Remote renewable energy hubs: a wonderful accelerator of energy transition.

Authors: Victor Dachet* and Damien Ernst*

*Institut Montefiore, Department of Electrical Engineering and Computer Science, University of Liège, Allée de la découverte 10, Sart-Tilman, 4000, Liège, Belgium

Let's face it, there is not much to smile about when it comes to energy policy in Europe at the moment: energy is expensive. The fight for the climate, to which Europeans are so attached, seems to have been lost in advance, especially with the decreed return to fossil fuels by the new American president. Europe itself is struggling to achieve the objectives it had set for itself in terms of the development of renewable energies. And yet, in this worrying situation, a feint glimmer of light could well give us hope: Remote Renewable Energy Hubs (RREHs). The idea is simple. The first step is to collect or harvest renewable energy in remote locations where it is particularly abundant, such as the sun-drenched Sahara Desert, the Atacama Desert in Chile, or the strong winds along the east coast of Greenland. Once harvested, the energy can be transported to major consumption centres such as Germany or South Korea. This is a magnificent opportunity to decarbonize these consumption centres where renewable energy generation potential is often very limited in relation to their energy needs.

How do RREHs work?

RREHs generate electricity from renewable energy by means of photovoltaic (PV) panels or wind turbines, as examples. It is then sent to large consumption centres. This can be done "live" via gigantic electrical links[1]. But another very promising technique already exists. It consists of using this electricity to produce, on site, hydrogen (H2) through the electrolysis of water, which is then combined with carbon dioxide (CO2) captured directly from the air or at the outlet source of CO2 of emitting industries, in order to synthesize hydrocarbon chains such as natural gas or kerosene. These energy-rich molecules are said to be carbon neutral, as they are synthesized using captured carbon.

Additionally, these synthetic fuels offer several advantages. First, they are as easily transportable as they are similar to the fossil fuels that are commonly transported today, since they are the same molecules. Secondly, they can directly replace fossil fuels and do not require additional investment in the so-called "downstream sector". A sound example? Take aviation. It is an industry which is known to be very difficult to decarbonise... However, with RREHs, it would "suffice" to synthesize e-kerosene, say, on the sun-drenched and windswept coast of Namibia, and then transport it directly to airports. It's that simple!

Why don't these RREHs currently exist?

As you have seen, this chemical synthesis is kind of "magical". So, one wonders why RREHs do not yet exist. In reality, some RREH projects are already appearing. But too slowly. It must be said that the production costs of the energy-rich molecules produced in these set-ups are still too high compared to the price of extracting their fossil fuel counterpart. For example, a megawatt hour (MWh) of fossil gas

[1] Chatzivasileiadis, S., Ernst, D., & Andersson, G. (2013). The global grid. *Renewable Energy*, *57*, 372-383.

currently costs around €50 on the wholesale markets in Europe[2]. Scientific literature suggests that the cost of an equivalent synthetic fuel imported from an RREH located in Algeria would be around €150 per MWh[3]. The price differential is therefore currently far too high for these synthetic fuels to be abundant on European markets.

However, the trend could be quickly reversed. Indeed, the cost of several technologies necessary for the deployment of RREHs is gradually decreasing. This is particularly the case for batteries, wind turbines, photovoltaic panels and electrolysers. This could make the fuels produced in this way more competitive in terms of price. In addition, the price per tonne of CO2 has been rising for several years on the EU-ETS carbon credit market in the European Union. This also helps carbon-neutral synthetic fuels to be competitive with their fossil-fuel CO2-intensive counterparts. Finally, the scientific community is beginning to become active in the field of RREHs, and the results of its research offer new perspectives in terms of cost reduction.

Finding the best RREH

The authors of this article are personally working on finding ways to reduce costs, in particular by seeking to identify the most competitive RREH model, as well as the most suitable places for its installation[4]. This transversal work has led them to develop a taxonomy to characterize RREHs[5], as well as to build complex programmes to optimise their design[6]. They have also met a multitude of actors from all walks of life to understand how to best integrate each RREH into its future environment, while expanding their potential. For example, hydrogen production requires investment in water desalination. This could allow an RREH located in the middle of the desert to provide water for the local populations and/or to develop agriculture. These RREHs would therefore not only be intended to collect renewable energy to export them to major consumption centres: they would also be formidable catalysts for development for the host countries.

Daring to think about another world of energy

RREHs not only offer a unique opportunity to rethink the energy systems of tomorrow, but they are also vectors of technological audacity and ambition. However, the prevailing gloom currently seems to overshadow the extraordinary developments in engineering that we observe every day. Boldness can, for example, involve asking whether, instead of collecting renewable energy from the land, we could harvest it from the sea. This idea also feeds into the research of the authors of this article, who are

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[2] Prices observed on the reference Dutch TTF index in January 2024.

[3] Berger, M., Radu, D., Detienne2, G., Deschuyteneer, T., Richel, A., & Ernst, D. (2021, April 19). Remote Renewable Hubs for Carbon-Neutral Synthetic Fuel Production. Frontiers. https://doi.org/10.3389/fenrg.2021.671279

[4] Victor, D., Amina, B., Diederik, C., Francesco, C., Raphaël, F., & Damien, E. (2024). Towards CO2 valorization in a multi remote renewable energy hub framework with uncertainty quantification. *Journal of Environmental Management*, *363*, 121262.

[5] Dachet, V., Dubois, A., Miftari, B., Derval, G., Fonteneau, R., & Ernst, D. (2023). Remote Renewable Energy Hubs: A taxonomy.

[6] Miftari, B., Berger, M., Derval, G., Louveaux, Q., & Ernst, D. (2024). GBOML: a structure-exploiting optimization modelling language in Python. *Optimization Methods and Software*, *39*(1), 227-256.

indeed studying the possibility of harvesting the very generous potential of offshore wind energy through unmoored floating wind turbines. A combination of AI-controlled drones and boats would then bring back onshore the harvested energy stored in battery containers[7].

Financing and RREH business models

For RREHs to truly change the world of tomorrow, research cannot be limited to the technological aspect. It must be multidisciplinary, if only to ensure there is sufficient financing for them as these are considerable investments that can be counted in billions of euros per RREH. The cost of financing itself is a key issue to ensure its feasibility.

Many developing countries are very promising candidates for the installation and development of RREHs. But the interest rates (i.e. the "the cost of borrowing money") for projects developed in these countries are often very high. International financial tools should be rethought from a new perspective to accelerate energy transition at the global level and thus help the countries that are signatories to the Paris agreements to comply with them.

Reinventing itself with ambition

There is an energy crisis in Europe. The old continent seems to be on a downward slope, despite the efforts of member countries. But the current prodigious technological developments, both in the field of cleantech, artificial intelligence and finance, open up countless prospects for a way out of this crisis. However, this means boldly rethinking and even reinventing our energy policies, to ensure that truly effective projects triumph. So, being ambitious, Remote Renewable Energy Hubs are one of these projects!

[7] Dachet, V., Maio, A., Counotte, P., & Ernst, D. (2025). *Remote Renewable Energy Hubs in the High Seas: a Battery-Based Fully-Electric Ecosystem*. ORBi-University of Liège. https://orbi.uliege.be/handle/2268/327232.