EMI National Forum

Management of Canada's Energy Transition and Associated Risks through Optimized CGE Approach

Institute for Energy, Environment, and Sustainable Communities

December 18, 2019

Part 01

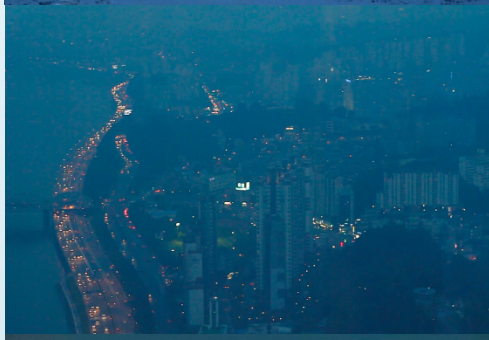
Introduction

Energy systems

❖ Various components

❖ Various activities

- ❑ Energy allocation
- ❑ Technology utilization
- ❑ Capacity expansion
- ❑ Emission reduction



❖ These issues are associated with …

- ❑ Complex interactions
- ❑ Nonlinear relationships
- ❑ Multi-level uncertainties

Climate Change

There are many direct and indirect effects of climate change on energy systems

Direct effects:

- Air temperature → space heating & cooling
- Precipitation → hydropower production
- Draught & Flooding → agricultural energy demand

Indirect effects:

- Policy implanted for adaptation of climate change, e.g., clean energy measures
- GHG mission mitigation activities

An interdisciplinary viewpoint is necessary

Increasing energy systems problems

Leading to emerging problems

- Growing energy demands
- Rising concerns over energy security
- Depletion of conventional energy sources
- Development of renewable energy sources
- Economic implication
- Impacts on environment

Integrated management of energy systems is desired :

- ✓ Determine system schemes
- ✓ Ensuring adequate energy capacities to meet the projected future system demand and operating requirements

Objective

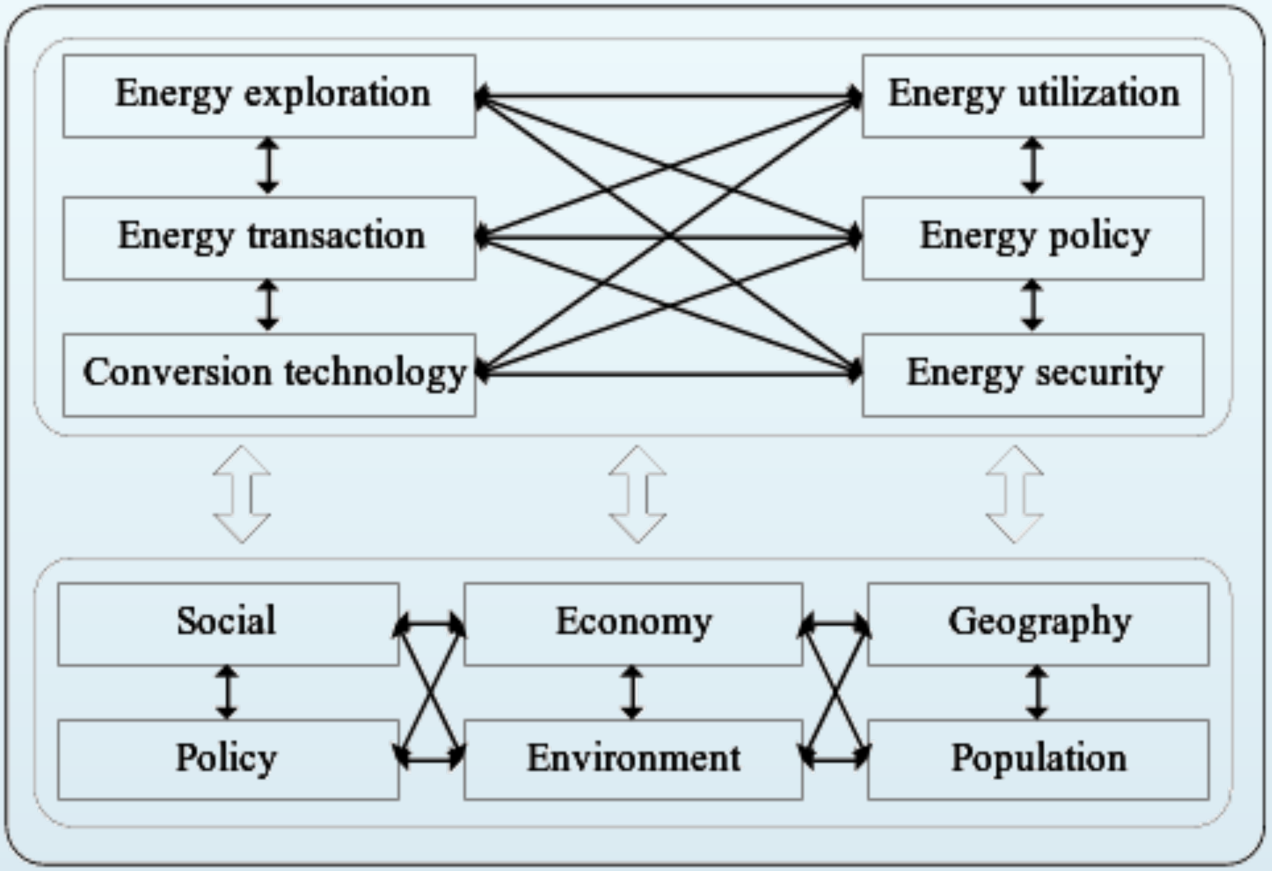
- Develop advanced energy systems optimization models and computable general equilibrium model under climate change conditions
- Apply the proposed models to representative regions in Canada to support effective systems planning and policy-making



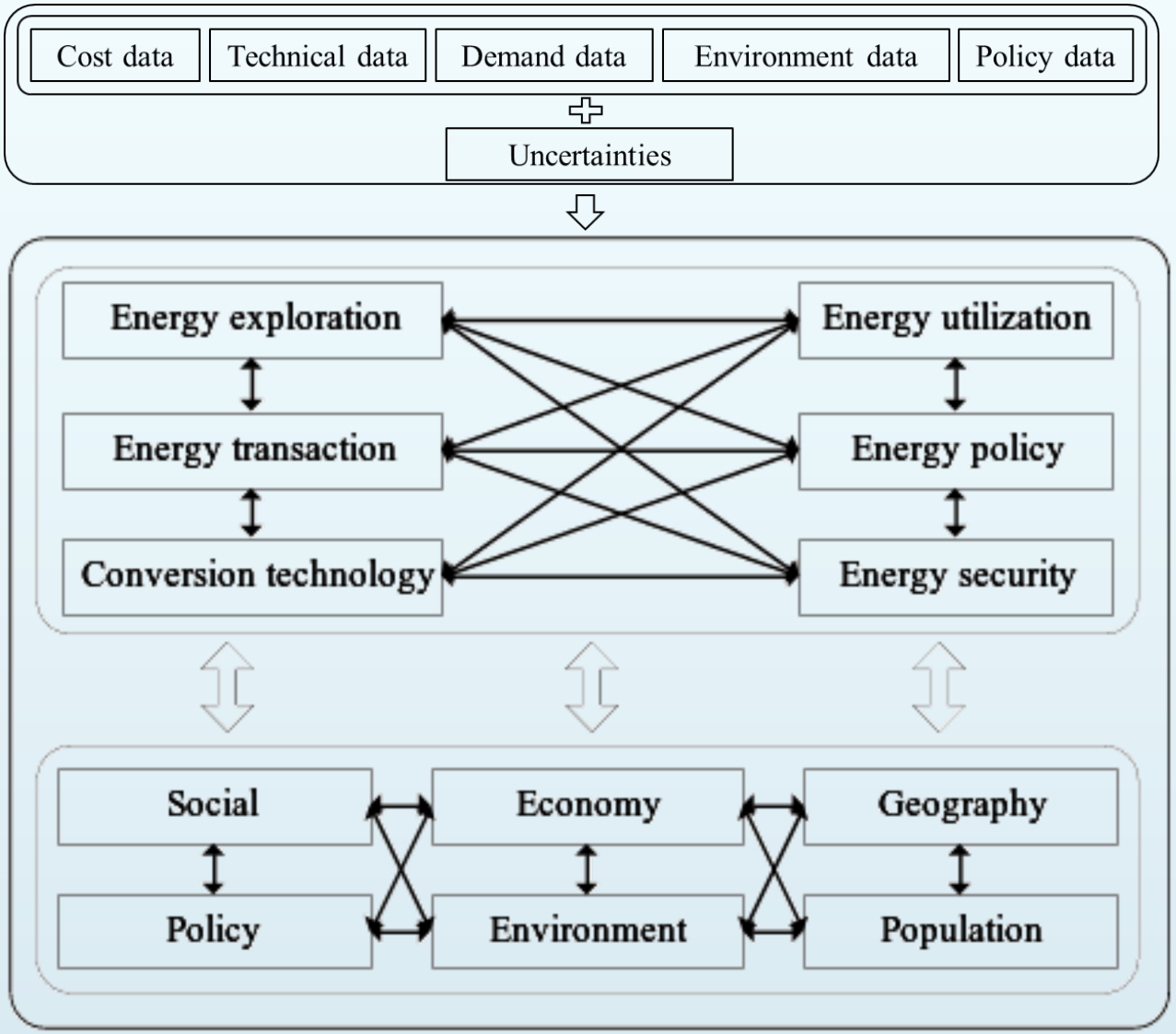
Part 02

Model

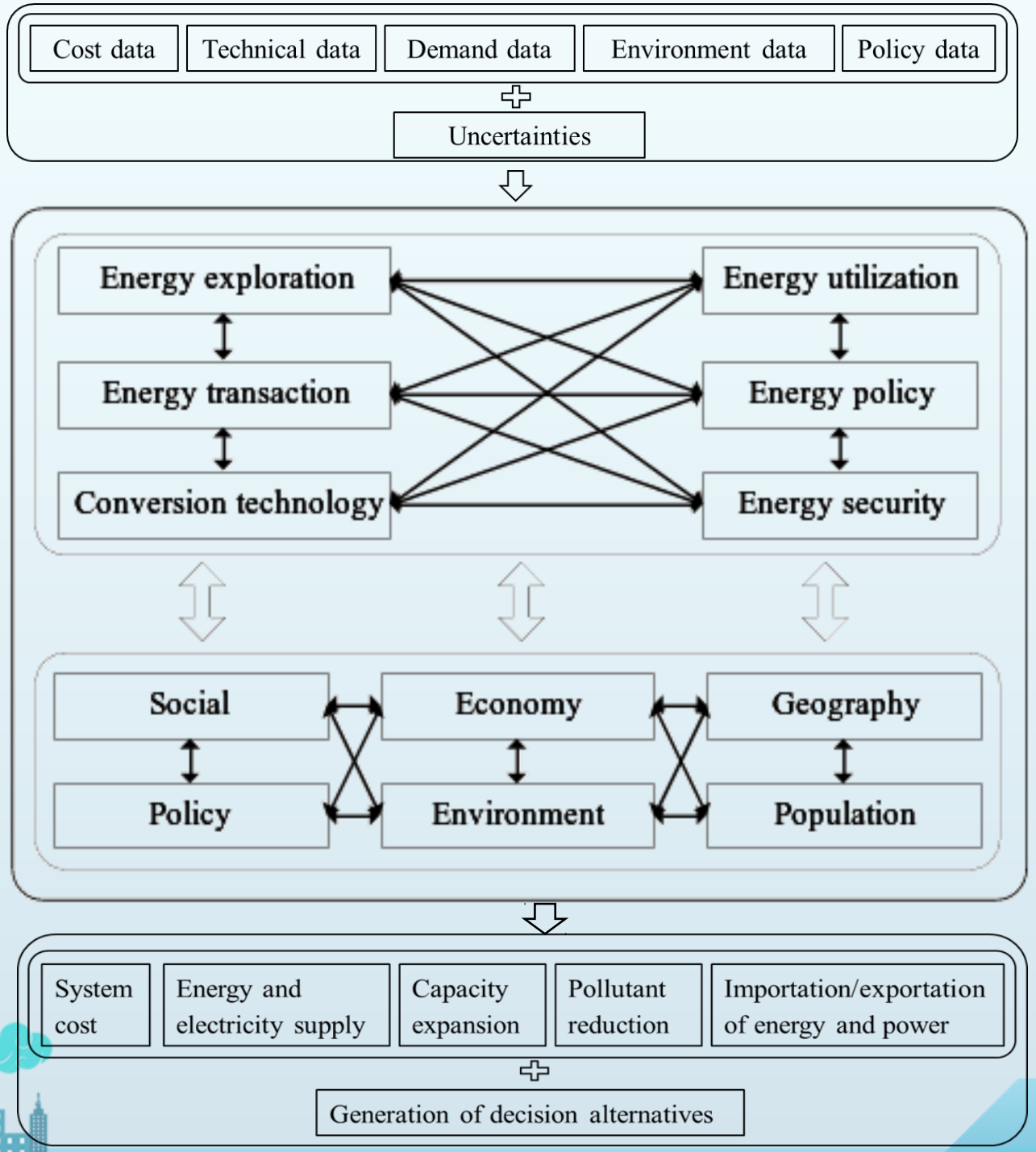
Energy optimization model



Inputs


Cost data
Technical data
Demand data
Environment data
Policy data
Uncertainties
Energy exploration
Energy transaction
Conversion technology
Energy utilization
Energy policy
Energy security
Social
Economy
Geography
Policy
Environment
Population

Inputs



Outputs

GHG management—AB model

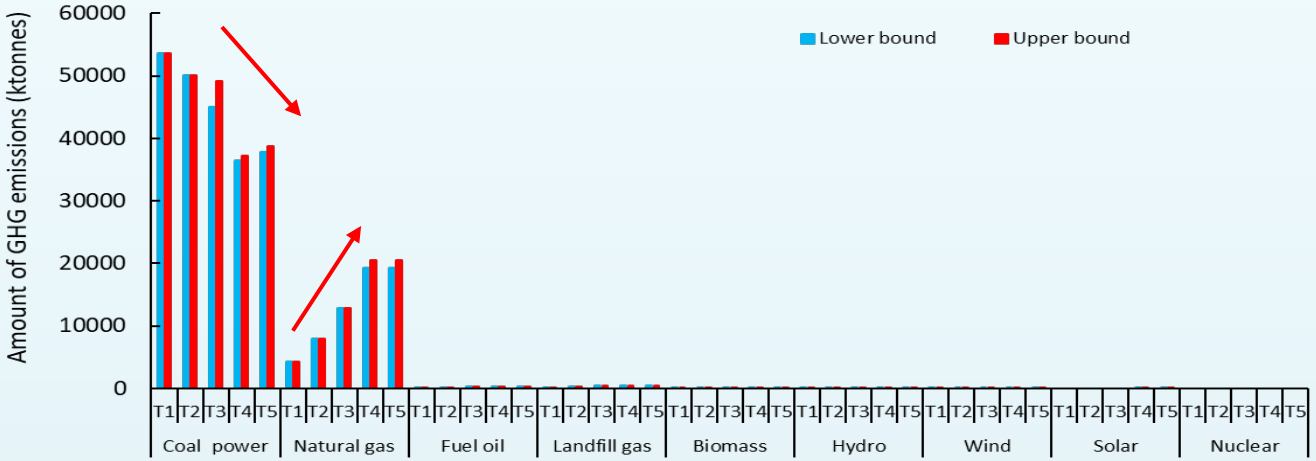


Fig. GHG emissions from power generation technologies

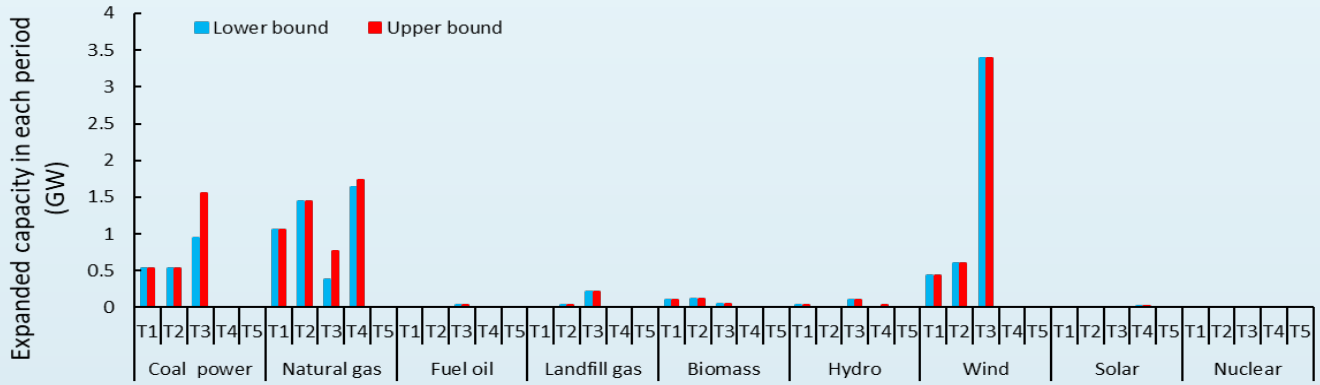
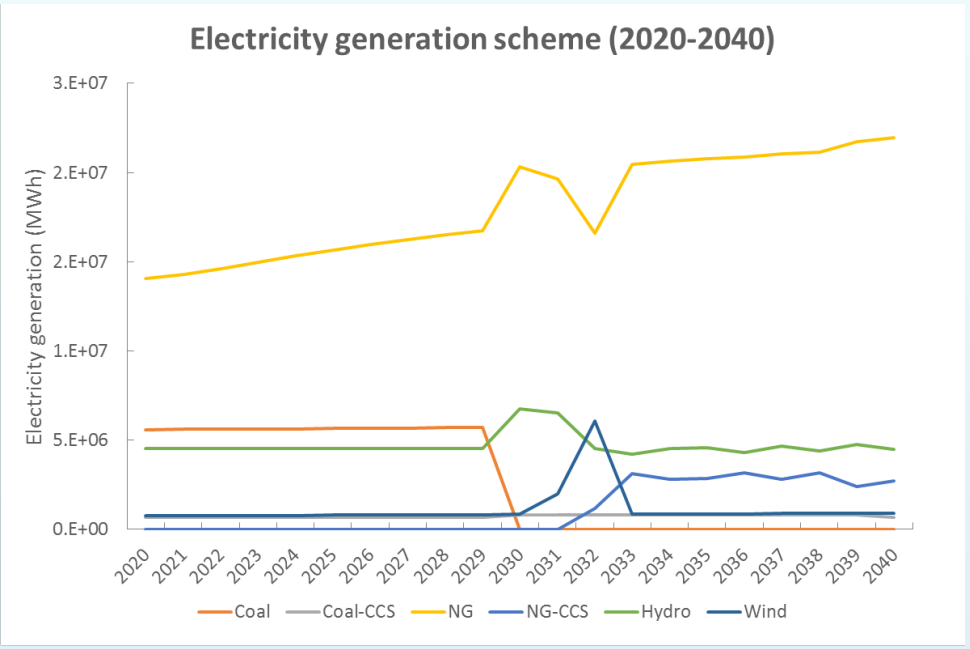
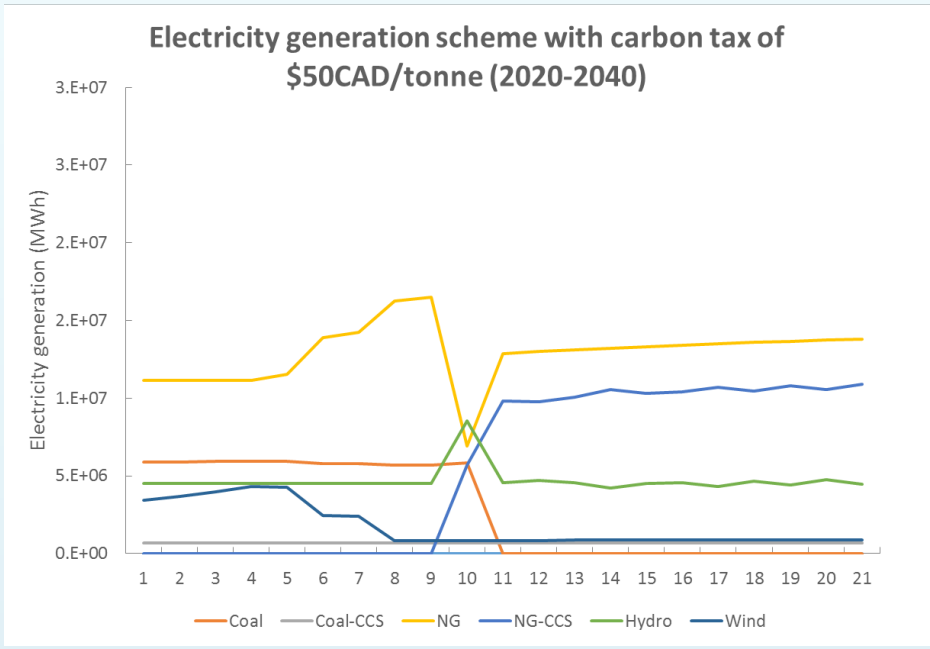


Fig. Capacity expansion of electricity generation facilities

- To reduce GHG emission and satisfy future power demand ✉ natural gas would expand [4.53, 5.01] GW
- The expanded capacity of renewable power generation ✉ 3.83, 0.26 and 0.16 GW of wind, biomass, and hydro power, respectively

GHG management—SK model





- In 2030, power generation ✉ coal to natural gas
- After applying a carbon tax of $50 CAD/ tonne ✉ power supply scheme will change
- More than 60% of increased natural gas capacity will transfer to NG-CCS capacity

Renewable energy planning—BC model

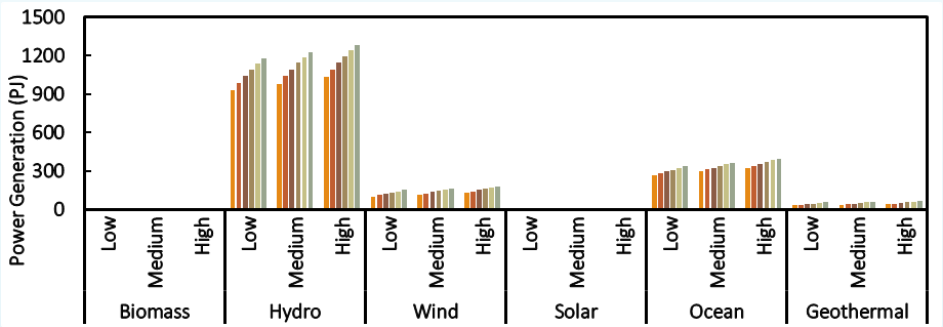


Figure: Power generation in BC for renewable energy

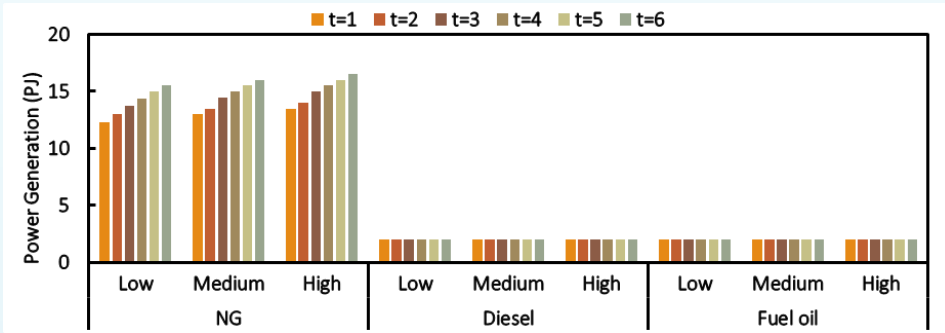


Figure: Power generation in BC for non-renewable

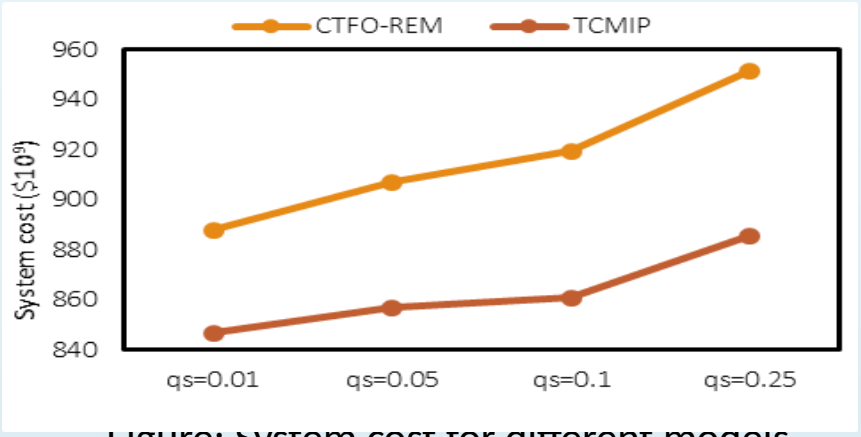


Figure: System cost for different models

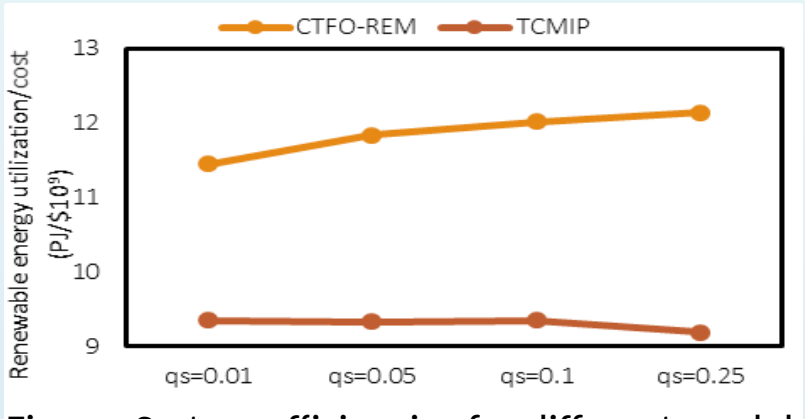


Figure: System efficiencies for different models

- Main power generation mode ✉ hydropower
- Notable renewable energy resources ✉ hydropower and wave/tide power
- CTFO-REM model ✉ effective tool for supporting other practical environmental management

Renewable energy planning—MB model

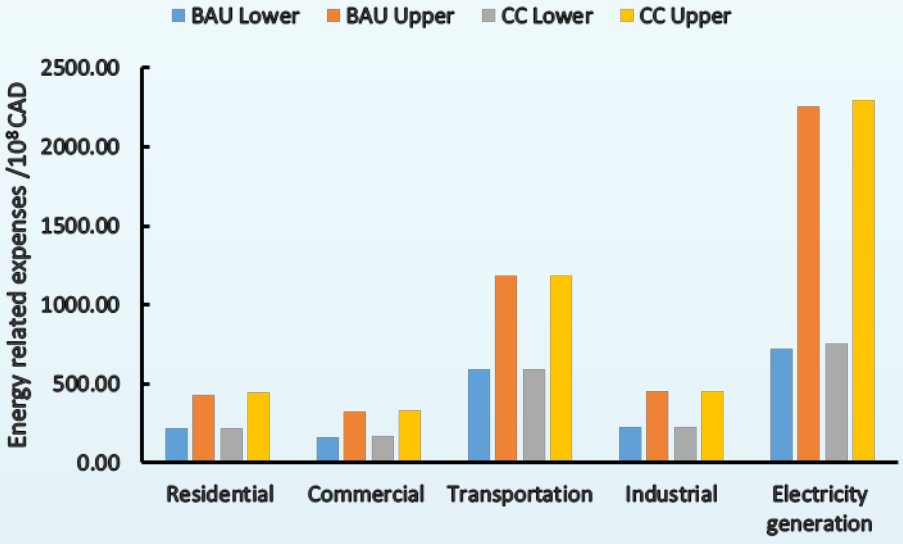


Figure: Energy related expenses

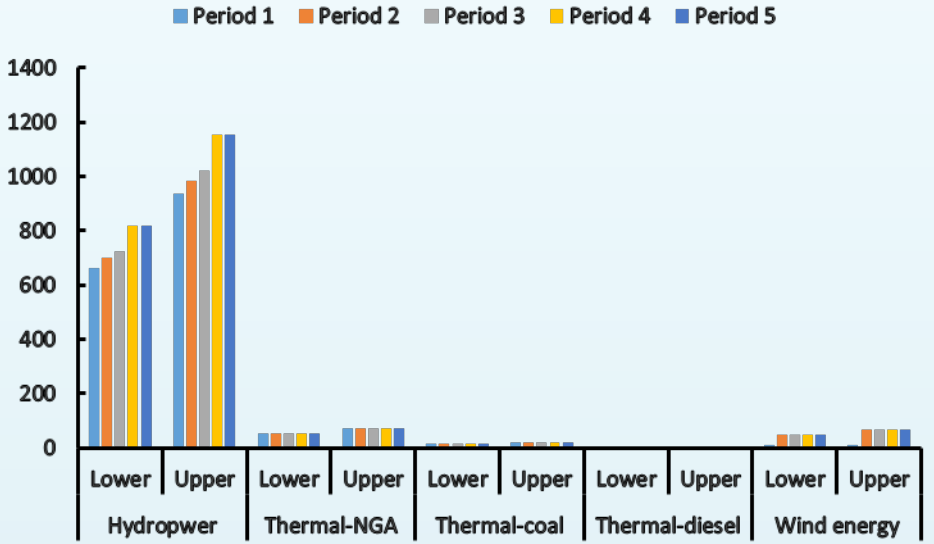
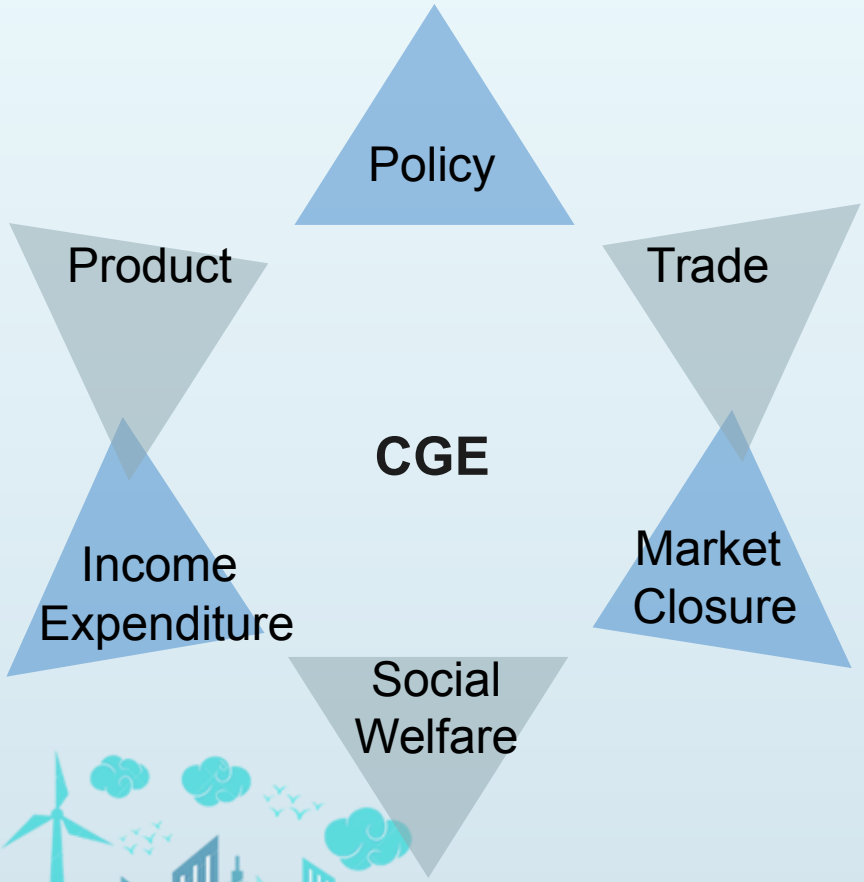
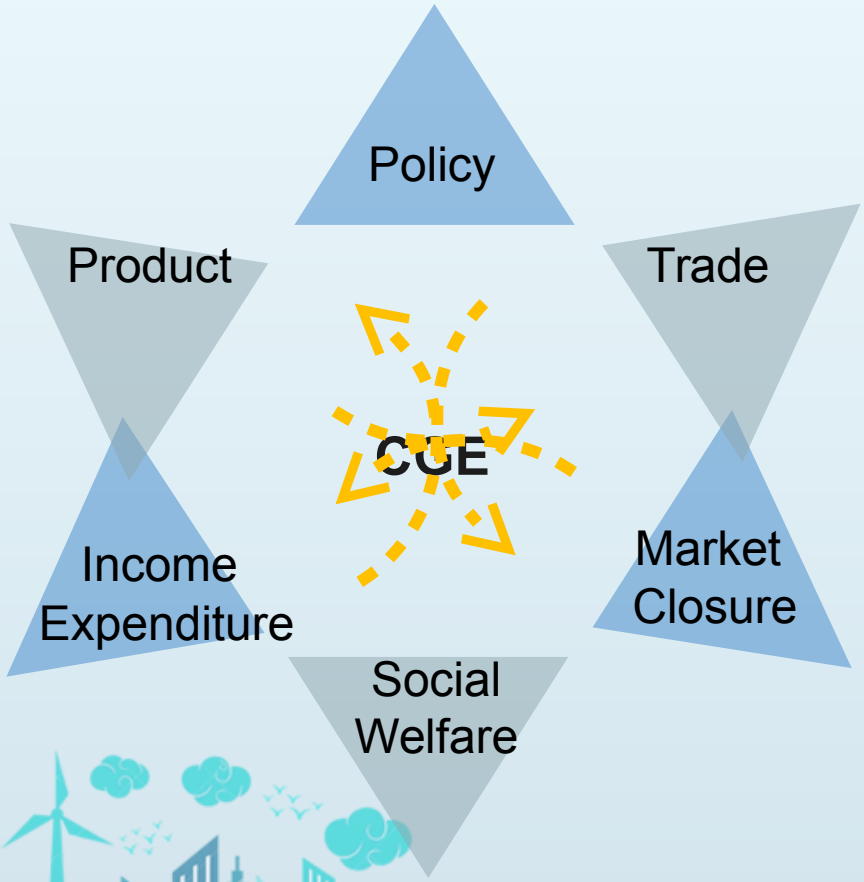


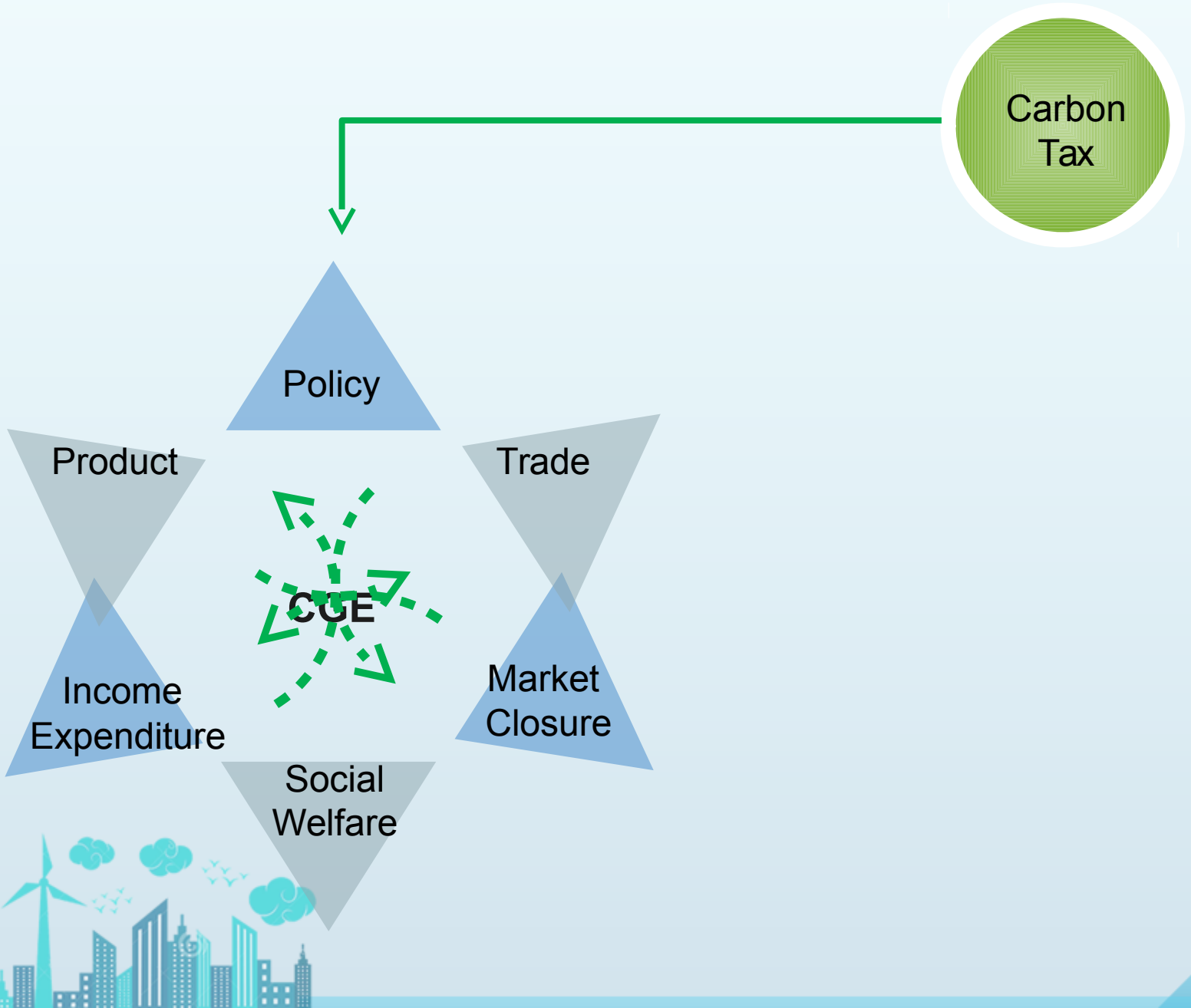
Figure: Power generation under BAU

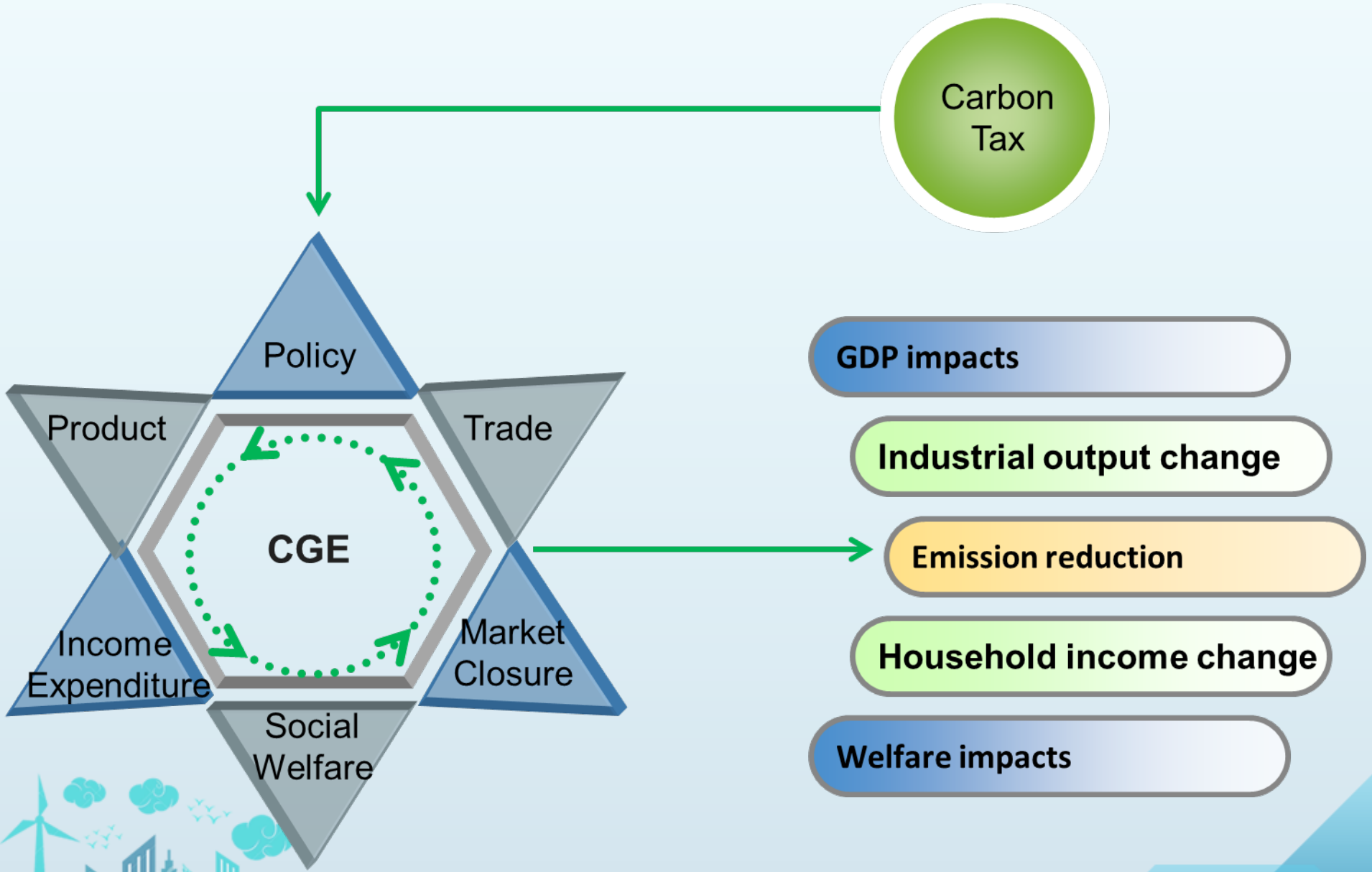
- The most sensitive sector under climate change impacts ✉ electricity
- Renewable energy resources comparative abundance in Manitoba ✉ particularly hydropower
- The lesser amount of electricity would be exported under changing climate than under the BAU case

Computable General Equilibrium Model




Policy
Product
Trade
CGE
Income
Expenditure
Market
Closure
Social
Welfare


Carbon Tax
Policy
Product
Trade
CGE
Income Expenditure
Market Closure
Social Welfare


Carbon Tax
Policy
Product
Trade
CGE
Income Expenditure
Market Closure
Social Welfare
GDP impacts
Industrial output change
Emission reduction
Household income change
Welfare impacts

GDP & Emission

- Scenario 1&2:

  GDP change less than 0.2%

- Scenario 3&4:

  Decrease faster when carbon tax continues to grow up

- Scenario 5:

  Affect the economy significantly (4.12%)

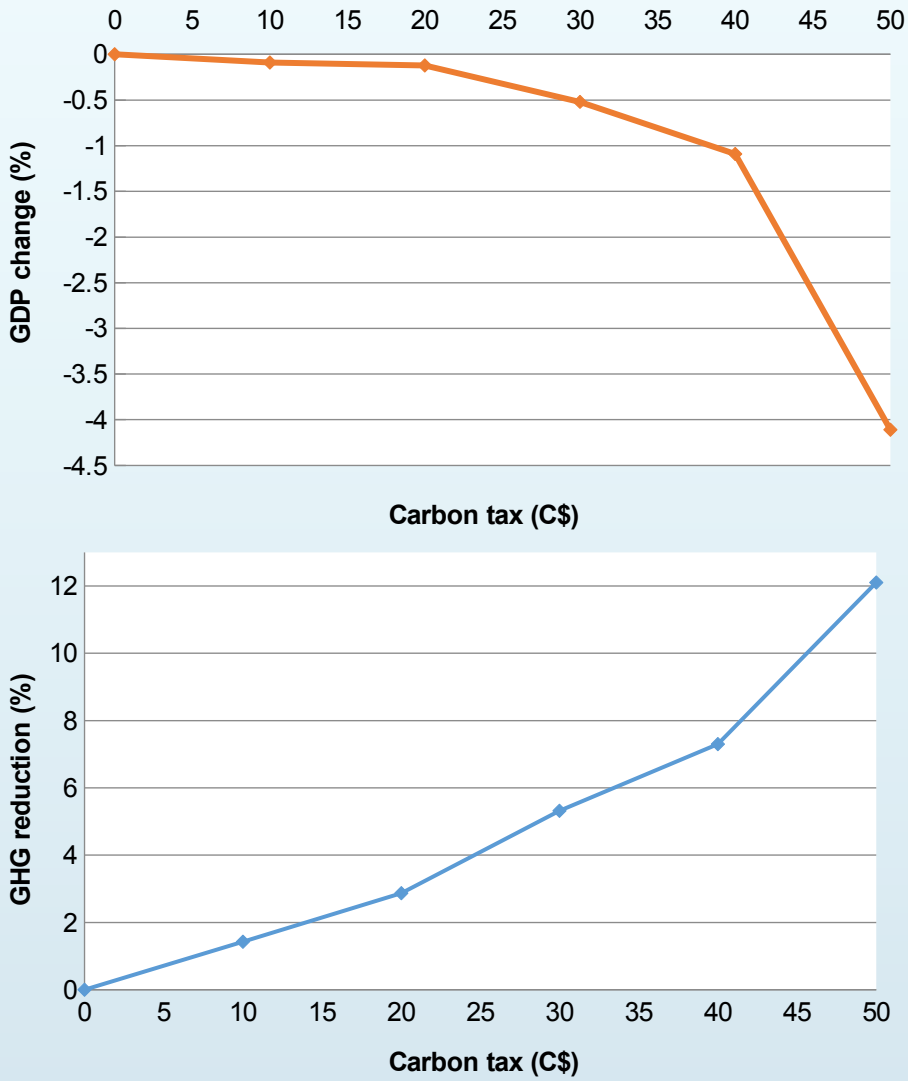


Figure: Impacts of carbon tax on GDP and GHG emissions

- Effective way to reduce the GHG emissions
- Growth rate is increasing along with the carbon tax rate
- Effects on GHG emission reduction is less obvious than the effects of carbon tax on GDP change

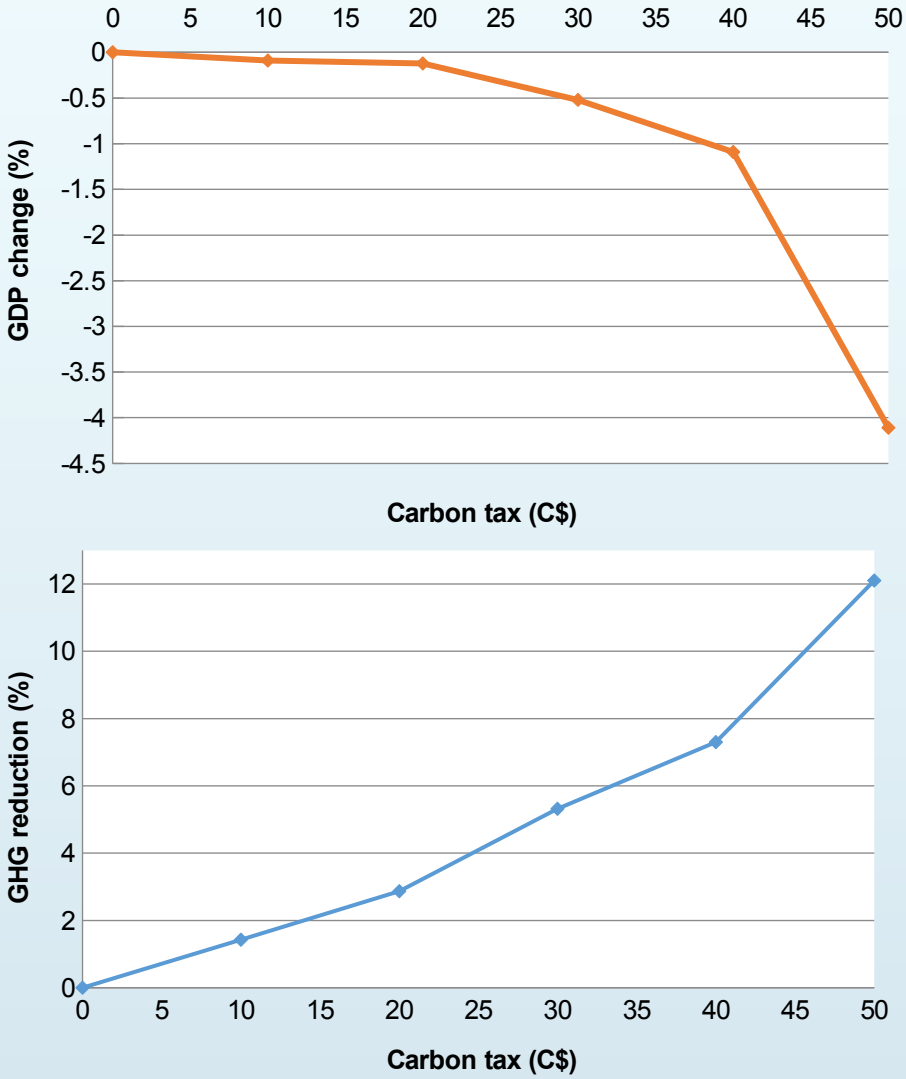


Figure: Impacts of carbon tax on GDP and GHG emissions

Industrial Output

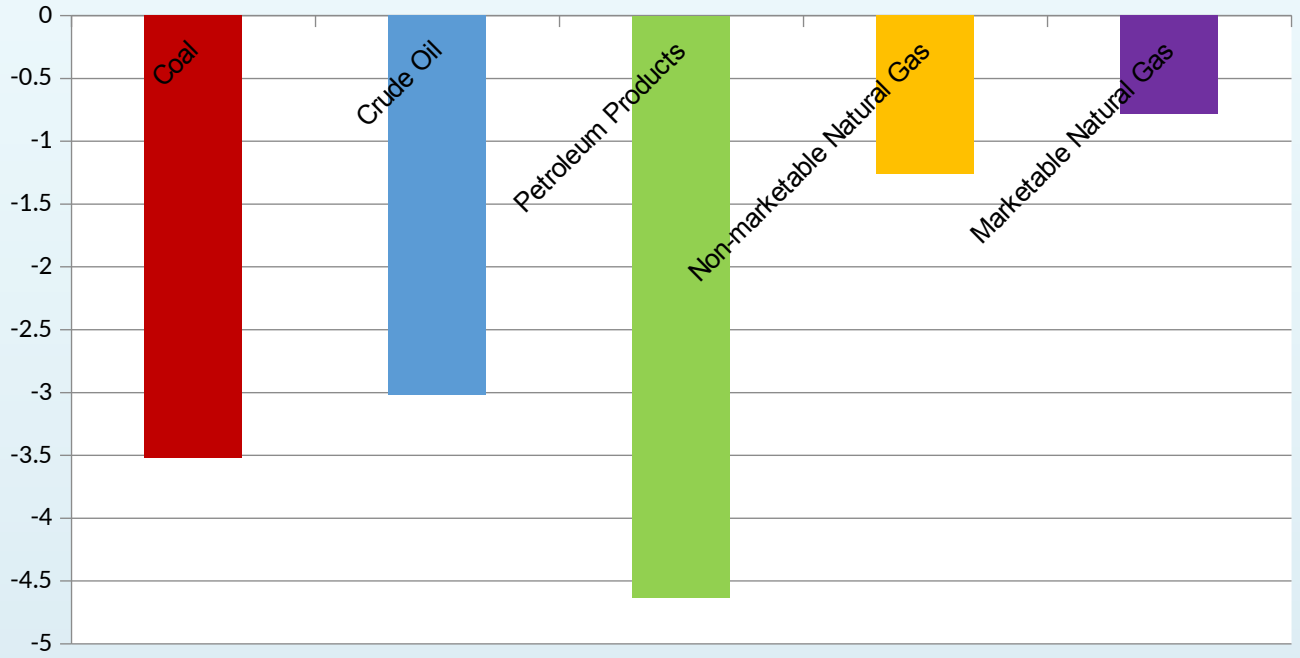


Figure: Total output change of five fossil energy sectors

The total output will all decrease

Industrial Output

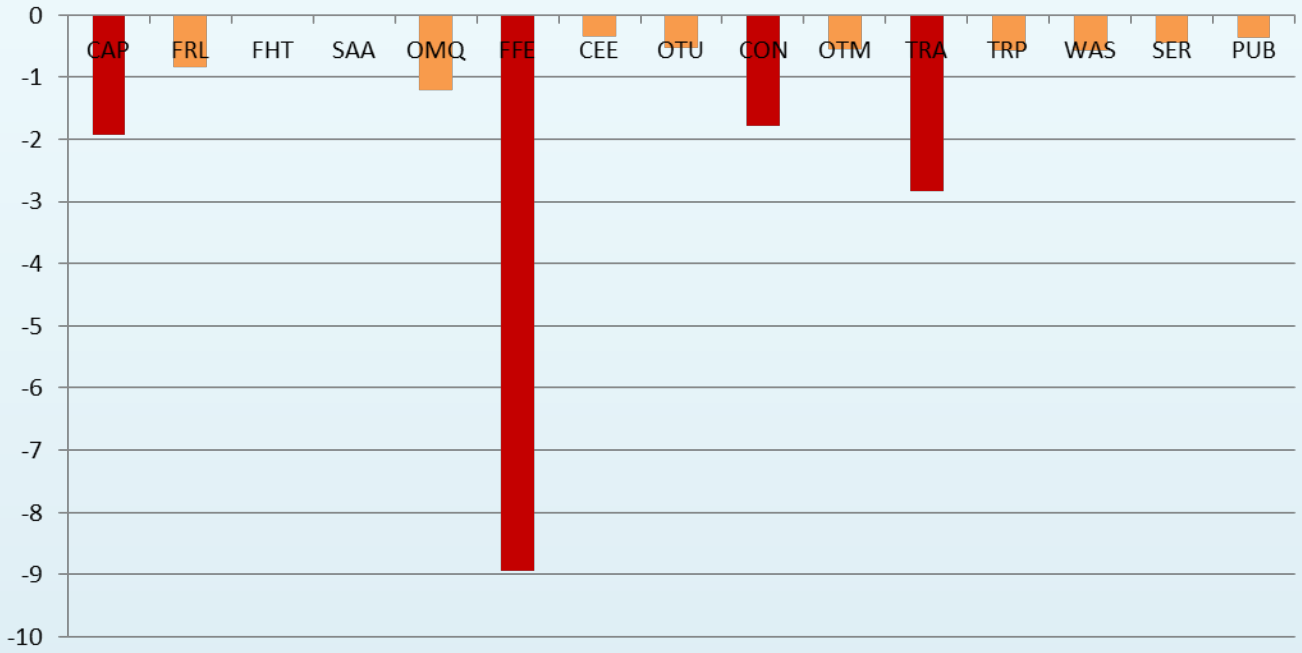


Figure: Total output change of common sectors

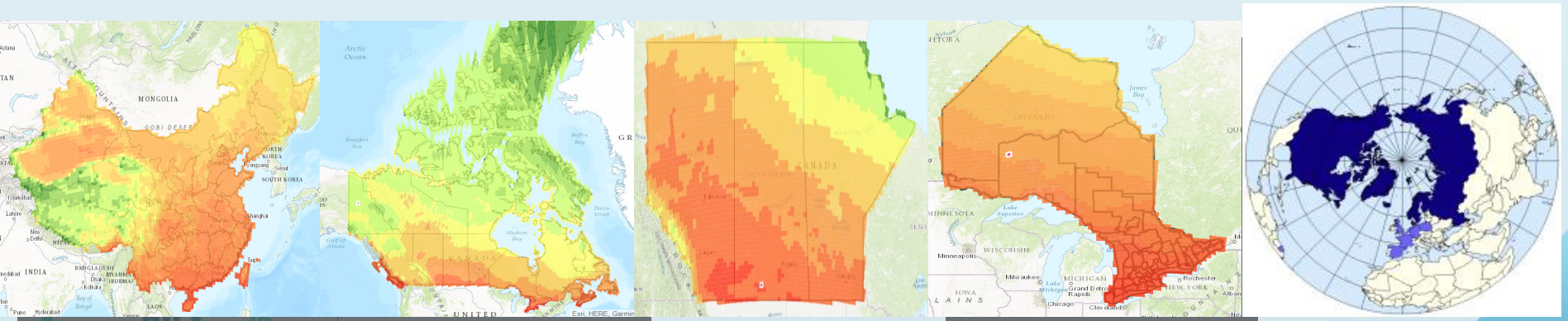
- All the output will decrease
- Fossil-fuel electric power generation will reduce the most

Part 03

Extension

Reginal Climate Model

- GCM: HadGEM, CanESM, GFDL, MPI, IPSL
- RCM: PRECIS, RegCM, WRF
  - China 25 km (A1B)
  - China 50 km (RCPs)
  - Canada 50km (RCPs)
  - Canada Ontario, Saskatchewan, Alberta, Manitoba 25km
  - Arctic 50km (RCPs)
- In progress (50 km):
  - Australia, Europe, North America, South America, and Africa



Reginal Climate Model

Climate Change Data Portal (CCDP) was launched in early 2014

to ensure easy acces
to refined high-resolutio
regional climate data

Available at:
http://ccdp.network/

Thank you!