A SURVEY OF GLOBAL AND REGIONAL ENERGY TRANSITION SCENARIOS

Pao-Yu Oei, TU Berlin & DIW Berlin, +49 30 314 75846, pyo@wip.tu-berlin.de
Claudia Kemfert, DIW Berlin, ckemfert@diw.de
Konstantin Löffler, DIW Berlin, +49 30 314 25139, kloeffler@diw.de
Thorsten Burandt, TU Berlin & DIW Berlin, +49 30 314 25196, thb@wip.tu-berlin.de

Overview

Upon signing the Treaty of Paris in 2015, virtually all nations worldwide committed to limiting global warming to below two degrees. However, there is no agreement on the regional distribution of the remaining CO_2 budget to meet the global target. Projecting regional scenarios in line with global climate targets therefore always imply assumptions regarding the development in other regions. This includes technical assumptions (e.g. learning rates) as well as macroeconomic trends (e.g. economic growth) (IEA 2016).

Methods

The global energy system model GENeSYS-MOD by Löffler et al. (2017) is based on the open-source model family OSeMOSYS (Open-Source Energy Modelling System) originally created by Howells et al. (2011). The model is a linear optimization program that takes into account a number of technological and economic constraints and determines a cost-optimized technology mix for the energy system. The discounted total costs for production plants, storage, and other flexibility options consist of capital and operating costs plus a residual book value at the end of the period of analysis. The model is divided into various time slices, and the energy demand from various sectors must be met constantly. By defining additional requirements, such as on reserve capacities or emissions, regulatory or political conditions, such as climate policy targets, can be taken into consideration.
The model maps various conventional and renewable energy sources to be used in the electricity, transportation, and heat sectors. Additional sensitivity analyses of the most important drivers are being used to test for the robustness of the results. This is of special importance as past cost projections for photovoltaics and electricity storage showed that even optimistic forecasts of cost trends were typically topped in reality due to cheaper production in a growing market and falling material costs.
Depending on the subject of study, regions and time-slices are aggregated in each model run. In order to make the best of the limited computing capacity available, users must trade off detail and scope. For example, aggregation makes it possible to capture broad spatial and temporal relationships. On the other hand, some specific requirements for integrating renewable energy into the energy system can only be considered in stylized form. This paper therefore compares the results of a global model run with 10 nodes with regional concentrated case studies of Europe, China and India.

Results

The results of a global energy system model indicate that the cheapest solution for meeting the global climate target is a combination of renewable energy and energy storage systems. The regional distribution of renewable energies hereby varies, depending on local (weather) conditions (see figure 1). A main driver for the distribution within the scenarios is different assumptions for learning rates for photovoltaics. Higher costs for photovoltaics result in additional investments in wind offshore capacities (see figure 2). Slower cost reductions for batteries, on the other hand, have only limited impact on the distribution of renewables. However, overall system costs in these scenarios are higher to account for the needed battery installments.
The spatial aggregation of countries into ten regions in the global model run abstracts from possible regional bottlenecks. In reality, locations with a reliable supply of renewable energy must not necessarily coincide with the locations where demand is concentrated. The global model run assumes unlimited transmission capacity within the ten model regions; ignoring technological issues regarding optimal grid dimensioning and management. A spatially differentiated representation of Europe, China and India results in higher needed expansion rates for renewable energy to meet the climate targets and therefore also slightly higher costs.

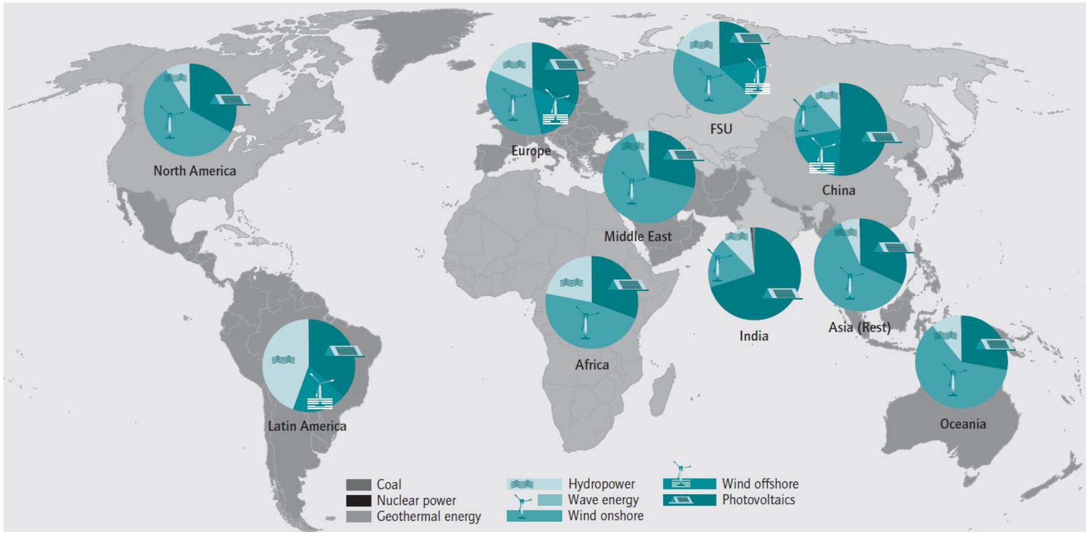

Figure 1: Regional electricity generation in the year 2050 in a 2° scenario; Source: Kemfert et al. (2017).

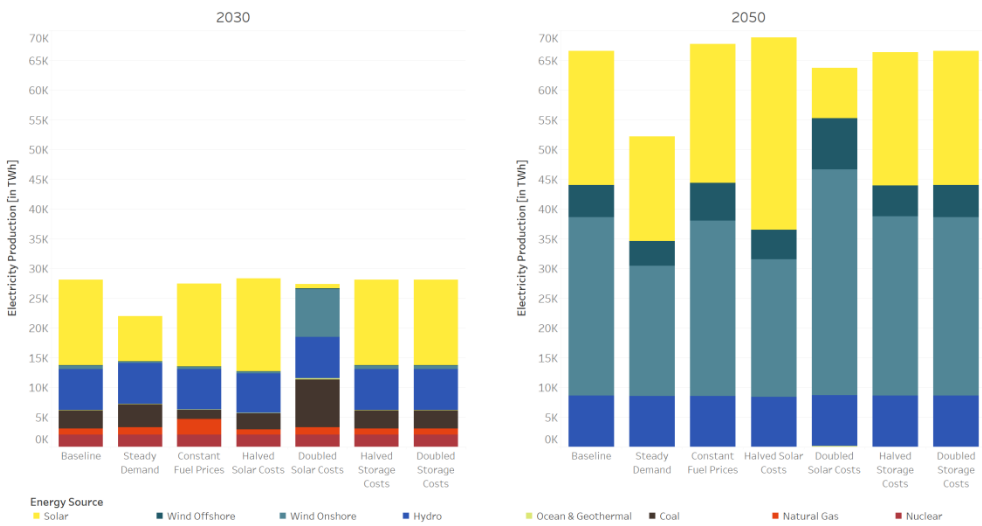

Figure 2: Results of the sensitivity analyses in a global 2° scenario; Source: Own illustration.

Conclusions

The model optimizes the expansion pathways for different technologies by minimizing the global costs of supplying energy for electricity, heat, and transportation. The sensitivity analyses of these results show uncertainties regarding the distribution of renewables as well as overall system costs. All results, however, indicate that renewable technologies in combination with electricity storage are the cheapest option to meet global as well as regional climate targets.

References

Howells, Mark, Holger Rogner, Neil Strachan, Charles Heaps, Hillard Huntington, Socrates Kypreos, Alison Hughes, et al. 2011. "OSeMOSYS: The Open Source Energy Modeling System: An Introduction to Its Ethos, Structure and Development." *Energy Policy*, Sustainability of biofuels, 39 (10):5850–70. https://doi.org/10.1016/j.enpol.2011.06.033.

IEA. 2016. *World Energy Outlook 2016*. Paris: OECD/IEA.

Kemfert, Claudia, Thorsten Burandt, Karlo Hainsch, Konstantin Löffler, Pao-Yu Oei, and Christian von Hirschhausen. 2017. "Nuclear Power Unnecessary for Climate Protection—there Are More Cost-Efficient Alternatives." *DIW Economic Bulletin* 7 (48):498–506.

Löffler, Konstantin, Karlo Hainsch, Thorsten Burandt, Pao-Yu Oei, Claudia Kemfert, and Christian von Hirschhausen. 2017. "Designing a Model for the Global Energy System—GENeSYS-MOD: An Application of the Open-Source Energy Modeling System (OSeMOSYS)." *Energies* 10 (10):1468. https://doi.org/10.3390/en10101468.