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TUMATIM - Results

Treating Uncertainty and risk in energy systems with MARKAL/TIMES

DURATION OF THE PROJECT
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414.774 €

KEYWORDS
Energy system modelling, climate change, uncertainty, energy price elasticity

CONTEXT

Changes in social, political, economic and environmental thinking have led to an increasing amount of questions about prospects of energy use and supply. Techno-economic, partial equilibrium energy models like TIMES have proven their ability to tackle some of these questions. As questions become more and more complicated adequately equipped models are needed.

OBJECTIVES

The objectives of this project are twofold: first, a further development of the model and secondly a set of case studies addressing issues important for the development of a sustainable energy system. It will allow a better integration of uncertainty in the evaluation of policy scenarios, where the uncertainty is related to the technologies and their parameters as cost and efficiency, energy prices fluctuations and climate change. The estimation of price elasticities allows to better take into account the reaction of the consumers in a partial equilibrium model as TIMES.
Regarding the case studies, by looking at issues on the policy table with both the partial equilibrium model and the general equilibrium model, the project can contribute in a rather comprehensive way to the debate and to the definition of specific policies regarding the energy and the environment.

CONCLUSIONS

The climate change issue faces different kind of uncertainty. Uncertainty can play a key role within an energy system. The effect of uncertainty depends highly on the possible scenarios and the variance between these different possibilities and on the adaptiveness of an energy system to take these scenarios into account .

Uncertainty can cover fluctuating energy prices, future carbon prices and environmental constraints, technology progress and/or security of supply. Besides, there is uncertainty about model parameters like price elasticities which can also influence the cost or the choice of technologies.

Through econometric analysis price elasticities of service demand were estimated. Energy price increase causes energy efficiency improvements. Consequently energy services or useful energy decrease will be less than energy consumption.

A pilot study was used to examine the willingness to pay for energy services in residential dwellings. Respondents were able to express their preference via a choice experiment. The analysis showed that the 'rebound' effect could be rather important, i.e. energy saving through investment in more efficient technologies would partly be compensated by an increase in the energy service demand. The estimation of the price elasticities revealed rather low price elasticities for energy services (between 0 and -0.5).

Modelling variability in fossil fuel prices in TIMES has shown that this variability leads to a diversification of the energy mix, and more specifically of the electricity generation mix. It can affect the optimal energy system in two ways. First, technologies not affected by the price variation enter the optimal solution, i.e. coal and renewables, though coal less when a CO_2 target is imposed.. However, with a high risk aversion the relative share of coal generated electricity can increase under a stringent CO_2 policy, when all non-fossil technologies are used up to their maximum availability. Secondly, the cost increases which induces higher energy service prices and thus a decrease in the demand.

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In general, the effects of uncertainty for the Belgian energy system were limited, especially when a CO_2 policy was implemented, as taking into account the price variability and covariance already induces a shift towards low carbon technologies. Introducing more variability in the prices, e.g. variability in biomass prices might increase the impact.

With stochastic TIMES, a hedging strategy was computed given uncertainty on the availability of carbon storage and the stringency of the carbon constraint. The information on these two issues was assumed to be available only after 2025. With the proposed scenarios, the difference between the hedging strategy and the corresponding deterministic strategy remains small but the lack of information on long term policy measures leads to higher costs of the energy system. For increasing risk aversion, the overall costs of uncertainty increase. However, the information value for the worst case scenario becomes lower as they gain higher relative importance in the objective function.

The policy cases analysed with the TIMES model covered the renewable target for Belgium and the EU proposal of a 30% reduction target in 2030 and of 80% in 2050 compared to 1990 emissions for the EU GHG emissions. The EU target (-30% in 2030 and -80% in 2050) was modelled with the Pan European TIMES model. This gives the cost optimal way to reach the target at EU level, inclusive the cost efficient allocation of the reduction between the EU countries. From this run, the implication for Belgium in terms of CO_2 reduction was derived. Then, with the Belgian model, the impact on the Belgian energy system, on the choice of technologies and on the energy system cost was explored, with a specific emphasis on the availability of nuclear and of carbon storage.

The analysis showed that it is possible to attain very stringent CO_2 reductions in Belgium. The welfare cost in annualised terms varies from 0.5% of the 2005 GDP when nuclear and carbon capture are available to 1.2% of GDP2005 when none of these options are available.

The participation in a global EU CO_2 market is essential for Belgium. Without the possibility of trade and the same EU target of -78% imposed on all EU countries, the cost increase to 0.8% of GDP2005. These costs are the cost within the energy system without considering any potential side benefits and assuming a EU permit system as policy instrument for achieving the CO_2 reduction target.

The CO_2 constraints do not impose major shifts in the energy system in the middle term. The use of more energy efficient technologies and a switch to gas are predominant. It should be mentioned that building insulation and saving lamps are already cost efficient in the reference scenario and because of the many barriers to their use in real life, it is important to address this issue by specific policies. Renewables such as wood and wind on shore are also penetrating rapidly.
In the long term, alternative fuels such as ethanol and biodiesel and electricity are penetrating in the transport sector, offering further reduction possibilities. Their relative cost seems to be rather close and therefore the choice between these different options is very sensitive to the potential of biomass production, the cost of biocrops and of electricity.
Also, in other sectors, the choice of technological options is dependent on the options in the electricity sector and the relative price of electricity when high reduction target are imposed. The availability or not of nuclear and carbon storage are important determinant of the price of electricity and thus of the choice of technological options.
A major contribution is also obtained from a reduction in the energy service demand. This reduction can cover a great number of changes outside the energy system: new production system, change in life style, in urban planning,… Nevertheless, sensitivity analysis showed that a larger reduction in the energy service demand can be very costly. The results indicate that there are reasons to believe that a policy primarily oriented towards deep or uniform demand reductions is questionable for efficient tackling CO2 emissions. Instead, a climate policy directly oriented to the reduction of CO2 emissions induces only modest relative reductions of energy services, but it will be more cost efficient and it will induce more technology development.

Focussing on a specific renewables target can contribute to the CO2 target but the technological choices might not be optimal regarding this last target and not induce R&D in the most appropriate direction. A renewable target is however not sufficient to reach the climate target.

The results from those scenarios show the importance of using a model covering the whole energy system with sector specific technologies to correctly evaluate the trade-off between the options given the overall CO2 target.

These different conclusions are clearly dependent on the cost and assumptions implemented in the model database and in the scenarios. Therefore this analysis should be complemented by sensitivity studies around the main parameters. Also, though the cost of implementing a complete infrastructure for the penetration of some option is integrated in annualised term in the cost of these options, large resources will have to be mobilised over a rather short period to invest in these infrastructure.

CONTRIBUTION OF THE PROJECT TO A SUSTAINABLE DEVELOPMENT POLICY

Climate change and security of supply, along with sustainable development have remained high on the agenda of the policy makers. The energy sector and the development and implementation of new technologies are important elements for the achievement of sustainable development. The contribution of the TIMES modelling framework on this issue can therefore be important. Keeping the model update and contributing to its development within the ETSAP IEA Implementing Agreement is essential. Policy scenario analysis with the model will also contribute in the definition of the Belgian policy regarding sustainable development (energy, environmental, R&D policy) within the EU context.

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