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The Atlantic Canada Energy System (ACES)Model Initiative

Building capacity in Atlantic Canada to analyze and implement pathways to net-zero emissions through energy system modelling

PEI’s climate change commitments

2030 by 2030 and for each subsequent calendar year, PEI greenhouse gas emissions will be less than 1.2 megatonnes of carbon dioxide equivalent per year; and

2040 by 2040 and for each subsequent year, PEI greenhouse gas emissions will be at a level where carbon neutrality is achieved.

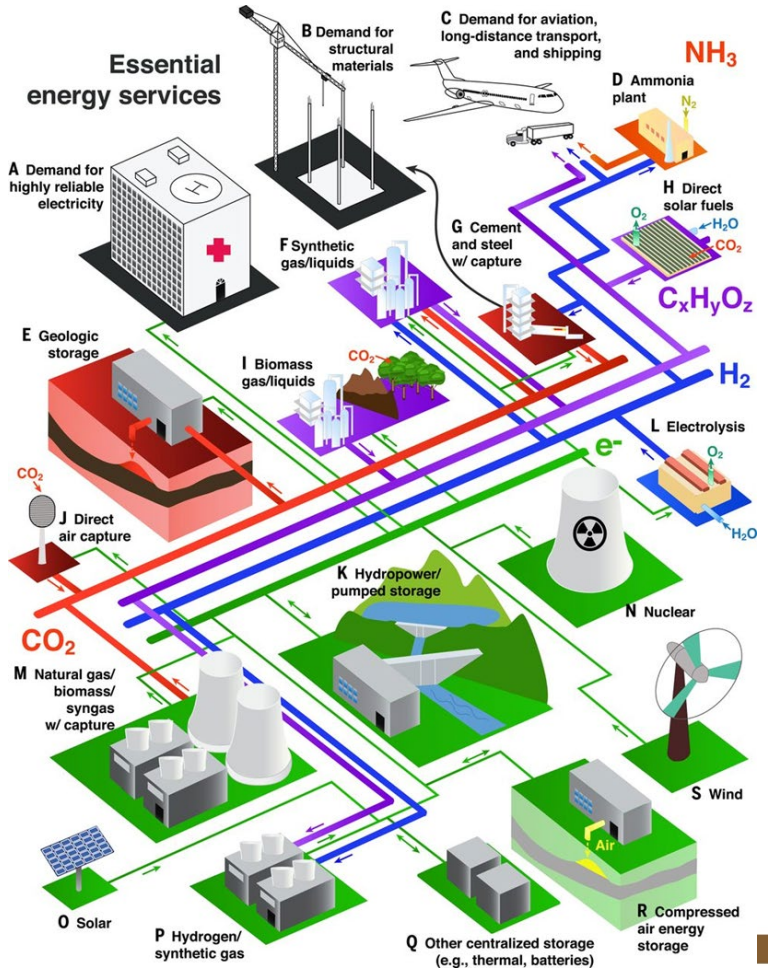
Government of PEI, 2022

Meeting climate change targets will be challenging.

Energy systems are growing increasingly complex and interconnected.

Technology disruption is creating more optionality.

There are many unknowns: future costs of technologies, adoption rates of electric vehicles, development of new technologies, population growth.



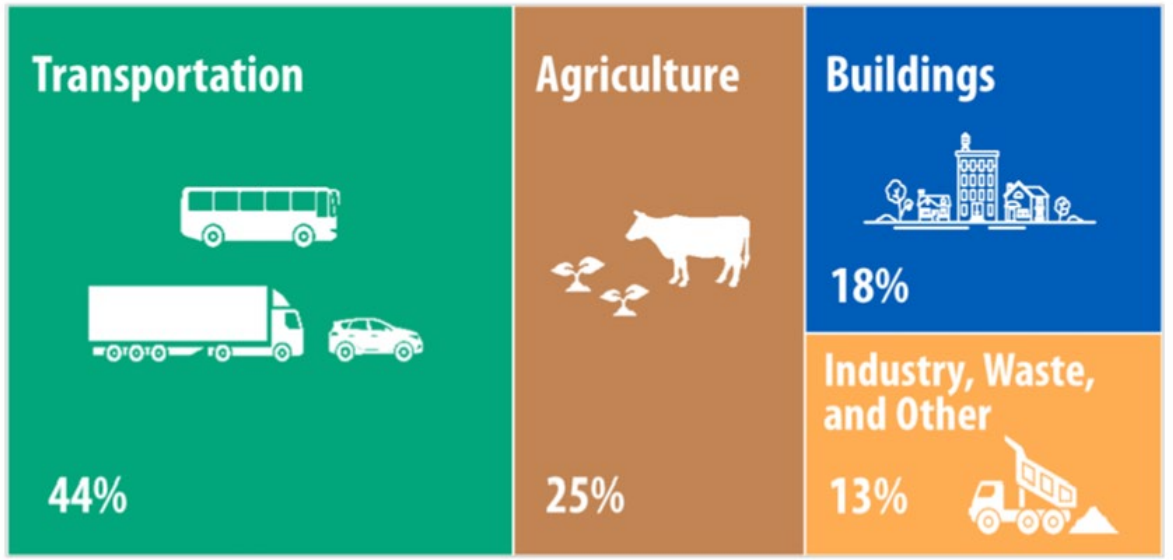
Davis et al., 2018

Meeting climate change targets will be challenging.

Distinct approaches will be needed to address the distinct processes of emissions.

Decisions need to be made quickly but also be transparent and democratically accountable.

Major Sources of Emissions in PEI

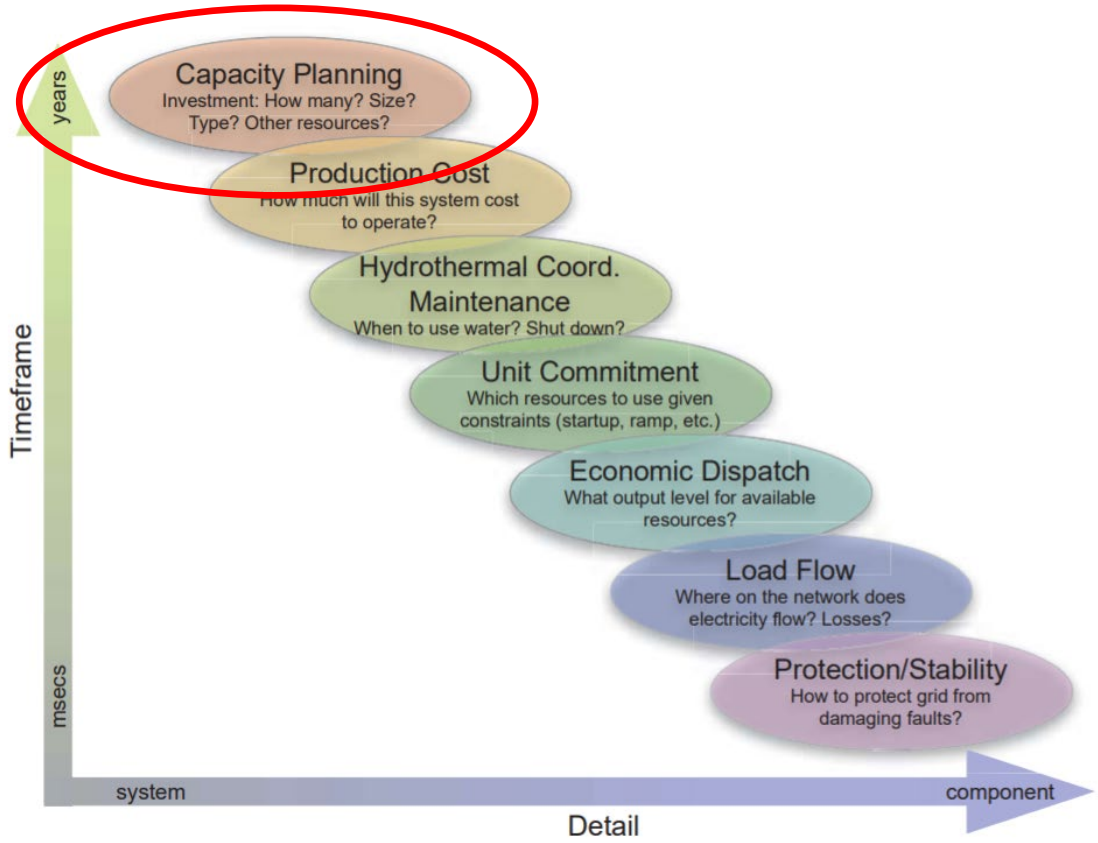


Source: 2019 GHG Emissions (from 2021 National Inventory Report: Greenhouse gas sources and sinks in Canada, Environment and Climate Change Canada).

Government of PEI, 2022

Energy system models can help.

- Computerized models that represent the energy system
- “Formalize the component parts of the system and their interactions, and allow for structured thinking about the implications of significant system reconfiguration” (Pye et al., 2020)



Palmintier, 2012

How do capacity expansion models work?

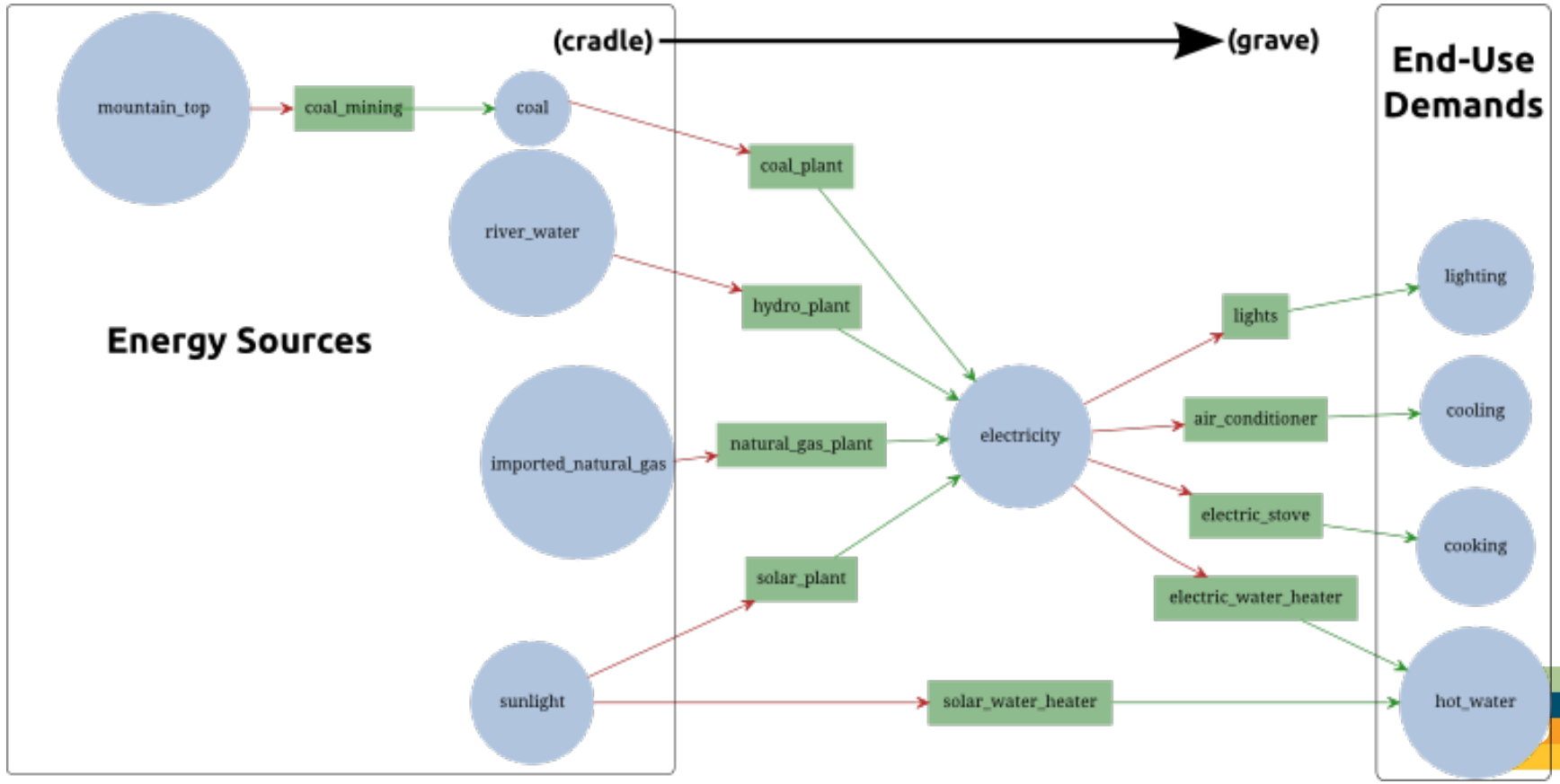
Capacity expansion models "optimize the installation and utilization of energy technology capacity over a user-defined time horizon. Optimal decisions are driven by an objective function that minimizes the cost of energy supply" (Temoa, 2021).

minimize	Total Discounted System Cost	Capital Costs + Variable Costs + Fixed Costs + Emissions Costs
subject to	• Technical constraints • Resource constraints • Emission constraints • Policy constraints	e.g. generator ramping limits e.g. NG pipeline capacity e.g. CO2e, Hg limits e.g. renewable portfolio standards

"What is the optimal set of investment and operational decisions that ensure supply reliably meets demand subject to a number of technical, resource, emission and policy constraints?"

How do capacity expansion models work?

Energy sources are transformed into consumable energy commodities by a set of energy technologies, which are ultimately used to meet demands (i.e., kilometers driven or kWh used).



Temoa, 2021

How do capacity expansion models work?

The model uses parameters to characterize the energy system.

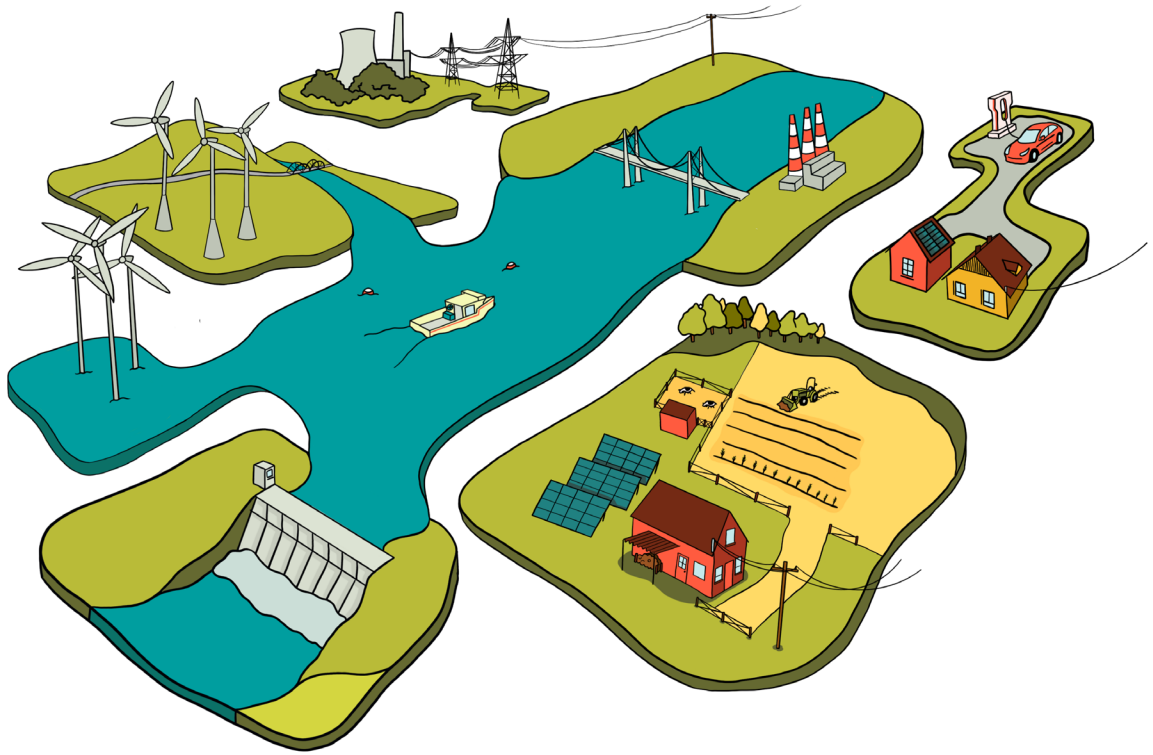
- Capacity
- Cost
  - Emissions
  - Fixed
  - Invest
  - Variable
- Demand
- Discount Rate
- Emission Limit
- Activity (Max, Min)

What can we use energy system modelling for?

Energy systems are growing increasingly complex and interconnected.	Analyze impacts of electrification on the electricity sector.
Technology disruption is creating more optionality.	Compare and contrast how different technologies impact energy system cost.
There are many unknowns.	Perform sensitivity and scenario analysis on unknowns.
Distinct approaches will be needed to address the distinct processes of emissions.	Create sector- and economy-wide roadmaps for all sources of emissions.
Decisions need to be made quickly but also be transparent and democratically accountable.	Evaluate pathways for reaching long-term goals, understand system impacts of policy intervention, and provide rational for policy decisions.

NZA built an energy system model.

- NZA built the Atlantic Canada Energy System (ACES) model.
- The model can help us to structure our understanding of and response to questions about the future of our energy systems and communities.
- Open-source: will allow for transparency, collective understanding and discussion → inclusive approach to decision-making.



ACES Model Overview

- Long-term capacity expansion model
- Includes all provinces and multiple sectors: electricity, buildings, transportation, agriculture, waste, and industry
- Temporal resolution: 2020 to 2055
- Fully open-source

How did we build the ACES model?

To ensure a robust and science-based approach to model development, a technical advisory board of academic members provide strategic and technical guidance to NZA's modelling team.

Dr. Taco Niet (SFU

Dr. Nathaniel Pearre (DAL)

Dr. Daniel Huppmann (IIASA)

Dr. Sally Benson (Stanford)

Dr. Wayne Groszko (NSCC)

Dr. Lukas Swan (DAL)

Dr. Heather MacLean (UoT)

How did we build the ACES model?

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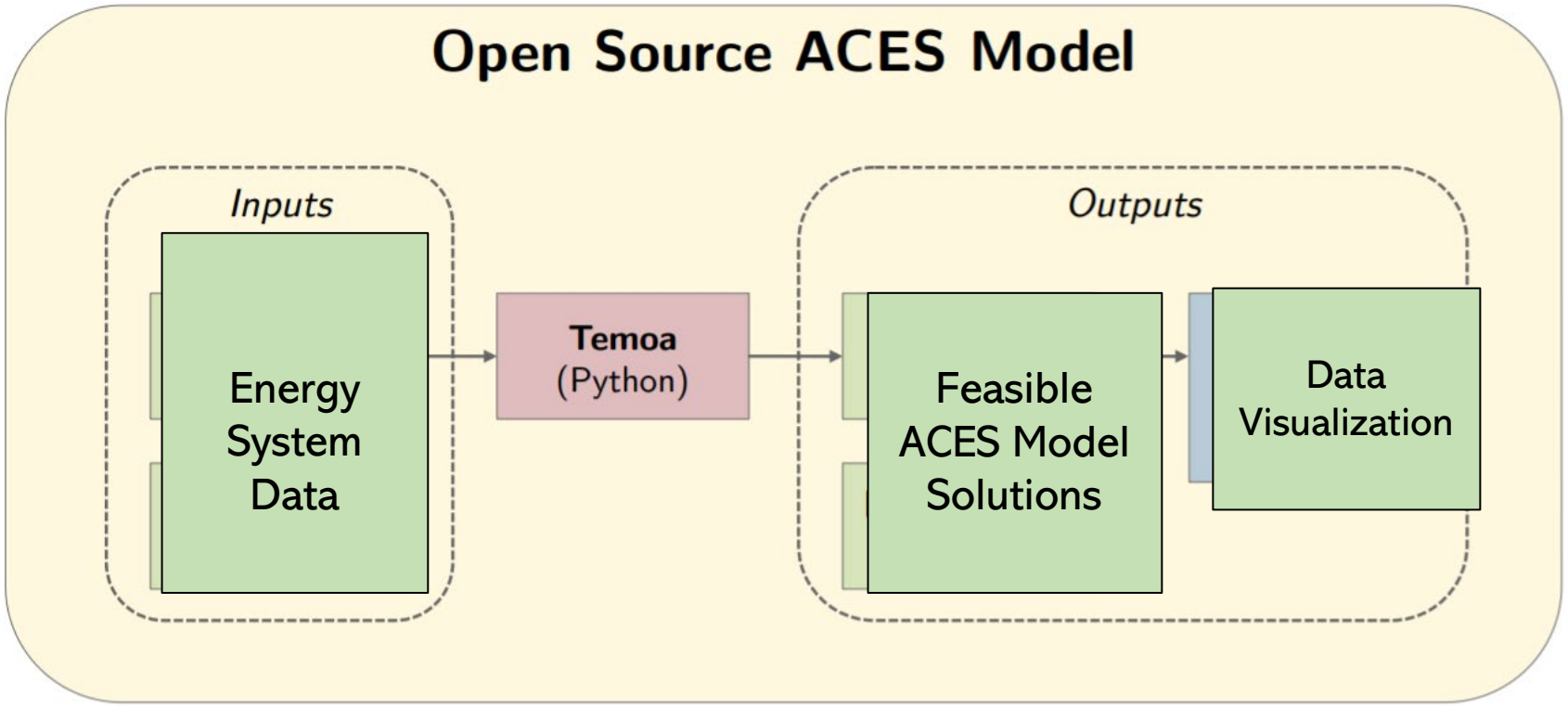
ACES Model Structure

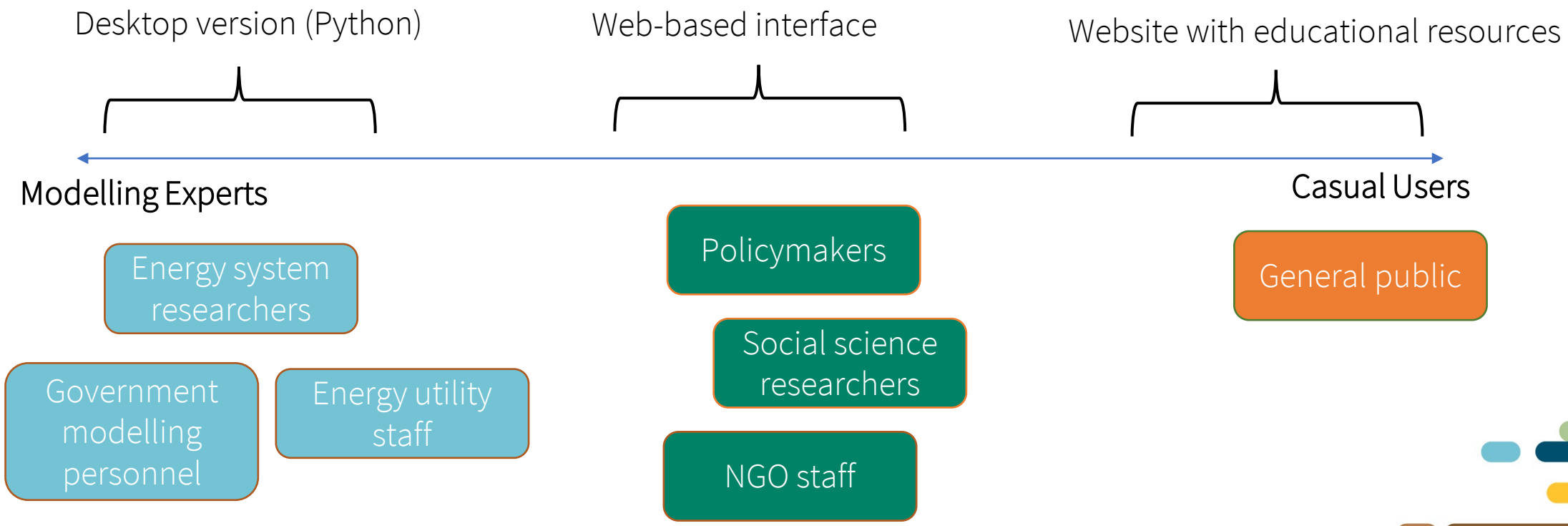


Sutubra Research, 2021

ACES uses Temoa as its model architecture.

- Developed at NC State by Dr. Joe DeCarolis
- Temoa is the basis for the well-supported Open Energy Outlook initiative in the United States.

Options for using the ACES model



Model Results: Sample Scenarios

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‘Baseline’

- Federal coal phaseout by 2030.
- No carbon tax
- No CO_2e emission limits

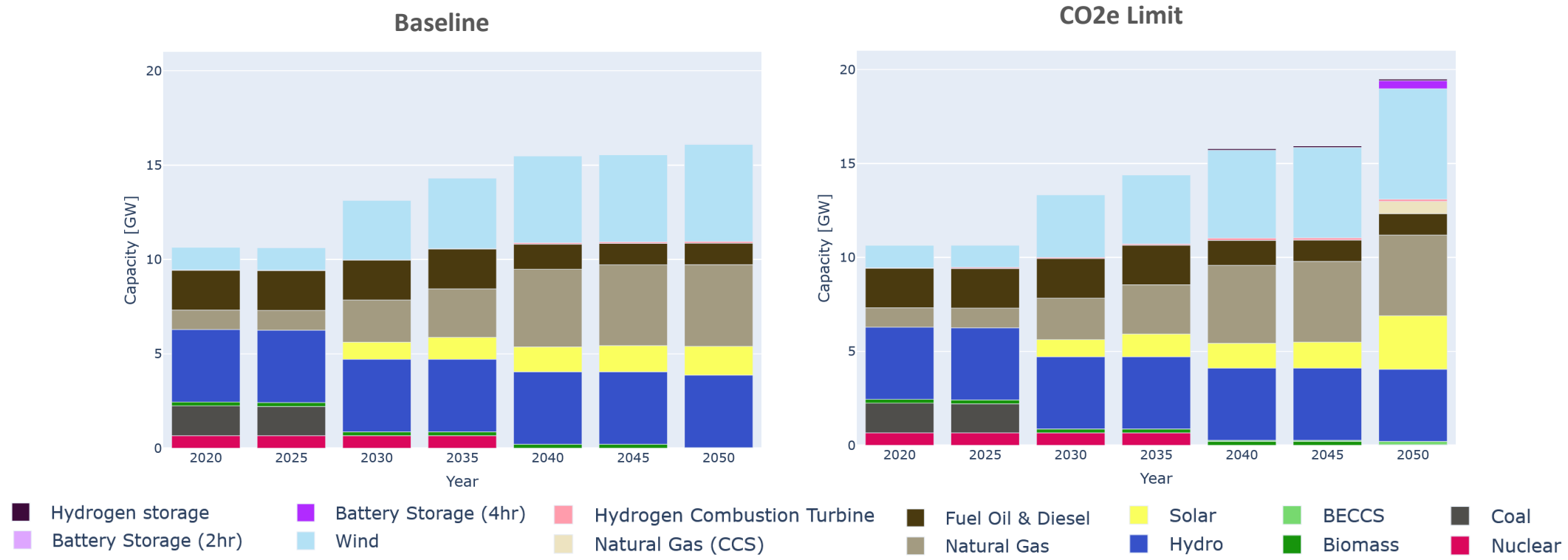
‘CO2e Limit’

- Federal coal phaseout by 2030.
- No carbon tax
- Announced provincial CO_2e emission limits imposed.
  - Zero CO_2e limit for all provinces except for NB (5 Mt CO_2e)

Please note that the scenarios above are simple example scenarios and their outputs are not designed to be analyzed further.

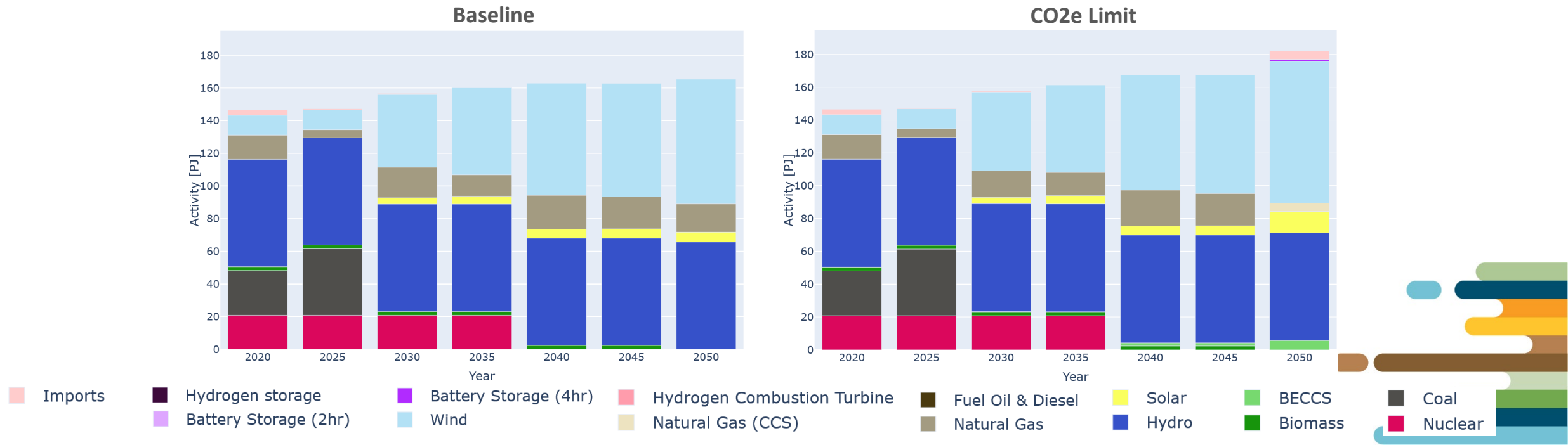
Sample Model Results: Electricity Sector Capacity

- Trends in ‘Baseline’ and ‘CO2e Limit’ are similar until 2050, at which point the most stringent emission limits are imposed.
- Additional wind and solar are installed to 1) replace fossil-based electricity generation and 2) provide the necessary resources to electrify additional end-uses such as heavy-duty transportation.
- Battery storage is added to help balance the intermittent resources.



Sample Model Results: Electricity Sector Activity

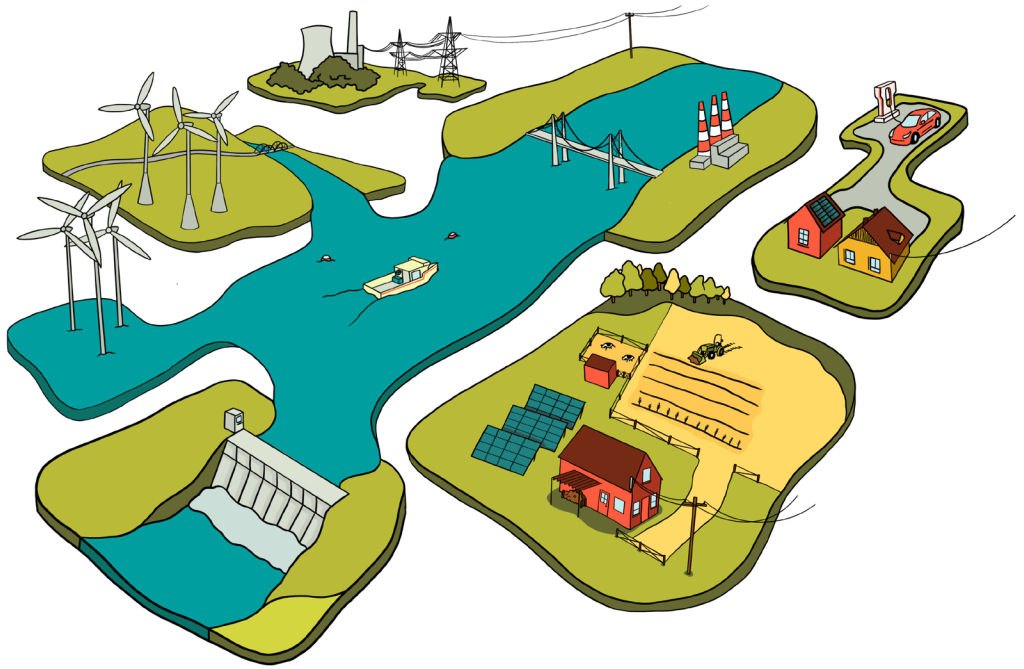
- Trends in ‘Baseline’ and ‘CO2e Limit’ are similar until 2045.
- There is slightly more electricity generation in the years 2040 and 2045 – a result of PEI’s net-zero legislation.
- There is a large increase in electricity generation in 2050 – a response to tight emission limits.
- Several resources are used to meet the increased demand – it is cost optimal to use diversified portfolio of clean technologies.
- The emission targets do little to influence the electricity system until 2050.



Exploring applications of the ACES model for PEI

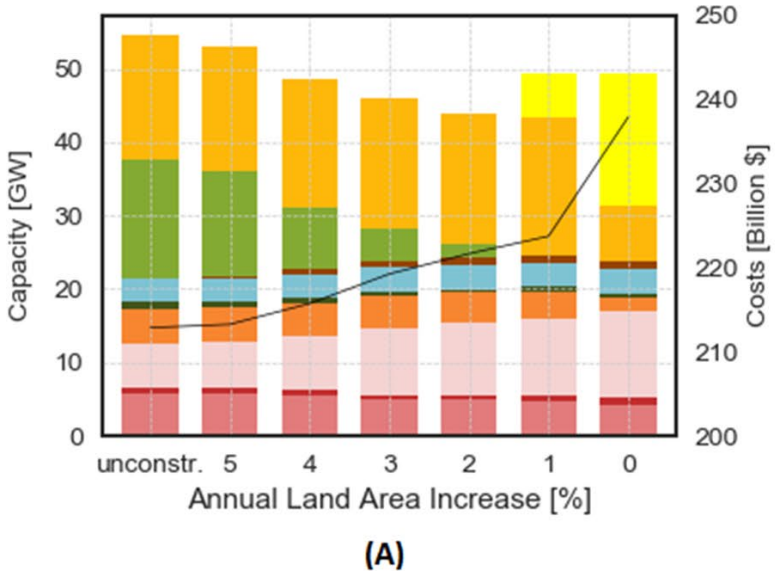
Land Use

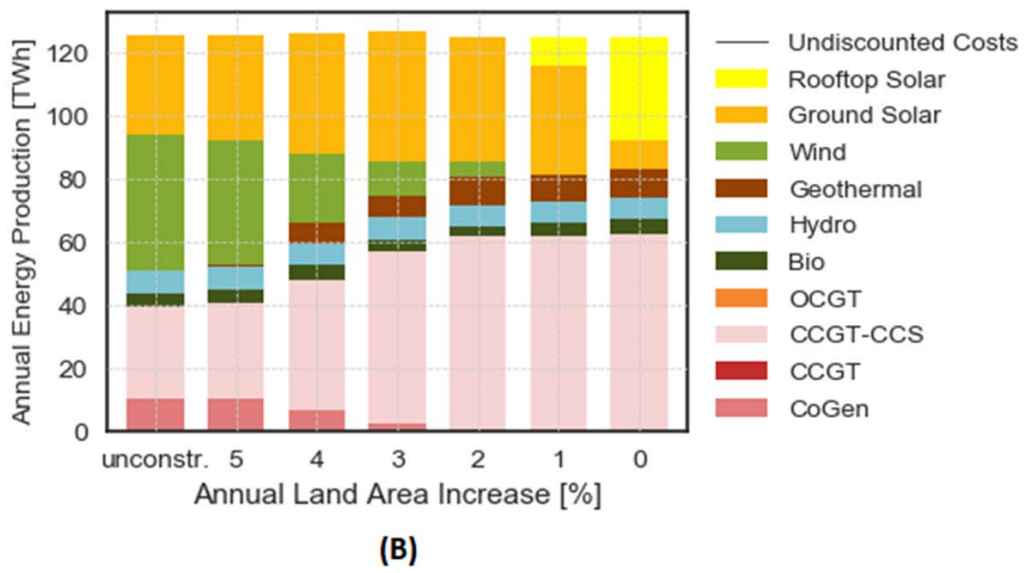
- Renewable energy requires more land per unit of energy generated than fossil fuel-based resources.
- Buildout of renewable energy infrastructure will need to be considered in the context of other land uses in PEI.
- Modelling opportunity: Analyze the land use impacts of meeting provincial climate change targets and other policy goals.



Exploring applications of the ACES model for PEI

Land Use





Palmer-Wilson et al., 2017 investigate the emission reduction pathways for the electricity supply system in Alberta while viewing land area as a constraining resource.

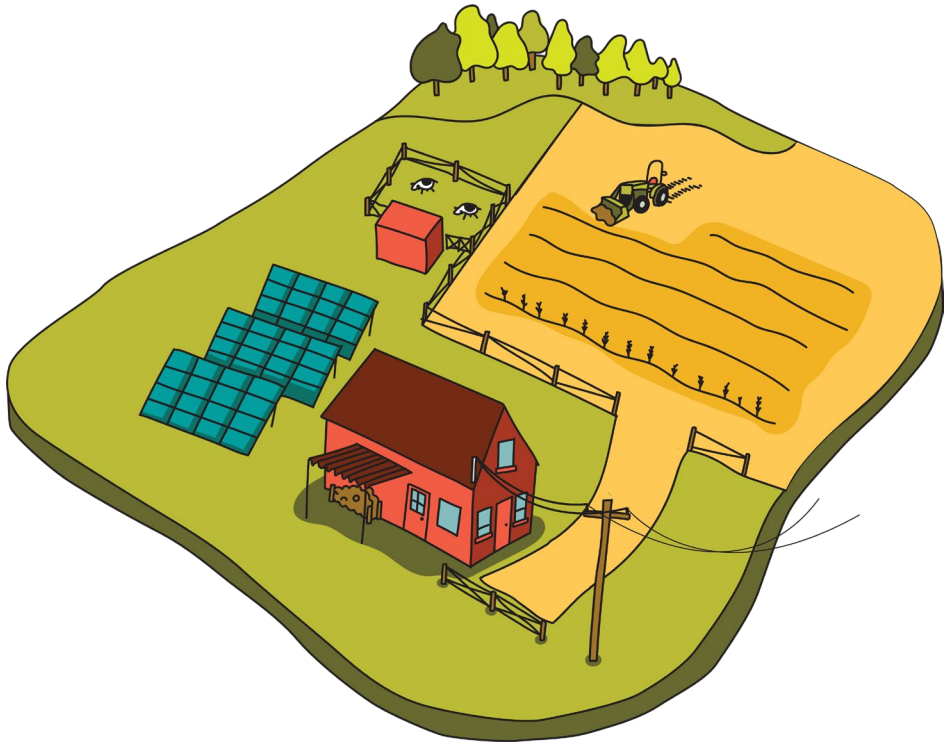
Stricter land use constraints lead to:

- Earlier expansion of spatially denser technologies,
- Buildout of more costly renewable technologies (e.g., geothermal),
- Decreased share of renewable energy and increased share of low-carbon energy (i.e. natural gas with CCS), and
- Increased total undiscounted system costs.

Exploring applications of the ACES model for PEI

Agriculture

- The agriculture sector is not typically included in energy system models because the processes that emit GHGs are largely distinct from those in other sectors.
- ACES Model includes the agriculture sector to ensure full accounting of emissions.
- Modelling opportunity: Analyze how the agriculture sector can contribute to meeting economy-wide net zero goals (technological abatement measures, nature-based solutions) and/or how other economic sectors can mitigate GHGs within the agriculture sector.



Exploring applications of the ACES model for PEI

Agriculture

Chiodi et al., 2016 integrate a model of the agriculture sector in Ireland with an energy system model.

- Aims: 1) to assess the emissions reduction potential via technological abatement options of the agriculture sector; 2) to gain insights into the dynamics between the energy and non-energy systems in response to GHG targets.

- Findings: 80-95% GHG emissions reduction by 2050 not feasible due to absence of technological abatement options for the agriculture sector.

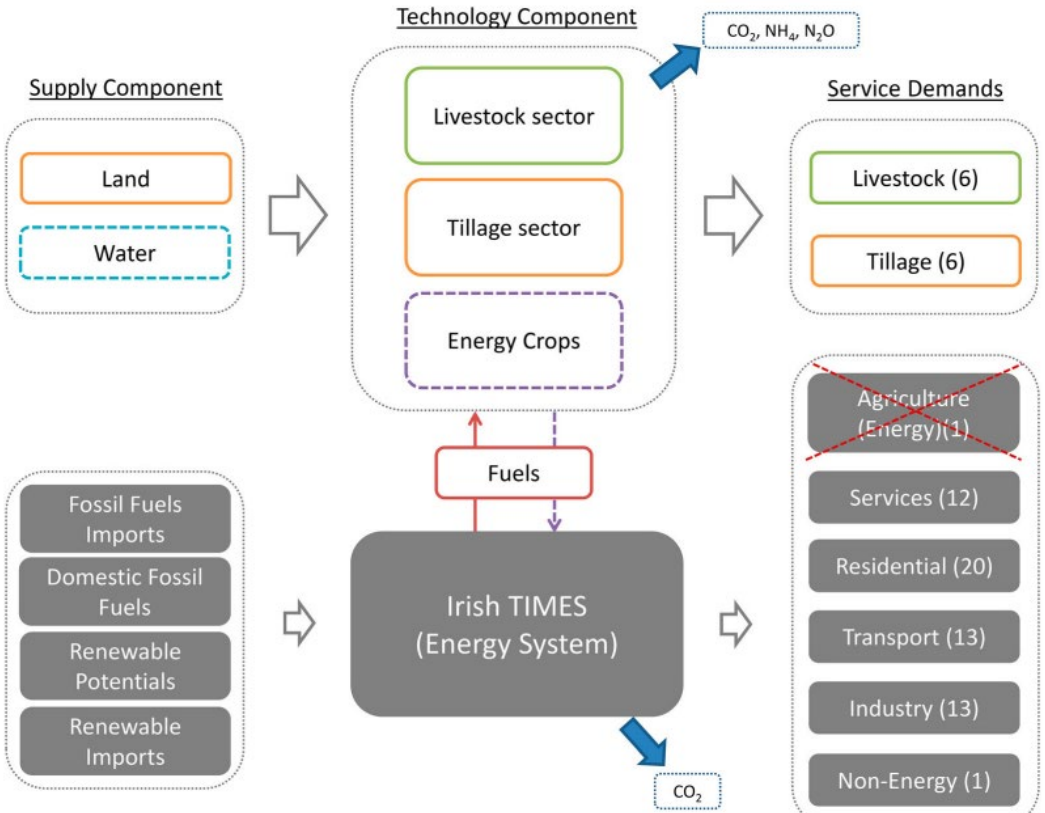


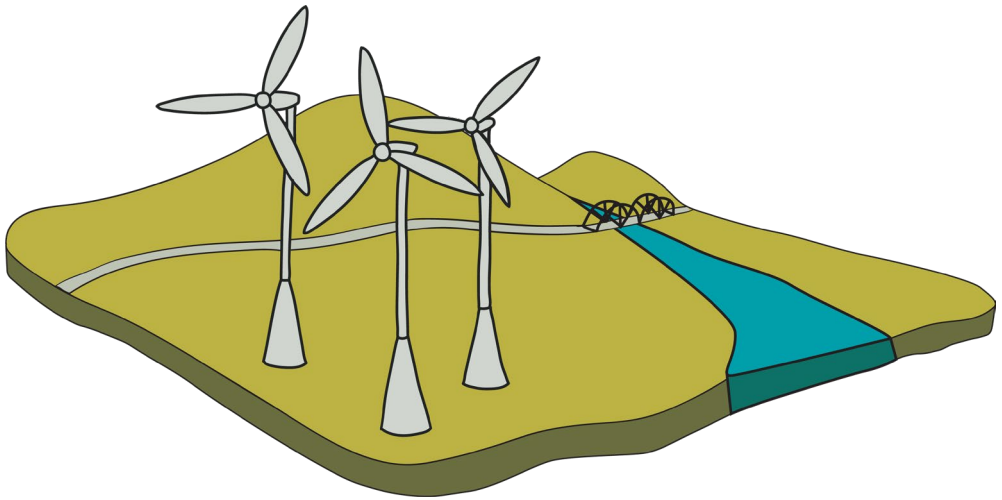
Figure 2 Flow chart of the Agri-TIMES module and interactions with Irish TIMES

Exploring applications of the ACES model for PEI

Climate Change

- Climate change impacts will have consequences for the energy system (i.e., increased cooling demand, decreased heating demand, changing wind speeds, reduced land mass for energy development).

- Modelling opportunity: Analyze how the optimal energy system solution for PEI may differ when future climate change impacts are accounted for.



Exploring applications of the ACES model for PEI

Climate Change

Seljom et al., 2011 integrate global climate models with Norway MARKAL model.

- Increased hydropower capacity results in lesser investment in offshore wind.
- Increased hydropower capacity and reduced electricity demand (due to reduced heating demand) lower Norwegian electricity production costs and increase electricity exports.
- Reduced electricity production costs lead to earlier adoption of EV and hydrogen vehicles.

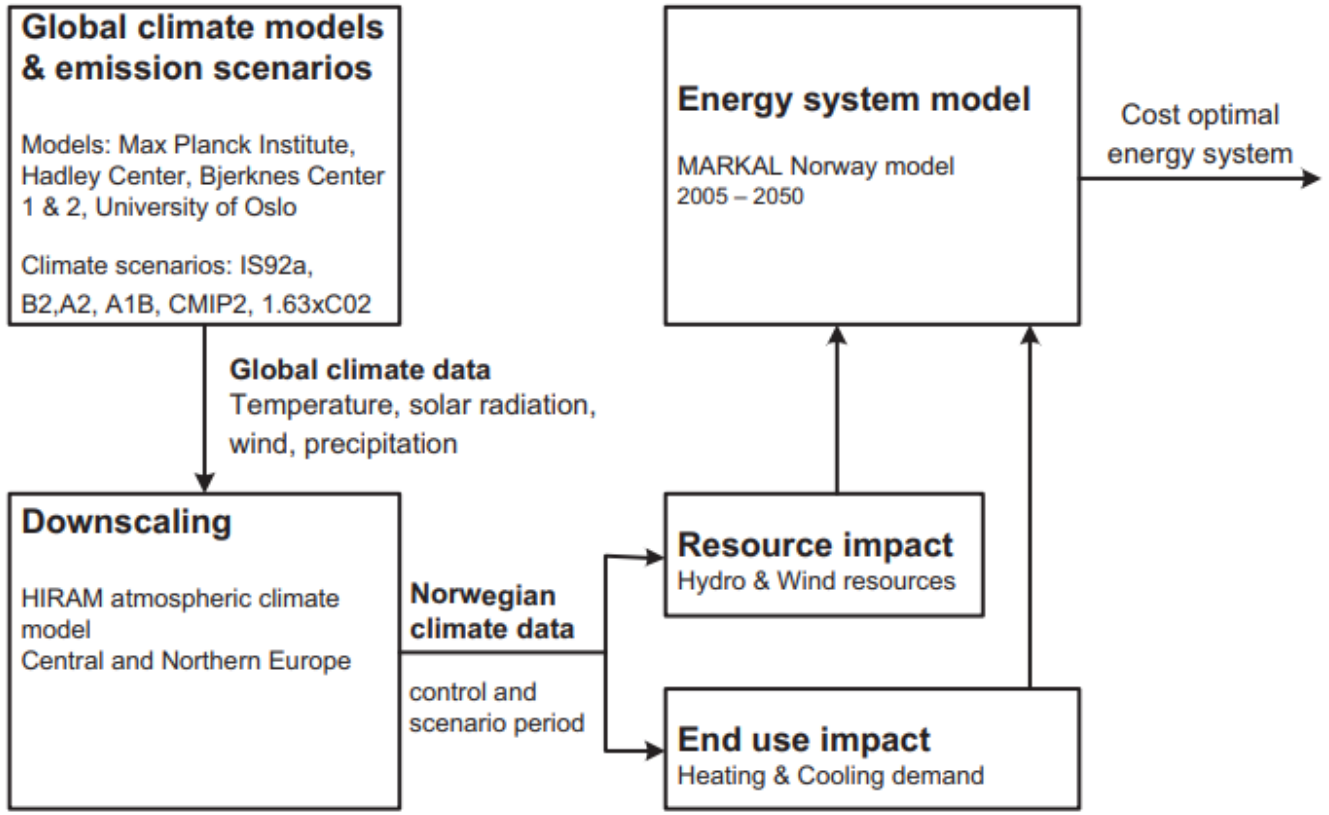
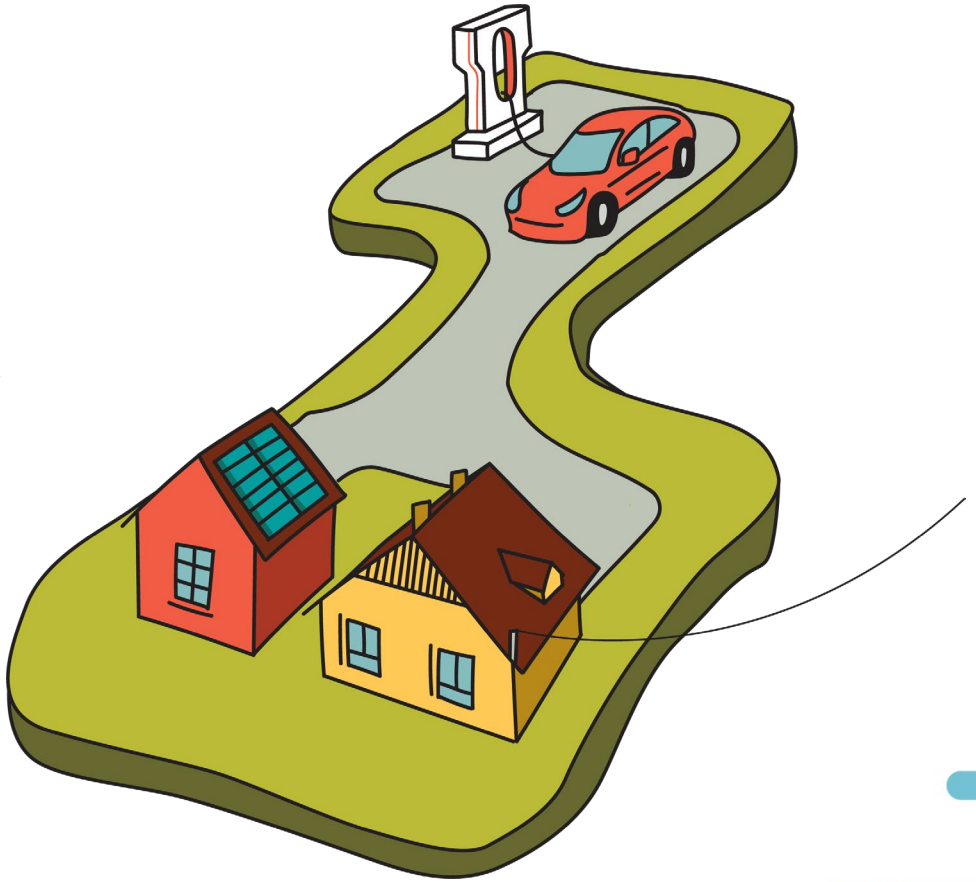


Fig. 1. Project methodology.

Exploring applications of the ACES model for PEI

Electric Vehicles

- When, how, and how much electrification of transportation occurs will profoundly impact the energy system.
- Cost of electricity production and associated emissions will impact when, how, and how much electrification of transportation occurs. Other constraints (i.e. infrastructure, consumer buy-in) will impact the speed of adoption and must be considered.
- Modelling opportunity: Analyze pathways to decarbonizing the transportation sector accounting for adoption constraints; characterize the impacts of electrifying transportation on other energy sectors.



Exploring applications of the ACES model for PEI

Electric Vehicles

Keller et al., 2019 explore impacts of vehicle charging profiles in Alberta.

- Charging vehicles at night increases CCGT, OCGT, and wind generation (no solar at night).
- If charging of vehicles occurs during day, solar PV generation nearly doubles. This also results in additional back up capacity to meet reserve margin constraints.
- Hydrogen for FCVs can be generated anytime during the day and stored. If heavy duty transportation demand is met by FCVs, more solar electricity generation occurs.

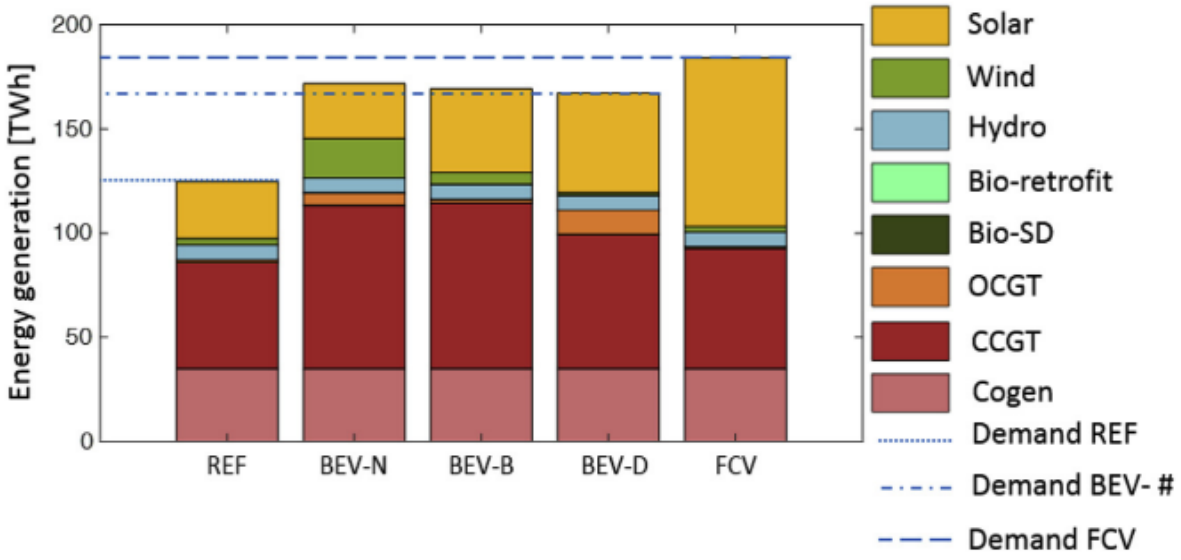


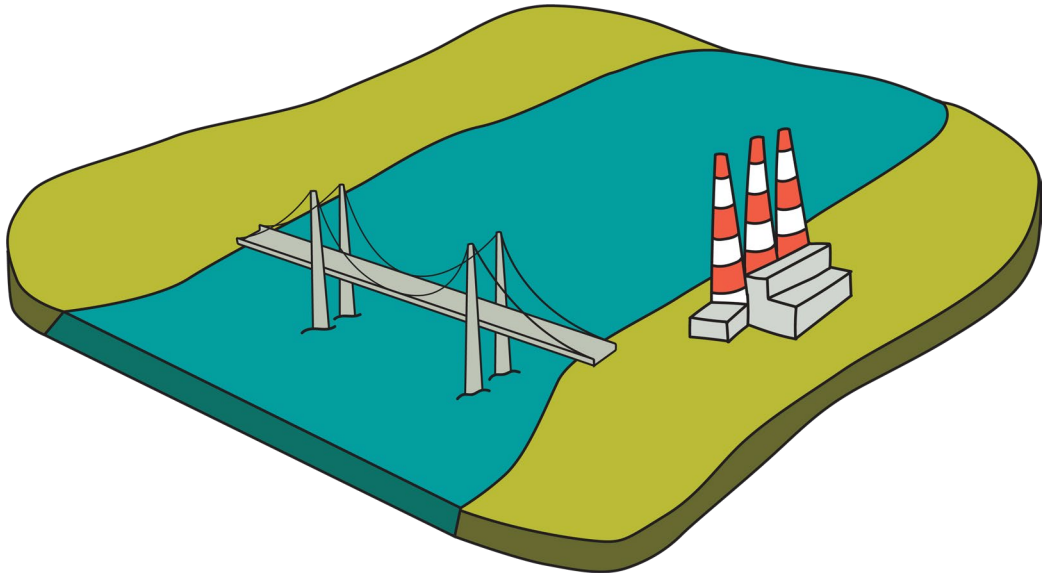
Fig. 7. Energy mix for the year 2060 for scenarios with imposed AFV market share and no carbon tax.

REF: No alternative fuel vehicle
BEV-N: Electric vehicles can only charge at night
BEV-B: Load for charging vehicles spread throughout the day
BEV-D: Vehicle can only charge during hours of daylight
FCV: Heavy duty transportation demand met by hydrogen fuel cells.

Exploring applications of the ACES model for PEI

Deep Reductions

- Provincial goal of achieving net zero emissions by 2040.
- Modelling opportunity: Identify critical gaps that could prevent PEI from meeting net zero emissions by 2040; understand the relative cost of different pathways for reaching net zero emissions.



Exploring applications of the ACES model for PEI

Deep Reductions

Oshiro et al., 2018 use the Asia-Pacific Integrated Model to identify challenges in reaching net zero in Japan.

- The cost to abate 1 tonne of CO_2 ranges from $520 (in 80% emissions reduction by 2050 scenario) to $2500 USD (in 100% emissions reduction by 2050 scenario).
- Phasing out nuclear power increases the cost of meeting climate change goals.
- Reaching net zero by 2050 requires large scale deployment of bioenergy with carbon capture (which is assumed to produce negative emissions).
- Energy efficiency (i.e., demand reduction) observed to be crucial for cost-effectively reducing emissions by 80 or 100%.

Discussion

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What are some other topics in addition to the ones discussed here that would be of interest and use to your team/department?

ⓘ Start presenting to display the poll results on this slide.

slido

If you could choose three of the topics discussed today to explore with the ACES model, what would they be?

ⓘ Start presenting to display the poll results on this slide.

Ways To Learn More

- You can contact us for more information/support on ACES such as :
    - Model training – *Desktop Model or Online Cloud Version*
    - Technical support
    - Educational resources
    - Model documentation

kmifflin@netzeroatlantic.ca

Questions

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