# The Socio-Economic Toolbox of the EU Hydrogen Roadmap Project HyWays

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## Introduction

HyWays is an integrated project, co-funded by research institutes, industry and by the European Commission (EC) under the 6th Framework Programme. HyWays will combine technology databases and socio-/techno-/ economic analysis to evaluate selected stakeholder scenarios for future sustainable hydrogen energy systems. This will lead to recommendations for a European Hydrogen Energy Roadmap reflecting country specific realities in the participating member states.

The main characteristic of this Roadmap is that it will reflect real life conditions by taking into account not only technological but also institutional, geographic and socio- economic barriers and opportunities as representative for the different member states. Therefore this Roadmap will be based on inputs from European industry, research institutes and government agencies, and backed up with the best-available data. It will describe systematically the future steps to be taken for the large-scale introduction of hydrogen as an energy carrier in the transport and power market and as a storage medium for renewable energy. It will result in an action plan for the implementation of the European Hydrogen Energy Roadmap. Moreover, it will describe the effects and impacts of this introduction on the EU economy, society and environment. It will propose concrete policy measures, priorities in technology development and in training and education.

## Aspects of socio-economic modelling

There are two broad approaches for modeling the interaction between energy, the environment and the economy. They differ mainly with respect to the emphasis placed on (1) a detailed, technologically based treatment of the energy system, and (2) an aggregate description of the general economy.

The models placing emphasis on (1) are purely partial models of the energy sector, lacking interaction with the rest of the economy. In general, they are bottom-up engineering-based linear activity models with a large number of energy technologies to capture substitution of energy carriers on the primary and final energy level, process substitution, process improvements (gross efficiency improvement, emission reduction), technology learning and spill over effects and energy savings. They are mostly used to compute the least-cost method of meeting a given demand for final energy or energy services subject to various system constraints such as exogenous emission reduction targets or pre-scribed energy technology paths (such as an administered phase-out of nuclear power or phase-in of green energy). These types of models can also threat impacts of technology specific policies (subsidies, standards) as well as provide information about development of investment costs and cost-effectiveness.

Yet, if economy-wide feedbacks of energy policies are important, the partial analysis approach by means of bottom up simulation, which does not account for the interaction between the energy system and the remaining economy, is less appropriate. The models emphasizing (2) are general economic models with a rather rudimentary treatment of the energy system. Following the top-down approach, they describe the energy system (similar to the other sectors) in a highly aggregated way. Typically, economy-wide models can not readily incorporate different assumption about how energy technologies and costs will evolve in the future and may violate fundamental physical restrictions such as the conservation of matter and energy.

Following the above categorization, MARKAL belongs to class of bottom-up models whereas – at first glance – GEM-E3 would be classified as a top-down model. The ISIS-model could be classified as a hybrid model, bridging the gap between the MARKAL and GEM-E3 model. However, both the ISIS as well as GEM-E3 model incorporate MARKAL bottom-up features while adopting different top-down settings which makes them suitable for complementary use in the HyWays project.

A common model to consider the effects of technological change is the use of an Input/Output (I/O) model of the economy. Linking such a model to a detailed technology and innovation oriented scenario analyses as performed with the MARKAL-model, yields an advanced modelling approach taking the relevant mechanisms in account. Furthermore, the results of innovation research on the export/import performance can be transformed into the effects on GDP and employment. By means of the ISIS-model, a meso-economic analysis on the basis of a micro-to-macro bridge can be carried out. ISIS (Integrated Sustainability Assessment System) is based on a static open multi-sectoral input-output-model and can be used for integrated sustainability assessment of technological strategies and measures, In addition, it is able to cover several socio-economic and environmental indicators (economic output / value added, sectoral and regional structural change, foreign trade, quantitative and qualitative employment effects, environmental pressure indicators like energy and greenhouse gases).

The input/output approache has some limitations though. The analysis of prices effects as well as the evaluation of policy instruments cannot be analysed with such an approach. For this type of analysis the well-known equilibrium models, can be used. More specifically, GEM-E3 is of the Computable General Equilibrium (CGE) model type that has become the standard tool for quantifying the impacts of policy changes on economy-wide resource allocation. The microeconomic foundation of CGE models provides a consistent framework for studying price-dependent interactions between the energy system and the rest of the economy. A simultaneous explanation of the origination and the spending of income for all major economic agents (households, firms, government, abroad) allows to address both, economy-wide efficiency implications as well as distributional effects of energy policy interference. The comprehensive analytical power of CGE models accounts for its wide-spread use in assessing energy policy issues such as energy market regulation or energy taxation with respect to environmental constraints and fiscal needs (e.g. environmental tax reforms). An innovative feature of the GEM-E3 model is the possibility to include an elaborate treatment of energy supply options by means of activity (or process) analysis (as is the case in the bottom-up models). The bottom-up description of a discrete set of energy based on engineering data provides a realistic picture of endogenous adjustment (such as capital stock turnover) to targeted energy policy measures.

## Final Remarks

Yet, even if the socio-economic modelling occupies a large portion of all efforts in the HyWays roadmap analysis work, the project's specific strengths lie in the definition of the framework for which the modelling results are used. The project scope includes an iterative process to validate the models by discussing them with a large number of balanced stakeholders from each of the 12 individual member states partnering with HyWays. It is claimed that these member states will finally be representative for all of Europe.

Thus, the purely academic economic modelling approach will be enriched by non-economical aspects trying to let the roadmap reflect real life conditions. Whereas models can assess only the economic aspects, not or hardly taking into account non-economical aspects resulting from country specific situations, HyWays will also reflect the fact that a country can not be "averaged out" but consists of cities and farm land, motorways and local roads, clusters of industry, locations of power plants and multiple energy and goods distribution systems (e.g. harbours), etc..