On the techno-economic benefits of a Global Energy Interconnection

Christian Breyer [1]*, Dmitrii Bogdanov, Arman Aghahosseini, Ashish Gulagi and Mahdi Fasihi*

Executive summary

1. Motivations underlying the research

The global energy supply in the coming decades is framed by several challenges. Climate change mitigation requires defossilisation of energy supply by mid-21st century to a net-zero greenhouse gas (GHG) emission society. Renewable electricity has been utilised and expanded for more than 100 years for the case of hydropower to achieve an installed capacity base of more than 1100 GW for an excellent energy return on energy invested characteristics, based on highest technical lifetimes of all power generating technologies. Since the 2000s, two variable renewable electricity (VRE) technologies, solar photovoltaics (PV) and wind energy, have received very high growth rates of about 46% and 22% per year, respectively, leading to a total installed capacity of about 500 GW and 593 GW, respectively, by the end of 2018. The advantage of these two major VRE technologies is their enormous scalability and huge resource potential, exceeding total global energy demand by orders of magnitude, particularly for the case of solar energy. The achieved cost level of about 20-25 €/MWh and 25-30 €/MWh for solar PV and wind energy, respectively, at very good sites, brings both technologies to the forefront as a major source of energy in the 21st century. A future energy system will be mainly built on solar and wind energy and thus will have high shares of renewables in the energy system.

The outline of the future energy system is based on solid fundamental insights and respecting sustainability guardrails. However, it is not yet discussed in broad what may be the optimised power system structure. Two poles are scientifically discussed and can be summarised as the Super Grid approach and a decentralised Smart Grid approach. The paper features the Super Grid approach from major regions and continents to a global perspective, so that the potential of a global energy interconnection can be discussed.

2. A short account of the research performed

A global energy interconnection has been suggested first by Buckminster Fuller 1971. In 1992, the Global Energy Network Institute shifted the view for utilising renewable energy sources. Kurokawa linked the concept of a global grid to the abundant global solar energy resource available in the 2000s. Liu further lifted the discussion on global energy interconnection in recent years.

Most of the studies outline the energetic benefits of the Super Grid approach, but often lack in comparative economic analyses showing that a Super Grid approach would lead to lower energy system cost than a decentralised energy system. The team of Breyer showed in recent years that major regions in the world would benefit from a Super Grid approach.

The Super Grid results clearly reveal the enormous benefits of the Super Grid approach. The most remarkable research result is the cross-border electricity trade from the highly decentralised approach to the Super Grid approach of 17%. Consequently, it can be concluded that the cost optimised power system shows mainly decentralised characteristics which are further supported

1 Corresponding author. christian.breyer@lut.fi

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by centralised elements of a Super Grid to achieve a least cost solution, which leads to the concept of a Super Smart Energy System.

The main research question of this paper is ‘What are the techno-economic benefits of integration of the major regions to super region clusters or an integrated global energy interconnection’. The hypothesis is that a further integration benefit is observed from a two-level integration of sub-national regions to countries and major regions. Results indicate that the economic optimum for geo-spatial power sector integration can be achieved on the level of major regions. A global energy interconnection may be still beneficial, but the respective electricity trade can be expected to be more within the major regions.

This may lead to the conclusion that the largest power system integration benefit may be already realised in interconnecting the sub-national regions to 23 global regions, whereas a further level of interconnection does not lead anymore to substantial cost reduction. A global energy interconnection does not lead to a global uniform cost level, since the power line interconnection adds to the cost, which requires respectively lower electricity generation for an overall cost reduction. In addition, first research insights are available for global energy interconnection of electricity-based products, which do not need power transmission interconnections for global trade.

Another effect requires more attention in global energy interconnection research: competition of long-distance power transmission with very low-cost electricity generation and low-cost storage technologies. Cost decline of solar PV is linked to stable and high learning rates for PV modules and systems. Respective learning rates for battery storage and electrolysers are also above average. The relative cost decline of power transmission technologies are much lower and not comparable to the above mentioned technologies. These trends lead to a relative decline in competitiveness of long-distance power transmission and more locally and regionally structured energy systems.

3. Main conclusions and policy implications of the work

Existing research clearly finds economic benefits of a power system integration of decentralised regional systems for a major region and on a continental level, whereas for clusters of major regions a global electricity interconnection cannot generate comparable additional benefits. This study represents the very first results of a global energy interconnection, including 9 major regions and 23 regions, calculated in full hourly resolution and for achieving highest levels of sustainability.

Comprehensive global energy interconnection research should enlarge the scope of energy from electricity to all relevant energy carriers of a sustainable future energy system, namely synthetic hydrocarbons (SNG, Fischer-Tropsch liquid fuels), methanol, ammonia and liquefied hydrogen. A high global granularity of geo-spatial structuring may reveal the relative range of economic benefits generated by power transmission, which may be complemented by progress in understanding future trade patterns for renewable electricity-based PtX fuels and chemicals and their respective transportation costs.