PROMETHEUS MODEL

A tool for the generation of Stochastic Information for Key Energy, Environment and Technology Variables

1. General Features

PROMETHEUS is a tool for the generation of stochastic information for key energy, environment and technology variables. In this section a short description of the model is given by presenting its main features.

It is a self-contained energy model consisting of a set of stochastic equations. It contains relations and/or exogenous variables for all the main quantities, which are of interest in the context of general energy systems analysis as well as technology dynamics regarding power, road transport and hydrogen production and use technologies. These include demographic and economic activity indicators, energy consumption by main fuel, fuel resources and prices, CO2 emissions, greenhouse gases concentrations, temperature change, technology uptake and two factor learning curves.

All exogenous variables, parameters and error terms in the model are stochastic with explicit representation of their distribution including in many cases terms of co-variance. It follows that all endogenous variables as a result are also stochastic.

2. PROMETHEUS Output

The basic output of PROMETHEUS is a data set of Monte Carlo simulations containing values for all the variables in the model.

This set can be used as strategically or analytically important information on risks and probabilities, regarding the variables incorporated in it or any pre-determined function involving them. Major applications could be in security of supply assessment environmental risk assessment, investment risk analysis etc.

It can also be used to fit joint Normal or Lognormal distributions for the impact variables to be used in the ISPA policy exploration tool. Note that the problem of estimating the covariance is satisfactorily solved by the process itself. Justifications for the co-variances can also be provided through the data set itself or through inspection of PROMETHEUS relations.

3. PROMETHEUS model characteristics

The forecasting horizon of the model is the period 2008-2050. However, for 2008 real data or official estimations are used where available from the various data sources.

The world countries are grouped in the following major regions in PROMETHEUS according to their economic characteristics:

1. OECD-Europe, which includes the EU-15, Norway and Switzerland
2. The NMS-12, the new members of the European Union (Czech republic, Slovakia, Slovenia, Malta, Cyprus, Poland, Hungary, Latvia, Lithuania, Estonia, Bulgaria and Romania).
3. North America, which includes the USA, Canada
4. Western Pacific, which includes Japan, Australia and New Zealand
5. India
6. China
7. Former Soviet Union excluding the Baltic Republics
8. The Middle East (from the Mediterranean to the Iranian border with Afghanistan and Pakistan) and North Africa (Egypt, Libya, Tunisia , Algeria, Morocco)

9. The emerging economies, which include the Latin America and South Eastern Asia
10. Rest of the world, which includes the least developed countries.

PROMETHEUS is triangular and it is logically divided into sub-models, which are interacting using time lags in their common variables in order to avoid simultaneity in the model equations. The sub-models are:

- The **demographic and economic activity** sub-model, which projects population, GDP and real interest rates.
- The **fossil fuel supply** sub-model:
    - Fuel “in Place”
    - Gross Additions to Reserves
    - Reserves
    - Production
    - Cost-supply curves for biomass and uranium
- The **fuel prices** sub-model, projecting international and consumer prices, with the latter being differentiated for each demand sector
- The **final energy demand** sub-model, projecting the demand in the following consumption sectors:
    - Industry (non-electric uses)
    - Industry (electric uses)
    - Transport
    - Residential/Commercial/Other (non-electric uses)
    - Residential/Commercial/Other (electric uses)

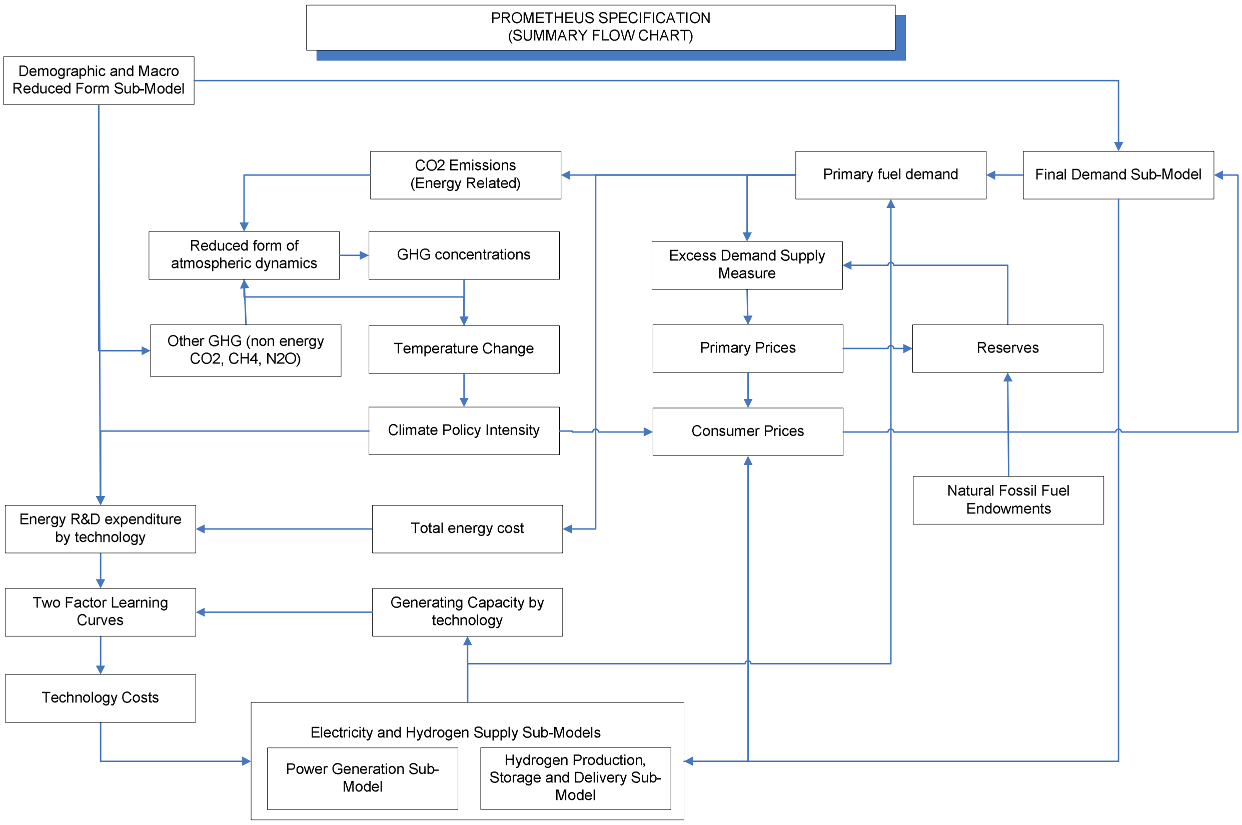
  The following fuel/energy forms are considered as options in the final demand sectors:
    - Coal
    - Oil
    - Biofuels
    - Natural Gas
    - Electricity
    - Hydrogen

  The private passenger cars sector is modelled in detail, by distinguishing seven types of passenger cars:
    - Internal combustion engine cars (gasoline, diesel, hydrogen, biofuels)
    - Fuel cells (hydrogen and gas reformer)
    - Electric cars (pure electric, conventional hybrid, plug-in hybrid)

  PROMETHEUS has been equipped with a decision mechanism in order to simulate social and infrastructure network effects in consumer decisions
- The **electricity generation** sub-model, identifying in detail more than 26 power generation technologies and also includes intermittent renewable sources economic potentials and pre-mature replacement of equipment
- The hydrogen production sub-model, identifying in detail more than 10 different hydrogen production options
- The **hydrogen storage and delivery infrastructure** sub-model
- The **climate sub-model**, which uses reduced form atmospheric dynamics, following the IPCC Third Assessment Report in order to calculate the GHG concentrations and consequently the global average temperature change.
- The **two factor learning curve sub-model**, which endogenises as much of the technical progress as possible through learning by research and learning by experience. In PROMETHEUS the technology dynamics for 51 technological options for electricity production, hydrogen production/storage/delivery and passenger cars were estimated. These include:
    - Capital costs parameters for 44 technological options

- Fixed O&M costs for 34 technologies; although they are basically labour costs, technical progress has been assumed based on the increased automation, reliability and the economies of scale
- Variable cost parameters for 7 technologies, adjusted for efficiency.
- Efficiency parameters for 20 technologies

The following figure presents a summary flow chart of the PROMETHEUS stochastic model:



4. Using econometric estimation for obtaining stochastic information

In constructing PROMETHEUS extensive use of econometric techniques was made in order to obtain the detailed stochastic information required for as complete a representation of their interaction as possible.

Main advantages:

- Provides an element of objectivity.
- Forces the analyst to investigate the nature and extent of stochastic elements (why past variability occurred).
- Is amenable to the analysis of co-variance both in terms of statistical dependence of the parameters and in terms of the simultaneous solution of sets of econometrically estimated equations.

Main disadvantage:

- Excessive reliance on history
- However, it is not clear whether this reliance leads to exaggeration or under-estimation of variability – therefore the method does not in itself produce systematic bias.

The derivation of stochastic elements takes into account that:

- The variance of the regression is unknown and hence itself a random variable (in the process of implementation in PROMETHEUS this has proved to be a major source of variability especially since the samples used were relatively small and the distribution of the variance skewed).
- The parameter estimates are stochastic. As these are used in PROMETHEUS as time independent variables it was found that it was preferable to specify equations in dynamic form to avoid excessive early variability and adequately represent accumulation of uncertainty in the longer term.

- The parameter estimates are not statistically independent (i.e. they co-vary). This has often proved an element of stability (example: negative covariance between autonomous efficiency gains and activity elasticities). However this is not a general rule: a positive (or negative) co-variance between activity and price elasticities combined with decreasing (or increasing) prices in the course of a Monte-Carlo run will increase variability.
- The residuals of the equations vary with time but are independent and hence their cumulative effect though it increases, does so at a decreasing rate.