Security and efficiency: The case for connecting Europe and North America

This paper analyses the ways in which an electricity interconnector could add value as the electricity systems on either side of the north Atlantic rapidly expand and decarbonise

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Executive summary

Improving security and efficiency

This paper examines how transatlantic interconnection could help both North America and Europe to achieve a more secure and efficient transition to renewable electricity.

Ember has consistently been a strong advocate for interconnectors as a key tool to help facilitate a faster shift to renewable electricity.

The future electricity grids of North America and Europe will be increasingly impacted by weather as they seek to decarbonise their energy systems.

This paper explores the weather complementarity between the two grids and concludes there is substantial value in interconnection, which can help provide security and efficiency between the energy systems of these two continents.

Specifically:

- The enduring impact of the six-hour time zone difference on electricity demand and solar production.
- The offset from uncorrelated wind conditions, and - for the windiest days - a possible negative correlation as weather systems sweep across the Atlantic.
- The offset from uncorrelated hot and cold days and of yearly rain systems.

In their quest for cheaper energy prices, security of supply and decarbonisation, transatlantic interconnection could be a valuable tool. Despite the high capital cost, it could be cheaper than other tools being considered by policymakers, such as nuclear and hydrogen.

We conclude that decision makers should further investigate transatlantic interconnection.

Chapter 1

The new role of interconnectors

An interconnector could bridge two decarbonised, weather-dependent and growing grids

Interconnectors are built to increase system resilience. As cables connecting over longer distances are currently being envisioned, this paper explores the potential value and options of interconnection between Europe and North America.

There are two major upfront trends assumed in this paper that underpin the value and need for transatlantic interconnection.

First, in the future, power grids on both sides of the Atlantic will be predominantly decarbonised. Much of Northwest Europe, the Northeast US States and Eastern Canada have charted scenarios and made commitments towards near-zero carbon electricity within 20 years – many as soon as 2035. Much of this decarbonised electricity will come from solar, wind and hydro, which is impacted by weather conditions.

Second, electricity demand will grow significantly in the next 10-20 years because of the electrification of transport, heating and industry, as well as increased electricity demand from data centres and air conditioning. It will also increasingly be impacted by weather conditions: electricity demand rises to power air conditioning that is expected to be used progressively more as the climate changes; equally on cold days, electricity demand rises when electric heating steps in, increasing proportionally as more homes switch from gas and oil to electric heating, especially efficient heat pumps.

The increased impact of weather conditions requires huge amounts of grid flexibility to match hour-by-hour electricity supply and demand.

It’s important to note that flexibility is needed both ways. First, to keep the lights on and prices from spiking when demand is high and supply is low. But also – and increasingly – to prevent huge wastage (curtailment) of clean electricity when renewable supply is high and local demand is low.

Interconnection would make both grids more **secure**, in that it would reduce price spikes and ultimately the chances of the lights going out, and more **efficient** in avoiding wasting clean electricity by reducing the need to curtail wind and solar generation when it is windy and sunny.

Already, there is more renewable electricity on some grids in certain hours than the system needs. In 2023, according to the IEA, 8% of variable renewable electricity (VRE) generation was curtailed in Ireland and 4% in the UK.

Electricity demand growth provides a strong political imperative for interconnection. The movement from an energy system dominated by oil, coal and gas, towards a clean electricity-based energy system will ignite a new level of political support for electricity.

The difference between one-way transmission and two-way interconnectors

There are currently two inter-continental interconnectors that are in early stages of development. These are both one-way, in that they will transmit renewables from one continent to fulfil demand on another continent. Therefore, they are more like "transmission lines" than a traditional interconnector. Those projects are:

Current longest planned interconnectors

To/From	Rationale and timing	Funding
Morocco to UK (4000km)	3.6GW: the first 1.8GW "within a decade".Wind + solar + battery, to import 8% of UK electricity demand.	Hoping to be underwritten by a fixed electricity price from the UK government via a Contract for Difference (CFD).
Australia to Singapore (5100km of which 4300 km subsea)	2GW "in the early 2030's". Wind + solar + battery, to import 15% of Singapore's electricity demand.	Possibly a PPA from the Government of Singapore.

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The distance from Europe to North America is similar to those two projects above. Examples of distances are:

- St John’s Newfoundland > Cork - 3200 km
- Bristol > Québec - 4800 km
- Boston > Le Havre - 5300 km

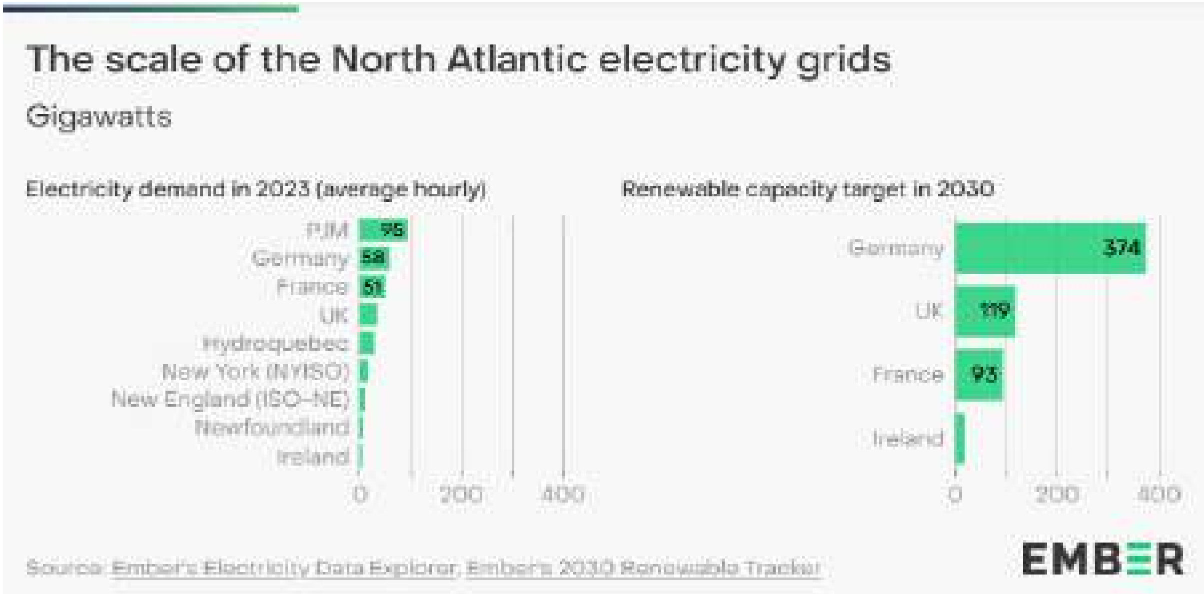
Both the Morocco and Australia interconnectors would be built by renewable developers, looking to transfer 24/7 renewable electricity from a supply country to a demand country. In both cases, the supply of renewables has to be built from scratch (Southern Morocco, Northwestern Australia).

A Europe to North America interconnector would not merely facilitate one-way electricity transmission; rather, it would link two of the largest and most interconnected continental grids. This connection would allow for the exchange of deep energy flows and enhanced price signals, promoting more efficient market operations across both regions. While this infrastructure might stimulate additional renewable energy investment along its route, this is not a prerequisite but rather a secondary benefit.

The primary value lies in integrating the energy markets, optimising grid resilience and allowing electricity prices to reflect real-time supply and demand conditions in both regions, smoothing out volatility and improving market efficiency.

Size of respective grids

The North American and European grids are two of the world's largest, so the potential for interconnection is large. Germany alone is planning to have 374 GW of renewables online by 2030.



The choice of landing points must be made with careful consideration, balancing:

- The best economic model
- Single point of failure
- The integration into existing grids (and their respective development plans)
- The willingness of regulators to welcome such an investment
- Local political approval, as well as Federal (North American) and EU support

The case for security and efficiency, as well as the concept of single point of failure, argues for multiple cables to different landing points. Large cables typically have an optimal range of 2 GW. It would make sense that there was not more than one cable going to/from the same landing points, but rather the landing points would be spread across Europe or potentially in the North Sea, along the East Coast of the US and Canada. Security is valued by its ability to keep the lights on (so there is no one weak point in either grid) and efficiency is valued by over- or under-supply, and a larger cable erodes the arbitrage.

Chapter 2

Complementarity of time zones and weather

The economic drivers for Atlantic interconnection are largely driven by the complementarity of time zones and weather. This chapter examines the impact of a six-hour time difference, and the correlation of weather using the last 10 years of weather data.

Impact of six-hour time difference

There is a six-hour time difference between France and New York, and this will provide hourly complementarity on both solar generation and the current electricity demand profile every day.

In summary:


How might electricity flow through the day?

Paris Time (GMT+1)	FLOW	New York Time (GMT-5)
1000-1600, excess solar on the grid	to US	0400-1000, morning demand pick up, little solar
1600-2200, evening demand pick-up, little solar	to FR	1000-1600, excess solar on the grid
2200-0400, overnight low demand	to US	1600-2200, evening demand pick-up, little solar
0400-1000, morning demand pick up little solar	to FR	2200-0400, overnight low demand

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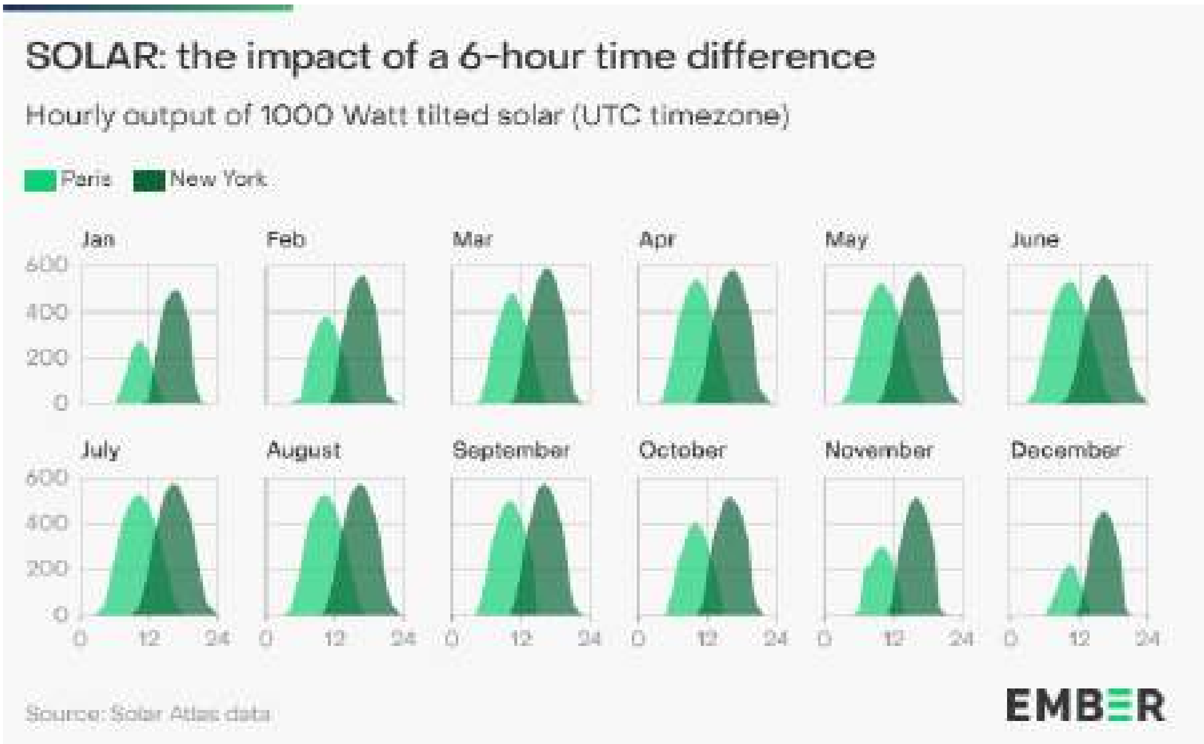
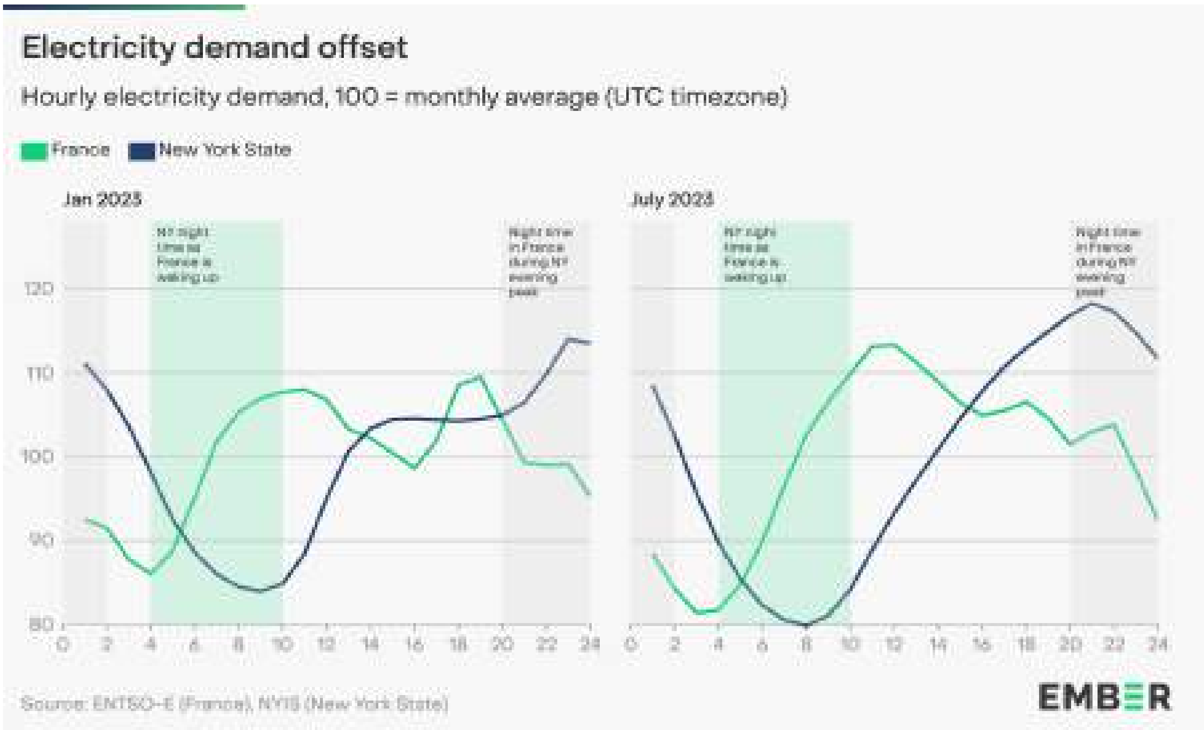
Solar will play a major role on both sides of the Atlantic. With a six-hour time difference between Paris and New York, the solar profiles will provide substantial arbitrage opportunities. Europe will have excess electricity when East Coast North America is waking up, and mid-day America will have excess electricity during Europe's evening.



The length of the cable allows for daily complementarity as daily peak demands are spaced by six hours. The six-hour offset means that the low demand overnight from 22:00-04:00 coincides with France during New York's evening peak, and in New York when France is waking up.

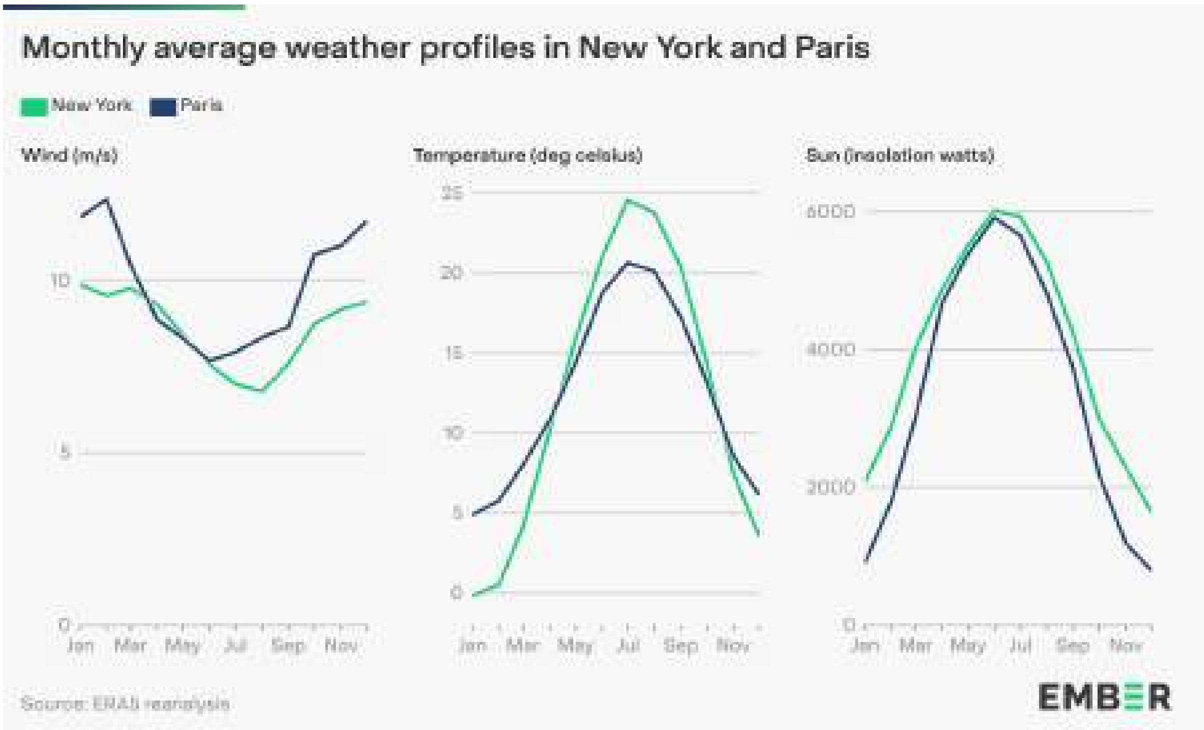


Seasonal patterns

When we start to analyse the weather impact, we need to acknowledge that, overall, Europe and North America are northern hemisphere continents that provide limited seasonal offsets.

In winter, both continents are windy and cold; in the summer they are hot and sunny; and in spring and autumn, both continents have relatively mild temperatures with quite good sun and wind.

Specifically, the hottest three months on average are the same in Paris and New York (June, July, August), as are the sunniest three months (May, June and July), the coldest three months (December, January, February), and the windiest three months (also December, January, February).



Wind correlation

It is well known that the correlation of wind speeds between two locations decreases rapidly with distance, falling to essentially zero at around 600km.

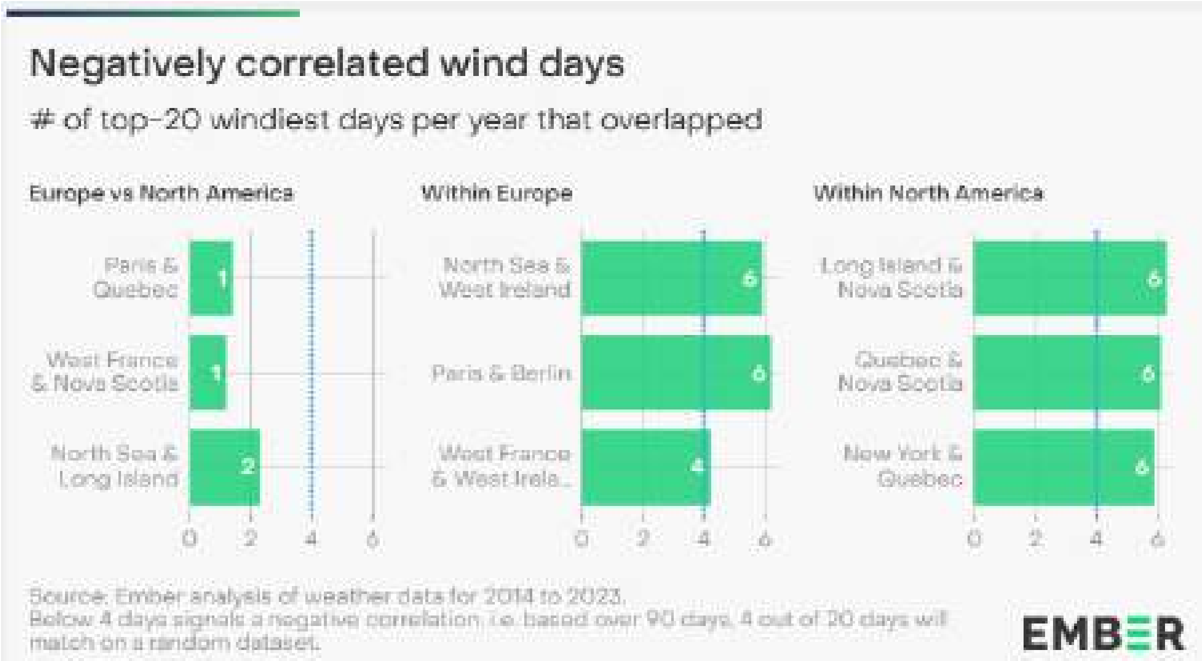
We analysed the last 10 years' wind data for three pairs of geographical points from Europe and North America. This confirms an overall hourly correlation of near-zero.

However, this analysis also shows there is some evidence of negative correlation for the windiest days of wind on each side of the Atlantic – i.e. when it is very windy in one location, it will tend to be less windy in the other location. This could be a powerful case for interconnection, since the value smoothing out the windy days could be expected to be high.

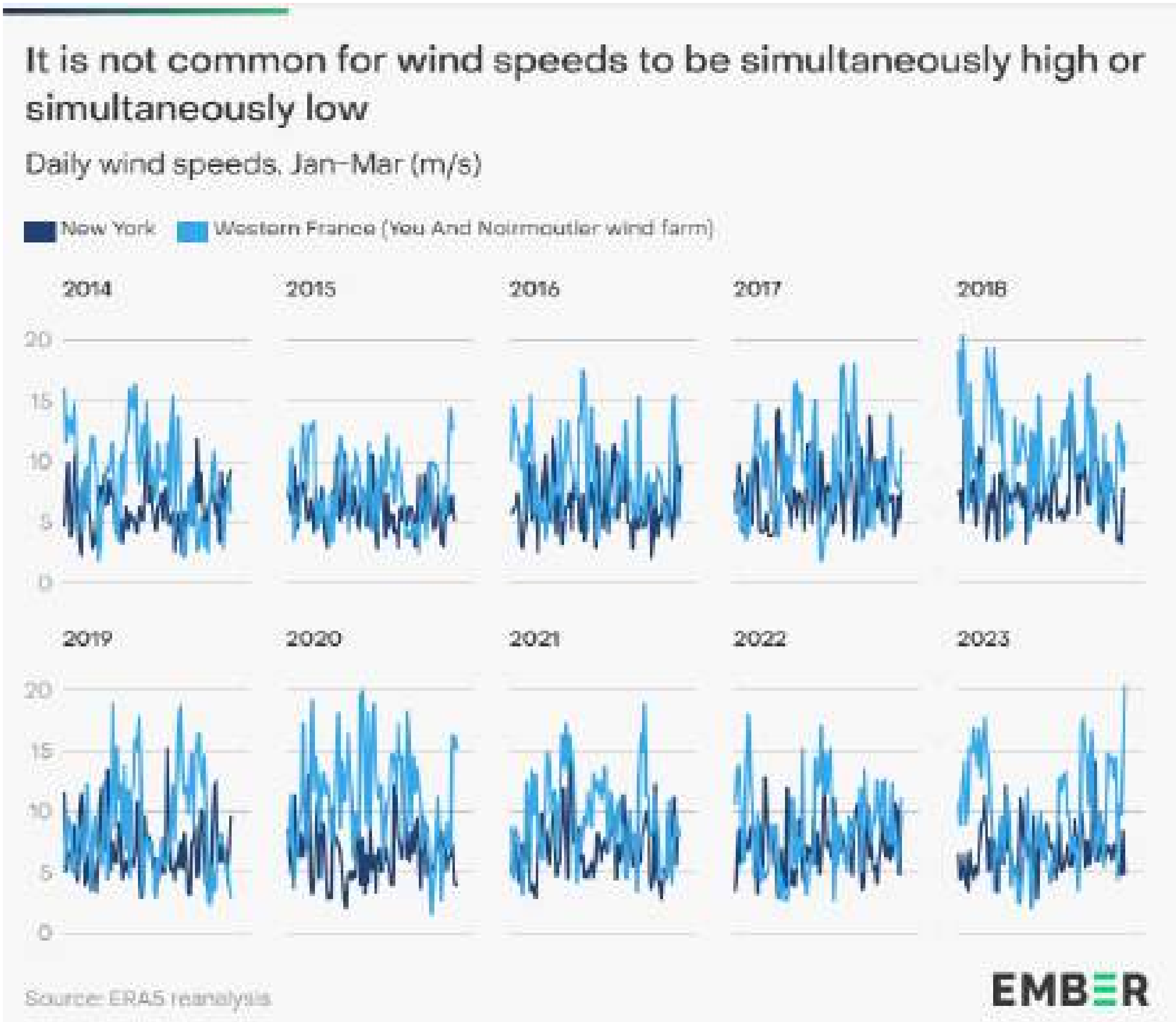
The negative correlation most likely comes from the way low pressure systems develop in North America then sweep over several days towards Europe, creating a partial asymmetry in wind speeds. This pattern is observed in the daily data.

Only one day of the top 20 windiest days each year was the same between Europe and North America. For a randomised dataset, four days would be expected i.e. when it is very windy in

North America, it is calm in Europe, and vice-versa. For pairs within North America and within Europe, six days out of the top 20 windiest were the same, implying – unsurprisingly – a positive local correlation.



Looking at the daily wind speeds for January to March (which are mostly the windiest months and also the coldest months), it is possible to see that wind speeds are rarely simultaneously high in both regions (above 12m/s), or simultaneously low (below 6 m/s).



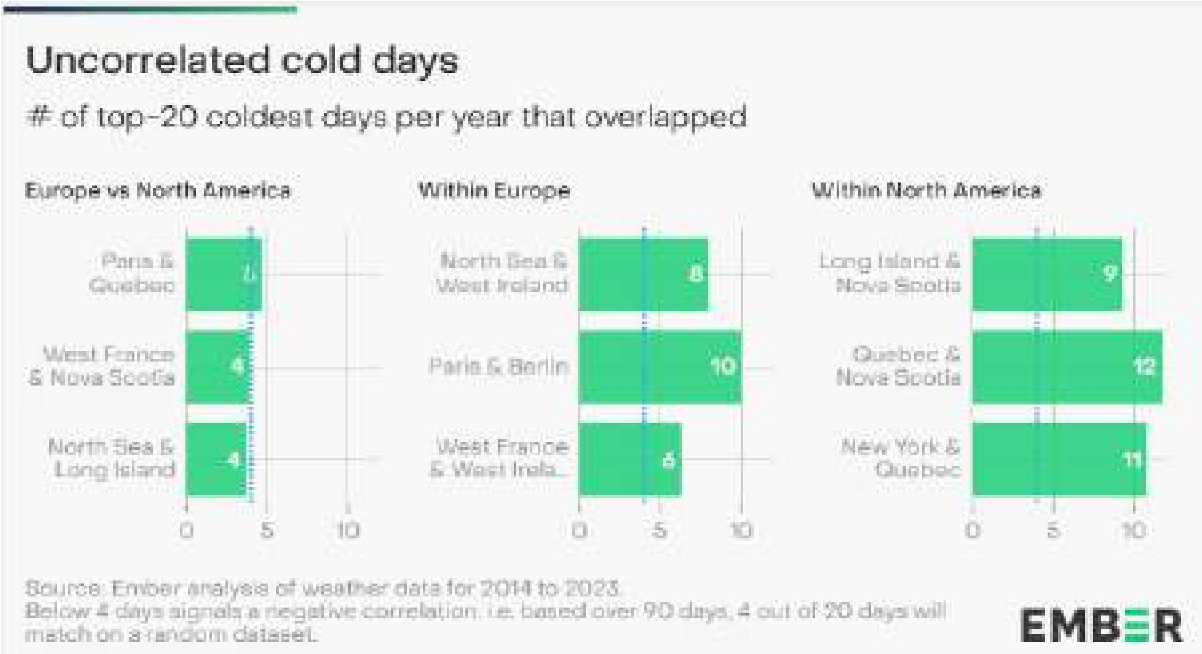
Uncorrelated hot and cold days gives value to the interconnection

We found both heatwaves and cold snaps show zero correlation (positive or negative) between Europe and North America, when analysing 10 years of temperature data.

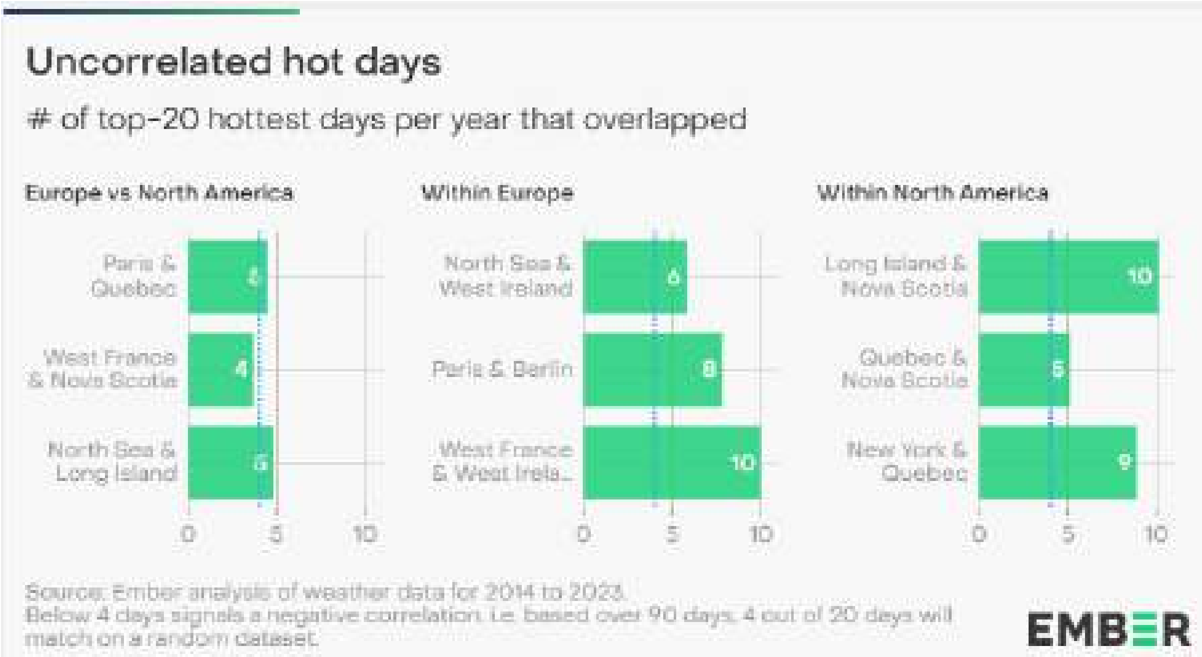
This gives ample value, in that it is not very likely to have concurrent hot or cold days in both places. This does not provide as compelling a case as the negative correlation of wind, but ruling out a positive correlation is important, as it could reduce the interconnector's value.

Only 4 of the top 20 coldest days each year overlapped between Europe and North America on average for the last 10 years. This is what a random sample would be expected to show.

The coldest days within Europe and within North America are – by comparison – very positively correlated, with about 10 of the top 20 coldest days each year the same.



The hottest days show a similar result – only 4 of the top 20 hottest days each year overlapped between Europe and North America. Again, that is in stark contrast to within North America and within Europe, both of which show a positive correlation.



Hydro: the new challenge

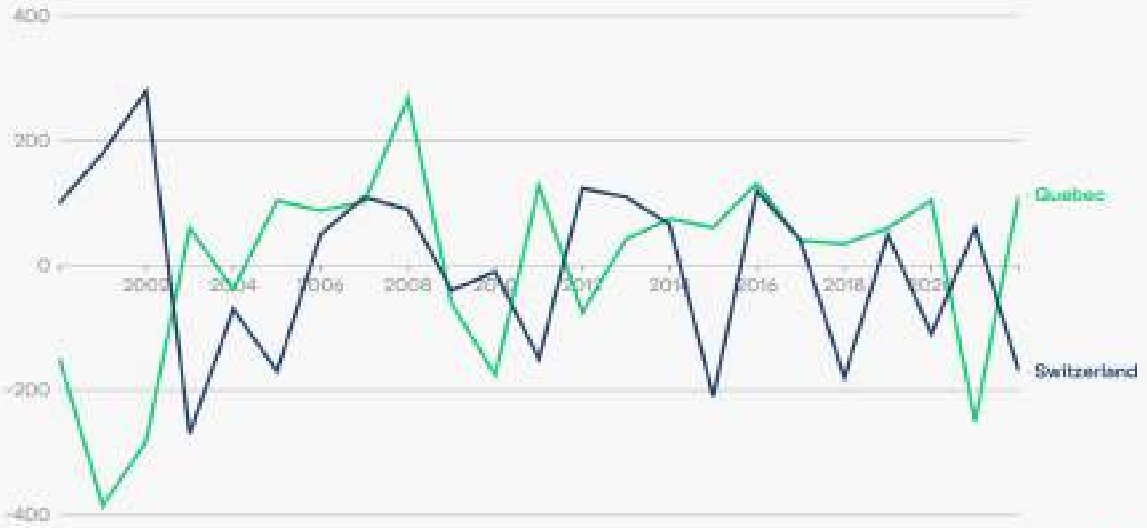
The Northeast side of the American Continent relies heavily on hydro, with a multi-generational investment by the Province of Québec. Blessed by a healthy surplus, Québec is exporting to New York Independent System Operator (NYISO), New England's Independent System Operator (ISO-NE) and Ontario. HydroQuébec has a fleet of 42GW of hydro, not taking into account the ones co-developed in neighbouring Labrador.

The introduction of interconnector capacity between North America and Europe is likely to have a disruptive impact on existing energy markets. It would grant Québec access to a larger and more lucrative market in Europe, where electricity prices are typically higher than in New England and neighbouring Canadian regions. This shift could challenge the current market dynamics, prompting a reassessment of future energy trading relationships and pricing structures.

Rainfall data from Québec and Switzerland over the last 20 years seem to show little correlation. The difference in annual electricity generation between a "wet year" and a "dry year" can be in the order of 20 TWh both in Canada and the Alps (which is 2.3 GW every hour).

Hydro impact: is rainfall correlated?

Rainfall variance from average in mm



Source: ERA5 reanalysis

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Chapter 3

Execution

This paper does not analyse the financial viability of interconnection as it is a complex and multidimensional dynamic calculation. Beside the value of hourly arbitrage, which we have established, the financial viability of interconnection comes predominantly from two factors:

How cheaply can the cable be built? Advancements in cable technology and installation methods (e.g. bigger boats) indicate a relatively stable long-term outlook, as technology improvements offset inflation. Records are regularly beaten in terms of depth and length. For instance, the recently inaugurated 800 km Viking Link (UK-Denmark) illustrates that the industry is constantly achieving new successes.

What government support might it get? Government support could come in many forms, including a cheap loan, equity stakes, regulatory frameworks such as a cap and floor regime or a guaranteed capacity price for when the cable is operational. Given the scale of the project, it would probably open the doors to a bespoke solution combining a lot of current best practices.

Governments would be most likely to see value in a project if

- It reinforces bonds between the countries – especially pertinent, given current international security concerns.
- It reduces the costs of shifting to a more decarbonised energy system.

Conclusion

Worthy of further consideration

A project of this size is strongly supported by the evolution of the grids and the need to optimise both renewable resources and variable demand.

Transatlantic interconnection would promise significant local economic benefits, particularly through job creation. However, it would need strong government support from financing to permitting.

This paper, an initial high-level exploration, lays the groundwork for a more detailed analysis to follow. It demonstrates a compelling case that the project would deliver valuable efficiency and security benefits for both continents.

Key factors include:

- The enduring impact of the six-hour time zone difference on electricity demand and solar production.
- The offset from uncorrelated wind conditions, and - for the windiest days - a possible negative correlation.
- The balancing potential from uncorrelated weather patterns, such as heatwaves, cold spells, and annual rainfall systems.

Further research is particularly recommended to understand the correlation of wind in more detail.

As the world builds a future based on clean energy, both North American and European governments should seriously consider this option alongside alternatives such as new nuclear developments or future technologies like hydrogen exports.

Public decision makers are also likely to act if they observe the increase in solar and wind curtailment, rising prices during “Dunkelflaute” or low hydro years, and growing concerns over lights going out (whether or not any risks are related to the transition, and whether or not those risks are real or perceived).

The project would be especially appealing if governments are looking toward a future electric economy, where the electric grid becomes central to the overall energy system — a scenario that is becoming increasingly likely.

Supporting materials

Acknowledgements

Cover photo

Electric power distribution in a rural region in Quebec.

Credit: Nav Pall / Alamy Stock Photo