Six regions one sun one grid

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Overview

The past decade has witnessed sustained cost reduction and rapid diffusion of renewable energy technologies such as wind and solar photovoltaic (PV) (IRENA, 2022). Though solar energy is the most abundant energy resource on earth, it is available only during the daytime and is dependent on the weather condition (Parida et al., 2011). However, the sun never sets from a global perspective, and half of the earth is bathed in sunshine at any given time. An idea to utilize the never-set solar radiation is to build an inter-continental transmission network to connect different time zones and trade renewable energy across borders. This initiative is known as One Sun One World One Grid Declaration (OSOWOG), which was jointly released by the Prime Ministers of India and the UK at the COP26 Climate Meet in Glasgow. One potential benefit of this initiative is to use energy at night in one part of the world generated from solar on the other side of the world where it is daytime. This might reduce storage and back up generation capacity needs at night, thus, enhancing the viability of solar projects.

There are a handful of studies investigating the interconnection of two or more continents for the renewable future. (Reichenberg et al., 2022) investigated the cost benefit of a Eurasian interconnection between China, Mid-Asia and Europe and showed that a super grid option decreases total system cost by up to 5%, compared to continental grid integration. (Breyer et al., 2020) evaluated the effect of integrating nine "major regions" of the world in a potential global grid and found that the cost benefit of doing so is 2%. (Bogdanov et al., 2016) suggested a cost reduction of 1.3% by connecting Europe, Eurasia, Middle East and North Africa. These studies all assume a homogeneous cost of capital across the world without considering the additional investment risk for less developed and less stable counties. Apart from the resource endowment, the economics of extracting solar resource also depend on the socio-economic, man-made reality. The cost to finance any economic endeavor, and especially so projects characterized by high upfront investment costs like solar, is highly dependent on cost of capital which varies between countries.

Methods

Here we assess the techno-economic cost benefits of connecting different time zones for the future renewable energy system. We also take into account the heterogeneity of cost of capital between countries, as argued by (Egli et al., 2019), the practical importance of which is emphasized in (Muttitt et al., 2021). Technically, we use a techno-economic cost optimization model for capacity expansion with hourly time resolution (Reichenberg et al., 2022) to model six interconnected sunny regions: Australia, South Asia, Middle East and North Africa, Central and South Europe, South America, Central and North America (see Figure 1). Specifically, we evaluate the inter-continental supergrid option for a renewable energy system in 2050 under different assumptions for technology costs; land availability for solar and wind installations; carbon cap; uncertainty of future electricity demand and availability of nuclear power.

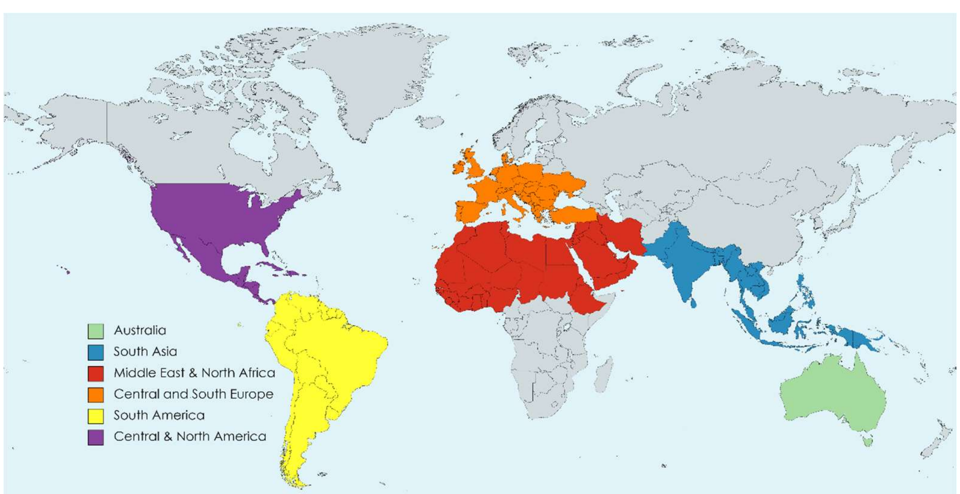

Figure 1 The modeled interconnected regions. Each region shown in this map is divided into several small subregions and these subregions are interconnected with transmission network.

Results

The cost for the entire energy system is evaluated with and without the inter-continental supergrid option. We first calculate the system cost based on a uniform cost of capital 5%. The supergrid reduces the system cost by 5% compared to the case in which the six regions are modeled in isolation. Wind and solar together dominate the generation capacity mix with the total share reaching 89%. The supergrid option favors more onshore wind power with the share increasing from 41% in the isolated case to 47% in the inter-continental case. By comparison, the share of solar PV experiences a slight decrease from 41% to 39% due to supergrid. We also investigate the benefit of connecting only neighboring regions. The largest cost benefit is observed for connecting Middle East and North Africa (MENA) to Central and South Europe, with the system cost reduction reaching 7%. Connecting the Americas reduces the system cost by 3%, while connecting Australia to South Asia only reduces the system cost by 1%. The relatively large cost reduction for connecting MENA to Europe is likely due to tapping the abundant renewable resources from MENA to meet the high energy demand in Europe.

To better evaluate the impact of trade between different time zones on the day-night smoothing of solar power output, we investigate one scenario where Europe is not included in the global electricity network. In this case, the regions included in the inter-continental supergrid span over 17 time zones, covering sunny countries from Australia to the US. The cost reduction due to supergrid is 2.8% which is lower than the cost reduction when Europe is integrated.

When considering the country-specific cost of capital, the inter-continental supergrid only reduces the system cost by 2.3%, which is not surprising. Some countries endowed with good renewable resources are enduring political and social unrest, where the cost of capital is very high, e.g., Venezuela and Sudan. The heterogeneity in investment risks highly influence the cost of developing renewable energy (Kan et al., 2022). One typical example is the region MENA. For the case of uniform cost of capital, when connecting MENA to Europe, Europe relies heavily on importing renewable energy from MENA. There are obvious surplus generation in African countries with good renewable resources. By comparison, the energy export from MENA to Europe is evidently lower when applying the country-specific cost of capital. Correspondingly, the generation in North Africa shifts to countries with relatively low cost of capital, e.g., Egypt. As for inter-continental connection, the transmission capacity between MENA and Europe in the case of country-specific cost of capital is only 38% of the capacity in the case of uniform cost of capital. Given this, using North Africa to tap solar resources, as previously suggested by (Van Wijk and Wouters, 2021), is perhaps not as economically attractive as the solar radiation data alone might suggest.

Conclusions

We evaultae the cost-effectiveness of an inter-cotinental supergrid connecting Austrila to the US for the renewable future. Our results show that the supergrid reduces the system cost by 2.3% with country-specific cost of capital, while the system cost is reduced by 5% for an optimistic future where countries experiencing political and social unrest evolve socio-politically such that their costs of capital decline over time. The globally heterogeneous cost of capital highly influence the cost of providing renewable energy in a future renewables-based energy system.

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