The Canadian Energy Systems Simulator (CanESS)

1. Overview

The Canadian Energy Systems Simulator (CanESS) is a powerful tool that rapidly assesses a wide range of energy systems scenarios from the present to 2100 allowing for iterative exploration of possible future outcomes. Since 2004, CanESS has been an established energy model providing insights to a variety of studies at the federal and provincial levels.

whatIf? Technologies Inc. has applied its vast expertise in model building methodology to develop CanESS and continues to expand the already extensive model logic and data as new information sources become available. CanESS resides on the whatIf? modelling platform that has been used for over twenty years to build transparent, easy to use models that allow users to create and compare multiple scenarios.

A high level overview of CanESS is shown in Figure 1. In CanESS, population via households and the size of the economy drive energy end-use. Energy end-use, in turn, creates demand for fuel. Fuel production requires energy feedstocks (e.g. oil, coal, and natural gas). CanESS calculates greenhouse gas and criteria air contaminant emissions at point of source in each of these segments.

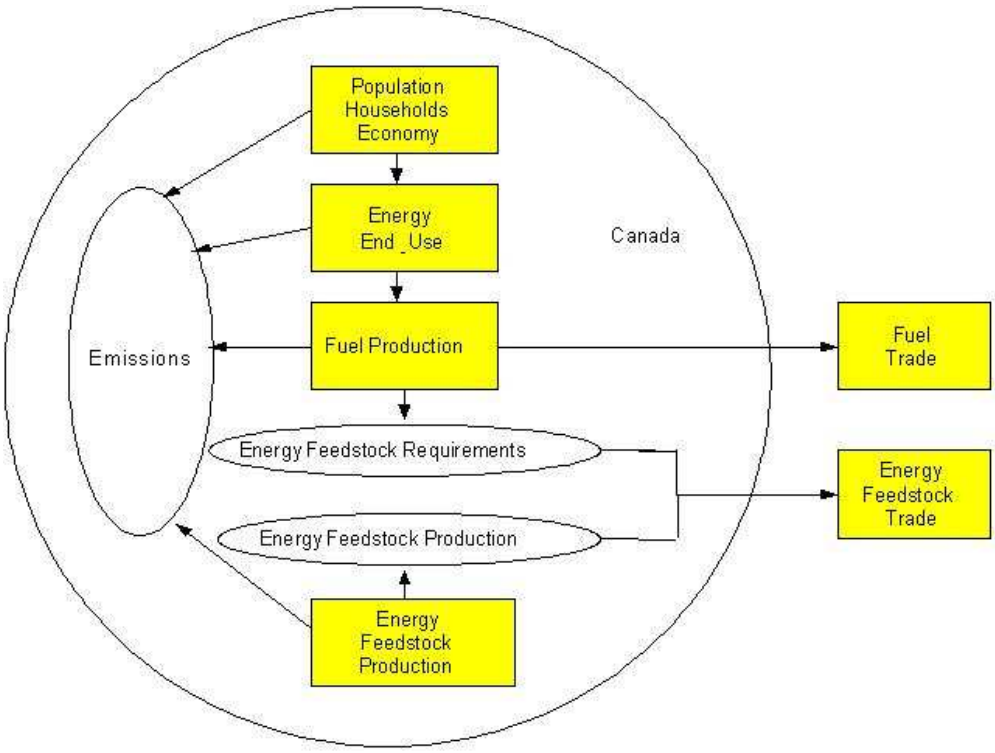

Figure 1 CanESS High Level View

The calculations represented in Figure 1 are performed for each Canadian province. Furthermore, the fuel trade and energy feedstock trade are modelled among provinces and internationally. This provicial disaggregation modularizes CanESS so that it can be easily run for a specific province.

Figure 2 shows a graphical representation of the fuel and feedstock trade in CanESS. CanESS tracks how much fuel and feedstock each province requires and produces. CanESS then allocates the surplus fuel and feedstock available in other provinces to satisfy requirements across all provinces. Outstanding requirements and unused surpluses are handled by international trade. In this way, CanESS calculates the full provincial and external trade disposition for each energy commodity.

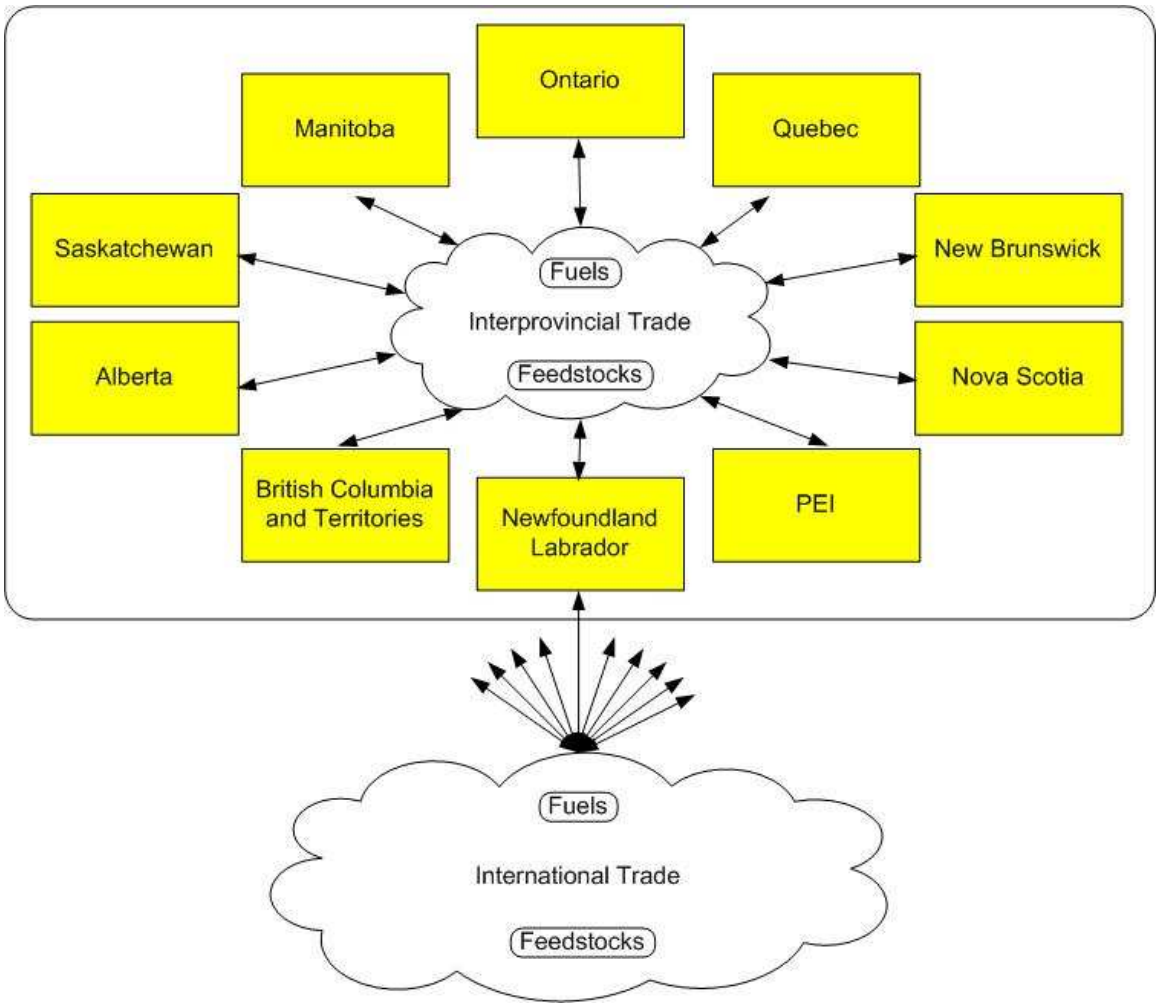

Figure 2 CanESS Fuel and Feedstock Trade

CanESS is also rich in compositional detail. For example, population is disaggregated by age and sex; passenger trips are disaggregated by type, length of trip, and mode; road vehicles are disaggregated by size of vehicle, age, engine type. It is also rich in the representation of pathways for producing fuels and feedstocks. The richness of the structure of CanESS makes it possible to simulate many alternative configurations of the energy system that are coherent with alternative evolutions of the demographic and economic context.

2. Selected CanESS Projects and Studies

CanESS has been used in the following projects and studies:

Natural Gas Possibilities for Canada to 2100 – Alberta Department of Energy - 2009
CanESS was used to run a range of scenarios based on possible changes in future trends in the production of natural gas from both conventional and non-conventional sources to explore impacts on Alberta and Canada.

Biomass Energy Possibilities for Alberta to 2100 – Alberta Energy Research Institute - 2009
CanESS was used to assess the long term impact of using biomass as an energy resource in Alberta. The project involved representing biomass available from forestry and agricultural sources in Alberta and the processes required to transform the biomass into energy currencies.

Residential Sector Energy Update – Natural Resources Canada - 2009
Natural Resources Canada Office of Energy Efficiency can use the residential section of CanESS to look at the energy and emissions implications of potential policies as well as to evaluate the impact of current policies. They are knowledgeable users who now have an in-house model that they can use to create various scenarios. They can create a scenario with multiple policies at once which takes into consideration the integrated effects and/or create scenarios for each policy independently. All scenario impacts can be easily compared.

For example, they can look at the future impact of a currently available program comparing the energy and emissions for three scenarios: continuing with the same trend of the policy uptake as in history, no policy uptake, and the desired or expected policy uptake. They also can do the same analysis retroactively over historic years to analyze the past effectiveness of the program.

Reshaping Canada's Energy Systems to Meet Proposed GHG Targets – Energy Futures Network - 2008
CanESS was used in a workshop setting to explore the impact of carbon capture and storage, green grid technologies, and fuel substitution to the reduction of greenhouse gas emissions.

The Potential Impact of an Increased Use of Synthetic Crude Oil and the Dieselisation of the Light-Duty Vehicle Fleet in Canada – National Research Council - 2006
CanESS was used to conduct a case study based on scenarios representing the projected rise in production of bitumen and synthetic crude oil, along with the rise in fuel consumption for road transportation due to growth in population and the economy. The simulation helped to quantify the potential implications for greenhouse gas emissions and natural gas use and to identify those areas where concerted effort will be

needed to mitigate these impacts. This project led to the elaboration of a process-based model of alternative oil sands production technologies in CanESS.

The Potential Impact of Biodiesel Under a Scenario of Increased Penetration of Advanced Diesel Engines in Light Duty Vehicles - National Research Council – 2005
CanESS was used to simulate the impact of the introduction of advanced diesel engines into 30% of the light duty vehicle stock, and the combined effect of the use of biodiesel blended fuel in the road transportation sector.

The Role of Systems Modelling for Sustainable Development Policy Analysis: the Case of Bio-Ethanol – Natural Resource Council - 2004
This study countered the results of life cycle assessments that had lead to the establishment of bio-fuel targets and production subsidies and raised the issue of the potential conflict between the use of crops for feed and fuel.

3. CanESS Modelling Approach

CanESS applies a physical economy approach to provide coherent scenarios that explore the long-term impacts of ongoing transitions in the energy system. CanESS is an integrated model in that it provides detailed representations of both the energy supply and demand within the Canadian energy systems from the bottom up. CanESS aggregates energy provided from individual sources (e.g. electricity generation and hydrocarbon fuel production) throughout Canada to model energy supply. For energy demand, CanESS aggregates energy consumed by the transportation, residential, commercial and industrial end use sectors. Data for all energy supply pathways and energy end-use sectors are allocated to provinces to allow CanESS to be run at the provincial or federal level.

An overview of the computational structure of CanESS is shown in Figure 3.

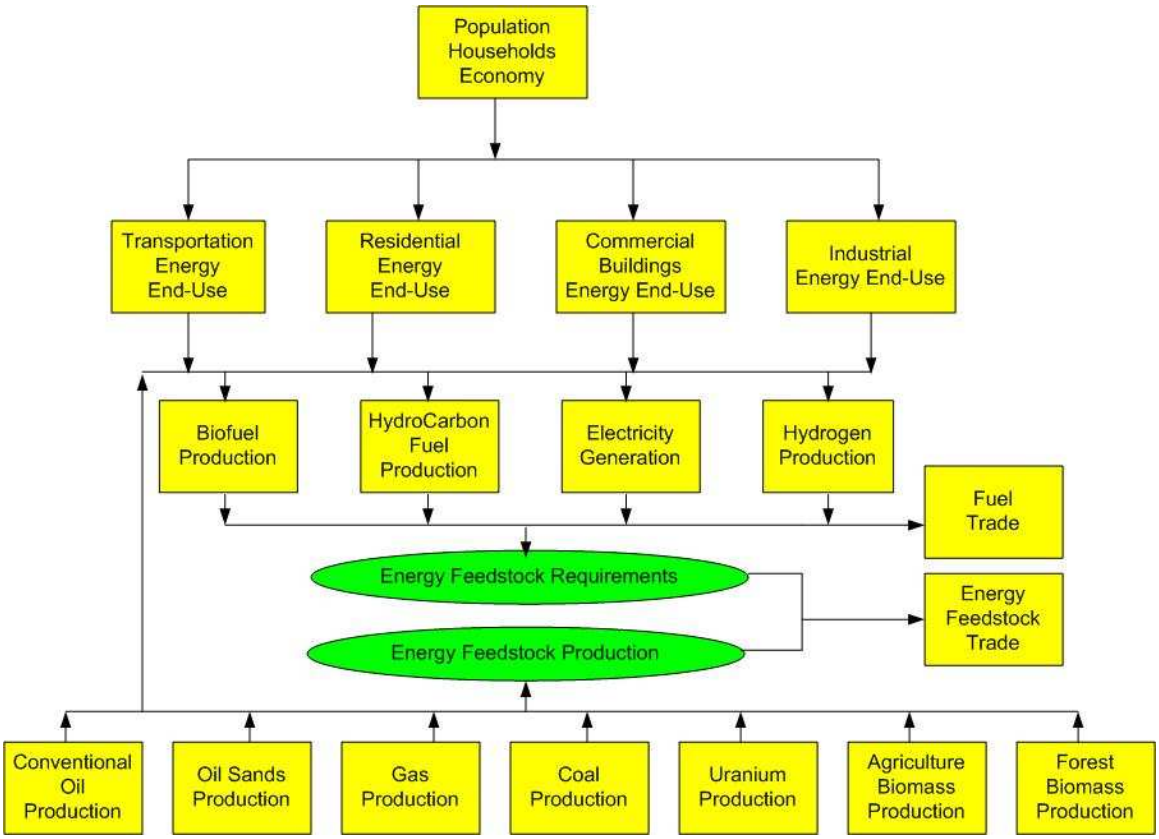

Figure 3 CanESS Computational Structure

3.1. Energy Demand

The context for the energy system is set in terms of population, households and gross domestic product to the time horizon of the simulation. The user can set values for migration flows, fertility and mortality parameters, and per capita GDP.

Within each end-use sector, CanESS tracks energy-consuming stocks (e.g. vehicles, dwellings, and appliances) over time and associates conversion efficiencies with the vintages of the stocks. The model user can set the efficiencies of future vintages and the rates at which new or alternative technologies penetrate into the stocks. The end-use models then calculate the energy currencies – hydrocarbon fuels, electricity, hydrogen, and biofuels - required to deliver services at a level commensurate with the stocks.

Figure 4 shows the structure of the energy end-use model for the transportation sector.

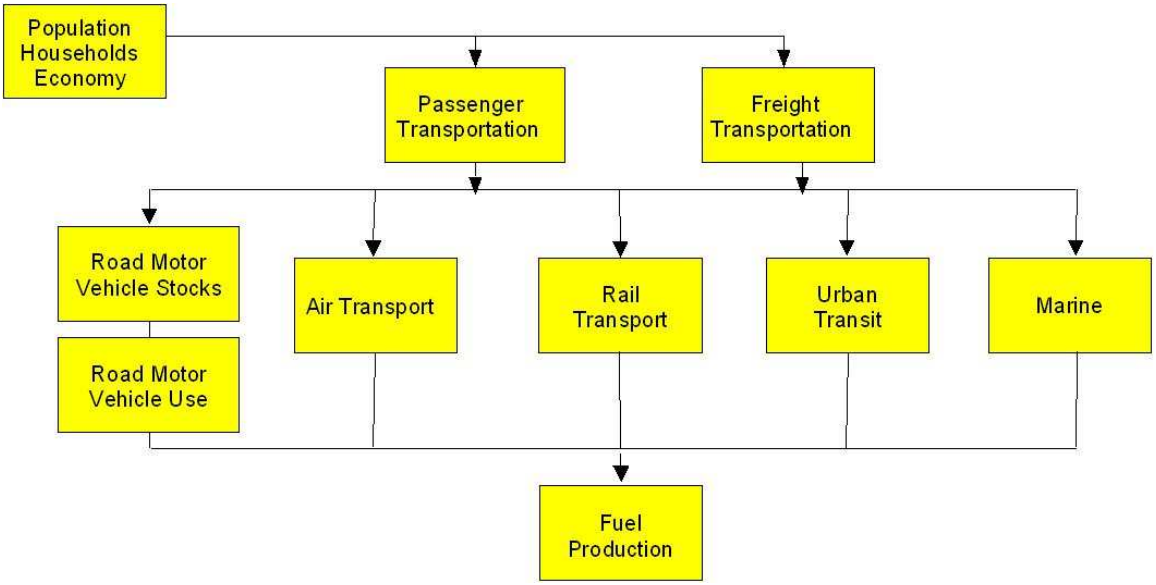

Figure 4 CanESS – Transportation Energy End-Use

Figure 5 shows the structure of the energy end-use model for the residential sector.

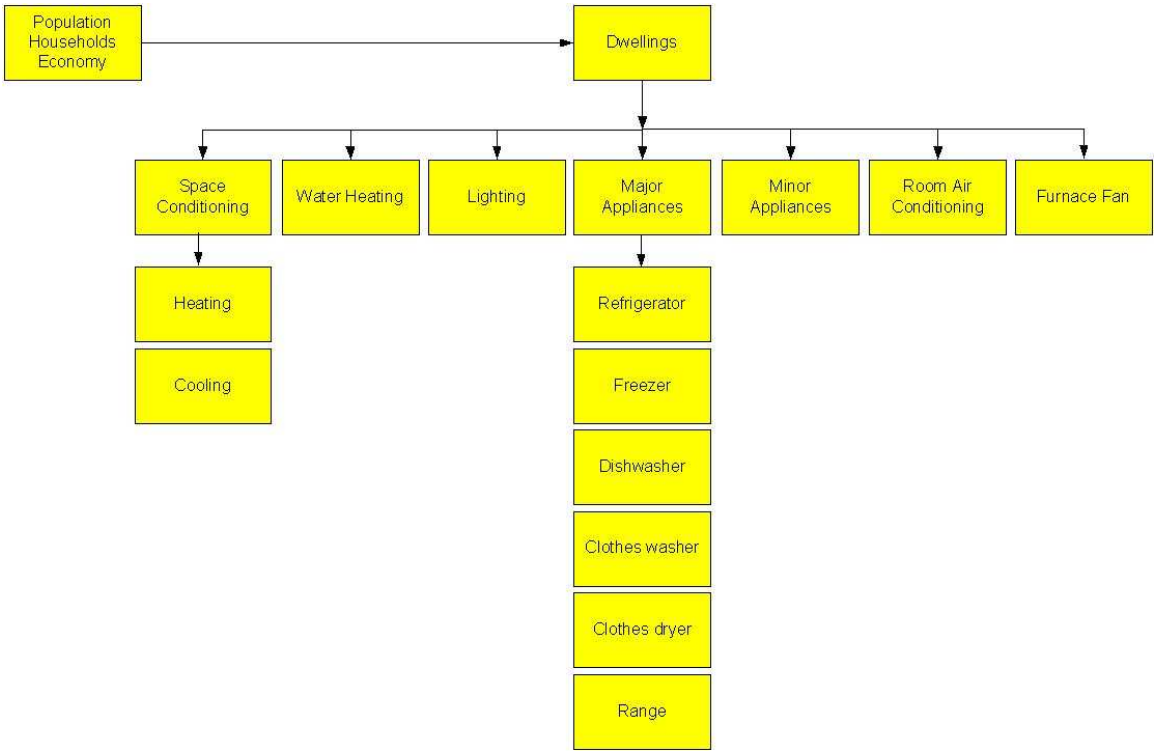

Figure 5 CanESS - Residential Energy End-Use

Figure 6 shows the structure of the energy end-use model for the commercial sector.

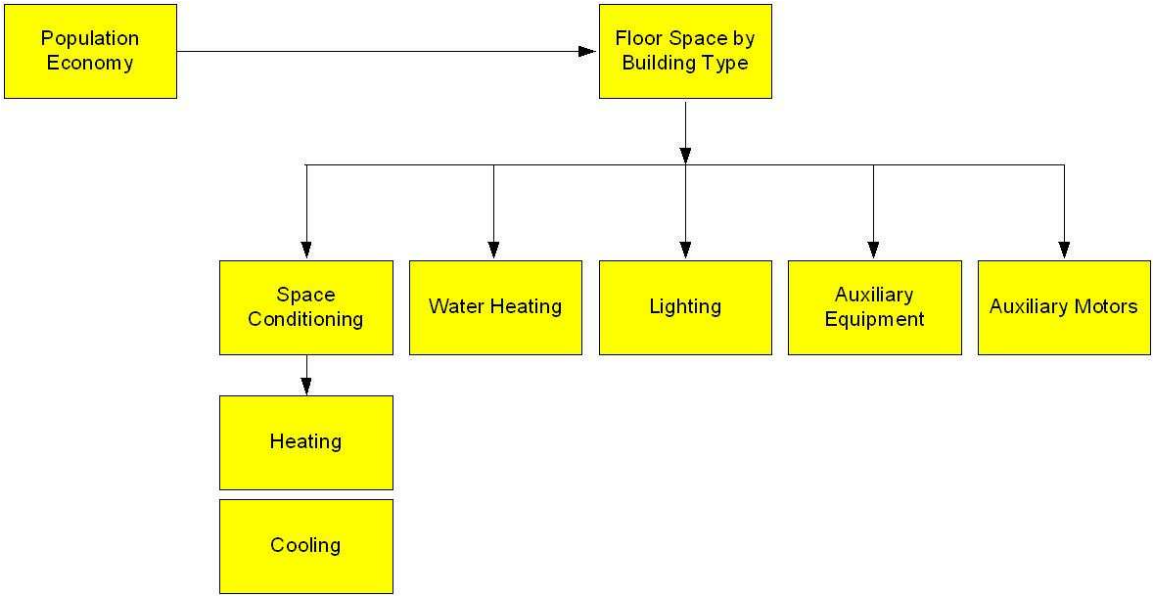

Figure 6 CanESS - Commercial Energy End-Use

3.2. Energy Supply

The fuel production model provides the energy currencies used by the end-use sectors. Differences between fuel consumed and fuel produced are balanced through international and interprovincial trade. Energy sources themselves use other energy sources (e.g. crude oil refining requires electricity). The energy currency requirements from the energy sources and from the end-use sectors are fed to process models that calculate energy feedstocks used to produce the energy currencies. Figure 7 shows the structure of the fuel production model.

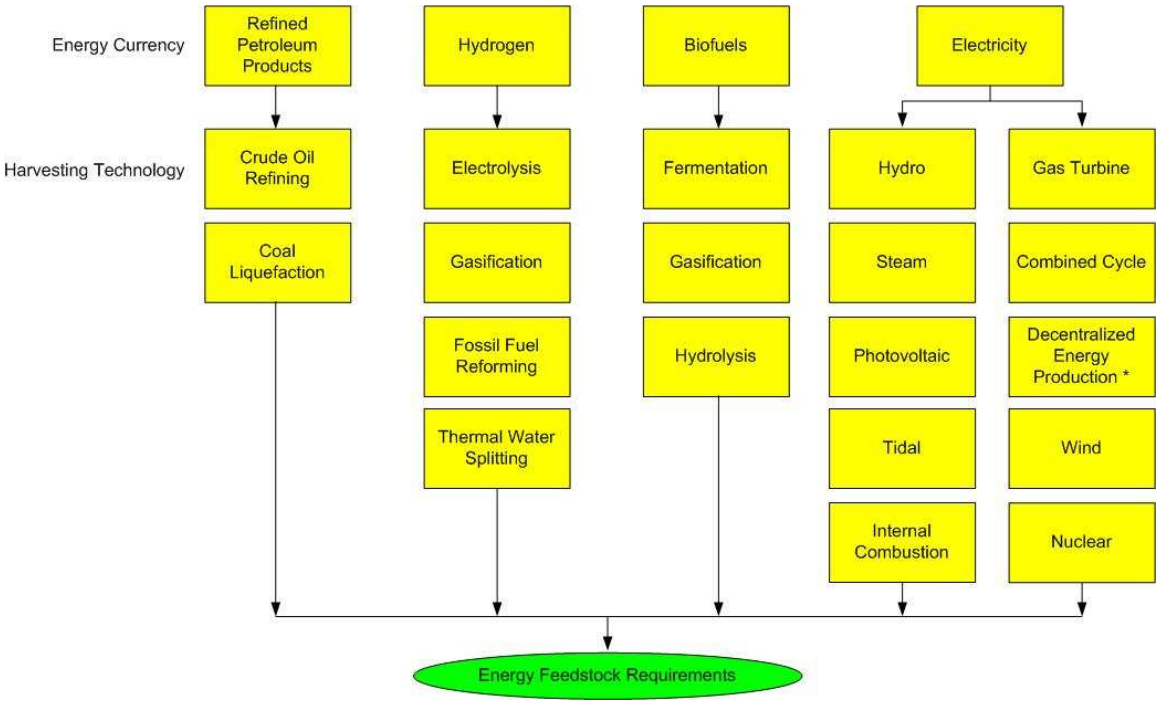

Figure 7 CanESS - Fuel Production

The feedstock production models – for conventional, oil sands, natural gas, coal, uranium, and biomass – represent the the resources and the rate at which the resources can be produced. International and interprovincial trade accounts for differences between energy feedstocks required and energy feedstocks produced.

4. Scenario Management and Reporting

CanESS scenarios run in one year steps from the present to as far as 2100 through the Scenario and Model Management (SAMM) component of the whatIf? modelling platform. SAMM facilitates the creation and display of of scenarios. As CanESS may be used to generate large numbers of scenarios, it is essential to keep track of the combinations of input values that give rise to each scenario. SAMM is unique in its scenario management capabilities in that it is designed to take advantage of the fact that values for input variables may be shared among multiple scenarios and that the values of the ouptput variables can be recreated if the pointers to the set of input values associated with each scenario is maintained.

While most modelling environments allow only a single scenario to be created and used at any one time, SAMM has allows for scenario comparison so that those input variables whose values differ from scenario to scenario can be easily identified and displayed. Scenarios are colour coded to enable comparative graphical displays of the output variables.

Graphical displays of scenario outputs are provided through the Graph software component of the whatIf? modelling platform. Line graphics provide a powerful way of seeing both change in time and composition. Unlike most graphics packages that are oriented towards printing a single static graphical image, Graph allows user interaction with the graphical image. Visual interaction is essential for comprehensive interpretation of large quantities of multi-dimensional data.

Alternatively, scenario outputs may be displayed in tabular format or exported to Microsoft Excel.

5. CanESS Data Sources

CanESS is calibrated over historical time from 1978 to 2006 in one year steps. The result of the calibration is a complete historical database of all of the variables in CanESS adjusted to be consistent with the stock-flow and supply disposition accounting logic of CanESS. This data base is a synthesis of data from a wide variety of data sources including:

- CanSIM (Demographics, GDP, Agriculture, Land Use)
- Statistics Canada Report on Energy Supply and Demand
- Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division
- GHG Inventory
- EPA Mobile 6 Model and Database
- Electric Power Statistics
- CanPlan (National Energy Board)
- Life Cycle Analysis Models (GREET, GHGenius)
- Scientific Reports (Sandia Labs, Battelle, USDA, …)
- Anecdotal Data