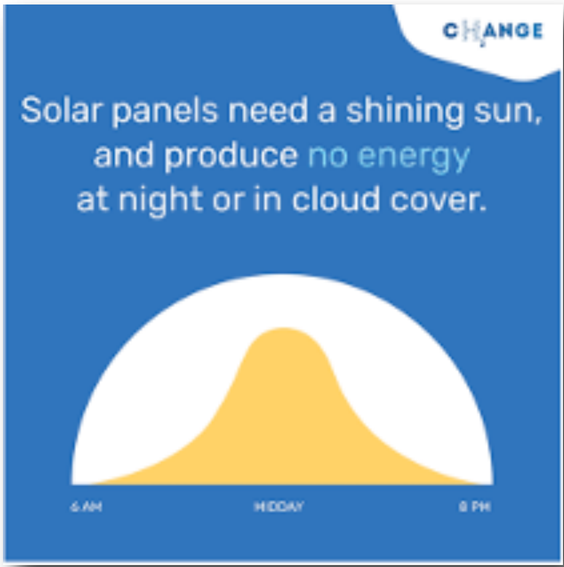
cH2ange - We need to change the way we use energy, now. We believe hydrogen is the missing element in a sustainable energy mix. Supported by Air Liquide.

August 24, 2017

Hydrogen Enables Renewables

On a breezy, sunny day in May 2016, something unusual happened in Germany. So much renewable energy was generated that electricity prices went negative, meaning that customers were effectively paid to use it. Unusual but not unique. For a few hours in March 2017, solar generation in California accounted for almost 40% of net grid power produced, reflecting a 50% growth in the state's utility-scale solar photovoltaic installed capacity in 2016. The result of which, as occurred in Germany, was that power prices were driven into the negative, an event that continues to occur periodically in the state.



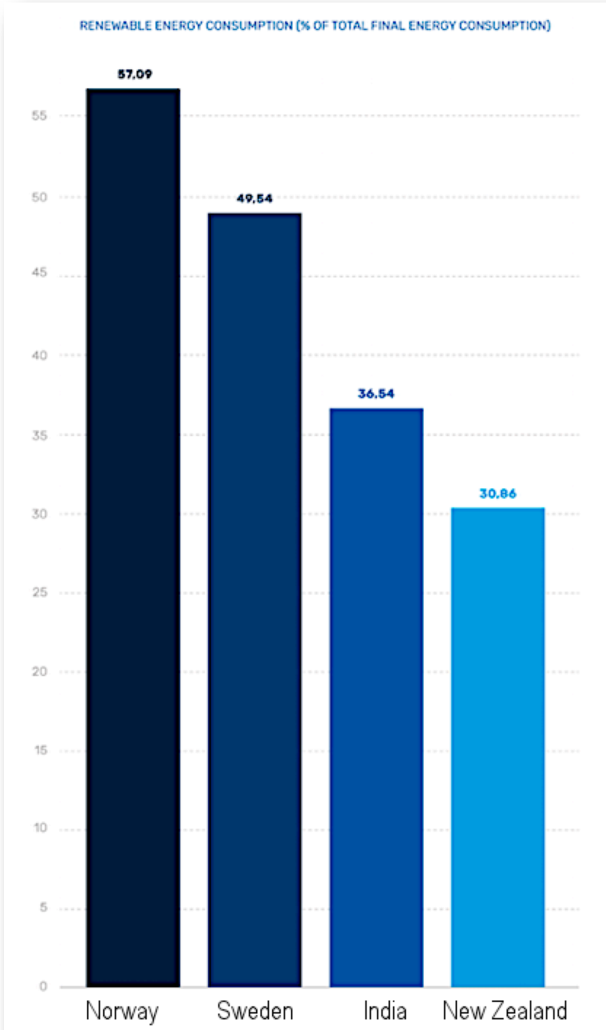
Negative electricity prices sound like a nice problem to have. This might be true if they were only indicative of the impressive improvement in the development, cost reduction and efficiency increase in renewable energy production. However, this phenomenon rather illustrates the intermittency and somewhat unpredictable nature of wind and solar power: supply fluctuates, surfeits cannot currently be stored to any great extent, and conventional grid balancing methods are not designed for power generation fluctuations caused by clouds or changes in wind speed.

Essential, expanding, inevitable

The growth in demand for electricity, the need to shift to low carbon energy sources, the geographically widespread nature of renewable energies, along with the development of increasingly more efficient technologies, are all leading to an important increase in the use of renewable energy.

The increase in the use of renewable energy is happening worldwide.

This increase is happening worldwide at a pace that far exceeds many projections. According to the *International Energy Agency*, in 2012 around 13.2% of the world's total primary energy supply was derived from renewable sources. While in terms of electricity, in 2013 renewables provided almost 22% of global production and the Agency estimates that this share will reach at least 26% in 2020. Moreover, certain countries are making particularly huge strides forward: according to *World Bank* data the use of renewable energies in 2014 as a percentage of total final energy consumption was 57% in Norway, 50% in Sweden, 36% in India, 31% in New Zealand… to mention just a few of the high achievers.



Source : World Bank

This trend must continue if the world hopes to mitigate climate change and reduce pollution. In fact, many experts consider that we have already moved beyond a turning point. The transition from fossil fuels to renewables is now irreversible.

However, renewable energy risks becoming a victim of its own success: without economically viable storage options, renewable energy integration has been supported by fast-reacting fossil-based technologies, which act as back-up capacity to compensate for supply variability.

But as the push for clean energy continues and renewable resources account for an increasing proportion of generated energy, there is simultaneously more variability and less fossil fuel buffering to absorb supply chain shocks.

Power supply, and demand

The integration of renewable energy presents a challenge to one of the fundamental imperatives of the power industry: the need to match electricity supply and demand. Why so?

Grid frequency fluctuates continuously, determined by the real time balance of demand and generation.

Electricity networks have a utility frequency of 50 Hz or 60 Hz, because this corresponds to an efficient rotation speed for the steam turbine engines that power most generators (3,000 RPM for 50 Hz, 3,600 RPM for 60 Hz). This frequency must be tightly controlled to ensure the safe operation of the grid and also because appliances are specifically designed to operate at one of these frequencies.

However, grid frequency fluctuates continuously, determined by the real time balance of demand and generation. If demand is greater than generation, the frequency falls, if generation is greater than demand, the frequency rises. The network operator has to compensate for such changes by requesting more or less generation in the hour leading up to real time, to keep the frequency in the acceptable range.

Traditionally, power systems have been based on fossil or nuclear-powered plants, which have rotating generators that can rotate slightly slower or faster to compensate for the immediate imbalance between power supply and demand, allowing the required frequency to be maintained.

And that's where the integration of renewables raises issues. Renewable energy sources, notably wind turbines and photovoltaic units, do not have the rotational inertia of conventional generators. This has implications on grid stability in terms of frequency control and ensuring the stable operation of the power grid, because renewables are displacing conventional generators with their rotating machinery.

Solar panels need a shining sun.

But also, solar and wind generation experience intermittency in terms of non-controllable variability and the partial unpredictability of the weather. This fluctuation in power output makes it more difficult to balance supply and demand on an instantaneous basis.

Solving the variables in the equation

Many solutions to the variability of renewable energy and its successful integration into the grid are already in use to varying extents around the world. A first step is minimizing challenges and costs from the outset by deploying a wide range of renewable energies where possible. Some sources—such as hydroelectric and concentrated solar power—offer greater control of output than others.

This solution can provide a higher degree of control and thus eases the challenge of balancing. It is not, however, always practical, as many renewables are geographically specific. Although this can be addressed by long-distance transmission and larger and more flexible grids with connections that cross international boundaries. The principle is that the larger area a network covers, the more chance there is that renewably generated power that is superfluous in one location will be able to supply a demand that is present elsewhere.

Power packed

Another option is storage. The storage of mass-produced electricity has been around for many years in the form of pumped storage hydropower, which relies on gravity to capture off-peak power, releasing it at periods of high demand. This accounts for 99% of bulk power storage capacity worldwide, however its application is limited to very specific locations.

> "If you want days, months, or even years of energy storage, and in massive volumes, then you can't do it with batteries."

Chemical storage in the form of batteries also has potential to support the energy transition. Large batteries are already in use in industry but their implementation in managing variation in grid systems is problematic.

Dr Graham Cooley, CEO at ITM Power.

Dr Graham Cooley, CEO at ITM Power, a manufacturer of integrated hydrogen energy systems commented:

"When most people think of energy storage, they think of batteries. And if you want one or two hours of energy storage, batteries are good. But if you want days, months, or even years of energy storage, and in massive volumes, then you can't do it with batteries."

Factors such as lifespan, cycle efficiency, power leakage and production costs all need to be addressed before batteries can be considered as a viable option for grid balancing. All this isn't sounding too promising so far. However, there is a technology that is already being implemented and has proven itself ideally suited to empowering the energy transition because it offers much more than just storage. And this solution is hydrogen.

With great power comes great flexibility

Hydrogen can store excess renewably generated power, and do so reliably, in massive amounts and over long periods of time. It can also be used to power fuel cell vehicles which produce zero local emissions and provide energy for the industry. It can be transported in high energy density forms either in a gas or liquid, and injected into gas networks to supplement or replace natural gas. So how does it work?

"An electrolyser can be turned off and on very rapidly"

The process, known as Power-to-Gas (P2G), involves converting surplus energy into hydrogen gas by rapid response electrolysis and its subsequent injection into the gas distribution network. Graham Cooley explained:

"P2G is about making hydrogen using renewable power. You use a device called an electrolyser that splits water into hydrogen and oxygen when an electric current is passed through. You use the hydrogen either in the gas grid or for refueling vehicles. And because an electrolyser can be turned off and on very rapidly, it provides very efficient grid balancing."

"An electrolyser receives signals from the grid based on frequency. When the network is overloaded and the frequency starts to fall, the electrolyser is switched off. When the network is under loaded, or has an excess of renewable power, it receives a signal to turn on. Our electrolysis equipment can be turned on and off in less than a second and can be bid into primary grid balancing (Enhanced Frequency Response or Frequency Control Demand Management)."

"When switched on, the hydrogen produced goes straight into the gas grid. In this way, when we are balancing against rising frequency, an electrolyser can be used to absorb an excess of renewable power. The gas grid in the UK for example is three times the size of the power grid: there's about 350 terawatt hours of energy flowing through the electricity grid every year, and about 1,000 terawatt hours in the gas grid. The primary difference between the two energy networks is that electricity has no energy storage, whereas there's a huge amount of energy storage in the gas grid."

It has been shown that hydrogen-enriched gas, containing up to 20% hydrogen, has no adverse impact on gas appliances. Surplus renewable power to produce hydrogen by electrolysis can also be combined with CO2, for example from biogas production, to form synthetic natural gas—which is the exact same molecule as the fossil natural gas that is used today—that can also be injected into gas networks.

Driving changes

Then there's the role of renewably-produced hydrogen in carbon-free transport.

"The same principle of using electrolysers for grid balancing can be used to generate very low cost hydrogen for fuel cell electric vehicles," said Graham Cooley. "Electrolysers can be installed directly at refueling stations so that hydrogen is made on site, meaning there's zero carbon footprint involved in transport. The electrolyser is turned on and off according to the grid company's balancing requirements, but here the hydrogen is stored in tanks and then deployed to vehicles. This means the hydrogen has the lowest possible carbon footprint and is absolutely clean: the water has never seen any carbon molecules and does not need purifying for use in vehicles."

"Electrolysers can be installed directly at refueling stations."

While this sounds promising, a number of critics have claimed that hydrogen fuel cell vehicles are a dead end technology. Prof. Dr. Christian Mohrdieck, Daimler's Fuel Cell Director, addressed this point:

“A very popular argument in the public discussion is that battery electric vehicles are more efficient than hydrogen. This is true because the conversion of hydrogen is an extra step that is not involved in battery electric vehicles. However, this is not taking the whole picture into account.

“If we want to move to renewable energy then we have to consider all aspects”

Prof. Dr. Christian Mohrdieck, Daimler’s Fuel Cell Director.

“We want to move away from fossil fuels towards renewable energy, and this means we also need to store electricity. So the big challenge is how can we store huge amounts of electricity over a long time, even from one season to the next. Very few technologies can do this, but hydrogen is one of them. Batteries cannot.”

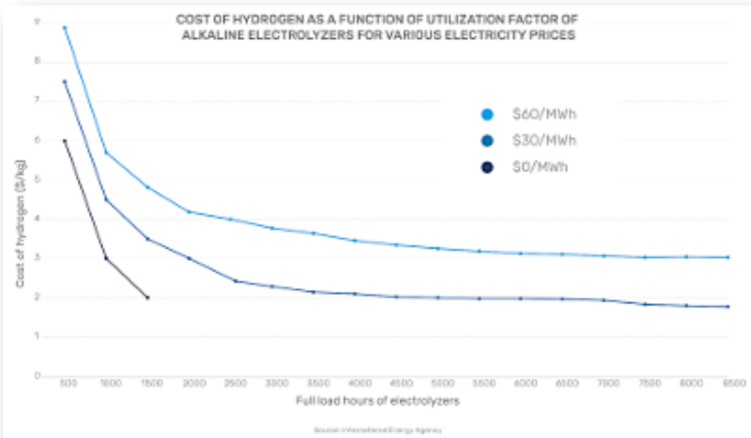
Indeed, batteries alone would not be able to do the work because the amount of energy to be stored for seasonal storage is too high. The amount of batteries needed would be significant—material, size and cost-wise.

“Once you factor in the need for hydrogen in the storage of renewable electricity, then hydrogen and battery electric vehicles become very close in terms of efficiency. This is a complex picture, but if we want to move to renewable energy then we have to consider all aspects”, Prof. Dr. Christian Mohrdieck adds.

In the past, the use of clean, electrolysis-formed hydrogen has been hampered by relatively high production costs. The capital price and running costs of electrolysers prevented this solution from being sustainable. This major issue is on the verge of being solved, as production prices have decreased steadily year after year.

Today, hydrogen production cost depends mainly on electricity cost, operational hours and *CAPEX (capital expenditure).*

Thanks to increasingly lower renewable costs and economies of scale, clean hydrogen will soon be price-competitive. In regions that combine medium electricity prices (between 30 and 60 dollars per MWh) and a medium utilization factor, the cost of producing hydrogen can be around 4–5 dollars per kilogram.



Hydrogen holds the key

Human societies now depend on a 24/7 energy supply. But neither the sun shines nor the wind blows all day, every day. And our electricity system is designed to function through the precise matching of supply and demand.

Hydrogen is one of the solutions to this intermittency problem. It can be produced from renewable energy through electrolysis and used for grid balancing, energy storage, heating, for refueling fuel cell vehicles and as a source of hydrogen for industry.

If the world truly intends to avoid climatic catastrophe, then expanding the use of renewable energy is essential, and hydrogen could well be the key to unlock its full potential.