Scenarios for Future Trade Flows of Energy Technologies

Jonas Eschmann, Institute of Networked Energy Systems, German Aerospace Center (DLR), +49-711-6862-8519, jonas.eschmann@dlr.de
Marlene O'Sullivan, Institute of Networked Energy Systems, German Aerospace Center (DLR)
Thomas Baldauf, Institute of Networked Energy Systems, German Aerospace Center (DLR)

Overview

The upcoming global energy transformation process towards climate neutrality requires a massive investment in technologies and their production methods. Many countries regard this necessity as an enourmous opportunity for their industrial development and strive to achieve favorable market position in these technologies. Especially new technological developments such as the need for green hydrogen spur the ambiton of countries to become a lead market [1] resulting in ambitious national goals for the development of this technology [2]. At the same time the current war in Ukraine shows the vulnerability of countries regarding their import dependency in the case of low diversification. Therefore this paper wants to provide an approach for deriving trade scenarios for energy technologies. The approach uses energy scenarios as well as trade data and the methodology of product spaces.

Methods

We begin by defining a list of critical technologies in the context of the global energy transition. This obviously includes technologies such as wind turbines and photovoltaic modules, but also electrolyzers, Fischer-Tropsch-, methane- and methanol- reactors. Following recent literature, we assign input vectors to each technology within the GECO [3] input-output scheme. In addition, specific product group baskets (Technology Spaces) are assigned to the technologies based on the Harmonised System (HS-6) of the UN-Comtrade Database. While established technologies such as photovoltaic modules and wind turbines have been assigned to their own HS-Code since 1996, no clear assignment is yet possible for many technologies that are still in transition from research to application. For these technologies, without a specific HS-Code, the following method has been established: First, we break down, for example, a Fischer-Tropsch plant into its components, such as pumps, compressors, and reactor vessels. We then calculate the Product Spaces of these individual parts to identify "related" product groups (see Principle of Relatedness [4]). Subsequently, the respective Product Spaces are weighted and put together into a Technology Space. Here, on the one hand, the Product Space distance to the central product group and, on the other hand, their weighting within the component list, which is determined by the investment cost distribution of the synthesis plant, are taken into account.

The second part of our analysis concerns the derivation of necessary imports to different countries. For this purpose, the required capacity addition (to achieve climate neutrality) is taken from a global energy scenario [5] and multiplied by the specific investment costs of the individual technologies. Based on literature a tradable and a non-tradable share is defined [6]. The import quota for each country is first calculated using the weighted import quota of the economic sectors involved via the input-output tables [3]. To account for country-specific production capabilities and spezialisation, in a second step, this more general import quota is refined with a correction factor resulting from the revealed comparative advantages within the previously calculated Technology Spaces. Finally, one or more exporting trading partners are assigned to the derived import demands of the countries. The distribution is based on the current trade flows within the calculated Technology Space and takes into account trends of this trade flows from the last 5 years (2016-2021). To account for the dynamic evolution of trade flows, this "trend factor" is weighted more heavily for later decades, while the static distribution of today's trade flows has a greater impact on the near future.

Results

The global market value traded internationally for the scenario assessed is 10,5 trillion US-$2020, cumulatively throughout 2070. While wind and photovoltaic technologies have the largest shares (63% and 31%, respectively), the market value share for electrolysers is much smaller (5.5%). Regarding the future global market shares of electrolysers, however, there is a much higher uncertainty as in comparison to established renewable energy technologies. Therefore, in the following we focus primarily on the future trade flows of electrolysers.

The left side of Figure 1 shows the tradable investment demand in electrolysers for the four countries with the highest investment demand worldwide. It has to be noted, that as the EU is divided into its individual member states, it does not have a place among the largest four. On the left side of Figure 1, it can be seen that the U.S. is starting to invest in electrolysers significantly earlier, but still has a permanent import requirement of 20-25%. India has the second highest investment needs, which will mainly occur in the years between 2050 and 2070.

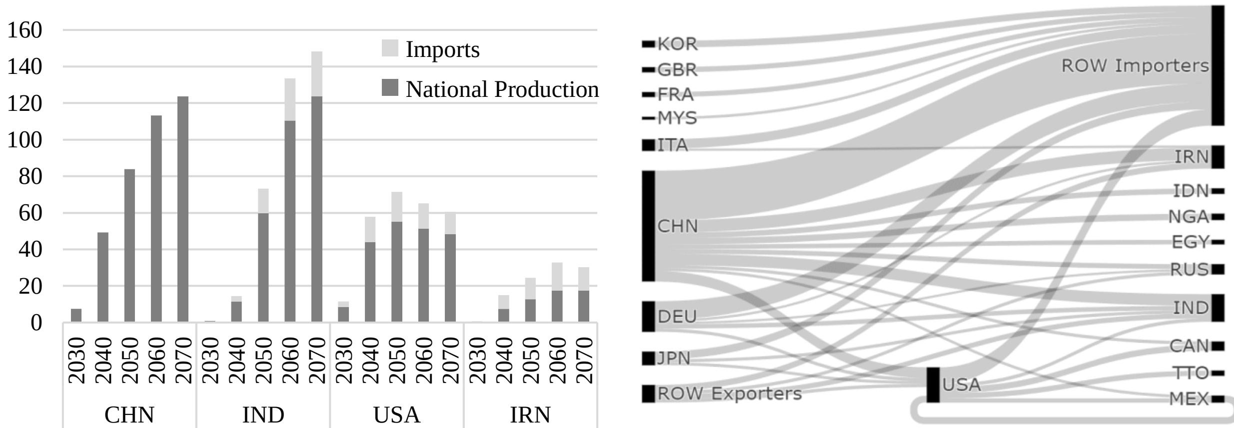

Figure 1: left: Investment demand for electrolysers covered by national production and imports of selected countries in Billion US-$$_{2020}$ sorted by decades (the year numbers refer to the preceding decade), right: International trade flows above 4 billion US-$$_{2020}$ of electrolysers between 2022-2070 (accumulated).

India already has a remarkably good position within the Technology Space for electrolysers, resulting in a comparatively low import share of 17 %. The production capacities and specializations that already exist in the Technology Space of electrolysers indicate that China may be able to meet its future electrolyser technology demands completely by itself, and will also be able to take the leading market position with a global market share of 35% (right side of Figure 1). The U.S. with a market share of 12 %, Germany (11 %), Japan (5,7 %) and Italy (5,4 %) are following. Further insights can be gained by comparing exports with local investment needs. While China exports only 35% of its production, Italy and Germany export a significantly larger share of around 63% of their production. The USA occupies a notable position in terms of intra-industry trade. With an export share of 25% of its production and a simultaneous import share of 22% of its needed investment, this economy has the strongest global trade integration in the Technology Space under consideration.

For illustration purposes, on the right-hand side of Figure 1 only trade flows above four billion US-$$_{2020}$ have been plotted. As a result, it appears as if individual countries cover their technology needs exclusively via one trading partner. Even though, this is not entirely the case, the impression of a strong one-sided dependence on imports remains true, which may pose a threat to the sovereignty of these countries.

Conclusions

The analysis shows that the major share of investment that is required for the transition of the energy system will be provided locally. Regarding the global trade of electrolysers for the production of green hydrogen, a number of countries have good prospects to provide a significant share of their production to the global market.. The analysis also shows that geopolitical considerations are important not only in the trade of energy itself but also in the trade of energy technologies. In order to maintain their sovereignity at all times, state leaders should be aware of their trade dependencies regarding key technologies for the energy transition.

The methodology applied in this paper has proven to be feasible for the development of trade scenarios. However, further research should be done in regard to the integration of additional indicators such as those described by the lead market theory.

References

[1] Beise-Zee, Marian und Thomas Cleff (2004), Assessing the Lead Market Potential of Countries for Innovation Projects, Journal of International Management Vol. 10, No. 4, 453-47

[2] IEA (2021), Global Hydrogen Review 2021, IEA, Paris

[3] Vandyck, Toon; Garaffa, Rafael; Weitzel, Matthias; Rey, Luis; Wojtowicz, Krzysztof; Tamba, Marie (2021): Baseline GECO 2021. European Commission, Joint Research Centre (JRC)

[4] Hidalgo, C.A. Economic complexity theory and applications. Nature Reviews Physics 3, 92–113 (2021)

[5] Keramidas, K., Fosse, F., Díaz Vázquez, A., Dowling, P., Garaffa, R., Després, J., Russ, P., Schade, B., Schmitz, A., Soria, Ramirez, A., Vandyck, T., Weitzel, M., Tchung-Ming, S., Diaz Rincon, A., Rey Los Santos. L., Wojtowicz, K.. Global Energy and Climate Outlook 2021: Advancing towards climate neutrality, EUR 30861, Publications Office of the European Union, Luxembourg, 2021

[6] O’Sullivan, M.; Edler, D. Gross Employment Effects in the Renewable Energy Industry in Germany—An Input–Output Analysis from 2000 to 2018 (2020): https://doi.org/10.3390/su12156163