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Elusive energy

How to keep it
For when we need it

A brief look into the problem and solution of energy storage

Eurogas is the association representing the European gas wholesale, retail and distribution sectors. Founded in 1990, its members are 43 companies and associations from 24 countries.

Eurogas represents the sectors towards the EU institutions and, as such, participates in the Madrid Gas Regulatory Forum, the Gas Coordination Group, the Citizens Energy Forum and other stakeholder groups.

Its members work together, analysing the impact of EU political and legislative initiatives on their business and communicating their findings and suggestions to the EU stakeholders.

The association also provides statistics and forecasts on gas consumption. For this, the association can draw on national data supplied by its member companies and associations.

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Introduction

Useful energy can be hard to find, but it's even harder to contain. This is one of the principal bottlenecks that a European sustainable energy future faces. Gas can help tremendously in providing the solution.

While we have done quite well in harnessing energy in ways useful to productivity, and while finding new ways to do so such that efficiency is optimised and environmental impact minimised, we have not yet been able to close the gap in completing a sustainable energy system.

So far, we do have increasing degrees of renewable electricity production in the energy mix. But here lies the key problem that this paper is addressing. With intermittent renewable electricity production unaligned with variable consumer demand, storage of the energy is essential. But there is a fundamental challenge with electricity: you cannot really store it.

This isn't such a problem as long as the demand can be instantaneously matched, everywhere, with the supply of power at a proper frequency. But that requires stable supply - and stable electricity supply is not typically the renewable kind. Electricity sourced from wind and solar are highly variable, both daily, as well as seasonally.

One of the greatest bottlenecks to realising a fully, or even predominantly, renewable energy system is, therefore, the storage of that energy. Many technologies are able to help solve this problem, but in the long run, the only viable full solution is a combination of many technologies. This includes an important role for the gas grid, which has massive capacity for storage and is or can be connected to other energy networks and decentralised nodes of production and demand. Gaseous energy is an energy carrier fully capable of energy storage and the European gas grids are existing infrastructure which can adequately cope with the storage needed.

Taking account of the problem & solution

The Commission's "High-RES" scenario in its "Energy Roadmap 2050" has a renewables share of 85% in 2050, with over 60% of total production variable in nature.

As a result of a solid percentage of renewable energy being deployed in the European energy system, two problems come to the forefront. These two issues must be overcome in order to integrate high levels of renewable electricity production into the electricity system:

i. Utilise the excess electricity that is produced when renewable generation production exceeds electricity demand.

ii. Have an adequate source of backup generation available when renewable generation production is low.

There are several different means to help accommodate increased generation of variable renewables. **Dispatchable generation** (e.g. biomass, hydro, gas, coal, nuclear) can be used when there is a deficit of renewable production, although it does not help alleviate the problem of using excess renewable production. Speedy ramp-up of energy to be dispatched when renewable power production suddenly stops is a key capability needed. **Developing the electricity transmission and distribution grids** offers a means to resolve both surplus and deficit electricity production situations. However, this option is limited if the renewable production is correlated to a very large area. Long construction times can also be prohibitive, along with social acceptance barriers where above ground high-voltage cables and piling installations are met with local resistance. **Demand-side management** provides a means to adjust the profile of demand to match the profile of production more closely, although it is limited by the amount of demand that can be shifted and the amount of time for which it can be delayed.

Energy storage can help alleviate both the problem of using excess renewable generation and producing electricity during times of low renewable production. Different forms of energy storage have varying strengths and weaknesses in this respect.

Components of the solution

Energy storage for the electricity sector is predominantly thought of as an electricity issue, to be solved by electricity solutions, commonly referred to as power-to-power. There are several power-to-power options:

Pumped hydro	Using electricity, water is pumped up to an upper reservoir and released through turbines to a lower reservoir when needed in order to generate electricity.
Batteries	One or more electrochemical cells that convert stored chemical energy into electrical energy.
Liquid air	Using electricity, air is turned into a liquid by cooling it. When heat is reintroduced the air is expanded, which drives a turbine producing electricity.
Compressed air	Using electricity, air is compressed and stored in a reservoir, before heating the air to expand it, which is then sent through a generator to produce electricity.
Flywheels	A rotor is accelerated to a very high speed and energy is held in the system as rotational energy. When energy is extracted from the system, the flywheel's rotational speed is reduced.

Another option is to convert the electricity to another form and then store the energy in this new form. Options for energy conversion include[1]:

Power-to-gas	Electricity is converted into hydrogen via an electro-chemical process called electrolysis. In this process electrolysers introduce water to electricity in order to separate the hydrogen from the oxygen, in order to make use of the hydrogen to produce energy. The hydrogen can be used directly in mobility, industry or injected into the gas grid, as hydrogen, or converted further into synthetic methane (see figure 3 for visual diagram).
Power-to-heat	Electricity is converted to heat for final consumption as heat. Heat can be stored for a limited time period in heat storage facilities, such as hot water tanks.
Power-to-liquid fuels	Transforms water and CO_2 to synthetic fuels (petrol, diesel, kerosene) using electricity.

[1] Note the storage of heat in sand at solar power plants was not included.

Figure 1: Assessment of different solutions for integrating renewables.

Res Integration Solution		Deficit Solved	Surplus Solved
Dispatchable Generation (hydro, biomass, fossil)		✓	✗
Grid expansion		✓	✓
Demand side management		✓	✓
Energy Storage	Power- to-power	✓	✓
	Conversion to heat and heat storage	✓	✓
	Conversion to hydrogen for use outside power sector	✗	✓

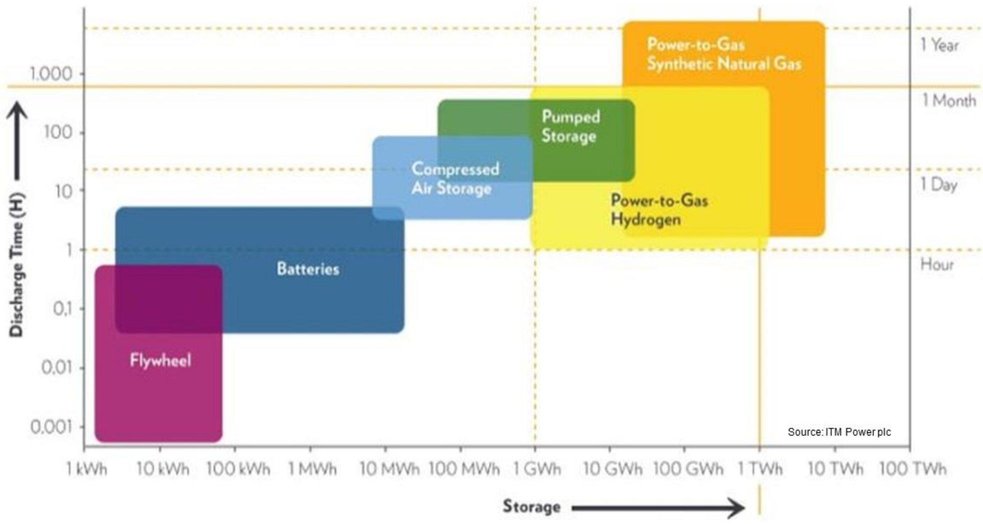
Source: Fuel Cell & Hydrogen –Joint Undertaking.

How do the characteristics of these different storage options compare?

There are three key parameters to consider when comparing storage technologies, the amount of energy that can be stored, the maximum amount of energy that can be stored or released per unit of time, and the lead-time for changing the level of storage or extraction. Depending on these characteristics, the different storage options will help address different issues in the integration of renewables.

It should be noted that although conversion to hydrogen for use outside the power sector does not offer directly a solution to temporal energy deficits, it can indirectly provide a solution via the option of using the gaseous energy to provide electricity at a later time when it is needed.

Figure 2: Comparisons of different energy storage forms capability



Source: ITM Power

Batteries are best suited for short-term daily storage, as they have limited charge volume, but high charge and discharge rates. Power-to-power storage in general is found to be optimal for grid-level daily time shift[2]. However, during periods of prolonged high renewable production or low renewable production, its usefulness declines.

Mechanical storage technologies (pumped storage, compressed air storage) are usually built on "utility" scale, with output capability in the tens or hundreds of megawatts. Their deliverability is limited by the space in which the storage medium can be stored and is typically hours or days. This makes mechanical storage more suitable for daily time-shift, as well as longer term time-shift.

The ability to store heat means that electrified heating can become a flexible load (e.g. storage heaters), as the consumption of electricity for heating can occur at a different time than the consumption of heat itself. However, power-to-heat faces the limitation of the availability of an electrified heat demand (which limits the number of storage heaters), the seasonality of this demand and the amount of heat that can economically be stored.

Comparably, power-to-hydrogen does not face such constraints, due to the large amount of energy that the gas grid can accommodate. Depending on the local rules for hydrogen injection, methanation[3] may be required – carbon can be taken from the air, or other sources, and added to hydrogen to make methane. This can, of course, provide a much welcomed side effect of reducing atmospheric carbon dioxide as well.

[2] Commercialisation of Energy Storage in Europe, 2015, Fuel Cell & Hydrogen Joint Undertaking

[3] Methanisation is the process of introducing (recycled) carbon to hydrogen to create methane molecules for use as energy in existing natural gas infrastructure.

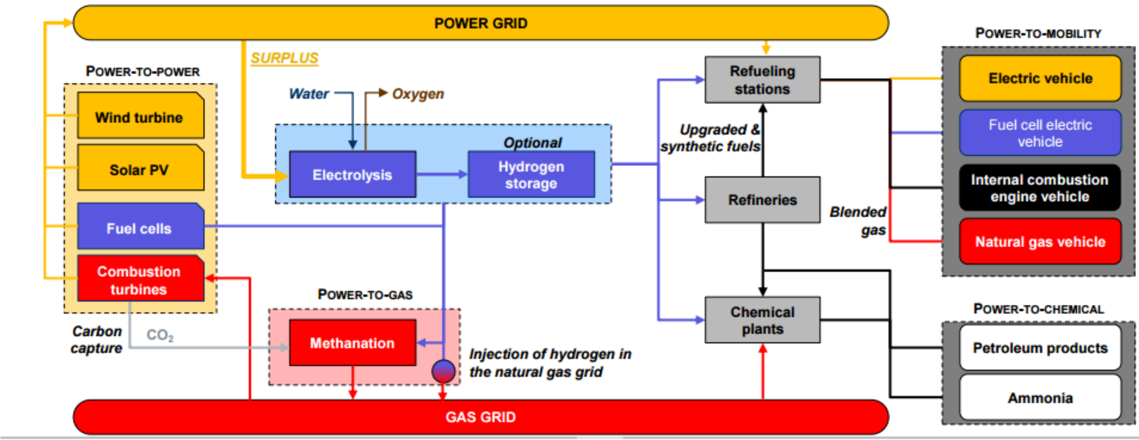
Power-to-gas, a central role

Large scale deployment of power-to-gas could provide benefits to both the electricity system and the gas system:

- it allows greater deployment of renewable electricity, and reduces curtailment (mandatory cessation of renewable power production);
- in some cases, it will avoid the need for additional electrical infrastructure;
- it can provide an additional means for the electricity grid operators to manage the voltage and frequency of the grid, by 'dumping' excess electricity when supply is too strong for demand, or extracting from the gas grid when needed fuel to power their generators;
- a relatively cost-efficient way of storing energy[4], which is particularly important to meet the heating profile of customers;
- the means to provide for the flexibility that an overall energy system requires;
- a tool to reduce CO_2 emissions: taking airborne CO_2, for instance, and using it for methanation of the hydrogen, the gas grids can become a highly sustainable means of storing and transporting renewable energy efficiently and reducing CO_2 emissions;
- conversion of electricity to hydrogen can productively utilise nearly all excess renewable energy in the high RES scenario[5]. Even by 2030, electrolysers could play a significant role if electricity transmission and distribution constraints are present.

[4] *Commercialisation of Energy Storage in Europe*, 2015, Fuel Cell & Hydrogen Joint Undertaking
[5] Commission's *Energy Roadmap 2050*

Figure 3: Gaseous energy as storage and energy carrier in the energy system



Note: Simplified value chain. End uses are non-exhaustive. Note that the power and gas grids are the main supplier to the residential and commercial end-uses (lighting, heating and cooling, cooking.
Source: SBC Energy Institute analysis.

Even though the total amount of renewable energy produced exceeds the total electricity demand, due to the time mismatch between supply and demand, considerable non-renewable backup generation is required for the time when there is little sunshine and wind speed is too low or too high. In an 80% RES scenario, that backup can be a combination of natural gas and hydrogen gas.

Policy considerations

In light of the problem our energy system faces and the potential that power-to-gas (P2G) offers, we encourage the following:

- There should be a possibility to waive consumption-based fees, taxes and levies, either fully or partially, for electricity that is used for energy conversion and storage, as it is used on an interim basis and not for final consumption.
- The evaluation of energy storage should be incorporated in consideration of network expansion in local, national, regional and the EU (ten-year) network development plans.
- Harmonisation of standards for injection of hydrogen into gas grids, taking into account best practices in countries[6] such as Germany and the Netherlands should be envisaged.
- P2G should be a major element of research and innovation plans and funding.

[6] *Commercialisation of Energy Storage in Europe*, 2015, Fuel Cell & Hydrogen Joint Undertaking