power supply...the Electric Utilities Amendment Act is passed April 23, 1998.
- By 1997 the value of electricity exports to the U.S. has grown to \$1.2 billion. The cost of importing electricity from the U.S. is \$108 million.

Electricity in Canada: A Brief History

Between 1990 to 1999

- In 1997 Canada becomes a signatory to the Kyoto Protocol to the Framework Convention on Climate Change, an international agreement aimed at reducing greenhouse gas emissions. Canada's commitment poses a challenge to the industry's ability to implement appropriate CO₂-reducing technology concurrent with remaining competitive in open markets.
- In 1998 six major Toronto area utilities are merged by the Province of Ontario in the wake of municipal amalgamation; Toronto Hydro-Electric Commission becomes the 4th largest electrical utility in Canada and the 2nd largest distribution utility in North America.
- By 1998 nuclear generation's share of total electricity production rises to 16 per cent Hydroelectricity's share stands at about 64 per cent, thermal generation at 20 per cent.
- In 1998 Ontario becomes the second province to introduce legislation in support of industry deregulation.

Electricity Generation in Canada

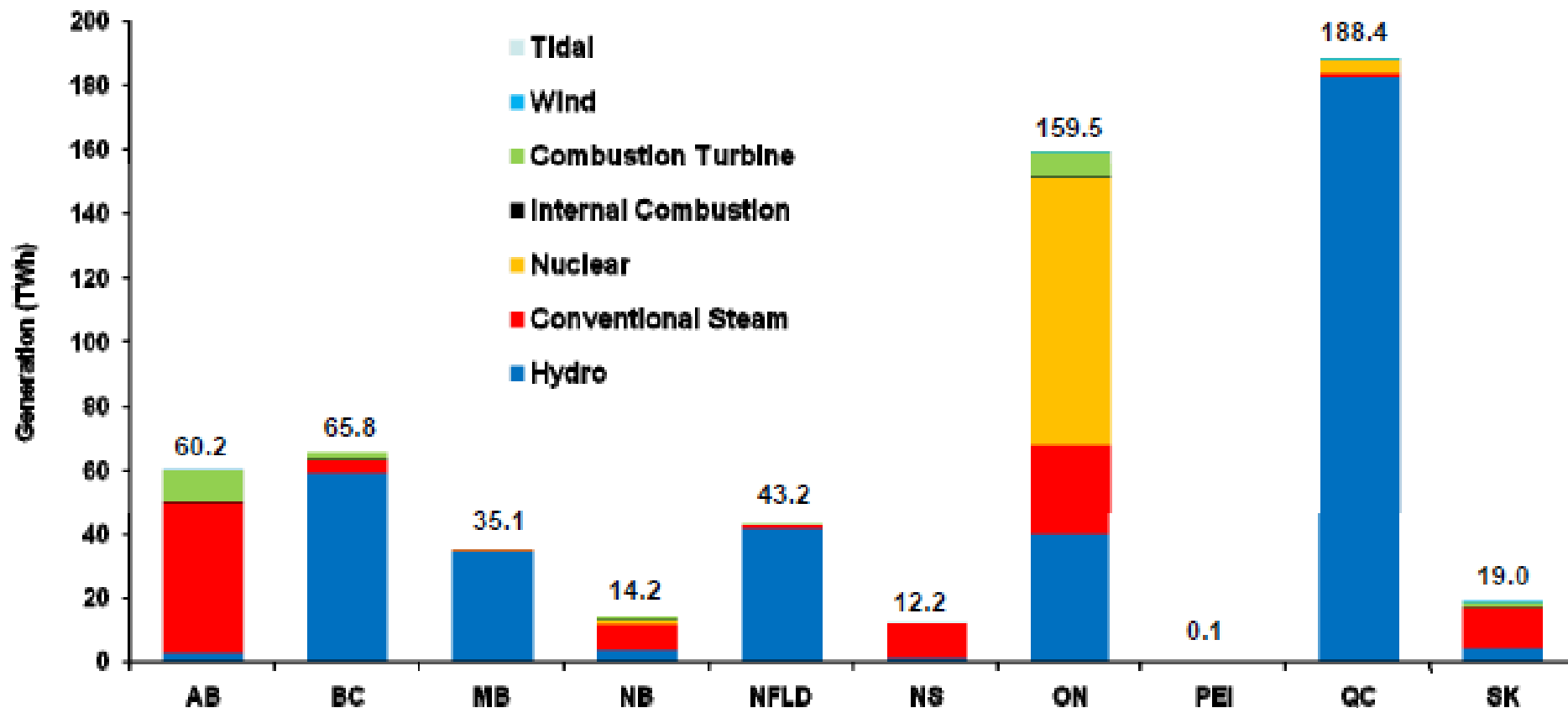
Canada is the sixth largest producer of electricity in the world, according to Energy Information Administration 2008

Electricity Generation in Terawatt-hours (TWh)

	Hydro	Conventional Steam	Nuclear	Internal Combustion	Combustion Turbine	Wind	Tidal	TOTAL
Alberta	2.3	48.1		0.1	9.7	0.1		60.2
British Columbia	58.8	4.4		0.1	2.5			65.8
Manitoba	34.6	0.5						35.1
New Brunswick	3.5	8.1	1.1		1.4			14.2
Newfoundland	41.7	1.1		0.1	0.3			43.2
Nova Scotia	1.1	10.7			0.3	0.1	0.02	12.2
Ontario	39.9	28.0	83.5		7.7	0.5		159.5
Prince Edward Island						0.1		0.1
Quebec	182.3	1.1	4.0	0.3	0.2	0.5		188.4
Saskatchewan	4.0	13.0			1.3	0.5		19.0

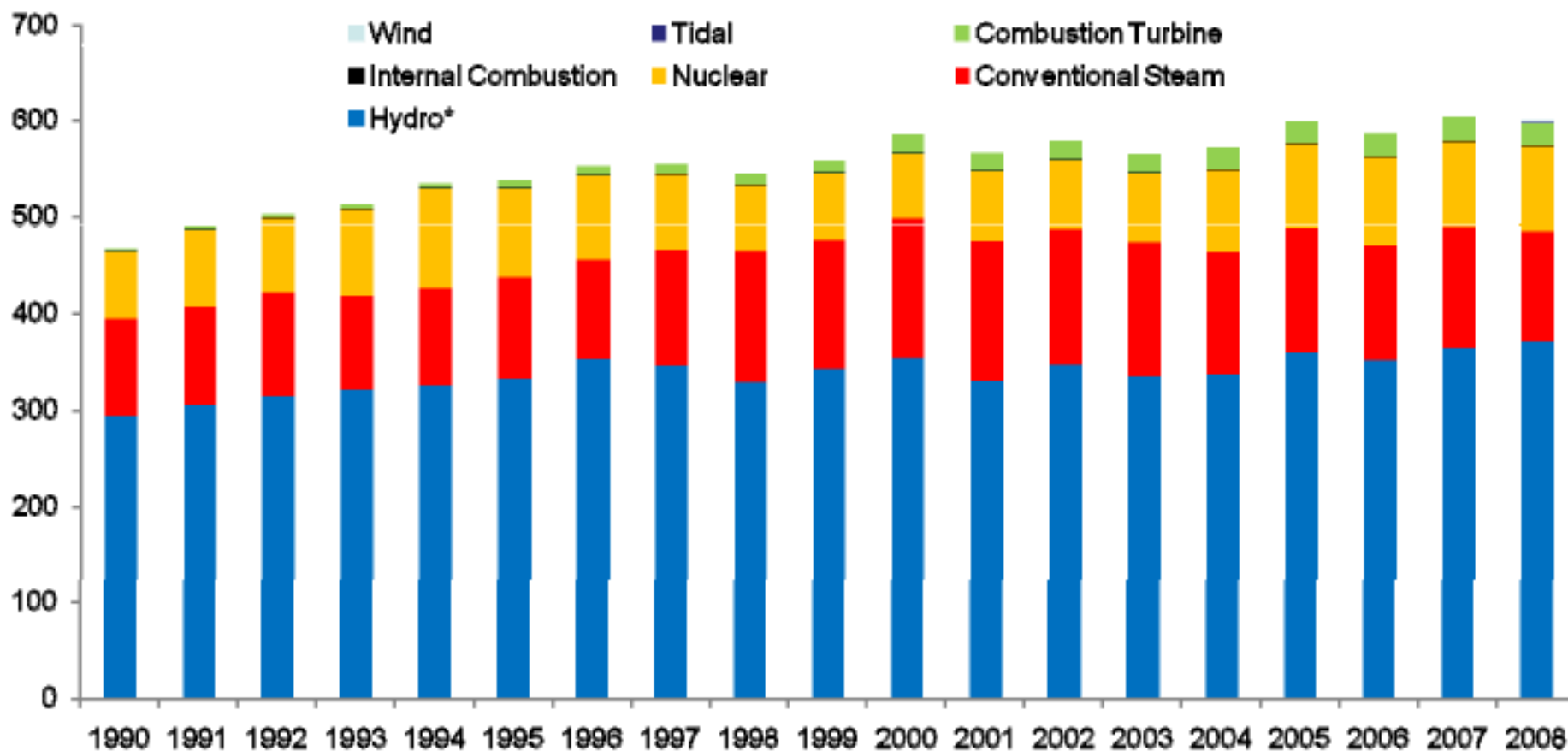
Electricity Generation in Canada

By Province and fuel type, 2008

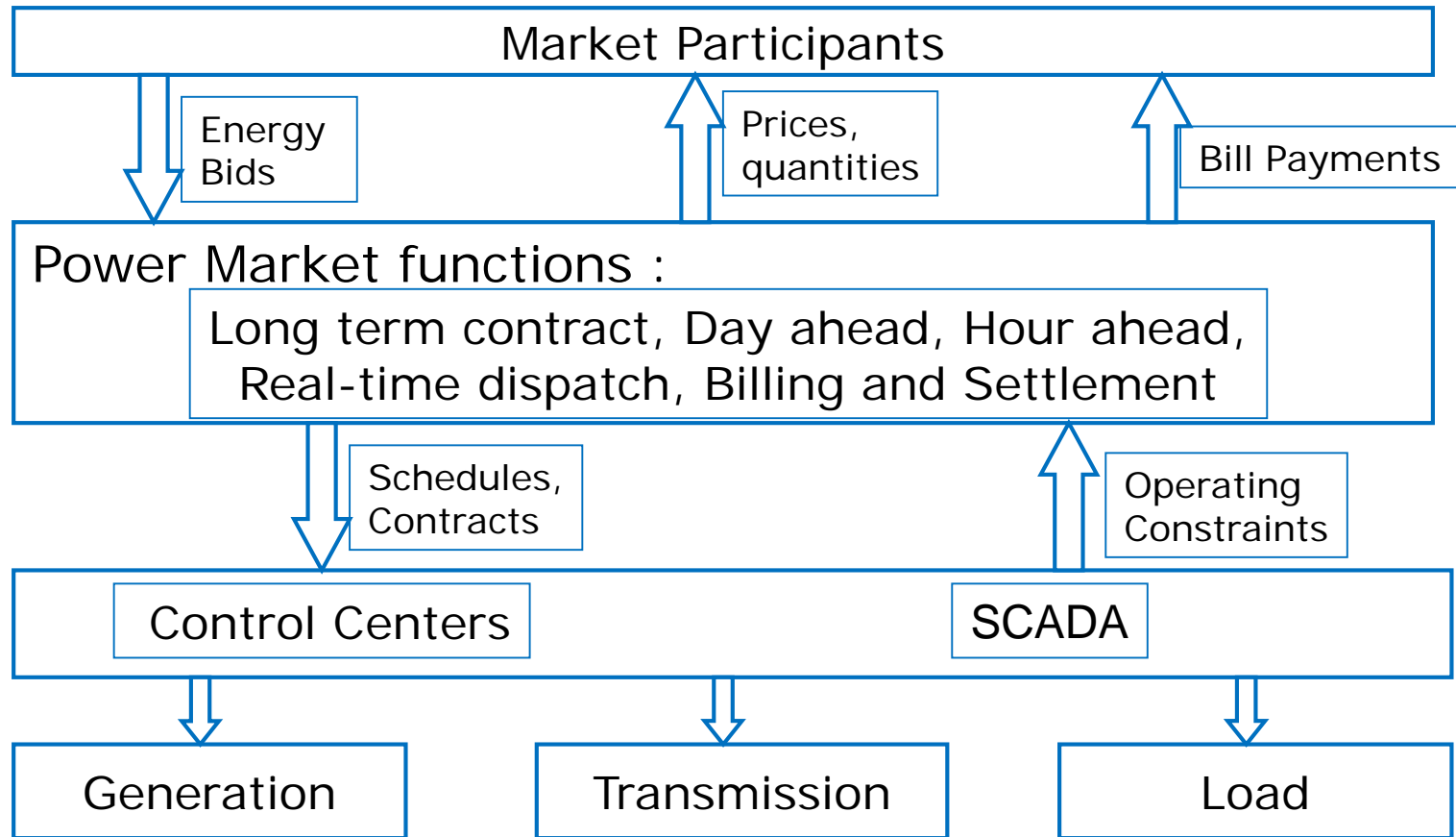


Electricity Generation in Canada

Total Electricity Generation in TWh between 1990 to 2008



Power Markets



- Power market gets continuous data from SCADA system and Load forecasting center through Internet based VPN communication (Leased line gives speed around 156 Mbit/s)

Power Market in Canada

Ontario



- Industry unbundling in 1998 – creation of OPG, Hydro One and IESO
- Functional separation with ISO
- Independent Market Surveillance Panel
- Wholesale & retail open access since 2002
- 2004 Regulated Price Plan – two-tiered pricing structure that better reflects the true cost of electricity for residential and small commercial consumers
- Retail competition remains available
- Coal Replacement program announced in 2003
- Electricity Act passed in 2004 establishing OPA - responsible for developing 20-year Integrated Power System Plan (IPSP), power procurement contracting and conservation

Power Market in Canada

Manitoba

- Wholesale open access
- Functional separation
- Coordinating member of Manitoba Independent System Operator(MISO)



Power Market in Canada

Saskatchewan



- Wholesale open access
- Functional separation

Power Market in Canada

Alberta



- Functional separation with ISO
- Independent Market Surveillance Panel
- Wholesale & retail open access since 2002
- 2004 Regulated Price Plan – two-tiered pricing structure that better reflects the true cost of electricity for residential and small commercial consumers
- Retail competition remains available
- Coal Replacement program announced in 2003
- Electricity Act passed in 2004 establishing OPA - responsible for developing 20-year Integrated Power System Plan (IPSP), power procurement contracting and conservation

Power Market in Canada

British Columbia



- Wholesale & industrial open access
- Independent Transmission entity

Power Market in Canada

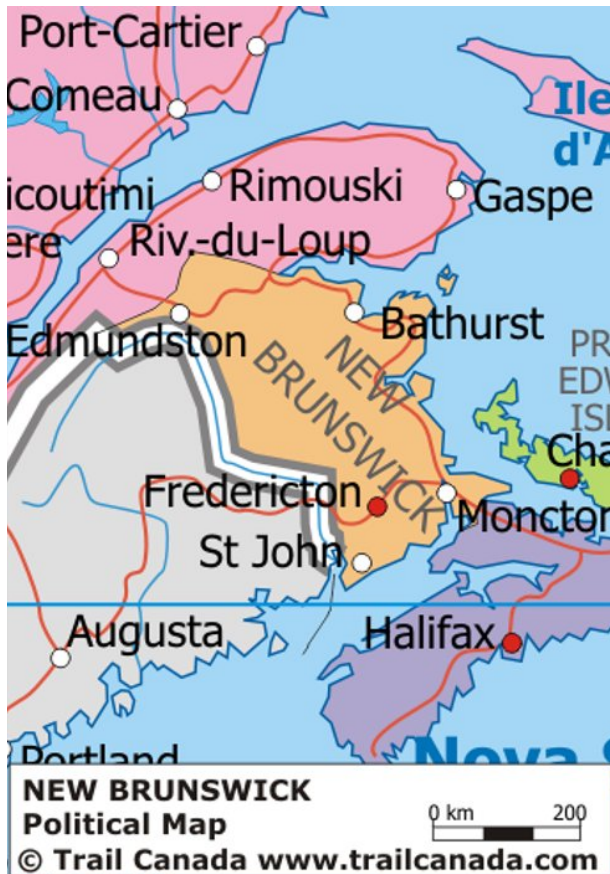
Quebec



- Wholesale open access
- Functional separation
- Wholesale competition for domestic load >165 TWh

Power Market in Canada

New Brunswick



- Wholesale & large industrial open access
- Bilateral market open and creation of independent NB System Operator in 2004

Power Market in Canada

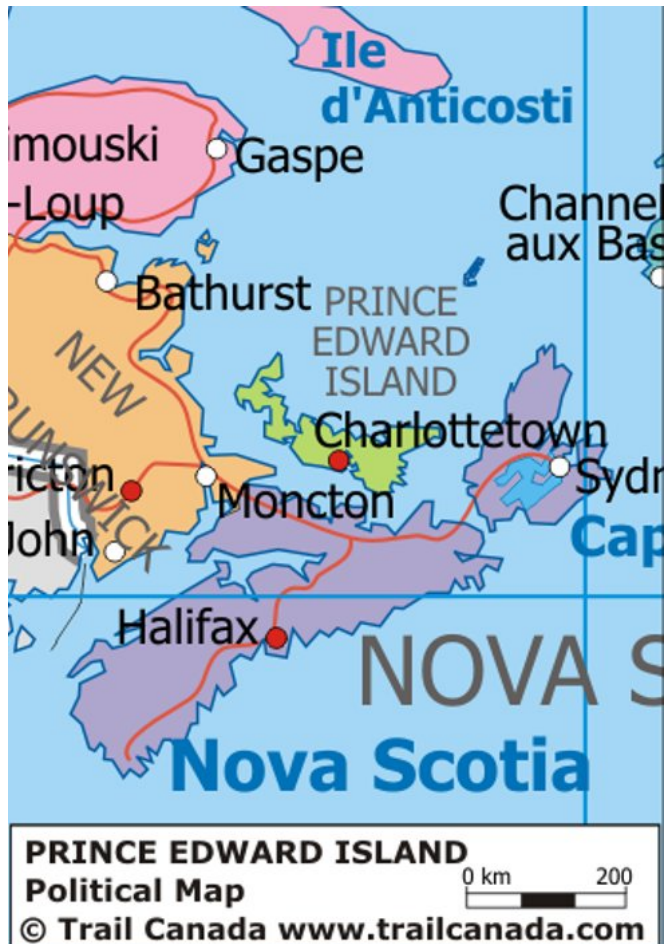
Nova Scotia



- Wholesale open access
- Functional Separation

Power Market in Canada

Prince Edward Island



➤ Distribution Network only

Power Market in Canada

Newfoundland & Labrador

- Energy policies under review



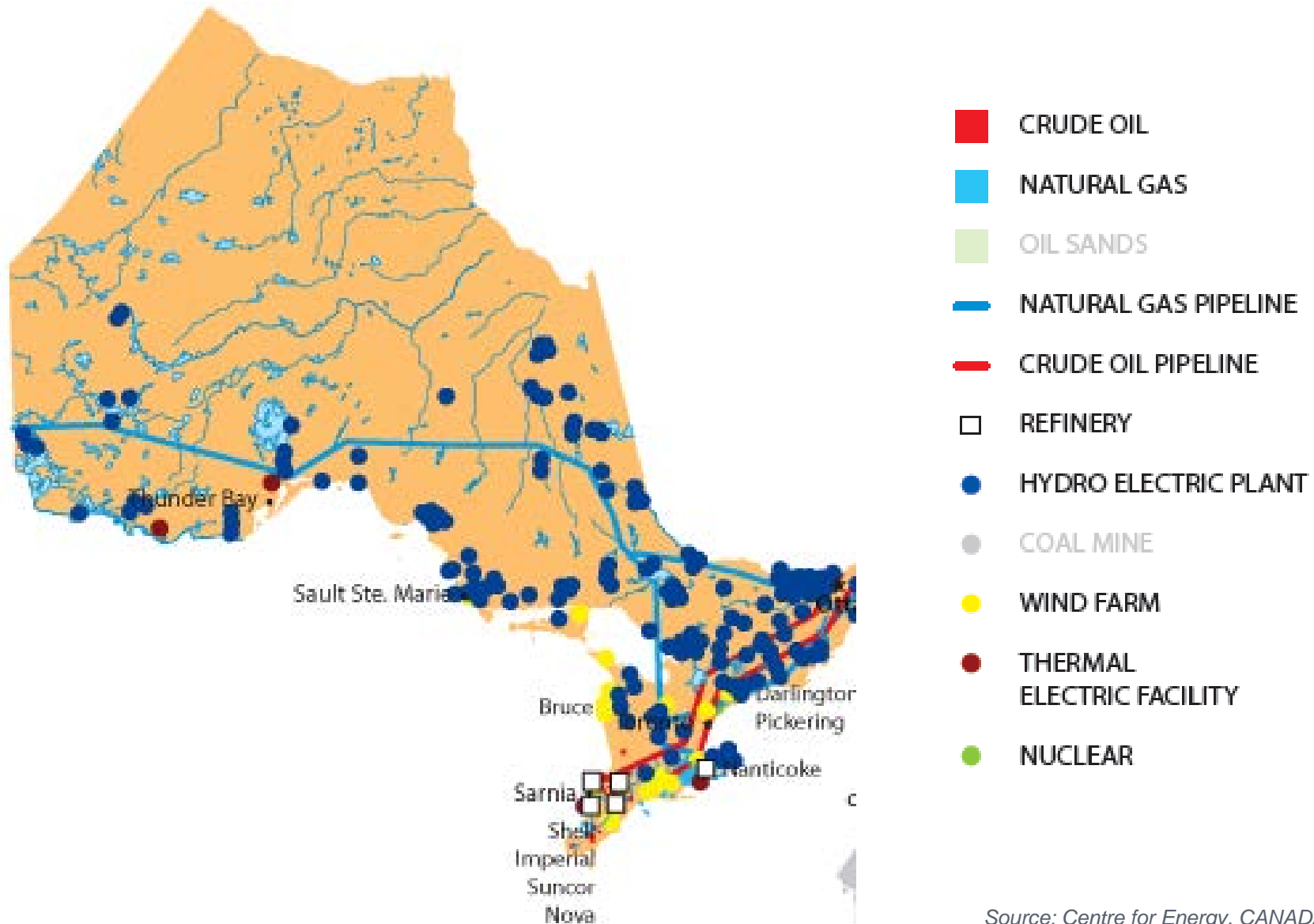


Questions ?

Ontario Power System

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Ontario: Energy Facts



Source: Centre for Energy, CANADA

Ontario ranks

- 1st in electricity generation from nuclear and wind power
- 2nd in electricity generation from thermal and combustion turbine
- 2nd in utility coal consumption
- 2nd in refining capacity
- 4th in hydroelectricity generation
- Leads in solar development

The energy industry in Ontario employs more than **65,5000** people.

Ontario Power System: History

➤ Ontario Hydro

- **Ontario Hydro** was the official name from 1974 of the **Hydro-Electric Power Commission** of Ontario which was established in 1906



➤ In April 1999, Ontario Hydro was re-organized into five companies:

1. Ontario Power Generation (OPG),
2. Hydro One
3. Independent Electricity System Operator
4. Electrical Safety Authority
5. Ontario Electricity Financial Corporation



Ontario Power Generation



- As one of the largest producers of electricity in North America, Ontario Power Generation operates
 - 65 hydroelectric,
 - 5 fossil and
 - 3 nuclear stationsproducing more than 21,000 megawatts of electricity.
- 2008 generation mix consisted of 45% nuclear, 34% hydroelectric and 22% fossil-fuelled electricity.
- In 2008, OPG generated about 70% of the electricity in Ontario, i.e. 107.8 Terawatt hours (TWh).

Hydro One Power Network



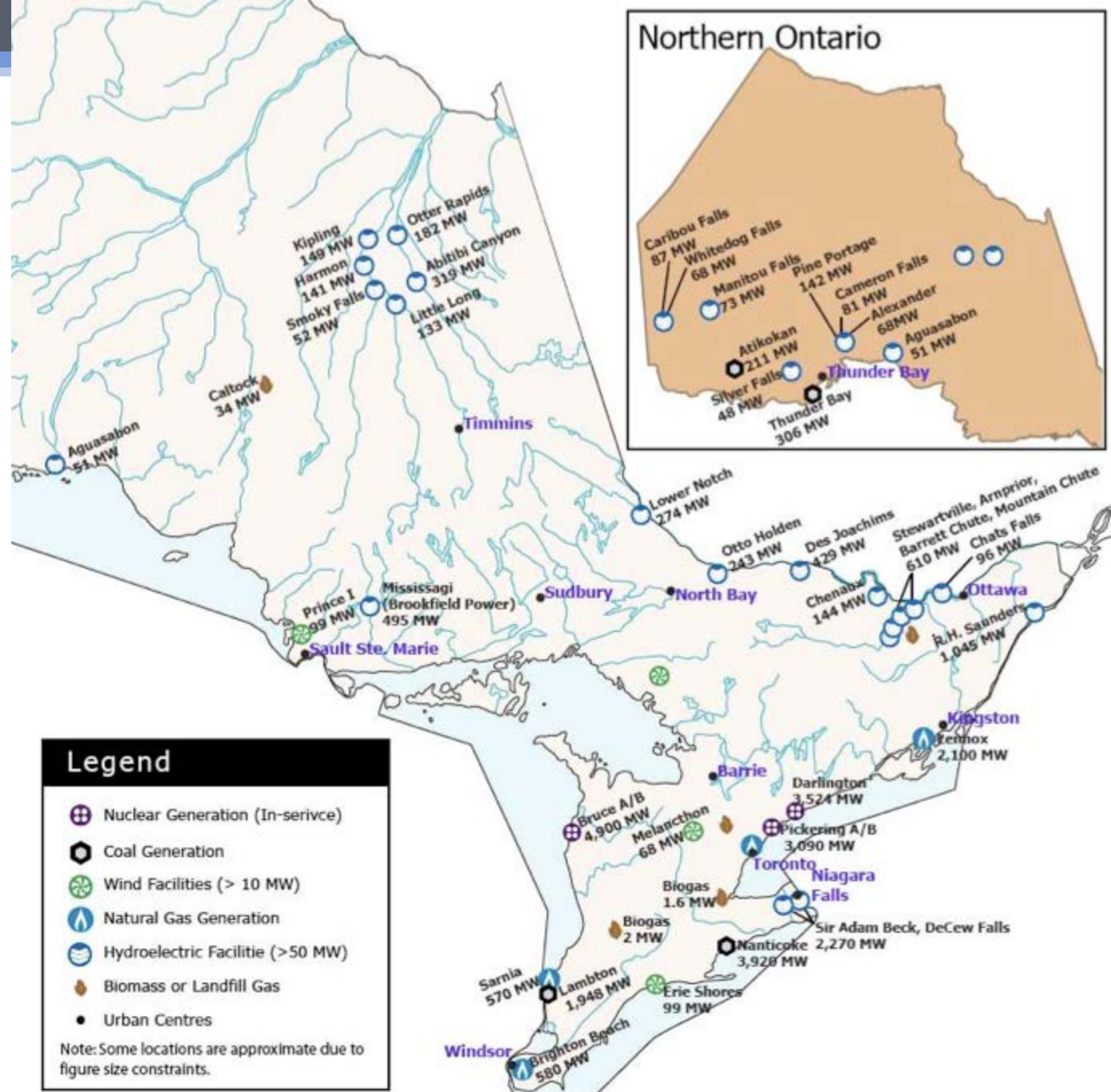
- **Peak Demand – 27,000 MW**
- **Transmission (500/230/115 KV):**
 - 97% of Ontario
 - 26 USA/Canada Interconnections
 - Sub Stations – 275
 - 113 Large Direct Customers
- **Distribution (44/ 27.6/ 13.8/ 8/ 4 kv):**
 - MV Stations: 1035;
 - LV Transformer – 520,000

Independent Electricity System Operator

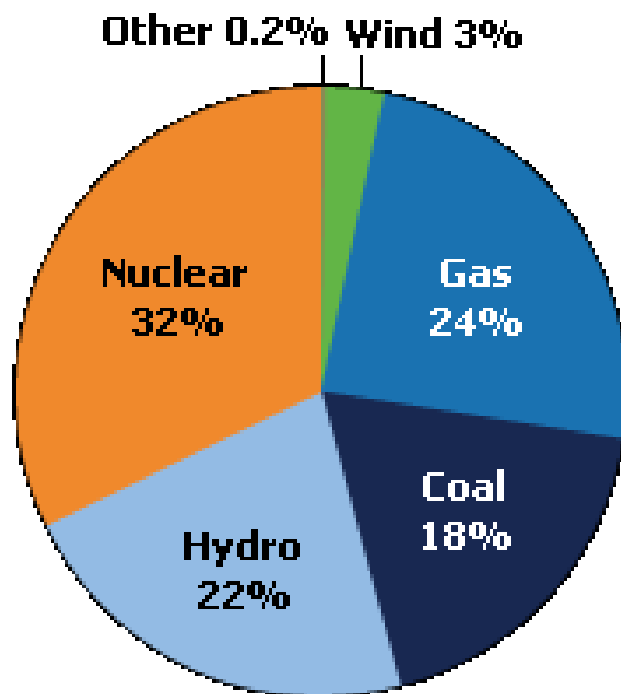


- IESO is a not-for-profit corporate entity
- IESO manages the wholesale electricity market and oversees the reliable operation of the provincial electricity grid
- Manage the settlements and financial operations of the \$13 billion wholesale market

Ontario Existing Generation



Ontario Power System: Generation



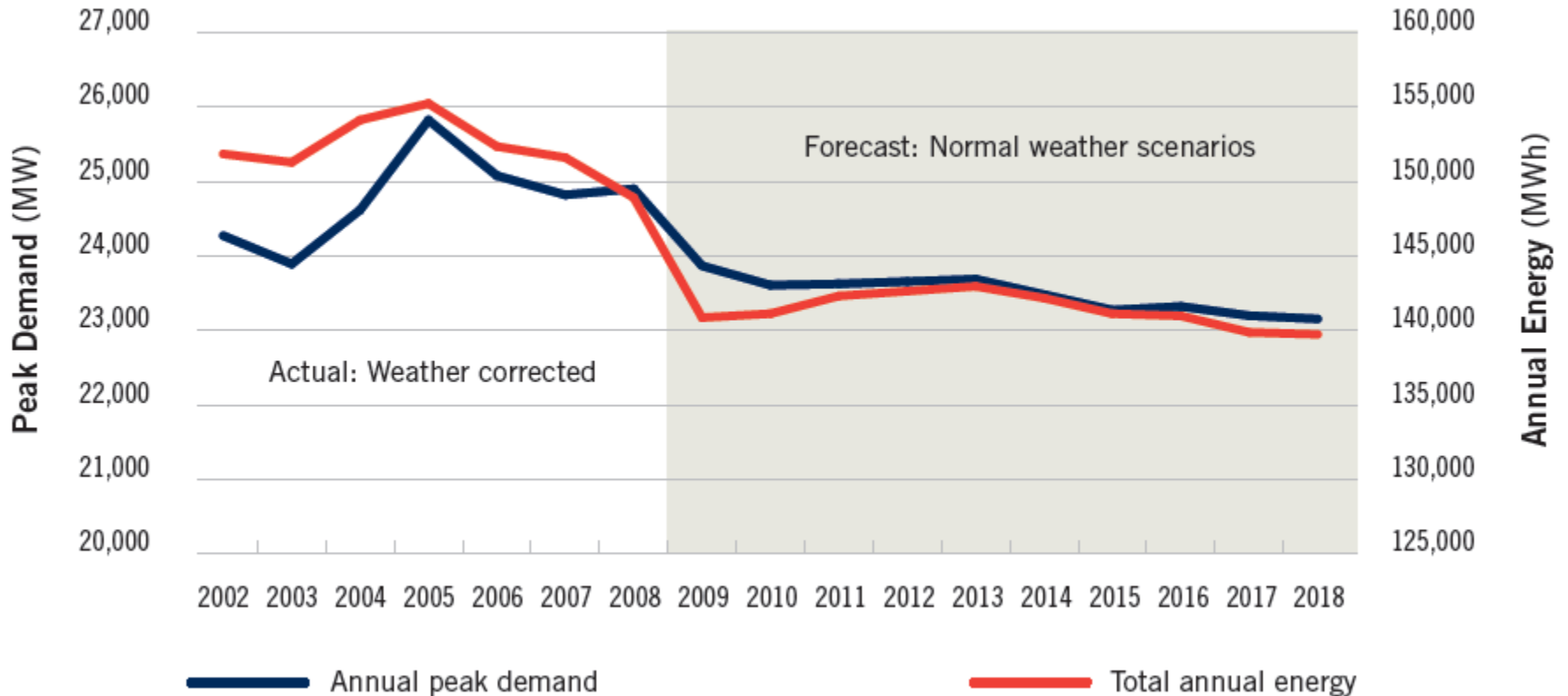
Ontario's existing installed generation capacity includes nuclear, coal, oil, gas, hydroelectric, wood and waste-fuelled generation, which results in a total installed capacity of approximately 35,465 MW.

Ontario Power System: Import Export

Ontario is capable of importing or exporting approximately 4,000 MW at any one time, depending on system conditions. The transmission grid is connected to Manitoba, Quebec, New York, Michigan and Minnesota.

Year	Imports (TWh)	Exports (TWh)	Net Imports (TWh)
2008	11.3	22.2	-10.9
2007	7.2	12.3	-5.1
2006	6.2	11.4	-5.2
2005	11.0	10.2	0.8
2004	9.8	9.5	0.3
2003	10.4	6.3	4.1
2002	7.1	3.9	3.2
2001	4.3	4.1	0.2
2000	5.1	5.5	-0.4
1999	6	4	2
1998	6	3	3
1997	3.8	6.4	-2.6

Ontario Power System : Demand overview



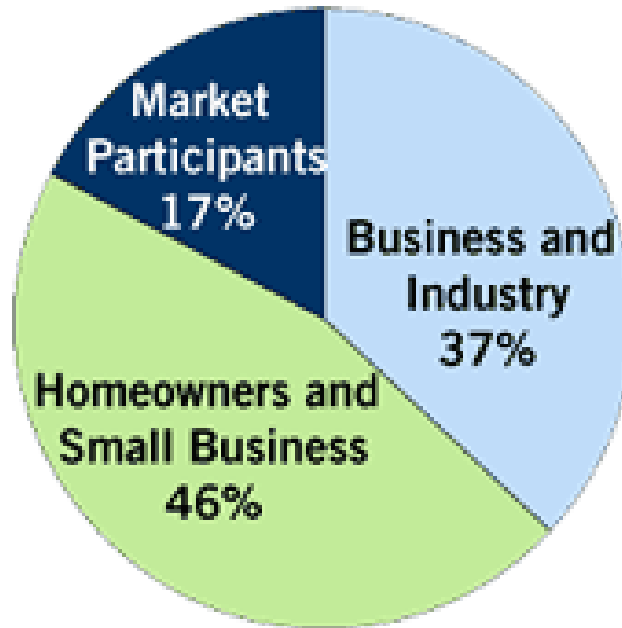
Ontario Power System: Demand overview

- The winter peak for electricity demand set on December 20, 2004 was 24,979 MW.
- The summer peak for electricity demand set on August 1, 2006 was 27,005 MW.

Year	Total (TWh)	Increase Over Previous Year
2008	148	-2.3%
2007	152	0.7%
2006	151	-3.8%
2005	157	2.3%
2004	153	1.1%
2003	152	-0.7%
2002	153	4.1%
2001	147	0%
2000	147	2.1%
1999	144	2.9%
1998	140	1.4%
1997	138	

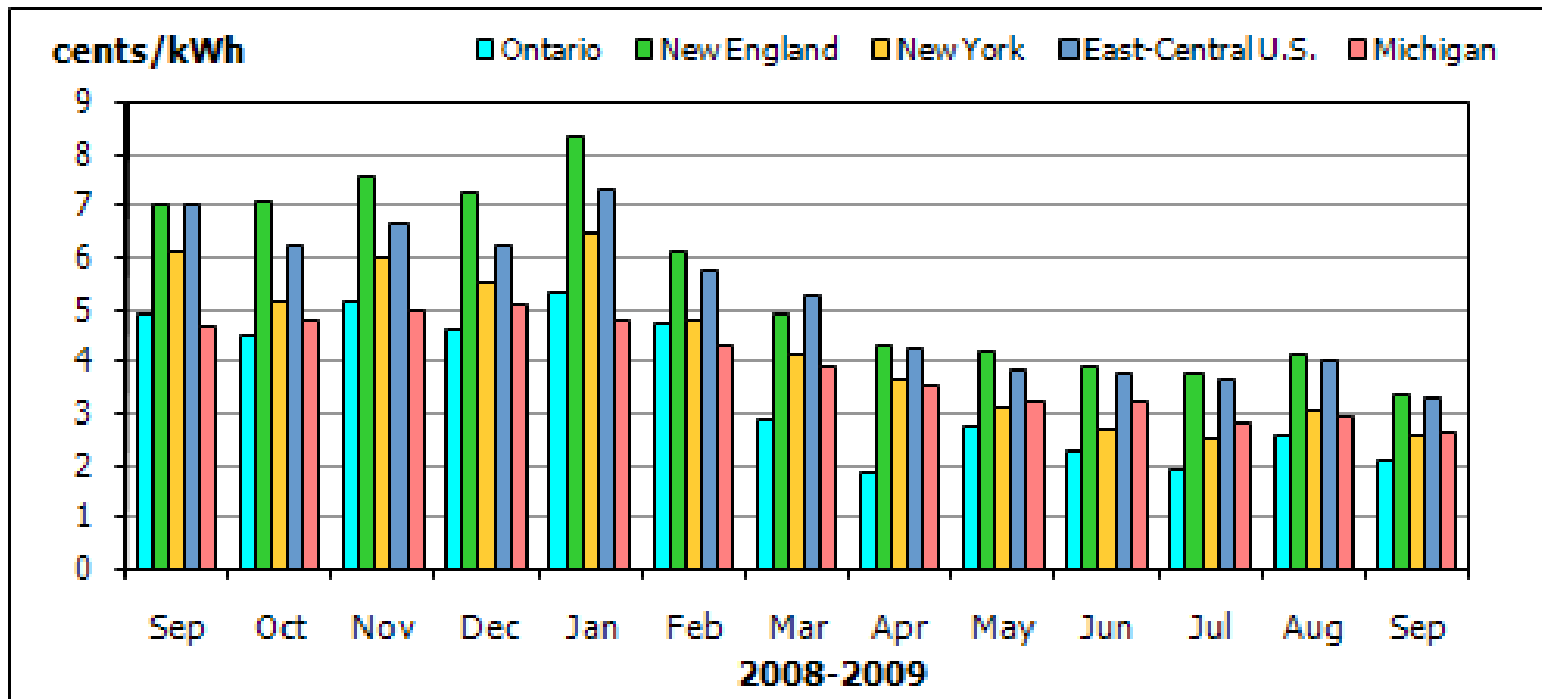
Ontario Power System: Demand overview

➤ Electricity Consumption by consumer group

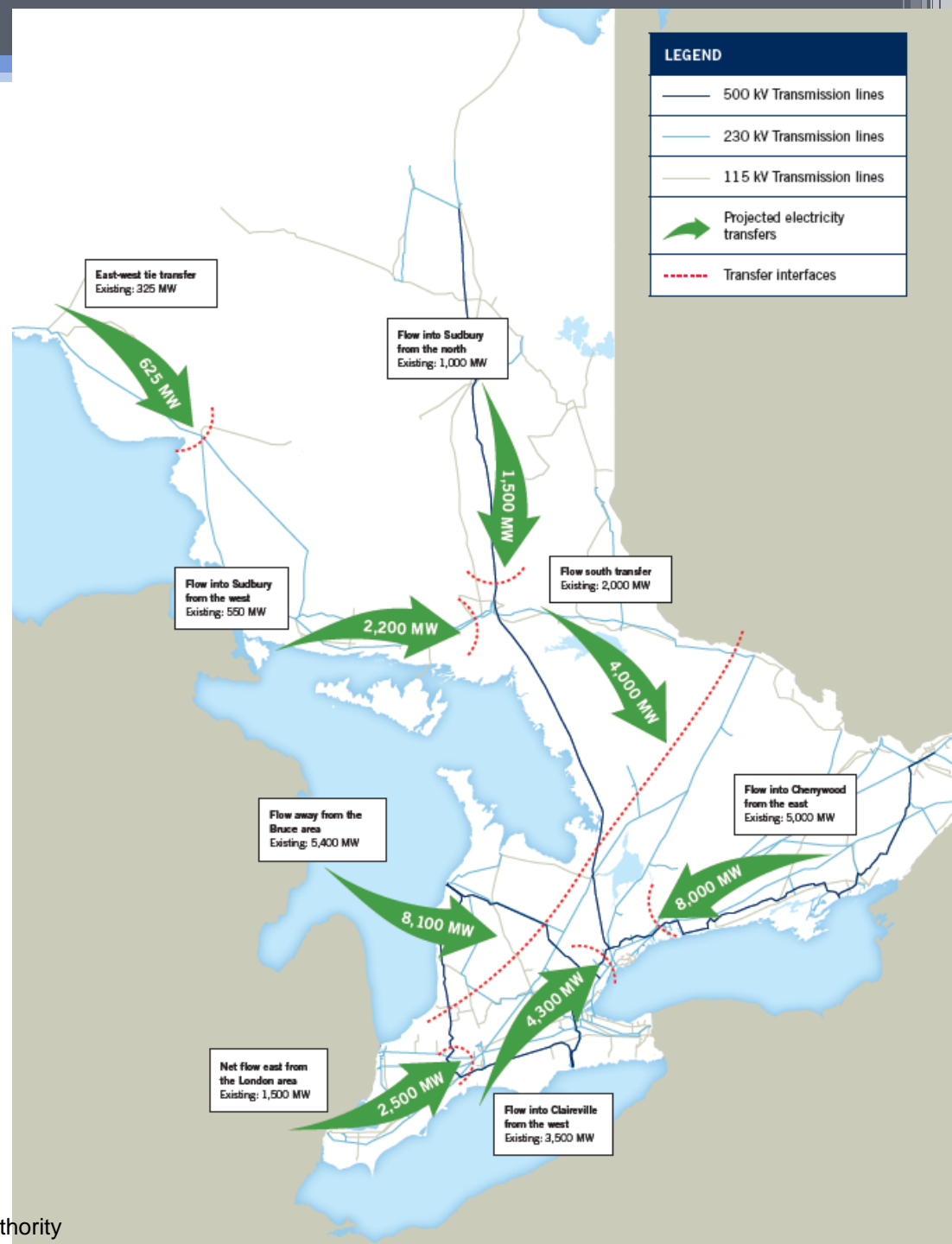


Ontario Power System: Price overview

- Ontario wholesale prices are consistently lower than prices in neighbouring jurisdictions that also operate wholesale electricity markets.

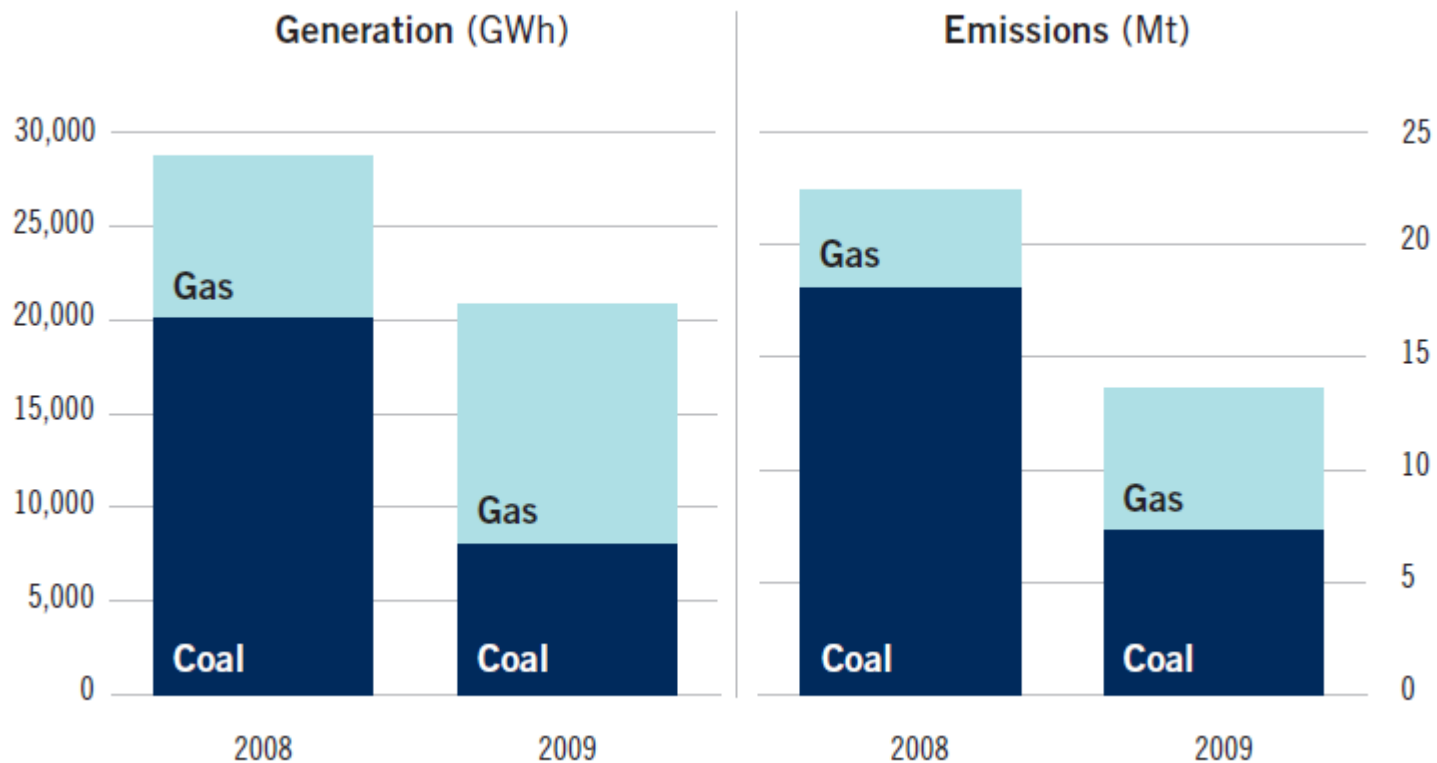


Ontario Power System: Projected Electricity Transfers



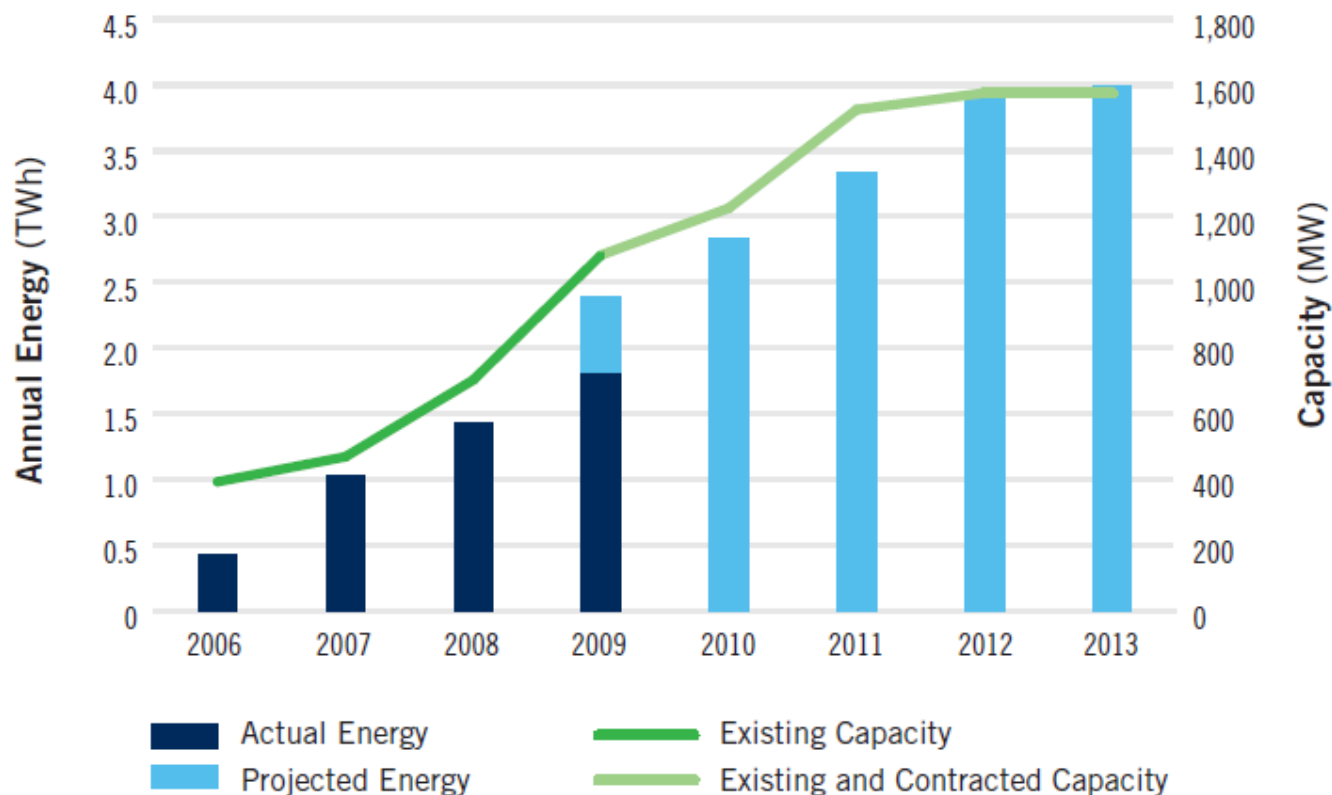
Ontario Power System: Coal Limitation

- The province is expected to be well within this year's coal emissions target limit of 19.6 Megatonnes (Mt).



Ontario Power System: Wind capacity

- Ontario's wind output capacity has increased steadily over the last number of years. The need to manage the variability of this energy resource has also grown.



Ontario Power System: Solar Energy

- Solar photo-voltaic (PV) outputs are less persistent than wind – meaning they can change output significantly within minutes or even seconds.
- Currently, solar capacity in Ontario is in its very nascent stages, but is expected to grow



Ontario Power System: Smart Meters

- Few jurisdictions have made as much progress in implementing smart metering and variable pricing as the province of Ontario.
- By the third quarter of 2009, more than three million smart meters were installed, with the majority of consumers to be switched to Time-of-Use rates by spring 2011.



Source: <http://www.goingwimax.com>

Ontario Power System: PHEVs



Source: Independent Electricity System Operator,
Ontario Power Authority



Questions ?