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# Linking a storyline with multiple models: A cross-scale study of the UK power system transition

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ABSTRACT

State-of-the-art scenario exercises in the energy and environment fields argue for combining qualitative storylines with quantitative modelling. This paper proposes an approach for linking a highly detailed storyline with multiple, diverse models. This approach is illustrated through a cross-scale study of the UK power system transition until 2050. The storyline, called *Central Co-ordination*, is linked with insights from six power system models and two appraisal techniques. First, the storyline is 'translated' into harmonised assumptions on power system targets for the models. Then, a new concept called the landscape of models is introduced. This landscape helps to map the key fields of expertise of individual models, including their temporal, spatial and disciplinary foci. The storyline is then assessed based on the cross-scale modelling results. While the storyline is important for transmitting information about governance and the choices of key actors, many targets aspired in it are inconsistent with modelling results. The storyline overestimates demand reduction levels, uptake of marine renewables and irreplaceability of carbon capture and storage. It underestimates the supply–demand balancing challenge, the need for back-up capacity and the role of nuclear power and interconnectors with Europe. Thus, iteratively linking storylines and models is key.



## 1. Introduction

Scenario exercises in energy, climate change and other technology- and environment-related studies are based on qualitative storylines, quantitative models or, often, on a combination of both (O'Neill and Schweizer, 2011; Alcamo, 2008; Wright et al., 2013; Swart et al., 2004; Kemp-Benedict, 2012; Guivarch et al., 2013). Storyline-based scenarios are expressed as qualitative narratives that in length may range from brief titles to very long and detailed descriptions. Examples of such scenarios are the Tyndall decarbonisation scenarios (Anderson et al., 2008; Mander et al., 2008), the CLUES decentralised energy scenarios (CLUES, 2012) or the energy visions in Switzerland (Trutnevyte et al., 2011, 2012a). The value of such storylines is threefold (Alcamo, 2008; Swart et al., 2004; Bowman et al., 2013; Weijermars et al., 2012; Schoemaker, 1993). First, when these storylines are developed through engagement of experts and stakeholders, they combine multiple perspectives and sources of expertise (Alcamo, 2008). They may lead to novel and creative ways of thinking about the future that go beyond modelling insights. Second, storylines are key for communicating the results of scenario exercises. Due to their qualitative nature, they are accessible

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and memorable to a broad range of audiences. When developed through stakeholder engagement, they are likely to be accepted, supported and used more often (Trutnevyte, 2014). Third, storylines represent a much broader picture than quantitative models and encapsulate a number of softer and subtler aspects, such as governance, institutional changes or energy-related behaviour, that cannot yet be modelled (Morgan, 2012). Storylines thus can form the input assumptions to the quantitative models and embed these models into a bigger picture (Hughes and Strachan, 2010; Hughes, 2013). However, storylines have two key limitations. First, storylines alone at times may be detached from reality as even experts can have a limited understanding of whether a particular storyline is feasible (Trutnevyte et al., 2011, 2012a; Trutnevyte, 2014). Second, as storylines are developed by combining multiple views of experts and stakeholders, they can be considered biased, not reproducible and not transparent (Alcamo, 2008; Lloyd and Schweizer, 2014). Despite the current research on formal techniques for developing better storylines (Schweizer and Kriegler, 2012; Girod et al., 2009; Scholz and Tietje, 2002; Weimer-Jehle, 2006), these limitations still remain.

Quantitative models-based scenarios are produced by a single or multiple models, such as in the ADAM (Edenhofer et al., 2010), Energy Modelling Forum (Weyant et al., 2006), Low Carbon Society modelling (Strachan et al., 2008) and NEEDS (Kypreos and Van Regemorter, 2006) projects. The key strength of these scenarios is that they satisfy the inherent need for numeric values in the technology- and environment-related fields (Alcamo, 2008; Trutnevyte et al., 2011; Weijermars et al., 2012; Trutnevyte, 2014). Models are based on the empirical data, physical laws, principles of economics and state-of-the-art knowledge about the technology and environmental processes. Thus, peer-reviewed, transparently documented models provide rigorous, internally consistent scenarios. However, models can address only a limited number of aspects, such as technology, economic, and environmental aspects. But they still have difficulty in capturing the afore-mentioned softer and subtler aspects. The research priorities are towards developing more detailed models and including softer aspects, such as behaviour and governance, into models (Hughes and Strachan, 2010; Hourcade et al., 2006). Yet, even better models alone can hardly offer the breadth and engaging nature of the storyline-based scenarios. For example, the models cannot picture organisational and institutional change needed to deliver a wanted transition, even if these elements are important for decision makers to envision and manage this transition.

In light of these strengths and weaknesses of storylines and quantitative models, state-of-the-art scenario studies argue for combining them (O'Neill and Schweizer, 2011; Alcamo, 2008; Wright et al., 2013; Swart et al., 2004; Kemp-Benedict, 2012). In order to complement the models, storylines can reflect such aspects, like (i) exogenous context in which the modelled system is embedded into, (ii) exogenous modelling assumptions, such as drivers for change, or (iii) aspirational targets for the future system. Many recent scenario exercises already have the elements of both storylines and models: storylines include numbers, while modelling outputs are described in short qualitative narratives. Several scenario exercises explicitly combine the storylines and the quantitative models in an iterative manner (Guivarch et al., 2013; Trutnevyte et al., 2011, 2012a, 2012b; van Vuuren et al., 2012; Kriegler et al., 2012). Examples of these include key international scenario exercises: the integrated climate change scenarios of the Intergovernmental Panel of the Climate Change (Nakicenovic and Swart, 2000; van Vuuren et al., 2014), the scenarios of ecosystem services in the Millennium Ecosystem Assessment (Carpenter et al., 2005) and of the global environment in the Global Environmental Outlook (UNEP, 2012).

Despite the fact that the combination of storylines and quantitative models has emerged as an established practice in the technology- and environment-related fields (O'Neill and Schweizer, 2011; Alcamo, 2008; Wright et al., 2013; Swart et al., 2004; Kemp-Benedict, 2012; Guivarch et al., 2013), existing literature runs short in providing methodological insights for how to link detailed storylines, which are developed through stakeholder and expert engagement, with multiple quantitative models. First, if the storylines are very detailed, then numerous additional assumptions are needed to 'translate' them into model parameters. Second, multiple diverse models may be needed to model detailed storylines with various spatial and temporal foci, disciplinary perspective (technical feasibility, economic or environmental appraisal), model objective, and the parts of the system addressed. This diversity is valuable because the storylines can be addressed from multiple angles and across scales, but it is challenging to relate such diverse models to each (Zurek and Henrichs, 2007). Thus, a new approach has to be developed for linking detailed storylines with multiple, cross-scale models, which have different spatial, temporal and disciplinary foci. This paper proposes such an approach. There is a growing number of interdisciplinary projects in energy, climate change and other technology- and environment-related studies. It can be expected that many of these projects will attempt to develop cross-scale scenarios by linking storylines with multiple models and will require such an approach.

The proposed approach is illustrated with the cross-scale analysis of the UK power system transition until 2050 as a part of the Realising Transition Pathways (RTP) consortium project. A detailed storyline, called the *Central Co-ordination*, was developed in the preceding Transition Pathways project (Hammond and Pearson, 2013; Foxon et al., 2010; Foxon, 2013) and is used for the cross-scale analysis with six quantitative power system models and two quantitative appraisal techniques. The idea for this analysis arose from discussions at RTP consortium workshops. The authors of this paper took the analysis forward and its results will be an input to further development of the consortium's research.

This paper is laid out as follows: Section 2 proposes a general methodological approach; Section 3 gives an example of linking the *Central Co-ordination* storyline with eight RTP models, present and discusses the findings; Section 4 discusses the general approach; and Section 5 concludes.

## 2. Proposed approach for linking storylines with multiple models

This section describes the proposed process (Fig. 1) of linking a detailed storyline with the insights from multiple diverse models. First of all, one of the biggest challenges in cross-scale scenario studies is ability to systematically combine insights from multiple cross-scale models. Understanding and