Clean grids with current technology

The need for new energy storage is often seen as an obstacle to integrating renewable electricity into national power systems. Modelling shows that existing technologies could provide significant emissions reductions in the US without the need for storage, however.

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With the new UNFCCC Paris Agreement as a foundation, the world is looking to clean, renewable energy solutions to global warming. Such solutions, if successful on a global scale, could avert millions of premature deaths associated with outdoor and indoor air pollution each year, create more jobs than are lost, allow countries to become more energy independent, and take billions of people out of energy poverty — including the 1.3 billion who currently have no access to energy. However, critics of highly renewable energy systems point to the potential high costs of storage to provide power when there is not enough intermittent wind and solar energy generation to meet demand.

Many studies examine whether high penetrations of clean, renewable energy combined with storage can allow the grid to remain stable1–9. Although most focus only on current electric grids, one recent study9 examined the effect of electrifying all energy sectors (electricity, transportation, heating/cooling and industry) and using low-cost electricity and heat/cold storage along with hydrogen and demand response to find low-cost, no-load loss solutions to the problem across the continental United States. However, no study had considered the limit to which wind and solar can be applied with zero storage to the current electric grid (before electrifying other sectors) by aggregating wind and solar generation over a super-large catchment area (namely the continental United States).

MacDonald, Clack and colleagues10 have now performed such a study. They use the National Electricity with Weather System (NEWS) model to assess wind and solar generation at 13 km horizontal resolution and 1 hour temporal resolution. The model provides lowest-cost solutions to match power demand with supply, considering intermittent wind and solar generation, high-voltage direct current (HVDC) transmission and time-varying energy demand. They find that, under various scenarios, these contemporary wind, solar and transmission technologies could reduce CO₂ emissions by 80% compared with 1990 levels (or 81% compared with 2030 levels) with no storage, at a 9% lower cost than the baseline fossil fuel grid cost. Smaller CO₂ reductions can be obtained at even lower cost.

One of the fundamental reasons for this is that whereas the intermittency of wind is significant over small catchment areas, power output becomes smoother with increasing catchment size11. Another reason is that a large catchment area allows locations with huge low-cost renewable energy resources to be connected to many high-energy-demand centres, thereby reducing the cost of energy compared with a scenario where only higher-cost resources are used. As such, although storage has an advantage for small catchment areas (because weather systems cause greater variation in renewable supply and low-cost generation may be limited), transmission can significantly replace storage for large catchment areas to provide lower-cost and less intermittent generation.

Interestingly, in the model’s high-renewable scenario, wind plus solar generators take up less than 0.1% of land in the continental United States. Furthermore, HVDC costs are only 4% of total electricity costs, and the use of wind and solar energy reduces water consumption in the electricity sector by 65%.

One limitation of the study, which could be addressed with future research, is that it considers the electric power sector before the electrification of other energy sectors (transportation, heating/cooling and industry). Electrification of other sectors has already started, and may occur even more in the future. Further, it assumes the excess electricity generated by wind and solar is discarded rather than used for some other purpose (for example, hydrogen production or district heating), thereby increasing overall costs slightly.

Whereas the model optimizes resource location based on cost and considers several types of land use limitations, it also does not consider societal constraints on areas of beauty that might prevent development in some of the proposed locations. Future work on this topic may also benefit from considering storage to eliminate the remainder of CO₂ emissions.
Despite these limitations, the study pushes the envelope to show that intermittent renewables plus transmission can eliminate most fossil fuel electricity while matching power demand at lower cost than a fossil-fuel-based grid, even before storage is considered. This finding — alongside previous modelling that suggests the electrification of all sectors combined with the use of low-cost electricity and heat/cold storage, hydrogen and demand response can result in 100% decarbonization of all US energy sectors — provides confidence that the goals of the Paris Agreement are within reach if high percentages of clean, renewable energy can be integrated worldwide.

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References

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