MS3 First version of Integrated Energy System Model developed

Model documentation and test results for

TIMES PanEU

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About this report

The current report constitutes a milestone of the REEEM project. It aims at providing a first version of the Integrated Energy System Model, which is developed within the project. The report includes a model documentation for the European energy system model TIMES PanEU and some results for the Pilot exercise.

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About REEEM

REEEM aims to gain a clear and comprehensive understanding of the system-wide implications of energy strategies in support of transitions to a competitive low-carbon EU energy society. This project is developed to address four main objectives: (1) to develop an integrated assessment framework (2) to define pathways towards a low-carbon society and assess their potential implications (3) to bridge the science-policy gap through a clear communication using decision support tools and (4) to ensure transparency in the process.

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1. TIMES PanEU model

The model generator TIMES is implemented in the modelling environment GAMS. TIMES is a model generator for bottom-up energy system models, which has been developed within the Energy Technology Systems Analysis Programme (ETSAP) by the International Energy Agency (IEA) [1], [2]. The user creates an energy system model by use of a data management system (VEDA-TIMES [3], [4], [5]). From this data system, the model structure and input data are given to TIMES and converted into mathematical equations. The model aims to minimize the total discounted system cost by taking into account all the costs allocated in the energy system [6].

The European energy system model TIMES PanEU is a linear optimization model, where the energy system of the EU28 including Norway and Switzerland is integrally optimized. The modelling period, split into 5 year- time steps, leads in 2010 and ends in2050. Greenhouse gas emissions (CO_2, CH_4, and N_2O) are also included in TIMES PanEU. In the optimization, an expansion and operational planning of technologies is actualised over the whole modelling horizon [7], [8], [9].

The reference energy system of TIMES PanEU includes several sectors: Public electricity and heat supply, other energy conversion (for example refineries), households, commercial, agriculture, transport, industry (including auto-production) and provision of energy carriers. Figure 1 shows the country-specific reference energy system of TIMES PanEU with the modelled storage options in the aggregated form.

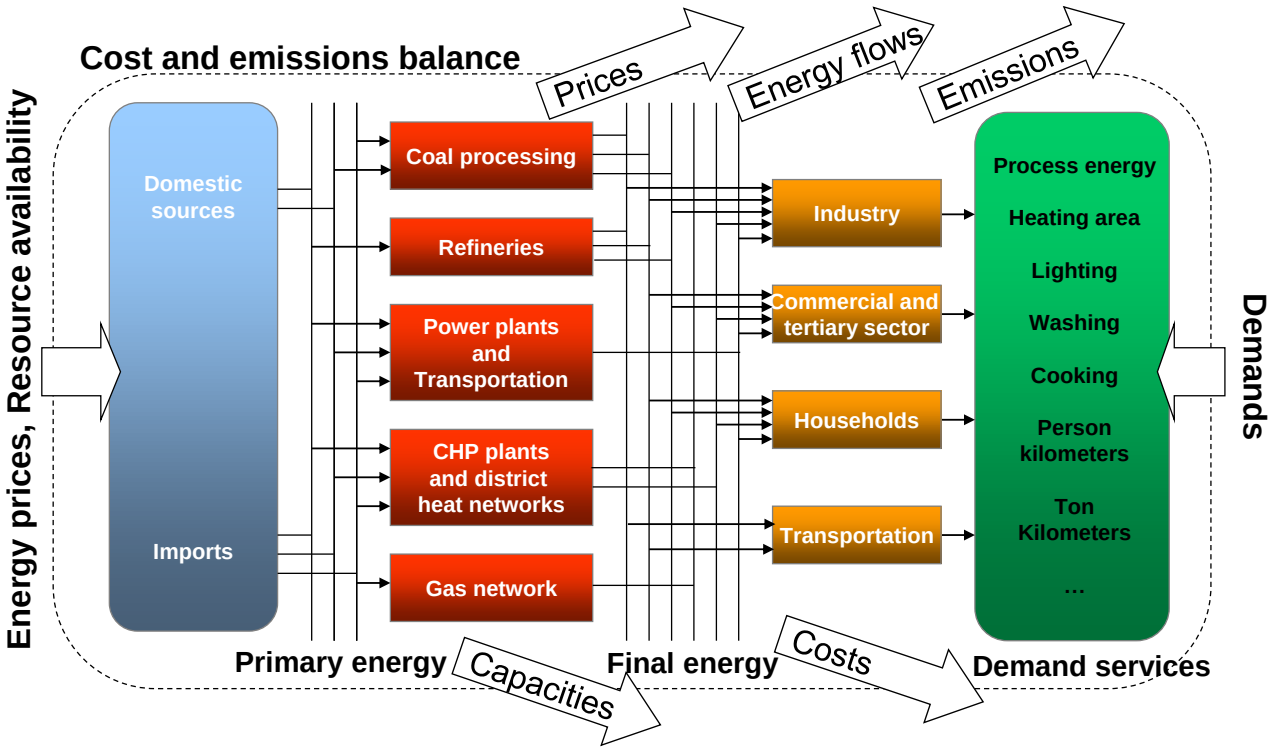

Figure 1. TIMES PanEU Reference Energy System. IER.

TIMES PanEU is divided into 12 time segments (one typical day per season with three time steps: day, peak, night). The reference energy system of TIMES PanEU contains 5 main sections, which are described below.

Supply of energy sources and other energy conversion

In the energy carrier supply sector, primary energy resources are modelled with different cost potential curves. Crude oil, natural gas, coal and lignite are included. In addition, various bioenergy carriers are modelled. Other conversion technologies such as refineries and Power-to-Gas are also available [10].

Public electricity and heat supply

On the electricity supply side, various power technologies are available that feed the electric power in different voltage levels. Whereas the large central power plants use the high voltage grid; decentralized power plants, such as pv systems use the medium and low voltage grid. Both the power plant stock in the year 2010 as well as the investment options for the following periods are aggregated according to technology types and fuel used. The hydroelectric power plants (pump storage, run river) as well as the compressed air energy storage Huntorf in Germany and new electricity storages are modelled in the electricity supply sector ([11], [12], [13], [14], [15]).

The centrally supplied district heat of public cogeneration plants (CHP) and heat plants are also converted into sector-specific district heat. These processes take into account costs and the loss of heat in the form of efficiencies. Power-to-Heat and with heat storages are also included in the public heat supply ([11], [12], [13], [14], [15]).

Households, commercial and agriculture

The energy service demand in TIMES PanEU is differentiated sector specific. For each demand category various technologies, aggregated by technology and final energy carrier, provide the energy service demands. In the household sector demand is divided into the following categories: Space heating, room air conditioning, hot water, cooking, lighting, cooling, dishwasher, washing machine, cloth drying, other electricity demand and other energy demand. The heat demand is further divided into the heat demand of urban, rural single-family houses and the multi-family houses.

In the commercial sector, the demand is divided into the following categories: Space heating, room air conditioning, hot water, cooking, lighting, cooling, public lighting, other electricity demand and other energy demand. The energy demand of agriculture is modelled as one general process.

Transport

In the transport sector following demand categories are displayed: Car, bus, truck, motorcycle, passenger train, freight, air traffic and navigation. The passenger transport is modelled in the unit Pkm, freight is modelled in Tkm.

Industry

In the industrial sector there is a differentiation between energy-intensive and non-energy-intensive industries. The energy-intensive industries are divided into the categories: iron and steel, aluminium, copper, ammonia, chlorine, cement, lime, flat glass, container glass and paper. The non-energy-intensive industries include the categories: other non-ferrous metals, other chemicals, other non-metallic minerals, food and other industries. Additionally, in TIMES PanEU industrial auto producers are modelled [10].

2. Pilot exercise results

To analyse the linkages for the further development and define the data flow between the models, with the existing structure of TIMES PanEU, two scenario runs are completed according to EU GHG emission reduction target by 2050:

- Pilot 1. The 80% decarbonisation target is imposed to the EU28+2 as a whole and the burden shared between the countries.
- Pilot 2. The 80% decarbonisation target is imposed by every country of the EU28+2 independently.

Figure 1 shows the net electricity production in the EU28 for both scenarios. The electricity supply consists of the public and non-public electricity generation and the net electricity imports. In both scenarios the decrease in fossil fuel power production and the increase in renewable energy generation can be seen.

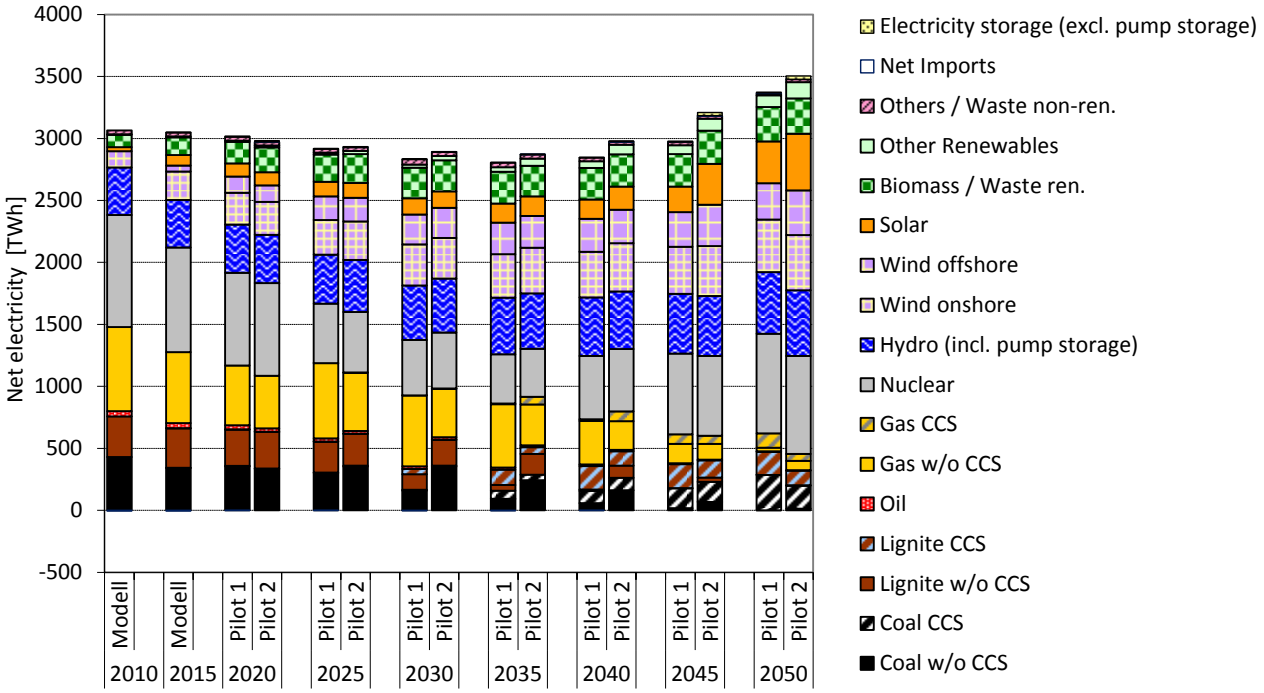

Figure 2. Electricity production in the EU28 in TIMES PanEU.

The increase of electricity production from renewables energies means the increase of the installed capacities (Figure 3). The increase of the capacities is higher than the increase of the overall electricity production. This is due to the lower full load hours of PV and wind plants compared to conventional power plants. Additionally it is invested in flexible power plants as reserve capacity. This means, that the minimum flexible capacity has to be higher than the maximum electricity demand.

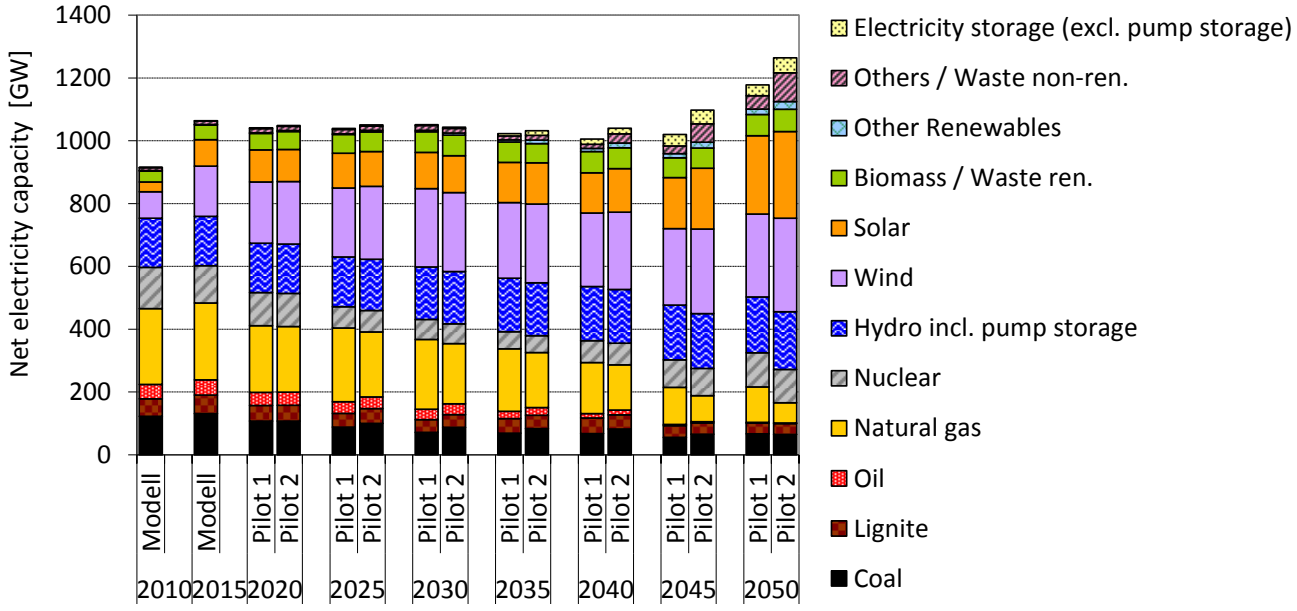

Figure 3. Electrical capacity of power and chp plants in the EU28 in TIMES PanEU.

Figure 4 shows the CO_2-emission reduction according to the level in 1990 in the year 2050 to achieve the 80% decarbonisation target in EU in Pilot 1. 16 regions share the burden for the 5 regions which reduce less than 80 %. It can be concluded that for these 5 regions, decarbonisation of the energy system is more costly compared to other 16 regions.

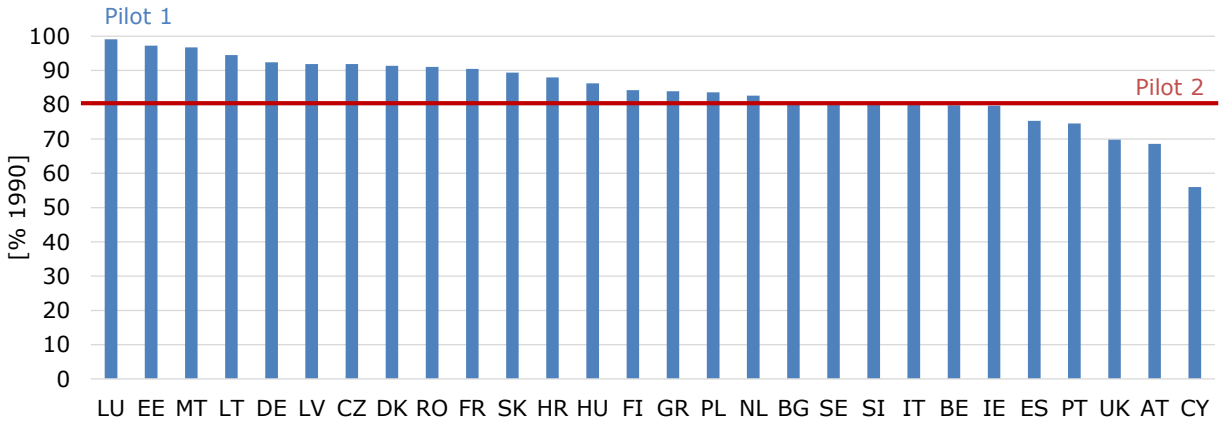

Figure 4. CO_2 emissions in 2050 as a percentage of 1990 CO_2 emissions.

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