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Myopic decision making in energy system decarbonisation pathways. A UK case study

Francesco Fuso Nerini [a, b, *], Ilkka Keppo [a], Neil Strachan [a]

[a] UCL Energy Institute, University College London, London, UK
[b] Unit of Energy Systems Analysis, Royal Institute of Technology (KTH-dESA), Stockholm, Sweden

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ABSTRACT

With an application on the UK, this paper shows that myopic planning might result in delayed strategic investments and in considerably higher costs for achieving decarbonisation targets compared to estimates done with perfect foresight optimisation energy models. It also suggests that carbon prices obtained from perfect foresight energy models might be under-estimated. The study was performed using a combination of the standard UK Times Model (UKTM), a perfect foresight, bottom-up, technology-rich cost optimisation energy model, and its myopic foresight version: My-UKTM. This also demonstrates that using perfect foresight optimisation models in tandem with their myopic equivalents can provide valuable indications for policy design.

1. Introduction

The UK legislated an ambitious target to tackle climate change: an 80% of reduction in greenhouse gases (GHG) emissions by 2050, compared to the 1990 levels [1]. For that to happen a number of ‘carbon budgets’ are being legislated [2]. Those set 5-year ‘budgets’ for all GHG emissions in the UK. The budgets are suggested by the Committee on Climate Change (CCC) to achieve the 2050 target with a ‘cost-effective pathway’. The carbon budget proposed by the CCC are then approved and legislated by the UK's Department for Business, Energy & Industrial Strategy (BEIS).[1] Five carbon budgets have been legislated to date (Fig. 1). To achieve the carbon budgets GHG emissions can be curbed in the so called ‘traded’ and in the ‘non traded’ sectors. The first one refers to sectors of the economy covered by the EU Emission Trading system (EU ETS), primarily electricity generation and energy-intensive industry. The second covers all emissions outside EU ETS, including transport, heating in buildings, agriculture, waste and some of the industry.

In this context, both BEIS and the CCC use perfect foresight optimisation energy models, among other tools, to translate these reduction goals into roadmaps and actionable strategies. For instance, to develop some of the past Carbon Plan strategies to 2050, BEIS used the UK MARKAL [3] and ESME cost-optimisation models [4]. UK MARKAL was also used for the Energy White Paper [5]. The UK TIMES (UKTM) model [6], a cost-optimisation energy model substituting MARKAL, is intensively used in policy making. Recently, UKTM was used by BEIS for the impact assessment of the 5th carbon budget proposed by the CCC [7].

Also internationally, cost-optimisation energy models have been extensively used to support national and regional energy planning. For instance, several TIMES (The Integrated MARKAL-EFOM System) - based optimisation models are being used by international organisations and governmental institutions for providing insights on how to reach national and international climate goals [8]. Similarly, IIASA's MESSAGE model is used to provide inputs for major international assessments and scenario studies, such as the Intergovernmental Panel on Climate Change (IPCC) and the Global Energy Assessment (GEA) [9]. Open source optimisation models, such as OSeMOSYS [10], are used to support planning in developing countries, for instance for electrification [11]. Numerous other optimisation models are being used and

* Corresponding author. UCL Energy Institute, University College London, 14 Upper Woburn Place, WC1H 0NN, London, UK.
E-mail address: f.fusonerini@ucl.ac.uk (F. Fuso Nerini).

[1] Formerly Department of Energy and Climate Change (DECC).

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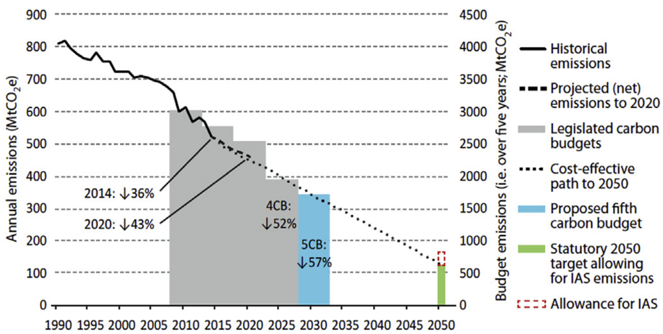

Fig. 1. UK's approved and under review carbon budgets [2].

developed around the world to support international and national energy strategies.

In fact, energy systems optimisation models provide valuable information regarding the pathway to reach the carbon reduction goals. Given a set of modelled assumptions, optimisation energy models can provide least-cost pathways for achieving the countries decarbonisation goals. That includes indications regarding the combination of energy technologies and their build rates needed to reach the set mitigation strategies. Also, those models can provide suggestions regarding the levels at which to set the carbon price for achieving the required decarbonisation targets.

Energy systems optimisation models generally assume perfect foresight for the modelled timeframe. That assumption is valuable for informing the formulation of energy policy goals with a long term view, but turns problematic when looking at an implementation phase. In fact, long-term perfect foresight energy models clash with the short-term nature of decision making. Governmental decisions are made with a limited decision horizon and imperfect knowledge of the long term developments of those decisions [12]. There is therefore a mismatch between the models used to inform national energy strategies and the actual decisions that are taken in the energy sector. Changing circumstances (e.g. governments, policies and international dynamics), future uncertainties and the high-capital requirements of energy projects often result in the adoption of short-term measures and in the postponement of long-term strategic decisions. Postponing the decisions, in turn, may result in the under-achievement of the decarbonisation targets due to the time requirements needed for the transformation of the energy system [13]. On the other hand, large-scale energy projects in the near-term can result in technology lock-ins for the future energy system (e.g. Ref. [14]).

To address these issues, optimisation models with a myopic foresight could be used in tandem with the respective perfect foresight model to better balance the short and medium term focus of decision making with the long term goals. In myopic optimisation models the foresight of the model is reduced to a limited number of years (also called as ‘myopic window’) that is shorter than the full timeframe studied. Therefore, decisions are re-iterated during the modelling period. This paper looks at myopic models obtained directly from technology-rich perfect foresight models. Myopic optimisation models obtained from perfect foresight models present a number of advantages. Such models can help linking normative (*should* happen) long term pathways with perfect foresight, to an implementation phase where planners are trying to understand what *will* happen as decisions are not intertemporally optimal. This can help policy-makers in moving from a target-setting perspective to an implementation phase in long term energy pathways. Additionally, myopic models obtained from technology rich perfect foresight models, having the same structure of the perfect foresight model, can be created with relatively little effort. For instance, TIMES-based models are by default clairvoyant (they optimise over the entire modelling horizon), though partial look-ahead (or myopic foresight) may also be employed[2] [15]. As a result, those myopic models have the same level of techno-economic detail of an energy systems optimisation model. Also, the myopic version of a model has considerably lower solution times than its perfect foresight version, possibly opening its expansion for analyses with higher spatial and temporal resolution with manageable computational times [16].

In literature, limited examples of usage of myopic and perfect foresight models in tandem are present. [12] developed a myopic version of the global MESSAGE model. Results from that study show how myopic foresight results in delayed investment decisions, stronger reliance on conventional energy sources and increasing difficulty in meeting energy demand cost-effectively. The paper argues that these results may better represent real world decision making than the results given by a model that optimises for a full century with perfect foresight. A version of that myopic model was also used in [17] to evaluate the influence of mid-century decarbonisation goals on the climate change outcomes in 2100. Additionally [18], modified the Global Energy Transition perfect foresight optimisation model for working myopically. [19] used that model in successive efforts to investigate the importance of induced technological change. The Brookhaven Energy System Optimisation Model has both a perfect foresight and a time-stepped version [20]. Additionally, numerous other myopic energy system models not obtained from technology-rich perfect foresight optimisation models exist in literature, such as SAGE [21], IKARUS [22] and BLUE [23]. Those models, however, have different applications compared to the models discussed in this paper: technology-rich optimisation models that can be used both in perfect foresight and myopic mode.

In fact, little literature is available regarding how myopic models obtained from long-term perfect foresight optimisation models could be used to provide policy-relevant insights, and no such applications exist for the UK[3].

To address that gap, this paper presents an application on the UK regarding how myopic and perfect foresight models can be used jointly to support energy planning. The Myopic UK TIMES model (My-UKTM) is presented and, through scenario analysis, used in combination with the perfect foresight UKTM to give policy-relevant insights for the achievement of UK's climate goals. Generalisable results show (a) the different investment decisions that myopia can cause, (b) the increase in costs of reaching decarbonisation goals due to myopia in the investment decisions, and (c) the effectiveness of carbon prices obtained from perfect foresight models in myopic investment environments.

2. Methodology

My-UKTM was developed starting from the UK TIMES energy systems model (UKTM) [6]. UKTM is a least cost optimisation model based on life-cycle costs (2010–2050) of competing technology pathways. It is a partial equilibrium model assuming rational decision making, perfect information, competitive markets and perfect foresight. It represents the entire UK energy system and it is

[2] This needs, however, some caution and reformulation of certain model constraints for the myopic model. For instance, cumulative cross-temporal constraints may cause problems when using the Myopic version of Times.

[3] It is out of the scope of this paper to include a systematic review of all energy models used in the UK. However, such a systematic review can be found at [36].