Energy Strategy Reviews 13-14 (2016) 67–76

Contents lists available at ScienceDirect

Energy Strategy Reviews

journal homepage: www.ees.elsevier.com/esr

Review

Limiting global warming to 2 °C: What do the latest mitigation studies tell us about costs, technologies and other impacts?

Olivier Dessens [a, *], Gabrial Anandarajah [a], Ajay Gambhir [b]

[a] UCL Energy Institute, University College London, Central House, 14 Upper Woburn Place, London WC1H 0NN, UK
[b] Grantham Institute, Imperial College London, Exhibition Road, South Kensington, London SW7 2AZ, UK

A R T I C L E I N F O

Article history:
Received 28 April 2015
Received in revised form
19 May 2016
Accepted 11 August 2016

Keywords:
Mitigation scenarios
2 °C target
Review paper

A B S T R A C T

There is now a wealth of model-based evidence on the technology choices, costs and other impacts (such as fossil fuel demand) associated with mitigation towards stringent climate targets. Results from over 900 hundred scenarios have been reviewed in the latest Intergovernmental Panel on Climate Change Assessment Report (IPCC AR5) including baseline scenarios under which no mitigation action is taken, as well as those under which different limits to global warming are targeted. A number of additional studies have been undertaken in order to assess the implications of global mitigation action. The objective of the paper is to provide a concise overview and comparison of major input assumptions and outputs of recent studies focused on mitigating to the most stringent targets explored, which means around the 2 °C level of global average temperature increase by 2100. The paper extracts key messages grouped into four pillars: mitigation costs, technology uncertainty, policy constraints, and co-benefits. The principal findings from this comparison are that, according to the models, mitigation to 2 °C is feasible, but delayed action, the absence or limited deployment of any of a number of key technologies (including nuclear, CCS, wind and solar), and limited progress on energy efficiency, all make mitigation more costly and in many models infeasible. Further, rapid mitigation following delayed action leads to potentially thousands of idle fossil fuel plants globally, posing distributional and political economy challenges.

Contents

* Corresponding author.
E-mail address: o.dessens@ucl.ac.uk (O. Dessens).

http://dx.doi.org/10.1016/j.esr.2016.08.004

1. Introduction

In March 1994 the UNFCCC entered into force and recognised that it is necessary to stabilize atmospheric greenhouse gas (GHG) concentrations at a level that would prevent dangerous anthropogenic interference with the climate system [1]. A consensus between stakeholders in Copenhagen in 2009 [2] concluded that to comply with this goal the warming achieved should be limited to below 2 °C compared with preindustrial times. In 2015, the Paris Agreement, to the surprise of many, included text on limiting warming to "well below" 2 °C and to "pursue efforts" to limit it to less than 1.5 °C [3].

There has been a great deal of analysis to consider whether the mitigation commitments (or 'Copenhagen pledges') made to date are consistent with achieving a 50:50 chance of limiting the surface temperature rise to 2 °C (UNEP objective [4]) with the conclusion that the scenarios including these near term pledges are not least-cost optimal pathways [5]. Many authors argue that with further ambitious global policies, the target is reachable ([6–8]), although others suggest it could be too late, as we are already locked into a fossil based energy system under the weaker-than-optimal "Copenhagen pledges" ([9,10]).

Part of the reason for this dichotomy of views is that the complexity of the climate system, as well as the extent of uncertainties embedded in it, gives rise to a wide variety of possible emission trajectories that are consistent with a 2 °C temperature rise. The additional uncertainties and complexities with modelling the global energy system lead to an even wider range of views on whether, or how, such cuts in emissions are possible.

This paper reviews recent major studies that analysed the latest GHG emission pathways that are compatible with limiting average global temperature rise to levels close to 2 °C by the end of the 21st century. The objective of this paper is to provide a concise, systematic summary of key metrics on climate change mitigation to scholars, by extracting key messages under the following four pillars: mitigation costs (Section 4), technology uncertainty (Section 5), policy constraints (Section 6), and co-benefits (Section 7).

In Section 2 we first present the studies covered and models and assumptions that have been used in the selected studies covered. In Section 3 we examine the global pathways to comply with targeted temperature rise and survey the technologies needed as well as the implied rates of deployment for a number of key electricity decarbonisation technologies. In Section 4 we consider the costs and feasibility of the target. In Section 5 we study the target feasibility under restricted availability of specific technologies. In Section 6 we focus on the effects of delay in beginning global mitigation action on the pathways, the technological development and the costs induced by the delay. In Section 7 we discuss the wider impacts (particularly co-benefits) of mitigation, as well as suggesting areas worthy of further investigation. Section 8 concludes by highlighting the most policy-relevant points emerging from these studies.

2. Models and assumptions used for the different studies included

2.1. Studies covered

A number of recent studies and model inter-comparisons are included in the analysis: Energy Modelling Forum 27 Study[1] (*EMF27*), Low climate IMpact scenarios and the Implications of required Tight emission control Strategies[2] (*LIMITS*), Assessment of Climate Change Mitigation Pathways and Evaluation of the Robustness of Mitigation Cost Estimates[3] (*AMPERE*), Global Energy Assessment: Toward a Sustainable Future[4] (*GEA*), The Roadmaps towards Sustainable Energy futures[5] (*RoSE*) and TIAM-UCL global modelling studies: The CCC 2013 report[6] and UKERC Global study 2014[7] (*TIAM-UCL*) and the RCP 2.6 scenario[8] (RCP2.6). In addition to these studies, the evaluations of two large assessment reports are also used in this paper: Climate Change 2014, Mitigation of Climate Change[9] (*IPCC 2014*) and The UNEP Emissions Gap Report 2012[10] (*UNEP 2012*). The assessment reports compile and compare in detail and at length the results from different studies, most of them included in the list above. These results include reference scenarios (no mitigation policies) and different levels of climate targets from 1.5 to 4 °C – although it should be noted that the majority of the most stringent scenarios are focused on 2 °C, with very few achieving close to 1.5 °C.

The results and conclusion of these major studies have been widely published in peer-reviewed papers as well as scientific and assessments reports. However, to our knowledge a comprehensive yet concise review of the key features of the model inputs and outputs has not yet been published. . This review paper focuses only on the 2 °C target compared to the reference pathways, to reflect the policy-relevance of this target to international negotiations; it integrates the key components and discusses the main conclusions of these research studies.

For the specific target of 2 °C, the majority of mitigation scenarios assessed over recent years have focused on GHG pathways broadly consistent with achieving atmospheric concentrations of GHGs between 450 ppm and 500 ppm [11]. However, as already discussed, there remains uncertainty in the relationship between atmospheric GHG concentrations and long-term temperature changes, broadly speaking the 450 scenarios are aimed at achieving an even or better chance of limiting surface warming to 2 °C.

2.2. Models included in this review

The models incorporated in the major studies analysing the transition pathways to the 2 °C target are listed in Table 1, along with some of their characteristics. As seen in the last column of the table, some models have been involved in more than one study. The studies examined assumed a range of values for global population increase and economic growth, with a higher variation noted in the

[1] https://emf.stanford.edu/projects/emf-27-global-model-comparison-exercise.
[2] http://www.feem-project.net/limits/.
[3] http://ampere-project.eu.
[4] http://www.globalenergyassessment.org/.
[5] http://www.rose-project.org.
[6] http://www.theccc.org.uk/wp-content/uploads/2013/11/TIAM-UCL_global_energy_modelling_2013.pdf.
[7] http://www.ukerc.ac.uk/support/UK+Energy+in+a+Global+Context+Ext&structure=Research.
[8] http://tntcat.iiasa.ac.at:8787/RcpDb/dsd?Action=htmlpage&page=welcome.
[9] http://www.ipcc.ch/report/ar5/wg3/.
[10] http://www.unep.org/pdf/2012gapreport.pdf.