An Energy Transition Tool for Canada Energy Sectors toward Deep Decarbonisation Pathway Projects (DDPP)

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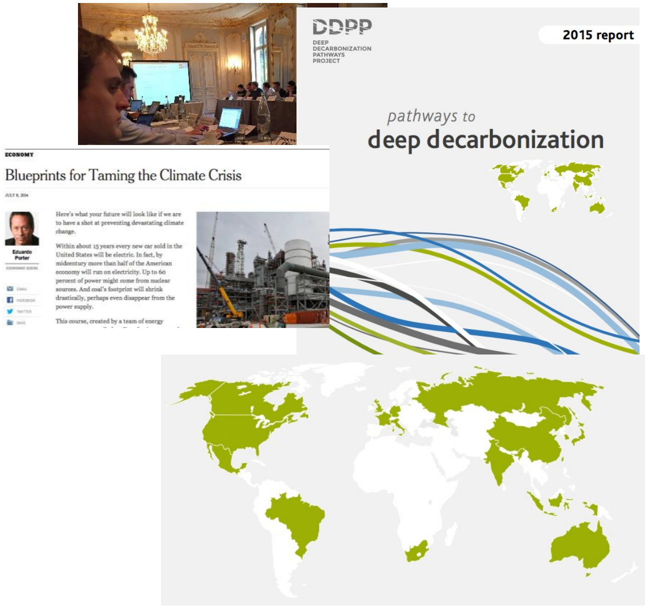
Introduction – Deep Decarbonization Pathways Project

- Deep Decarbonization Pathway Projects (**DDPPs**)
  - Global efforts trying to find out a "**pathway**" for every country to transition to **a free-carbon society** in the expansion planning.
- DDPPs in Canada
  - Reinforce Current Trends:
    - **Pathway 1**: Decarbonize electrification.
    - **Pathway 2**: Improve energy productivity.
    - **Pathway 3** : Reduce non-energy emissions.
  - Pushing Towards Next Generation Technologies
    - **Pathway 4** : Move to zero emission transport fuels
    - **Pathway 5**: Decarbonize industrial processes.
  - Pathways of Structural Economic Change (**Pathway 6**)



Introduction – Energy Modeling

Behind all energy models, there are both **general purposes** and **specific purposes**.

The <u>general purposes</u> of the energy model are reflected by how the model addresses the future. These general purposes for three main energy modelling are provided as

- ***<u>Forecasting Models</u>***

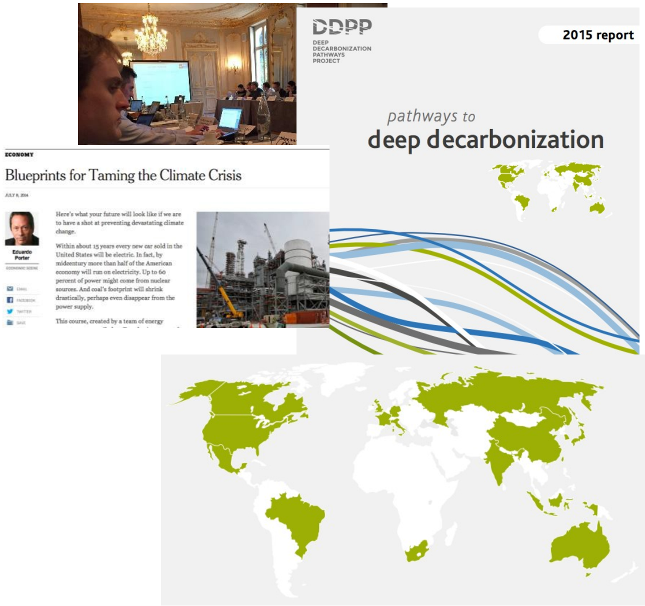
To anticipate the future challenges which may be faced with an energy system, by extrapolating historical trends to analyze the short-term impact of certain actions, such as economic behavior and general growth patterns.

- ***<u>Backcasting Models</u>***

To construct visions of various desired future outcomes for an energy system based on a backward approach, identifying policies and programs that will connect that specified future to the present.

- ***<u>Scenario Analysis Models</u>***

To explore the future pathways for an energy system based on a comparison between a limited number of desired future scenarios with a reference scenario (i.e., a baseline).



Introduction – Energy Modeling (cont'd)

The <u>specific purposes</u> reflect the detailed aspects addressed by an energy model, such as patterns in the way energy is generated and consumed in different sectors

<u>Demand-Side Models :</u>
These consist of a broad range of methodologies which focus on determining the final energy consumption in the entire economy or a particular sector, such as the buildings (residential, industrial, and commercial), industrial energy use, and the transportation system. These models rely on bottom-up simulation techniques or top-down techniques.

<u>Supply-Side Models</u>
Mostly focused on energy supply technologies, with a particular focus on renewable energy systems, fossil-based power plants, oil and gas industries, etc.

<u>Integrated Models</u>
These models integrate supply-side models and demand-side models.

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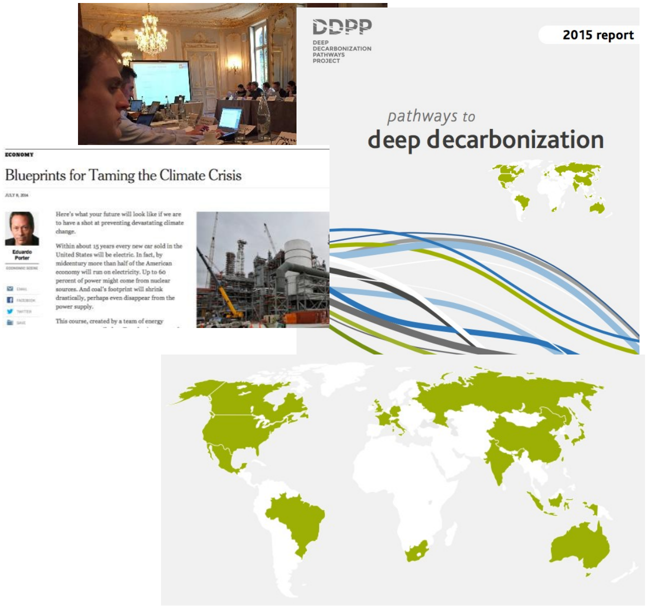
Motivations

- An open source energy transition tool should be developed for Industrial/academic purposes.

- The proposed energy transition model should be capable of considering all sectors of energy. Considering only one sector of energy is not efficient any more.

- A detailed representation **electricity sector** should be considered in energy modelling.



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EnergyPATHWAY characteristics

- EnergyPATHWAYS is a bottom-up energy sector model with stock-level accounting of all consuming, producing, delivering, and converting energy infrastructure

- Latest iteration has been released under an MIT License, and can be used to conduct analysis in a variety of geographic locations at different jurisdictional levels – countries, states and provinces, cities, etc. (https://github.com/energypathways)

- Initial platform development by E3 with support from a number of clients; continued development and maintenance by Evolved Energy Research and the Deep Decarbonization Pathways Project (DDPP)

- 3x drop in energy use per unit GDP
- 30x reduction in emissions intensity of electricity
- 2.5x increase in the share of energy from electricity or electrically derived fuels

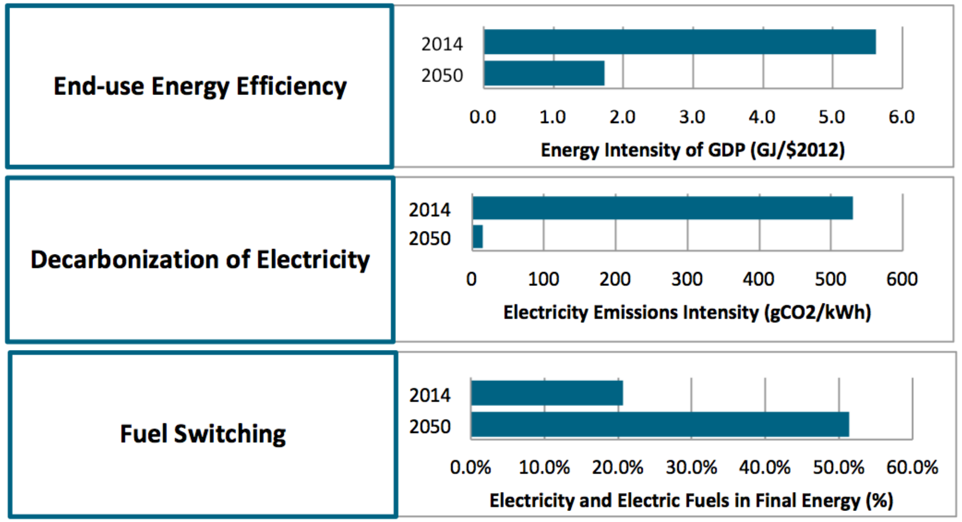

Fig. 1. EnergyPATHWAYS pillars

CanESS vs energyPATHWAY

Table 5: COMPARISON BETWEEN CANESS AND ENERGYPATHWAY

Section	CanESS	energyPATHWAY
Demand Drivers	Demographics and Macro economy	Population and vehicle miles traveled per capita
Demand Sectors	Residential Commercial Industrial Transportation	Residential Commercial Productive Transportation
Supply Sector	Electricity Refined Petroleum Biofuels Other Transportation fuel Hydrogen Liquid Natural Gas Steam Decentralized Energy Primary source	blend Conversion Delivery Primary source storage
Hourly dispatch	distributed merit order method	Optimization algorithms for electric fuel production (hydrogen electrolysis and power-to-gas); short-duration energy storage, long-duration energy storage; flexible end-use loads
Economic method	Bottom-up approach	Bottom-up approach

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- **Future Steps**
- **Questions**

SWITCH characteristics

- Objective function: The objective function of power system planning model in SWITCH includes:

  - capital costs of existing and new power plants and storage projects
  - fixed operations and maintenance (O&M) costs incurred by all active power plants and storage projects
  - variable costs incurred by each plant, including variable O&M costs, fuel costs to produce electricity and provide spinning reserves, and any carbon costs of greenhouse gas emissions (carbon costs are not included)
  - capital costs of new and existing transmission lines and distribution infrastructure
  - annual O&M costs of new and existing transmission lines and distribution infrastructure

- The model includes a main sets of constraints as:

  - 1. those that ensure that demand is satisfied
  - 2. those that maintain reserves for reliability purposes
  - 3. those that enforce public policy constraints (such as a cap on carbon emissions)
  - 4. those that enforce resource constraints for generation projects
  - 5. those that govern the installation of additional transmission and distribution capacity
  - 6. those that model the operational characteristics of generation and storage projects
  - 7. those that govern the dispatch of demand response

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Integrating energyPATHWAY and SWITCH

energyPATHWAYS:

-A model for pathway planning

-Considers all energy sectors

-Compute service demand for transportation

- A simple model of electricity sector

- **Optimal plans for expansion and operation of power systems**
- **Hourly electricity dispatch considering existing uncertainties**

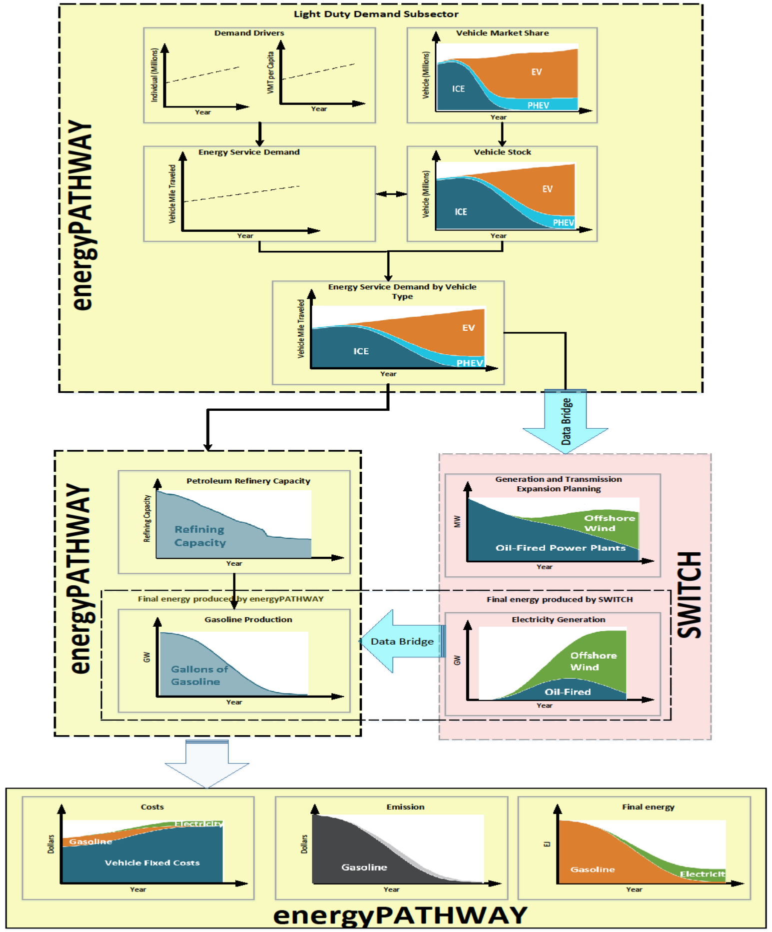

Fig. 2. Architecture of proposed tool

Integrating energyPATHWAY and SWITCH (cont'd)

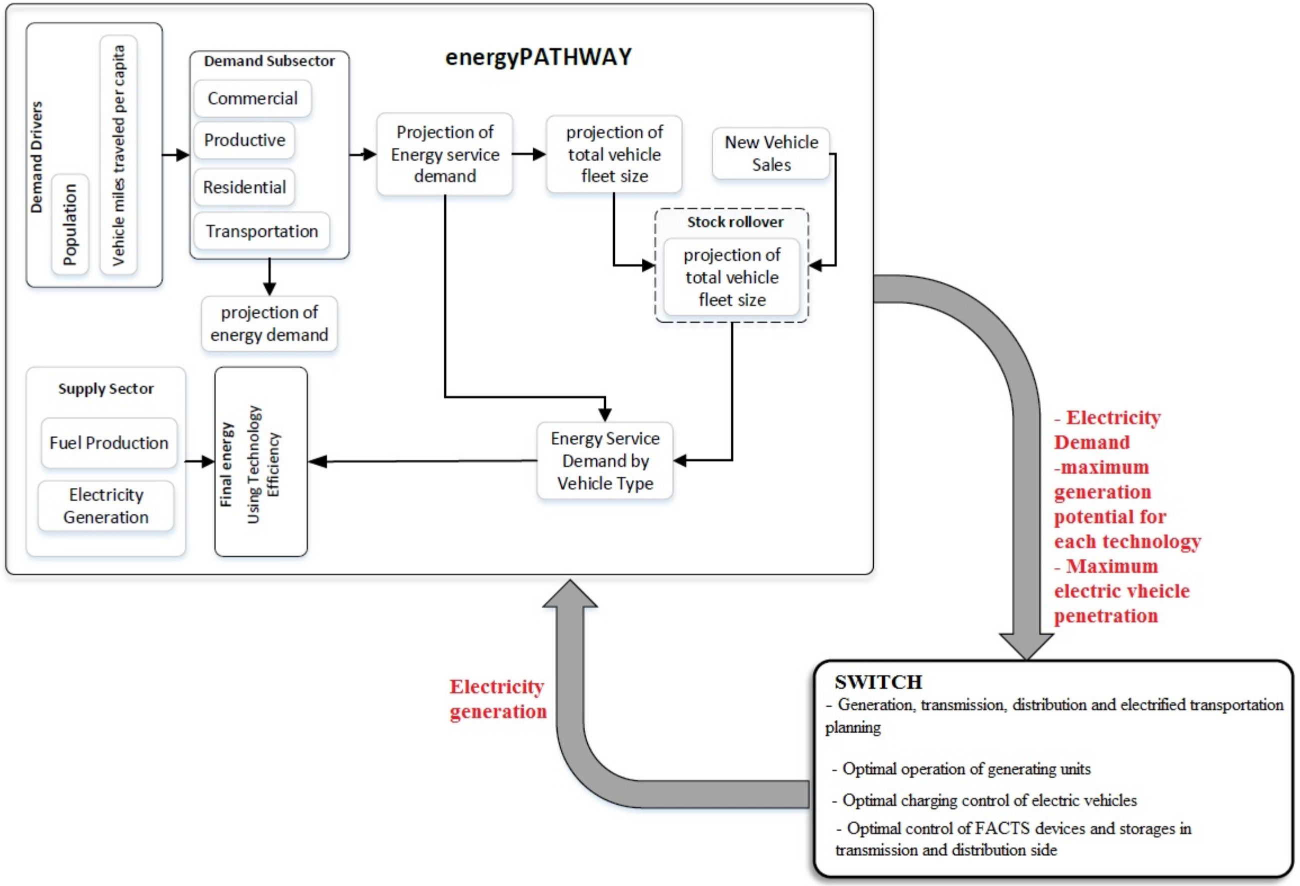

Fig. 3. The data that is shared between two models

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Future Steps

- Developing a data base for Quebec energy sector which can be extended to other provinces.
- Running SWITCH and energyPATHWAYS for benchmark database.
- Constructing the data bridge between two models (energyPATHWAYS- SWITCH).
- Investigating the possibility of considering a detailed representation of other energy sectors like transportation sector, gas sector and etc.

Our team

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