Maintaining Canada's Economic Prosperity while Achieving Net-Zero by 2050; Net Zero Webinar #1

Presentation by;

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Trottier Energy Futures Project (TEFP)

An example of Canadian expertise and capability for deriving optimal pathways, strategies and policies for integrated, comprehensive, fact based planning for economic growth, GHG mitigation and transformation of energy systems

Trottier Energy Futures Project (TEFP) Goal & Report

Goal; To assess options and pathways for reducing greenhouse gas emissions (GHG's) in Canada by 80% by 2050, relative to 1990

Report; Canada's Challenge & Opportunity; Transformations for Major Reductions in GHG Emissions

(publically accessible from CAE website)

Trottier Energy Futures Project (TEFP)

1. **Funded by Trottier Family Foundation (TFF)**
2. **Co-sponsored by Canadian Academy of Engineering (CAE) and David Suzuki Foundation (DSF)**
3. **Carried out during 2013 to 2016 Period – Presentation at Trottier Energy Institute: April 2016**

Trottier Energy Futures Project (TEFP) Approach and Methodology

1. **Assembly of strong multi-disciplinary team from across Canada**
2. **Complementing use of two calibrated mathematical models; optimization model and simulation model**
3. **Data for models peer reviewed; expert review panel; electricity by CEA; petrochemicals by CAPP**
4. **Eleven scenarios**
5. **Objective was maximize present worth economic value for 2011 to 2050 period, to meet increasing demands and GHG mitigation targets, for all of Canada, and 13 jurisdictions**

Trottier Energy Futures Project (TEFP)
Special Considerations

1. **Growing demands with increasing population, GDP/capita, and industrial output; "real" growth in demand more than 100%**
2. **"No constraints" premise**
3. **Long term planning us a three phase process;**

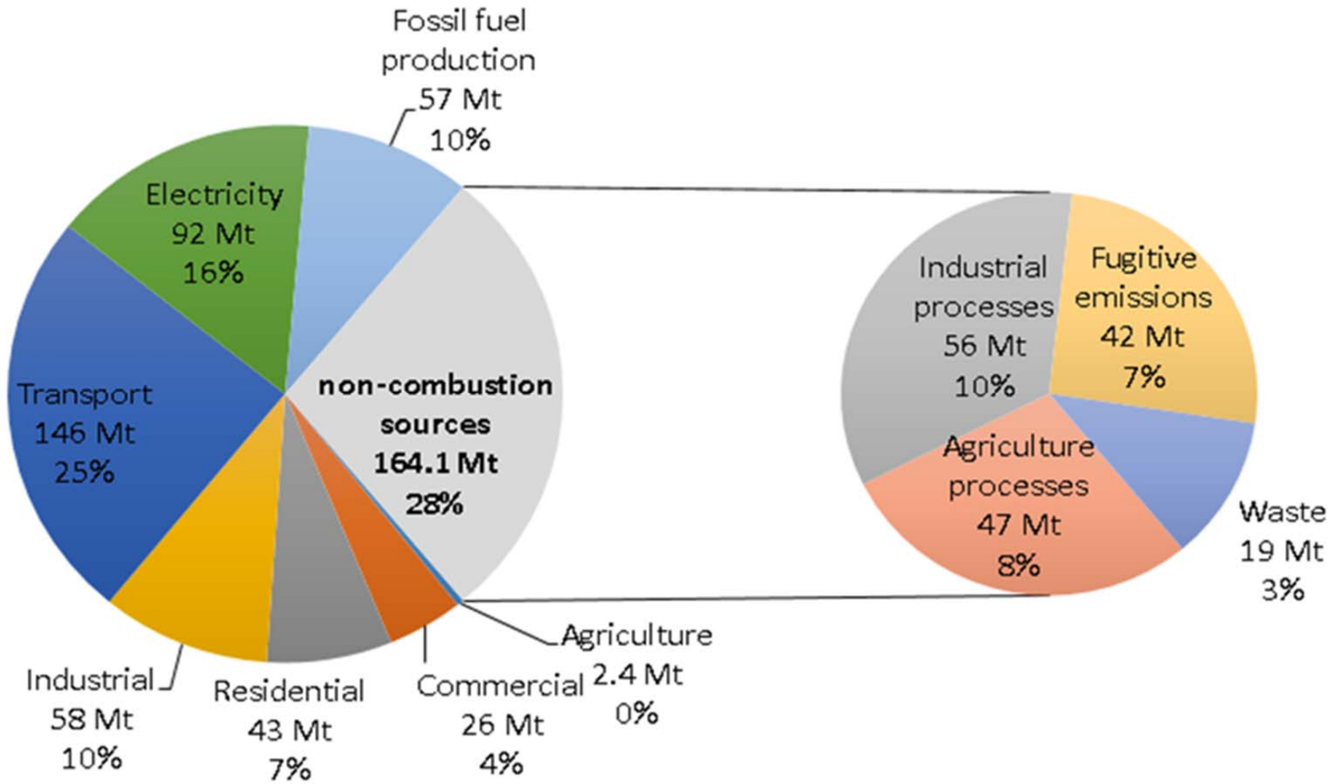
   - long term "pathways"

   - strategies

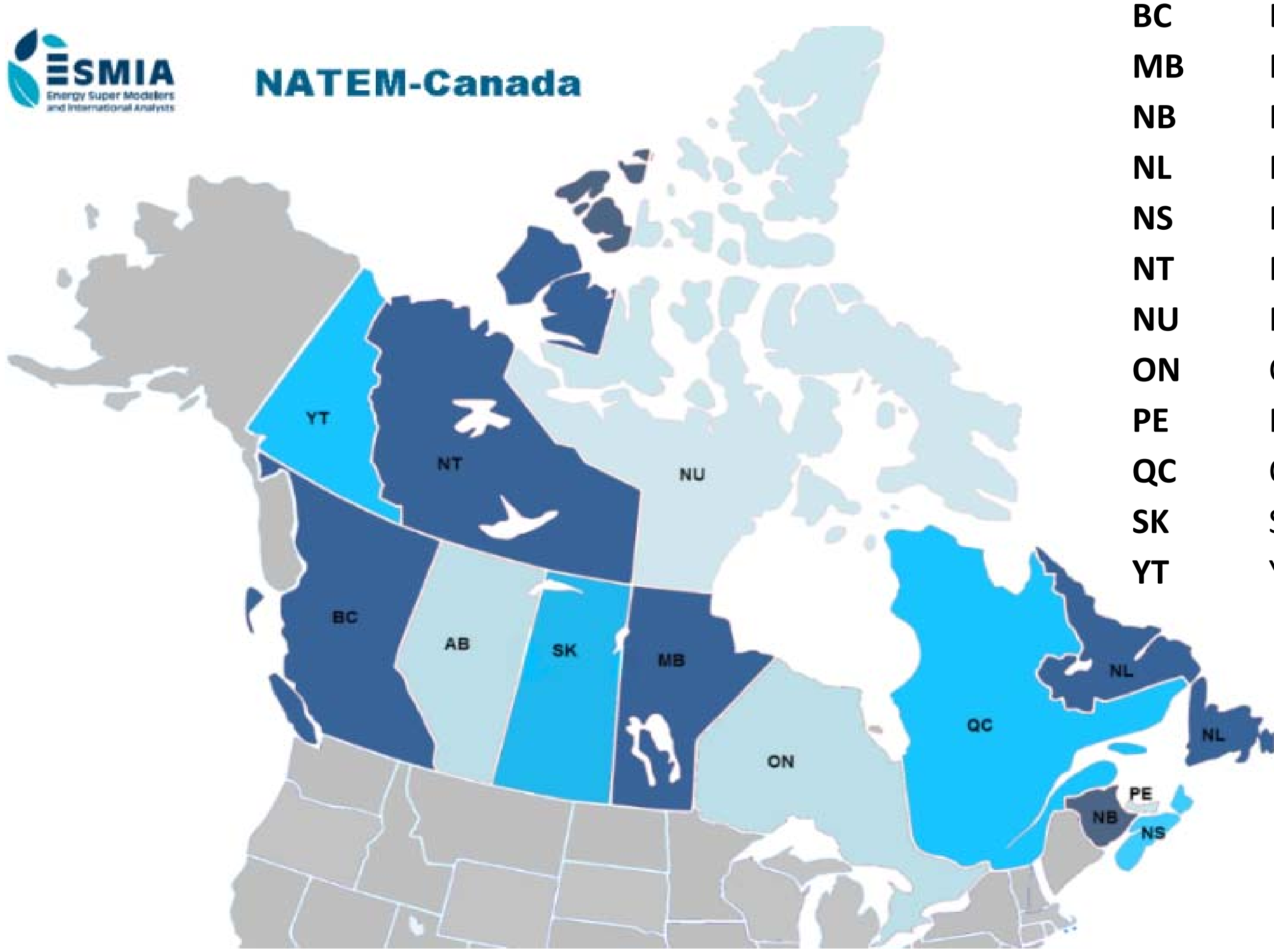
   - policies
4. **Considerations, such as dispatch constraints and dependable capacity with intermittent renewables, differential costs of transmission grids, grid storage, changing costs over time, etc.**

Trottier Energy Futures Project (TEFP)
Total and Non-combustion Emissions in 1990

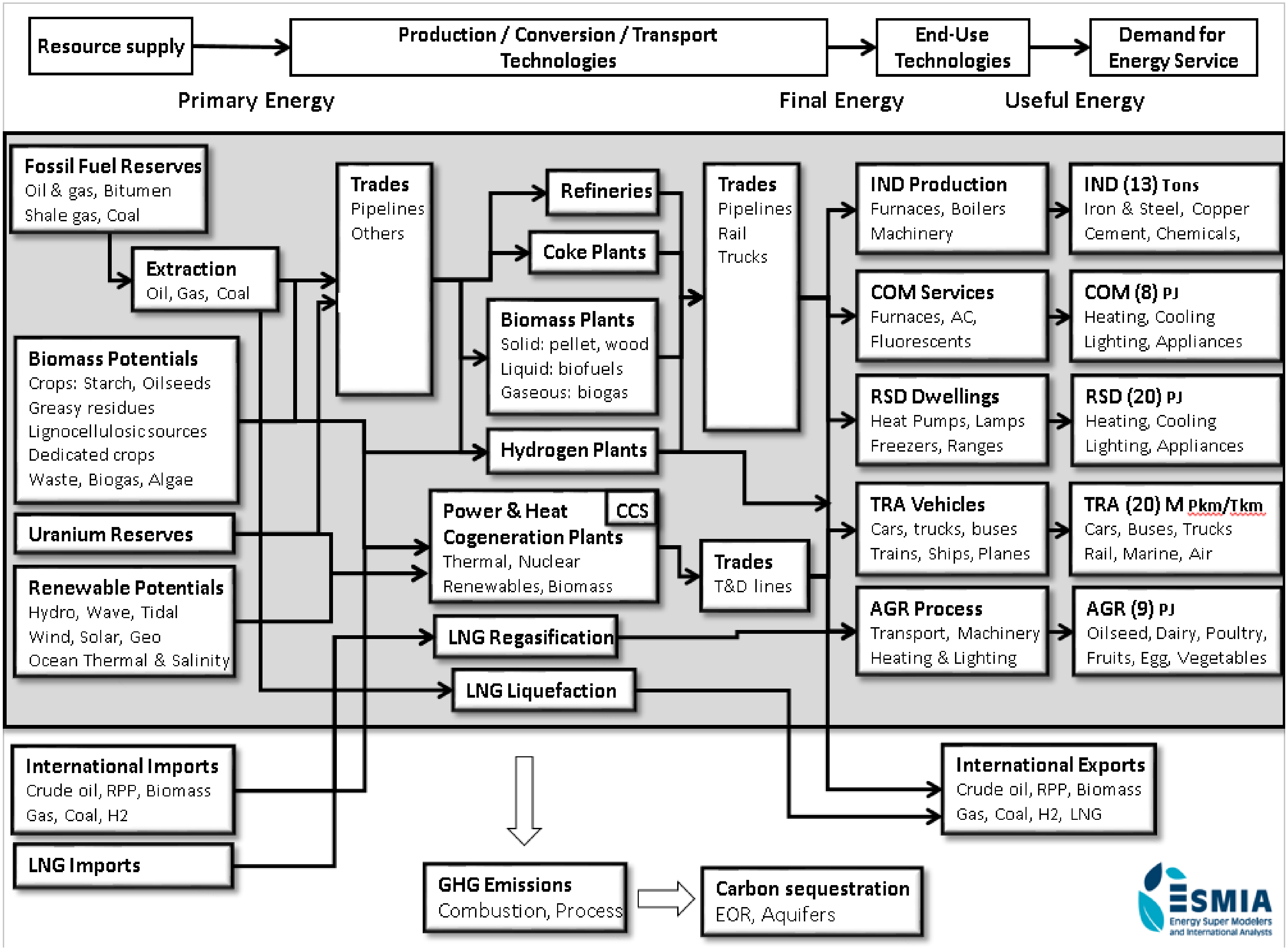
GHG Emissions in Canada (1990): 589 MT



Representation of Canada



Code	Province/Territory	Region
AB	Alberta	West
BC	British Colombia	West
MB	Manitoba	West
NB	New Brunswick	East
NL	Newfoundland	East
NS	Nova Scotia	East
NT	Northwest territories	North
NU	Nunavut	North
ON	Ontario	Central
PE	Prince Edward Island	East
QC	Quebec	Central
SK	Saskatchewan	West
YT	Yukon	North

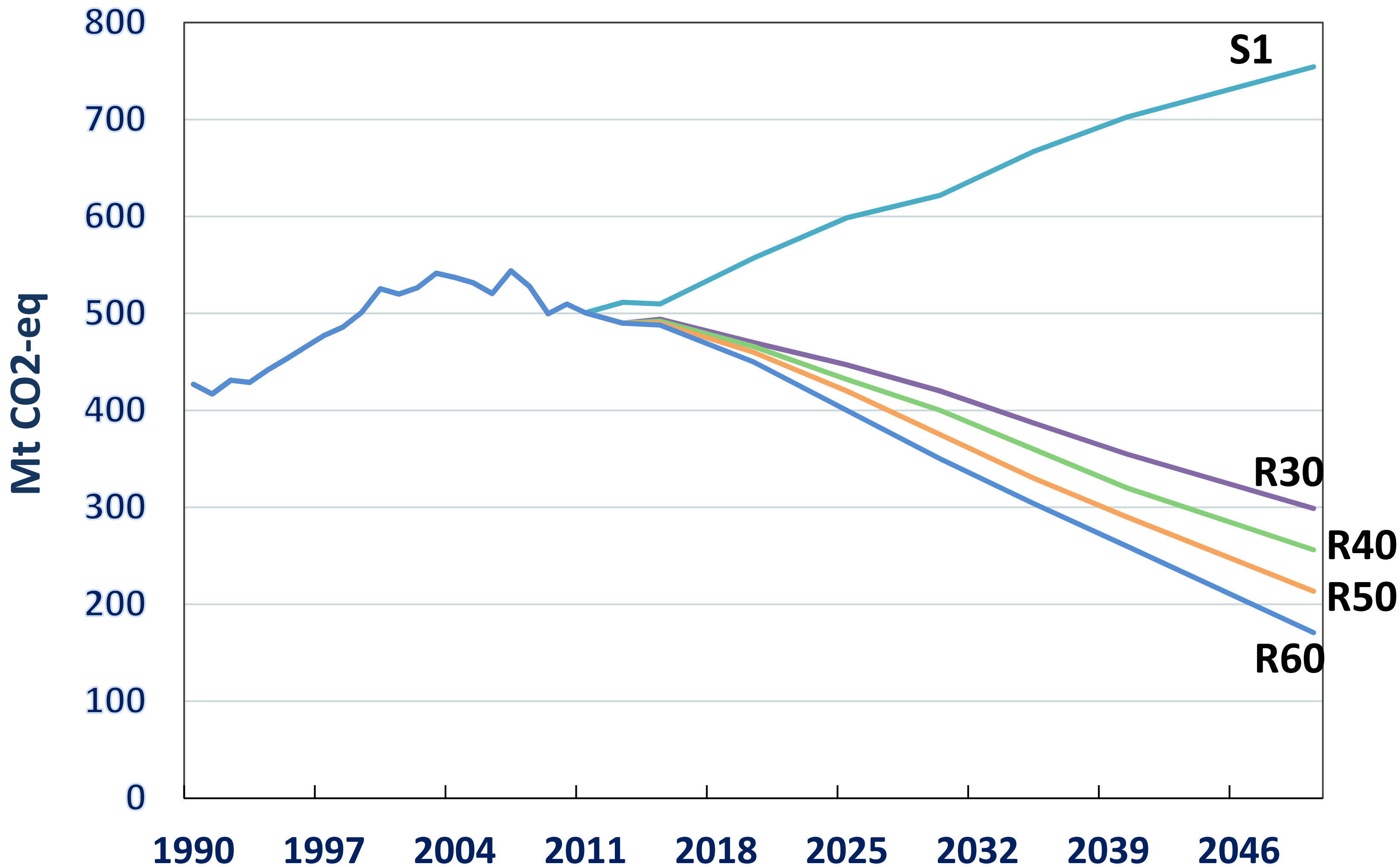


Resource supply
Production / Conversion / Transport Technologies
End-Use Technologies
Demand for Energy Service
Primary Energy
Final Energy
Useful Energy
Fossil Fuel Reserves
Oil & gas, Bitumen
Shale gas, Coal
Extraction
Oil, Gas, Coal
Trades
Pipelines
Others
Refineries
Coke Plants
Biomass Plants
Solid: pellet, wood
Liquid: biofuels
Gaseous: biogas
Hydrogen Plants
Trades
Pipelines
Rail
Trucks
IND Production
Furnaces, Boilers
Machinery
IND (13) Tons
Iron & Steel, Copper
Cement, Chemicals,
COM Services
Furnaces, AC,
Fluorescents
COM (8) PJ
Heating, Cooling
Lighting, Appliances
RSD Dwellings
Heat Pumps, Lamps
Freezers, Ranges
RSD (20) PJ
Heating, Cooling
Lighting, Appliances
Biomass Potentials
Crops: Starch, Oilseeds
Greasy residues
Lignocellulosic sources
Dedicated crops
Waste, Biogas, Algae
Uranium Reserves
Renewable Potentials
Hydro, Wave, Tidal
Wind, Solar, Geo
Ocean Thermal & Salinity
Power & Heat Cogeneration Plants
CCS
Thermal, Nuclear
Renewables, Biomass
Trades
T&D lines
TRA Vehicles
Cars, trucks, buses
Trains, Ships, Planes
TRA (20) M Pkm/Tkm
Cars, Buses, Trucks
Rail, Marine, Air
AGR Process
Transport, Machinery
Heating & Lighting
AGR (9) PJ
Oilseed, Dairy, Poultry,
Fruits, Egg, Vegetables
LNG Regasification
LNG Liquefaction
International Imports
Crude oil, RPP, Biomass
Gas, Coal, H2
LNG Imports
International Exports
Crude oil, RPP, Biomass
Gas, Coal, H2, LNG
GHG Emissions
Combustion, Process
Carbon sequestration
EOR, Aquifers
ESMIA
Energy Super Modelers and International Analysts

Trottier Energy Futures Project (TEFP)

Scenarios											
Premises Included	High Fossil Fuel Production								Low Fossil Fuel Production		
	1	2	3	4	5	6	7	8	1a	3a	8a
No Reduction in GHG Emissions	X								X		
Reduction in GHG Emissions		X	X	X	X	X	X	X		X	X
No Additional High Voltage Inter-connections		X									
Additional High Voltage Inter-connections			X	X	X	X	X	X		X	X
Change in "Urban Form"				X							
Addition of Second Generation Biofuels					X			X			X
Addition of Carbon Capture and Storage (CCS)					X			X			X
Additional Electricity Export to U.S.						X					
Addition of Nuclear Generation	X	X	X	X	X	X		X	X	X	X
No Additional Nuclear Generation							X				
Addition of Biojet Fuel								X			X
Addition of Bioenergy with CCS (BECCS)								X			X
Addition of Conventional Large Scale Hydro in B.C.								X			X

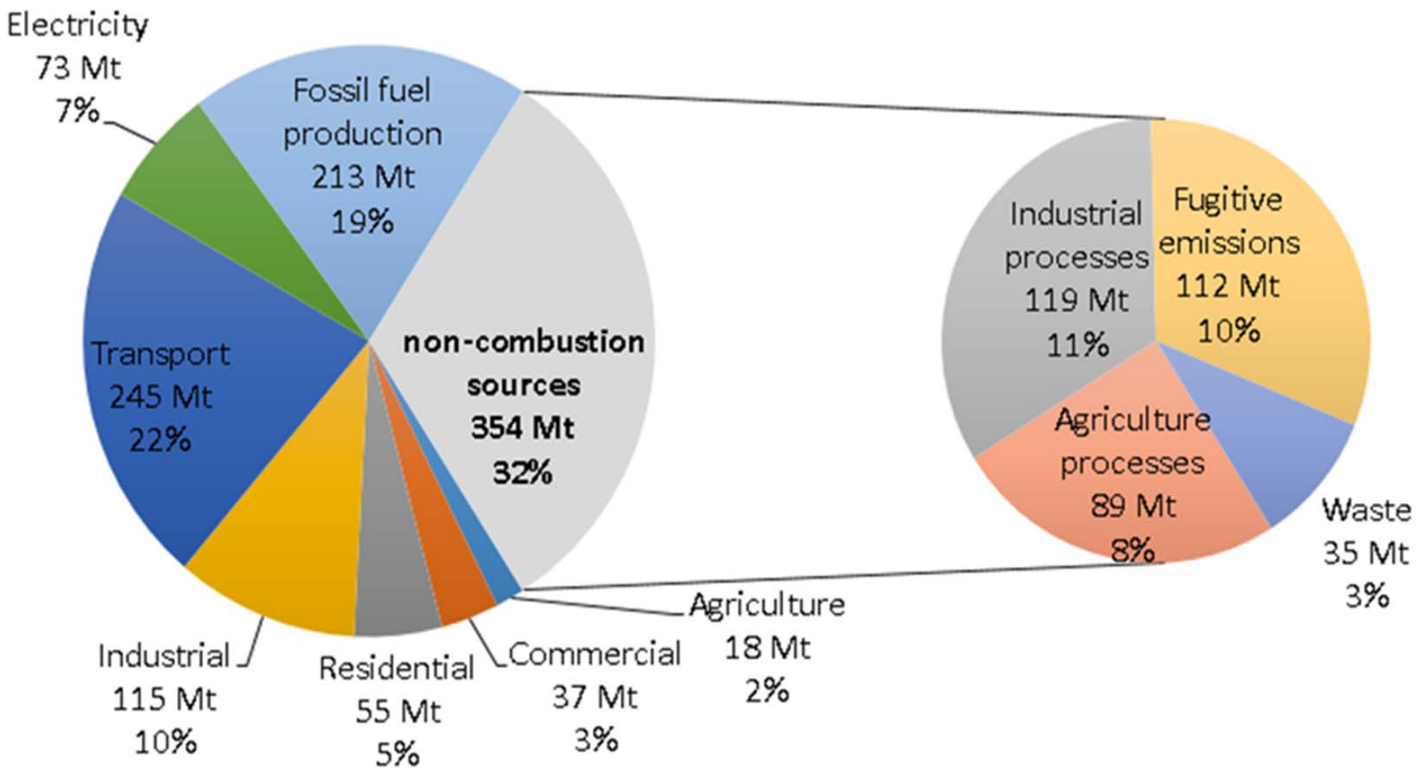
GHG combustion emission targets



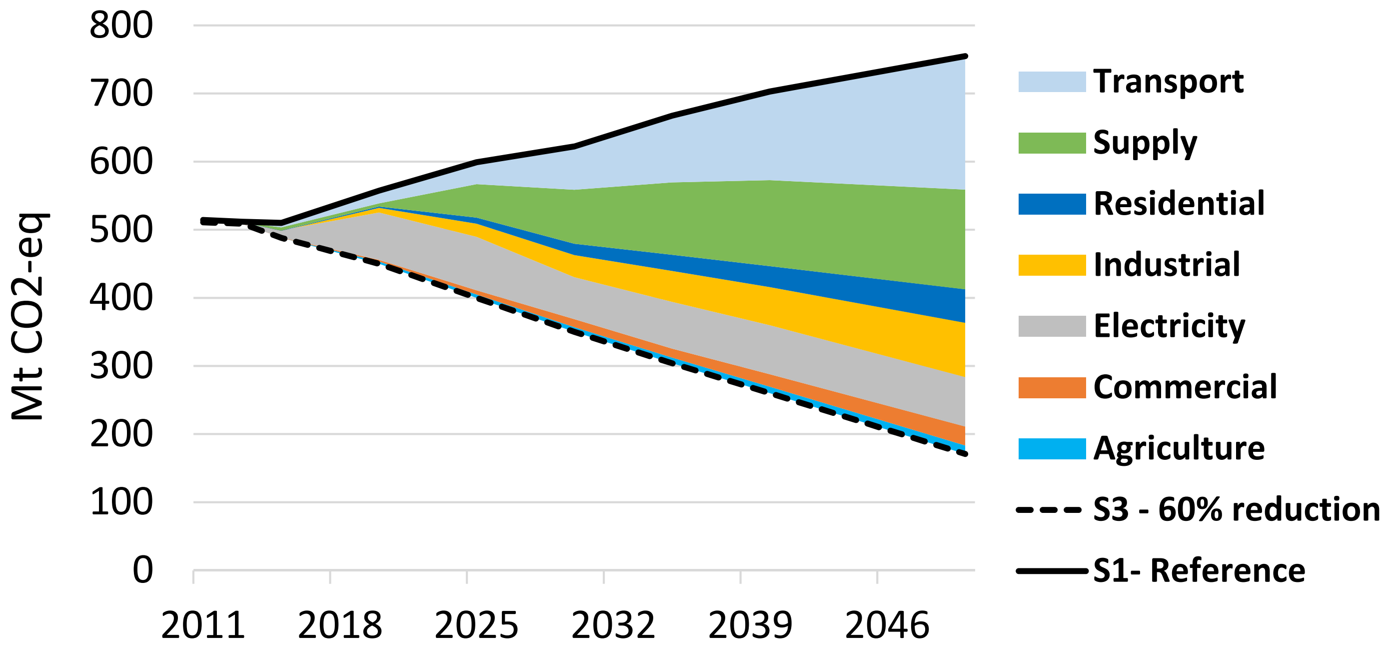
Trottier Energy Futures Project (TEFP)
Reference Scenario (BAU)

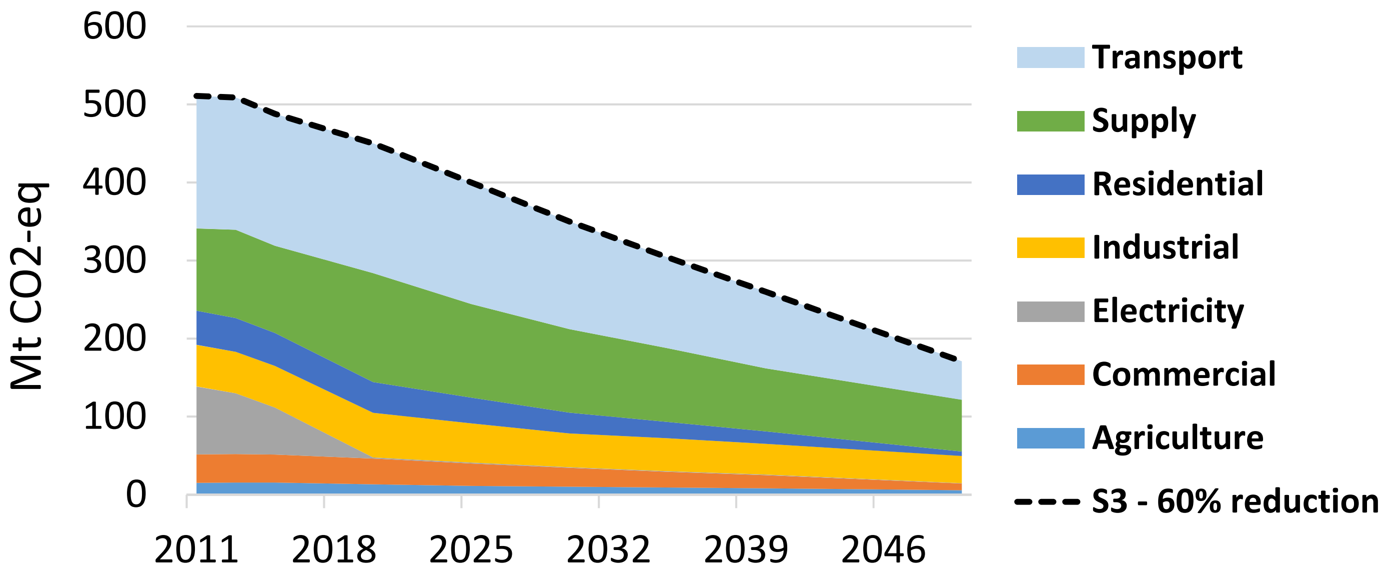
GHG Emissions in Canada (2050): 1109 MT

(Comparison to 1990: 589 MT)



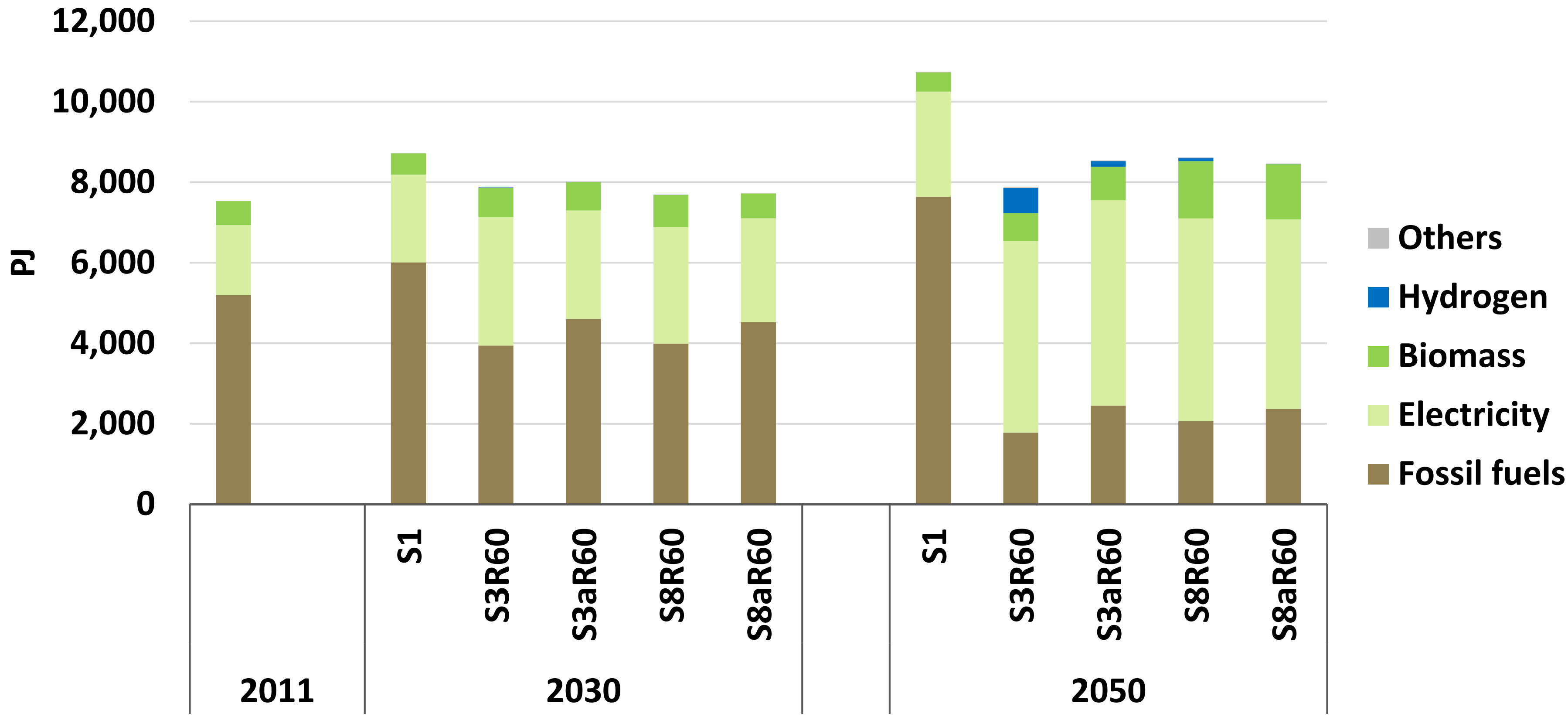
Scenario 3: 60% GHG Reductions





Final Energy in Canada -

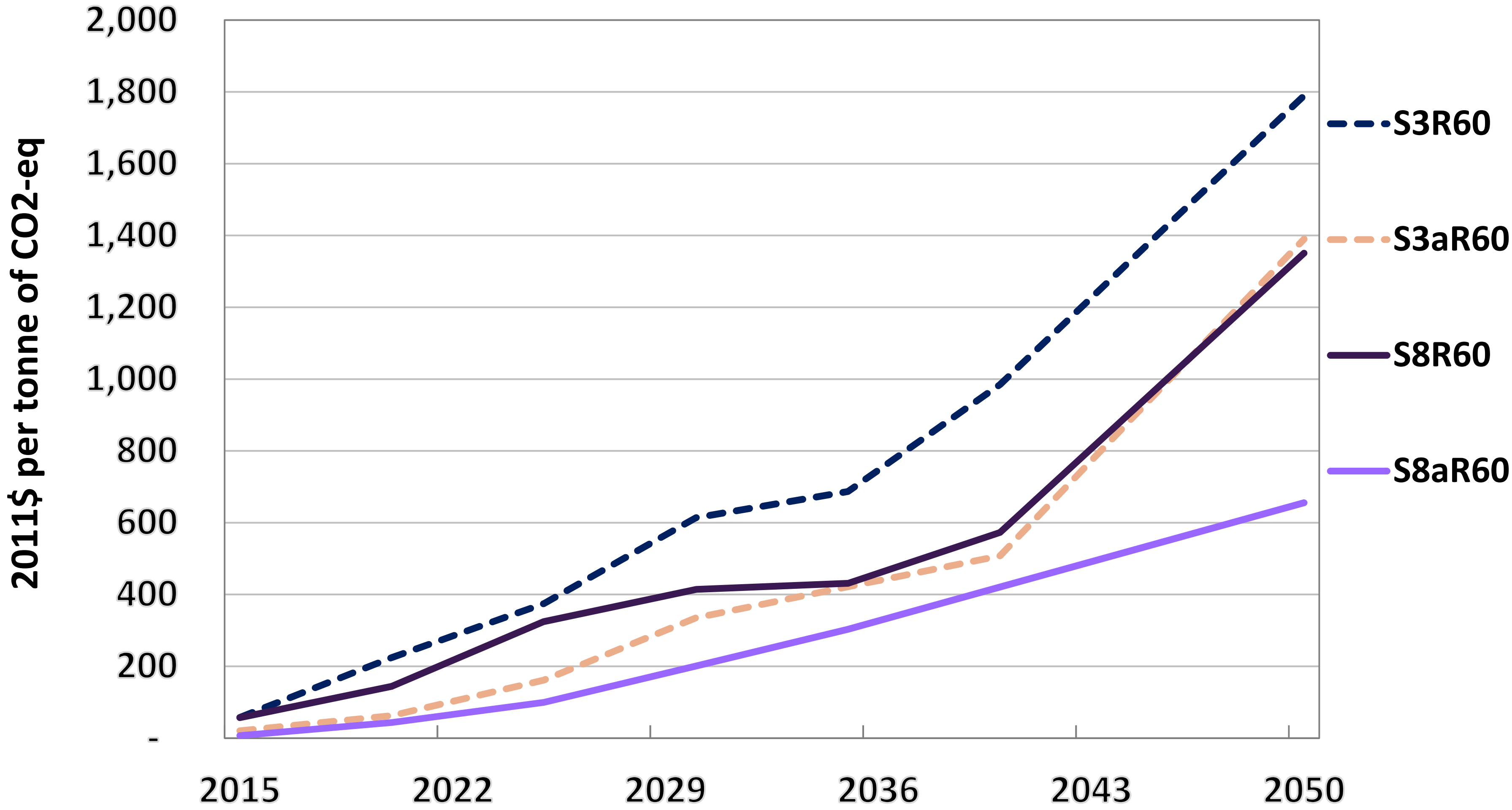
- Scenario S1, S3, S3a, S8, S8a



22%	33% - 40%	56% - 60%

Electricity component

Marginal Costs for Mitigating Combustion Emissions



Trottier Energy Futures Project (TEFP) Principal Observations

1. **Dominant source of combustion emissions is end uses (85%)**
2. **First priority is energy conservation and energy efficiency**
3. **Dramatic changes for meeting energy based end uses: fossil fuels decreasing from 74% to less than 25%; electricity increasing from 22% to more than 60%; biomass/biofuels increasing from 4% to more than 15%**
4. **Generating capacity increasing in Canada from 135,000 Mw to more that 500,000 Mw.**
5. **Decarbonizing electricity supply and transportation is early priority**
6. **Major increase in high voltage interconnections**
7. **CCS, carbon retention in forests and agriculture, and other carbon sinks and uses early priority for GHG mitigation**

Engineering, Management and Technologies for Net Zero: Challenges and Strategies

The next five power points are a few selected examples of challenges and strategies that combine major engineering, management and technology developments, for achieving net zero, while simultaneously contributing optimally to Canada's economic growth, and transformation of its energy systems.

Challenges and Opportunities Grid Scale Electricity Supply

Challenges:

1. Three fold increase; 130,000 Mw to 500,000 Mw plus
2. Decarbonizing existing supply
3. Replacing and upgrading existing capacity
4. Interconnections
5. Grid scale storage

Strategies:

1. Bulk generation supply dominated by hydro, nuclear, thermal
2. Thermal supply increasingly dominated by natural gas; however, will require carbon capture – recent studies show this as very promising, especially in Western Sedimentary Basin
3. Hydro, including incremental capacity at existing sites, best complement for wind and solar intermittency
4. Interconnections, with large scale export from hydro dominated jurisdictions to thermal dominated jurisdictions
5. Large scale grid storage, for regional integration

Challenges and Opportunities Low Cost Wind and Solar

Attraction:

1. Low cost
2. Quick and easy to install
3. Good public support

Challenges:

1. Virtually no contribution to dependable capacity
2. Highly variable output, requiring fast response compensating supply; hydro, pumped storage, batteries, grid expansion

Strategies:

1. Wind and solar should be maximized, up to system integration limits – limits which may be 20% or less, depending on composition of supply system
2. Planning for fast response compensating supply critically important; refer to CAETS Report: Solutions for High-Level Penetration of Intermittent Renewable Electricity

Challenges and Opportunities Engineering and Project Delivery for Large scale Power Projects

Challenges:

1. **Canada has lowest cost electricity supply in G7; derived from past investments in major projects – hydro, nuclear and thermal**
2. **Currently, major cost overruns and project completion delays with large projects; hydro, nuclear**
3. **Lack of public confidence in managing delivery of large projects**
4. **This was not the case 50 years ago; what has changed??**
5. **Expertise for engineering and delivery of large scale projects, in many organizations, has retired, and not been replaced; decision processes more politicized**

Strategies:

1. **Need to acknowledge politically and institutionally that this is a serious problem**
2. **Need to rebuild Canadian capacity for engineering and managing delivery of large infrastructure developments**
3. **Need to maintain this capacity by ensuring an ongoing sustained infrastructure development program – engineering, construction and installation**

Challenges and Opportunities Expanded Role for Forest Sector

Challenges:

1. **Forest sector is major resources sector for long life harvested wood products (lumber), pulp & paper, biomass/ biofuels and specialty bio-products**
2. **Major potential as carbon sink;**
   - **Afforestation and reforestation**
   - **Lumber for buildings (long life carbon retention) and for export**
   - **Displacement of emissions intensive building materials (concrete, steel)**
   - **Bioenergy**
   - **Bioenergy with CCS (BECCS)**
   - **Improved harvesting**

Strategies:

1. **Expanded and optimized role of forest sector for economic growth (including export), and large scale carbon retention – integrated systems approach combined with bioscience**

Challenges and Opportunities
CCUS

Opportunities:

1. Natural gas likely to assume major increased role for electricity supply in Canada and globally – will require CC. Current technologies include CO_2 emissions down by 96% compared to conventional coal without CCS
2. Western sedimentary basin is one of best land based storage sites in the world for permanent deep CO_2 sequestration
3. CO_2 is feedstock for urea based fertilizer and methanol production, and other products; also, used for enhanced oil recovery.
4. Opportunities for capture, transport and disposal of CO_2 important for industrial sectors, such as cement production

Strategies:

1. Acceptance that CCUS is absolutely essential for achieving net zero
2. Continued engineering and research for alternative capture technologies and improving existing approaches for efficiency, reduced thermal energy, and reduced parasitic losses
3. Comprehensive systems approach for optimally integrating capture, transport, use as feedstock, and disposal of CO_2 in a multi-jurisdictional context

Integrating Engineering Developments with Comprehensive, Integrated Fact-based Planning for Achieving Net Zero

1. **Challenge is to systematically define "optimal pathways" to achieve economic growth, reduce emissions and transform Canada's energy systems**
2. **Recognition that the challenge is very complex, and that interplays between various sectors of the economy are very substantial**
3. **Costs for GHG mitigation are in trillions of dollars, but can be contained at a modest percentage of GDP, with systematic selection and implementation of "best decisions"**
4. **Planning needs to be fully integrated with progressive engineered improvements in technologies and innovations**
5. **Long term planning is three phase process;**
   - **long term "pathways"**
   - **strategies**
   - **policies**

6 **Output from planning and consensus building should serve as basis for continually updating engineering and research priorities**

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Thank you

Q & A

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