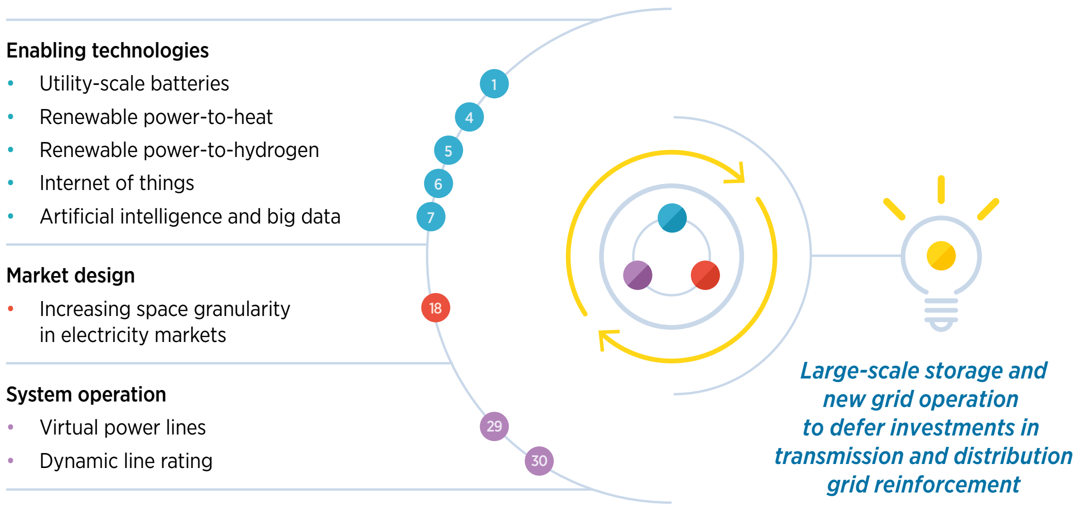
SOLUTION V

Large-scale storage and new grid operation to defer grid reinforcements investments

Figure: Synergies between innovations for investments in transmission grid reinforcement



Increased deployment of VRE may result in network congestions at both the distribution and the transmission level. **In terms of market design**, zonal or nodal prices would help reflect the network constraints and provide better operational and investment signals. *(Key innovation: Increasing space granularity in electricity markets)*

Interconnections and grid reinforcements are key enablers for integrating a high share of VRE generation. However, these may require substantial investments, and most of the time the entire grid capacity might not be fully used. Therefore, innovative solutions emerge from **system operation** to increase VRE integration while deferring grid investments:

One solution involves using **enabling technologies** such as 1) utility-scale battery storage or 2) power-to-hydrogen or power-to-heat solutions. Operating these technologies in a certain way can make them serve as virtual power lines.

Another solution involves 3) dynamic line rating, which implies allowing higher "dynamic" current, meaning allowing more VRE through the grid when actual atmospheric conditions offer better cooling (*e.g.*, cables and lines can be utilised to maximum capacity without risk of overheating). The meteorological variables that influence the thermal state of the conductor are: the speed and direction of wind, the ambient and the solar radiation.

1: Utility-scale battery storage systems

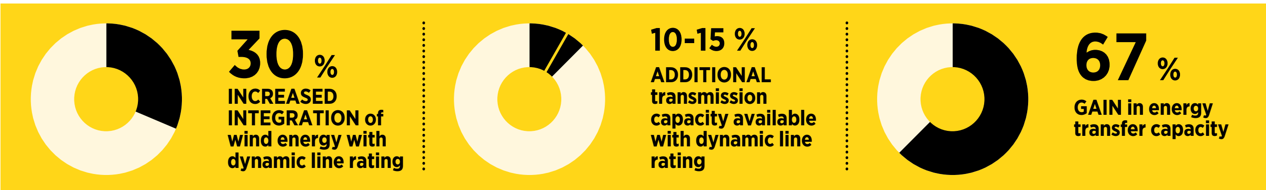
Utility-scale storage systems can be deployed at different points in the distribution and transmission network to store excess power during non-peak hours. These systems can then be discharged to meet load requirements in the local area during peak hours, without the need for transporting electricity through congested grid lines. This reduces network congestion and forms virtual power lines. In this case, instead of being merchant assets, batteries are network assets owned by the grid operator and used exclusively for managing the grid. For instance, Terna, a transmission system operator in Italy, has planned a pilot battery storage project of 35 MW on part of its 150 kV grid in southern Italy, for grid congestion management (Terna, n.d.). RTE, the French transmission system operator, is carrying out a similar project called Ringo. *(Key innovations: Virtual power lines; Utility-scale batteries)*

2: Power-to-hydrogen or power-to-heat

Some of the best wind resources are located in offshore or rural areas. Wind energy can be converted into hydrogen, which can be liquefied and transported to regions with energy deficits or demand centres. This facilitates wind power development without requiring large investments in new transmission capacity, although the costs and energy losses of electrolysers are still very high. Similarly, the renewable power can be converted to heat in order de-congestion the grid and avoid investments in network infrastructure. *(Key innovations: Virtual power lines; Renewable power-to-hydrogen; Renewable Power-to-heat)*

3: Dynamic line rating

Power lines can carry only a specific amount of current at any given temperature. If more current is allowed through, this can lead to overheating of the cables. The amount of electric current that a transmission or distribution line can safely carry without overheating is often expressed in terms of static ratings, which system operators use to calculate the line capacity. However, these static ratings ignore the effect of cooling of power lines by weather conditions (the speed and direction of wind, the ambient and the solar radiation), especially in windy areas where wind energy plants are also installed. In such areas where lines are co-located with wind energy plants, weather monitoring equipment can be used to estimate the power line temperature and the resultant increase in current-carrying capacity. *(Key innovation: Dynamic line rating)*



Impact on renewable energy integration:

- In the UK, E.ON Central Networks has applied dynamic line rating systems, and estimates increased integration of wind energy into the grid by 30% (Fernandez *et al.*, 2016).
- The TWENTIES project – involving various stakeholders such as European transmission system operators, generation companies, power technology and wind equipment manufacturers, etc. – concluded that dynamic line rating forecasts lead to an average increase in transmission capacity of 10% to 15% (Alen Pavlinić, 2017).

Impact on operational costs:

- A study by Durham University, ScottishPower Energy Networks, Imass, PB Power and AREVA T&D concluded that the adoption of dynamic line rating can provide a 67% gain in energy transfer capacity at 62% of the re-tensioning cost (Roberts *et al.*, 2008).

IMPLEMENTED SOLUTION

RINGO Project – virtual power line in France

The virtual power line designed by the French utility RTE, called the Ringo Project, will come into service in 2020 for a test period of three years. The project will use energy storage systems to relieve congestion instead of constructing extra power lines. The concept relies on artificial intelligence solutions to aid the dispatching process and to optimise the management of the electricity current in the grid.

Because the grid operator cannot disrupt the market by injecting electricity into the grid, a simultaneous battery storage and retrieval system has been designed to operate at three locations in the network. These battery storage systems will be placed where the lines are congested and will absorb large amounts of VRE resources. The battery capacity at each site will be 12 MW/24 MWh.

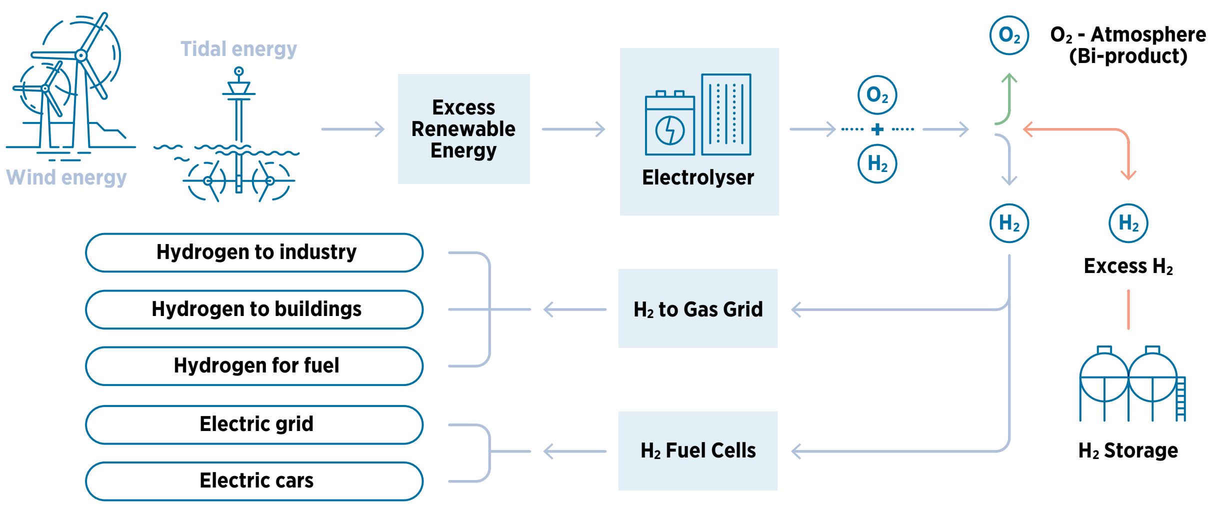
The project envisions that from 2020 to 2023 the batteries will be operated solely by RTE as virtual power lines. Starting in 2023 they will be open for use by third parties for potentially multiple uses such as frequency regulation, demand and supply adjustment, congestion resolution and energy arbitrage, among others.

Surf 'n' Turf Initiative – Orkney, UK

The Surf 'n' Turf initiative uses the power generated from the tidal and wind energy produced at the island of Eday, Orkney. Eday is home to 150 people who collectively own a 900 kW wind turbine that was vulnerable to curtailment for various reasons, including lack of network infrastructure. Now the Surf 'n' Turf initiative converts excess wind and tidal energy to produce hydrogen via a 500 kW electrolyser in Eday. In Kirkwall (Orkney's capital) systems are being developed to make use of the hydrogen produced, which is transported from Eday via ships (Surf 'n' Turf Initiative, 2018). The hydrogen can be used either during emergencies in industries and households, or during lean seasons when renewable energy generation is low. The figure below shows the schematic structure of the initiative.

Later, another 1 MW electrolyser was added in the island of Shapinsay, which also transported hydrogen to Kirkwall. Based on this, the BIG HIT project is being initiated which is expected to demonstrate that the Orkney Islands of Scotland have a replicable model and that hydrogen can be used as a flexible local medium for energy storage. Hydrogen is used for multiple purposes that include producing auxiliary power, heat for ferries in the Kirkwall harbour, fuelling a fleet of hydrogen range-extended light vehicles and heating of buildings in the Kirkwall area (BIG HIT, 2018).

Figure: Illustrative structure of the Surf 'n' Turf initiative



Terna's pilot applications of dynamic line rating

The Italian transmission system operator Terna is conducting pilot applications of dynamic line rating systems on four of its transmission lines: Spezia-Vignole (380 kV), Bargi-Calenzano (380 kV), Misterbianco-Melilli (220 kV) and Benevento2-Foiano (150 kV). The project involves deploying two sets of dynamic line rating equipment on the transmission line itself and deploying dynamic line rating equipment on the two end-point substations. It also utilises the weather forecast data taken from the Epson Meteo Centre to estimate the dynamic line rating value. This has allowed greater capacity of transmission lines during favourable weather conditions, enabling increased integration of wind generation from nearby wind farms (Carlini *et al.*, 2013).

Dynamic line rating system in US

Oncor Electric Delivery Company, a transmission and distribution utility operating in Texas, implemented a dynamic line rating system in a project funded under the US Department of Energy's Smart Grid Demonstration Program. The dynamic line rating system monitored the real-time capacity of eight transmission lines that were being used for daily operations and wholesale market transactions. Oncor observed that the real-time transmission line capacities were above ambient-adjusted ratings by 8% to 12% for 132 kV transmission lines, and by 6% to 14% for 345 kV lines for about 84% to 91% of the time. Oncor now plans to deploy additional dynamic line rating systems in West Texas for congestion relief (US DOE, 2014).

E.ON Central Networks has proposed calculating the rating of the Skegness-Boston line dynamically in its control system (ENMAC) from local weather measurements to co-ordinate allowed generation automatically. This takes into account the cooling effect of the wind. This enhancement through dynamic line rating should facilitate the connection of around 30% more generation as compared to fixed winter/summer ratings (Yip *et al.*, 2009).

SUMMARY TABLE: BENEFITS AND COSTS OF AVOIDING INVESTMENTS IN TRANSMISSION AND DISTRIBUTION GRID REINFORCEMENT

AVOIDING GRID REINFORCEMENT USING STORAGE TECHNOLOGY

Avoiding grid reinforcement using storage technology	Low	Moderate	High	Very high
BENEFIT				
Potential increase in system flexibility			●	
COST and COMPLEXITY				
Technology and infrastructure costs		● for power-to-heat solutions	● for utility-scale batteries	● for power-to-hydrogen solution
Required changes in the regulation framework			● Clear regulation established for the technologies used as network assets as opposed to market assets	
Required changes in the role of actors		● New tasks for transmission and distribution system operators		

AVOIDING GRID REINFORCEMENT WITH INNOVATIVE OPERATION OF EXISTING POWER LINES

Avoiding grid reinforcements with innovative operation of existing power lines	Low	Moderate	High	Very high
BENEFIT				
Potential increase in system flexibility		●		
COST and COMPLEXITY				
Technology and infrastructure costs	● Potential cost of the control system			
Required changes in the regulation framework	●			
Required changes in the role of actors	●			

Note: This cost-benefit comparison is confined within system boundaries and focuses on the power sector alone. Wider benefits, which are excluded from this comparison, can be significantly higher than costs.

This document is extracted from a longer report:

IRENA (2019), ***Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables.*** International Renewable Energy Agency, Abu Dhabi (**ISBN 978-92-9260-111-9**).

The full report and related materials are available on the IRENA website (**www.irena.org**).