***How much transmission capacity will Europe need in 2050?***

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## Overview

Electricity demand in Europe is likely to be significantly higher in 2050 than today with electrification of heat and transport, while the level of intermittent generation will also be much higher. The cost of accommodating these changes may be reduced through international cooperation, so that trade flows smooth out national imbalances between supply and demand.

Alongside the technical challenges of HVDC transmission, there are economic challenges around how to finance such a substantial investment in new infrastructure. Will it be profitable to build the amount of interconnection that is needed to balance renewables, or will these interconnectors cannibalise their opportunity for arbitrage by bringing markets into equilibrium?

Major scenarios and roadmaps from the IEA or European Commission present only coarse results such as annual demand for electricity, which prevents the implications on the transmission system from being studied. A meaningful analysis needs to account for the hourly pattern of demand and price differentials between neighbouring markets, in order to assess the power flows and revenues of interconnectors.

We look at a case study of a hypothetical link between Norway and the UK. Current plans for a 1.4 GW link are envisioned to expand to 2–3 GW (Desertec) or 9 GW (ECF) by 2050. How likely will such large interconnectors be profitable, and will Nordic hydro be saturated with inflows from the UK and the rest of the continent?

## Methods

This paper introduces and demonstrates the **DESTinEE** model, which synthesises hourly profiles of the **D**emand for **E**lectricity, **S**upply and **T**ransmission **in** **E**urop**E**. This model is programmed in Microsoft Excel and will be made freely available to the community.

The model operates in four stages:

* Annual demand for energy services (thermal comfort, movement of people and goods, etc.) are projected from 2010 to 2050 levels for eight sectors in 40 countries using simple econometric relationships;
* Technology and fuel mixes are allocated to meet these services, representing the diffusion of electrification and efficient appliances, to give the final energy demand for ten energy vectors on an annual basis;
* Hourly electricity profiles are synthesised for each country using a bottom-up methodology, accounting for the sectoral breakdown of demand, correlated weather events across countries and inherent national characteristics;
* The supply and transmission of electricity are simulated using a multi-region merit order stack model with constrained power flows, which minimises the cost of electricity and finds the long run equilibrium generator and interconnector capacities.

We use this model to consider the IEA’s 2 Degrees scenario, with a mix of installed generation and transmission capacity that meets an 80% reduction in Europe’s CO2 emissions by 2050. Within this scenario, the capacity of a link between the UK and Norway was varied from 0 to 16 GW.

## Results

Increasing transmission capacity helps to equalise average wholesale prices in the two regions (below left). The Nordic price increases more sharply than the British price declines as more of the available water can be exported and its shadow value therefore rises.

Utilisation of the interconnector remains high (>90%) up to a capacity of 6 GW, then begins to fall rapidly. This, combined with reduced profits from arbitrage means revenue from transmission peaks at 10 GW installed capacity. With a tentative cable cost of €1 bn per GW (€1,500 per GW-km), a 5 GW interconnector would prove optimal with a 7% ROI requirement (below right).

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## Conclusions

A coordinated model of the European electricity system is presented, and used to investigate the economic impacts of interconnection capacity between the UK and Norway. As DESTinEE is an open-source model, we hope that it may be used in many future studies which focus on other parts of the European energy system.

As could be expected, transmission reduces extreme prices caused by reliance on intermittent renewables. This increases the risk of “missing money” for generators, suggesting that a move to capacity markets could be advisable. Early entrants may be dissuaded from investing, knowing that small increases in transmission capacity can change equilibrium prices in the connected markets, reducing the potential advantage of competitive merchant interconnectors over regulated schemes. This flattening of the price-duration curve leaves fewer arbitrage opportunities for electricity storage technologies and demand-side resonpse; however, it should be noted that storage can also provide reserve and/or relax transmission and/or distribution constraints.

## References

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