Chapter 1
Introduction

Sven Teske and Thomas Pregger

Abstract Brief introduction to the UNFCCC Paris Agreement and its main goals, followed by the project background, motivation and objectives. Presentation of the specific research questions for the energy and climate scenario development. Short overview of published 100% renewable energy scenarios and the main differences between those scenarios and the newly developed 1.5 °C and 2.0 °C scenarios presented in the book. Overview about the basic assumptions in regard to technology preferences in future energy pathways. Discussion of the advantages and limitations of scenarios in the energy and climate debate.

UNFCCC Paris Agreement, Article 2:

1. *This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change,in the context of sustainable development and efforts to eradicate poverty, including by:*

   (a) *Holding the increase in the global average temperature to well below 2.0 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;*
   (b) *Increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emission development, in a manner that does not threaten food production; and*

(continued)

S. Teske (✉)
Institute for Sustainable Futures, University of Technology Sydney, Sydney, NSW, Australia
e-mail: sven.teske@uts.edu.au

T. Pregger
Department of Energy Systems Analysis, German Aerospace Center (DLR), Institute for Engineering Thermodynamics (TT), Pfaffenwaldring, Germany
e-mail: thomas.pregger@dlr.de

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> (c) *Making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development.*
>
> 2. *This Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.*

The Paris Climate Agreement aims to hold global warming to well below 2.0 °C and to "pursue efforts" to limit it to 1.5 °C. To accomplish this, countries have submitted Intended Nationally Determined Contributions (INDCs) outlining their post-2020 climate actions (Rogelj et al. 2016). The aim of this research is to develop practical pathways to achieve the Paris climate goals in an economically feasible and sustainable matter.

The study described in this book focuses on changing the ways in which humans produce energy, because energy-related CO_2 emissions are the main driver of climate change. The analysis also considers the developmental pathways of non-energy-related emissions and mitigation measures because it is essential to address their contributions if we are to achieve the Paris climate change targets. The analysis considers options or 'scenarios' for the transition to net zero emissions across all sectors that allow unnecessary techno-economic, societal, and environmental risks to be avoided.

Scenario studies are an important way of linking expected or assumed anthropogenic activities and their resulting emissions with environmental effects, such as global warming. They also provide important insights into these techno-economic, societal, and political options and their various effects. Therefore, they are widely used to analyse possible carbon emission pathways, to guide decision-makers, and to motivate or justify interventions and developments. However, comprehensive, transparent, and robust results and conclusions are required as the bases for such decision-making. Ideally, this information will come from scenario studies that investigate a broad range of possible conditions and available options. Such studies must adopt a holistic approach and integrate comprehensive state-of-the-art background knowledge, including about the impacts of sectoral and technological changes, the influence of market developments, and the effects of certain pathways.

Existing global scenario studies do not provide a comprehensive view of the possible development pathways and technological options required to achieve these ambitious climate targets. Each study usually provides a few selected pathways, representing a narrow range of possible energy futures. One reason for this is that most scenario models are based on objective cost-optimizing functions, which overemphasize the cost efficiency based on uncertain cost assumptions. Another reason is that disruptive developments are not usually considered in scenario narratives. The history of scenario-based systems analysis is littered with many examples of misleading and fallacious 'optimized' scenario pathways and derived policy recommendations (see e.g., Mai et al. 2013; Mohn 2016).

Furthermore, in most existing 2.0 °C and 1.5 °C scenarios, achievement of the climate targets is based on technologies that have significant, and to some extent unknown, disadvantages. These technologies include nuclear power generation, carbon capture and sequestration, and geoengineering (see e.g., Rogelj et al. 2018; Kriegler et al. 2015). Such scenarios involve considerable risk. Moreover, the reader is usually given only limited access to the model assumptions and results, and therefore has limited information about the transparency and traceability of the factors that influence these model-based analyses and the conclusions drawn from them.

The primary objective of this report is to provide a holistic picture of what will be involved in the transition to 100% renewable energy. This report examines power, heat, and fuel supplies on a global scale. Its main focus is on the role of efficiency and renewable energies. We aim to contribute a different and complementary view of the global transition to renewable energy. We provide two exemplary development pathways for each of the 10 regions of the world. We consider both pathways to be achievable, based on the current state of knowledge, and both are consistent with the "well below 2.0 °C" climate target.

In addition to scenario building, we assess the major economic and infrastructural implications of the two pathways in comparison with a 5.0 °C 'reference' scenario based on the International Energy Agency (IEA)'s Current Policies scenario published in the *Word Energy Outlook 2017* (IEA-WEO 2017). We do not claim that our scenarios are optimal with regard to the economy or society. We want to provide a transparent basis for the further concretization and development of energy system transformation, and to demonstrate the enormous challenges we face and the need for action. In contrast to most other studies, we have excluded options with large uncertainties about the economic, societal, and environmental risks associated with technologies such as nuclear power, unsustainable biomass use, CCS, and geoengineering.

Another important objective is to combine bottom-up energy scenarios with non-energy greenhouse gas (GHG)-mitigation scenarios to construct a complete picture of possible climate mitigation pathways and the contributions of the illustrated strategies to achieving the Paris targets. Land-use changes and emissions of other GHGs and aerosols are the focus of this analysis. Finally, GHG concentrations, radiative forcing, and the implications of global mean temperature and sea-level rises are modelled by applying a feasible model with reduced complexity, which is frequently used for integrated assessment models, as the climate model.

Any scenario building on a global scale must severely simplify the complex transition processes and their interrelations. The introduction of different new technologies occurs under very different conditions and at different scales, and an in-depth analysis is required in each case to identify the optimal or feasible solutions. Global governance will also be required for the fast and deep decarbonisation of the world's energy systems, especially in relation to carbon pricing and efficiency standards.

However, all perspectives need a common understanding of what is required to meet the ambitious Paris climate targets. We believe that the results of this study will contribute to such a common understanding and will demonstrate how urgent is the need to act.

The 2.0 °C Scenario represents a far more likely pathway than the 1.5 °C Scenario. Whereas the 2.0 °C Scenario takes into account unavoidable delays due to political, economic, and societal processes and stakeholders, the 1.5 °C Scenario requires immediate action. Under the 1.5 °C Scenario, efficiency measures and renewable energy options must be deployed, and the further development of energy services must be limited and constrained. Furthermore, for the 1.5 °C Scenario to be achievable, it will be essential for developing countries to avoid inefficient technologies and behaviours.

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