Overview of the application of TIMES at IER

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To support research at the Institute of Energy Economics and the Rational Use of Energy (IER) at the University of Stuttgart in the area of energy system modelling, the TIMES methodology has been used to develop different models which will be described shortly in the following.

German Electricity Sector model (TIMES-GES)

To study the effects of a phase-out of nuclear energy in Germany a model of the German electricity sector including CHP generation has been developed for the time horizon 1995-2030. The model consists of seven regions which are linked by exchange processes for electricity. The electricity and CHP sector within each region are described by a set of around 180 processes. Three voltage levels are being considered for electricity, while heat is divided in local and district heat. The model has been used within the model experiment II of the Forum for Energy Models and Energy-Economic Analysis (FEES), whose results are described in more detail in the ETSAP Newsletter of April 2001.

TIMES Bavaria

For the "Energy Discourse Bavaria", a forum of stakeholders from policy, industry and public groups, a TIMES model of the Bavarian energy sector has been built covering the time horizon 1995-2020. To better address regional differences in district heat supply, six different district heat networks and their connected residential areas have been introduced in the model. Main focus of the scenario analysis was to study the realization of GHG abatement targets under various policy measures, concerning e.g. nuclear energy and renewables.

TIMES-D2

TIMES-D2 is a model of the German energy system for the time horizon 1995-2050 being divided in 5-year periods and four typical time segments. The model consists of the two regions East and West Germany. Parts of the model are based on the German E^3Net model, which has been used so far at IER. The demand side is divided in industry, commercial, residential and transport sectors, The demand sectors are further disaggregated and contain around 420 end-use technologies. The supply side comprises public and industrial electricity and CHP generation, refineries, coal conversion, gas transport, import, export and transport of energy carriers and energy supply by renewables. The supply side contains around 200 conversion technologies. The model is currently applied in the third model experiment of the FEES, the ACROPOLIS project of the European Union and a study for the Enquete Commission "Sustainable energy supply under the conditions of globalisation and liberalization" of the Federal Parliament.

TIMES-WEU

Together with ECN and Gary Goldstein, TIMES-WEU has been generated from MARKAL-WEU based on the database MARKAL-SAPIENT 0.2 provided by ECN. M2T utility has been applied to transform the model from MARKAL to TIMES. Because of the detail representation of processes, the model in TIMES framework is scaled up by 6-7 times than MARKAL in terms of number of equations and variables. TIMES-WEU is running for the model horizon of 1990-2100 with a period duration of 10 years. It is a single region model that includes EU15, Iceland, Norway, Switzerland. Sector-wise demand for energy services is exogenous to the model. Model database includes techno-economic-emission data on about 700 end-use and supply technologies. Its database is available in TIMES-ANSWER framework.

TIMES-WEU model is used for the SAPIENT project. Endogenous single factor technology learning has been introduced in TIMES-WEU, based on mixed-integer programming approach.

Conclusion

In the different applications described above TIMES has been proven to be a valuable tool to build and analyse energy system models. In the following a few remarks on our experience with TIMES so far.

During the phase of building the models it was very convenient that TIMES offers the possibility to inherit input data from a coarser timeslice[1] level, e.g. annual, to a finer level, e.g. a daily one. Thus it was possible to first build a model with an annual time slice resolution and later, when the annual model works, refine it by adding load curves etc. and switch to a finer resolution without having to enter the data for the finer timeslices again.

The capability to describe flexible processes, i.e. the ratio of input or output flows is determined by the optimisation, has been used extensively in the models, e.g. to describe extraction condensing CHP plants which can be operated with a flexible electricity to heat ratio. A problem concerning CHP modelling is the annual availability or utilisation period of maximum load. For instance, due to heat load curve many district heat producing CHP plants have a utilisation period of maximum load of about 4500 hours per year, although technically they could be used about 8000 hours a year. Describing the load curve with only four timeslices (Winter-Day, Winter-Night, Summer-Day, Summer-Night) and using the technical availability as restriction leads to much higher utilisation periods than observed in reality. Increasing the number timeslices to better depict the heat load constrains the maximum utilisation of CHP processes, however it also drastically increases the model size. Therefore we have restricted the annual availability to a value corresponding to the utilisation period observed in reality (e.g. 4500 hours) while assigning the technical availability to the daily timeslices. Another problem related to district heat networks is the fact that a larger region contains not a single district heat network but several ones. The profitability of a district heat network, which is competing with residential heating systems, is influenced by factors as

[1] In TIMES a year can be divided in representative timeslices to depict for example demand load curves for heat and electricity or seasonal variations in the availability of hydropower.

total heat demand, status of the existing district heat network and of the competing heating systems. To better reflect the variations of these factors in the Bavarian energy system, six district heat networks and their competing residential sectors have been introduced in the Bavarian TIMES model.

User constraints (corresponding to ADRATIOs in MARKAL) are very powerful to formulate problem-specific equations, e.g. introducing a quota for electricity generated by renewables or limiting the penetration of a technology over time by a growth constraint. Though powerful, support in formulating and maintaining the user constraints is essential, e.g. when adding a new renewable technology one should not forget to add it in the user constraint for the renewable quota. This problem could be overcome by introducing process and commodity trees in TIMES code itself or in the TIMES shell as presented by Amit Kanudia on a previous ETSAP meeting.

As already noted on previous occasions the initial matrix generated from a TIMES model can be quite large, e.g. around 400,000x400,000 for the German TIMES-D2 model. Commercial solvers like CPLEX contain however a reduction algorithm that in the case of the German model drastically reduces the matrix (by dropping redundant constraints, row or column singletons) by a factor 5-6. So the large initial model size is in so far only a problem that it requires according amount of working memory to store the initial large matrix (around 400 MB for the German model).

In the TIMES-WEU Model, technology learning has been tested for 12 technologies with the data on learning parameters provided by ECN. Similar to MARKAL, clustering approach has also been implemented to analyse the learning behaviour of a large number of technologies. A cluster of technologies is defined as technologies sharing a common component called the key technology whose investments costs can reduce due to technology learning. For the SAPIENT project, six key technologies are chosen: gas turbine, steam turbine, gasifier, fuel cell, solar PV and wind turbine. The corresponding six technology clusters are limited only to power generation sector and contain 52 power generation technologies altogether. Same data on progress ratio, investment cost, maximum cumulative capacity for key technologies, and upper bound on cluster technologies as used by MARKAL are applied for TIMES to carry out the analysis for the SAPIENT project.

For the analysis of model results the VEDA Analyst is a very convenient tool. It allows for example to build tables based on process and commodity sets, so that when adding processes or commodities to the model one only has to ensure that the corresponding set entries are updated to get new correct result tables. Also the possibility to directly compare the results of several scenarios helps to identify the effects of different scenario assumptions. In the process of converting a model from MARKAL to TIMES and validating the converted model, the direct comparison of both model results is helpful in tracing possible errors in the conversion process.