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Assessing effects of exogenous assumptions in GHG emissions forecasts – a 2020 scenario study for Portugal using the Times energy technology model

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ABSTRACT

Energy-economy-environment models are fundamental in developing realistic cost-effective climate policy. However, such models by necessity are simplified based on assumptions which co-determine the outcomes of scenario modelling. Major assumptions relate to demographic and economic development, technology evolution and deployment and policy decisions. The core of this analysis is to quantify how specific assumptions influence the outcomes of scenarios; not taking them together as usually in the literature but instead looking into them apiece. The TIMES modelling framework is broadly used for climate policy support and here we used the Portuguese version as an example. As the structure of TIMES modelling is similar in other countries and also for larger aggregates as the EU and the World, the method can be applied there quite directly, although outcomes will differ between countries due to differences in energy technologies and energy markets. The outcomes for the Portugal Baseline scenario using TIMES_PT show the relevance of this exercise in this sensitivity analysis on assumptions. Contrary to what might be expected, varying assumptions on the availability and price of energy resources lead to minor variations on GHG emissions in the modelling outcomes, less than 2% of the Baseline scenario emissions in 2020. The more relevant assumptions to overall uncertainty are related to socio-economic development, followed by assumptions on technology deployment. This detailed uncertainty analysis on assumptions helps to assess the robustness of modelling outcomes in the TIMES model framework, next to other aspects like model structure and validity.

1. Introduction

Energy-economic-environment models such as Markal/TIMES family of models (Loulou et al., 2005a, 2005b), but also PRIMES (Capros, n.d.) and POLES (Russ et al., 2009), are frequently used to support policy makers in climate change mitigation policy decisions. They are used to develop greenhouse gas (GHG) emission scenarios, exploring possible pathways. Examples are the EU Energy Climate 2020 Package (European Commission, 2008) and the 2030 Policy Framework (European Commission, 2014) that relied on emission scenarios developed with the PRIMES model (Capros et al., 2008); the French National Climate Change Plan[1] (NCCP) which used GHG scenarios for the electricity sector derived from POLES (DGEC, 2011); the Italian official energy and GHG emission scenarios built with the TIMES Italy model (ENEA, 2012); and the United Kingdom's 4th Carbon Budget of the country's Carbon Plan, using the MARKAL model (Hawkes et al., 2011). Such models require a set of exogenous assumptions, such as the rate of demographic and economic development, rate of energy-efficient technology evolution and

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[1] The emission scenarios used in the French NCCP are also an input in other national policies, especially the National Energy Efficiency Action Plan.

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deployment, the availability and price level of energy resources, and the pace of implementation and effectiveness of policy decisions. The assumptions reflect the different levels of knowledge that energy system models integrate: socio-economic-environmental knowledge basis, the range of policy measures, and finally the uncertainty and subjectivity in the system (Rotmans and van Asselt, 2001).

Naturally, each of these assumptions has an associated uncertainty, as defined by the Intergovernmental Pannel on Climate Change (IPCC) (Field et al., 2012)[2] and typified in three groups by (Rotmans and van Asselt, 2001) as: technical uncertainty (regarding quality of input data), methodological uncertainty (regarding appropriateness of the modelling tool) and epistemological uncertainty (due to structural uncertainty and variability and managed via improved model completeness). Each of these lead to assumptions on exogenous parameters which will affect the overall degree of uncertainty of each GHG forecast (Moss et al., 2010; OECD/IEA, 2012; DECC, 2012; Strachan, 2011; Pilavachi et al., 2008). It is common practice to model sets of alternative scenarios (formal scenario analysis) representing different sets of assumptions combined, as interesting pathways (Riahi et al., 2007). Each pathway combines two or more sets of exogenous assumptions, resulting in a range of emission scenarios (Rotmans and van Asselt, 2001; Usher and Strachan, 2013). One of the most well-known examples of this approach is in the Special Report on Emission Scenarios (SRES) of the IPCC (IPCC, 2000). For example, the IPCC A1F1 emission scenario considers a pathway that describes a world with fast economic and population growth peaking in 2050, continued use of fossil fuels and moderate deployment of new and efficient technologies. On the contrary, the A2 scenario has a continued population growth beyond 2050 but slower economic and technological change (IPCC, 2000). There is good reason to combine different pathways into feasible scenarios, namely avoiding the burden of assessing multiple combinations of assumptions, which might become impossible considering limited time and resources. In that combined process, however, information on the individual role of the different assumptions is lost and it is not possible to assess the contribution of each individual assumption on the overall uncertainty of scenario outcomes. In other words, without separately assessing the role of individual assumptions as inputs in highly detailed energy system models, it is not possible to identify which of those are more relevant regarding model outputs and consequently more significant for policy decision that should be studied in more detail. An example is that substantial effort might be allocated to define and run different hydro or wind resources climatic variability scenarios or different oil and gas import prices scenarios, as part of an energy system modelling exercise, when these changes are not critically influencing model results. On the contrary, assumptions that are not perceived as critically influencing model outcomes and are thus taken as “granted” can be found to have a more important effect in results and thus merit further exploration in their design. This paper is set out to fill this gap in assessing individual relevance of main energy system model assumptions, by making systematic individual variations in model inputs and assessing the different in results regarding climate and energy policy commitments (i.e. GHG abatement and renewable energy consumption targets). The paper's results allow guiding other energy system modelling exercises for climate policy support by: 1) proposing an approach to highlight the more relevant assumptions influencing model results and 2) by identifying which of such assumptions should be designed with more care in order to generate model results with more meaningful insights for policy making.

Typically, policy makers and modellers place special emphasis on assumptions on variations of socio-economic growth, on fossil fuel prices and on the availability of key energy technologies (e.g. variable renewable energy resources (RES) or nuclear). Assumptions on the pace of the implementation/decommissioning of planned electricity plants and detailed deployment of end-user energy efficient equipment (e.g. appliances or insulation) are not always perceived as equally relevant for uncertainty, possibly because these are areas that can be more easily controlled by national or regional policy making. Most national and EU GHG emissions scenarios do not explicitly address these two last exogenous assumptions (detailed in the next section), and to our knowledge, individual variations to each of the exogenous assumptions were never performed with the TIMES family of models, or with other energy system models. Although there are several papers relying on the use of TIMES and similar energy system models for a number of climate policy relevant questions (such as (Chiodi et al., 2013; Kanudia et al., 2013; Capros et al., 2014; Anandarajah and Strachan, 2010)) they do not cover their effective application for GHG emissions scenarios generation for policy support, nor do they analyse the individual roles of the considered exogenous assumptions. Typically, such studies include sensitivity analysis to a few specific assumptions, but these do not cover the whole range of exogenous model assumptions. Within the field of assessing uncertainty in GHG emission scenarios, the literature mostly deals with improving the methods used to address “epistemological uncertainty” as defined by (Rotmans and van Asselt, 2001). That is, it covers aspects related to trying to improve model completeness to better deal with structural uncertainty and variability, such as variability of climatic conditions. Examples are the work of (Michel, 2009; Labriet et al., 2012; Li et al., 2014). The work of (Strachan et al., 2009) is the closest in the literature[3] to the approach we use here as the authors compared the effect of different assumptions in the MARKAL model for UK. However, the authors combined scenarios developed for different purposes over many years and did not focus on a systematic assessment of each assumption. In this paper we try to bridge the gap between policy support modelling exercises and more academic modelling work. The former exercises are usually not published in scientific literature (hence our overview of these in Section 2), whereas the latter, although published, do

[2] In this paper we use the IPCC definition of the term: “An expression of the degree to which a value or relationship is unknown”. It can result from many reasons as “quantifiable errors in the data, ambiguously defined concepts or terminology, or uncertain projections of human behaviour” and thus can be represented both quantitatively and qualitatively.

[3] We performed an exhaustive literature search in the science direct database using key-words as: energy system modelling; GHG emissions forecast and scenarios; GHG emissions uncertainty assessment; uncertainty assessment; exogenous assumptions; model uncertainty; TIMES model; national GHG emission projections, both individually and combined. We have studied the references section included for each of the nine GHG emission projections to identify other relevant publications for our analysis.