Clean Burn
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VERSION 2

Introduction

Renewable electricity generation by wind turbines, solar panels and similar ambient energy capture technologies is inherently variable, and so the wide deployment of renewable energy must include both backup generation capacity, for when power demand usurps power supply; and also storage of excess electrical power, for those times when supply surmounts demand.

As the transformation of energy from one form to another incurs an efficiency penalty, at first it seems most optimal to store electricity as electrochemical potential energy in power batteries. However, there are four major issues with electric batteries which limit their contribution to energy storage : the first being that they require a lot of metal in their manufacture; which, without far higher levels of metals recycling, and new discoveries of unusual metal ores, keeps batteries expensive, even when compared to compressed gas containment (Friedman et al., 2012; Pellow et al., 2015). In comparison, many forms of gas storage are and will remain much less materials-intensive, and therefore less costly. The second concern with energy storage via electric batteries is that the amount of energy that can be stored in any one battery is not flexible above its highest rating. In other words, although batteries can store any amount of energy from zero up to their designed capacity, they cannot store anything above that amount. In order to ask a battery storage operator to increase the amount of energy they are storing, they would need to commission new batteries, all of which would take time and financing. By comparison, creating additional gas requires the same equipment and plant as before; and additions of storage capacity for gas simply require a place to contain it, and a pipeline in and out, which could be anywhere, provision perhaps offered through a storage market. The third main limitation of batteries is that they take up an incompressible amount of space – in other words, it is not possible to minimise the physical volume of a battery of a given storage capacity beyond certain physical design parameters. Where power grid operators are considering battery parks to help with grid balancing, they need to have access to a calculable amount of land on which to site the facility. It will not be smaller than this. And if the grid operator is asked to increase the storage capacity, the amount of land taken up will only be larger. There would be a range of problems resulting from attempting to construct “tower blocks” of batteries, not least of which, servicing, maintaining and replacing the individual units. To counter this issue, it has been proposed to utilise the storage capacity of an “Internet of Batteries”, where all appliances and vehicles containing a battery could be brought into the charge and discharge cycle of battery storage on the power grid; however, although this proposal would be useful for grid balancing for minor fluctuations in voltage, it would be unclear how this distributed network of batteries could compensate for a major loss of generation in the power grid, or how the owners of the appliances or vehicles could recover from a case where their batteries have been completely discharged, to meet a short period of high demand. The final major drawback to focusing on electric batteries for energy storage is that of discharge time. The fast discharge time of batteries makes this form of energy storage highly responsive to demands for backup power; providing balancing services within a second. Even so, a battery can only provide high rates of backup power within their maximum discharge capability – which depends on their remaining stored energy at any one moment, rather than their total storage capacity; so the faster they are discharged to cope with rapidly changing grid conditions, the shorter the time they can be relied upon. There is also the question of natural discharge. A battery left unused slowly “leaks” charge, so the potential to generate degrades over time. These discharge issues imply that batteries are best used for temporary short-term power generation displacement, for example, soaking up power from solar fields during daylight, and making that power available overnight; or should there be a short-term small- to medium-scale dip in power output from somewhere else in the grid, leading to a need for voltage smoothing.

Given the boundary conditions for metal batteries as energy storage, the prospects for other technologies must be considered. Most of the solid state options, including purely electrical devices, are suitable for low volume energy storage and short cycle storage. Whilst Phase Change Materials can be expected to be widely used for storing energy, most of the applications will not be able to generate electricity, as they will be using relatively low temperatures. Energy storage options that deploy liquids can achieve a better performance over longer storage times, and are more expandable – such as flow batteries, which use liquid electrolytes. Another option to use liquids is energy storage in the form of heat, as many liquids, such as water, have a high heat capacity; but here again, thermal tanks will not be able to generate power owing to their low temperatures. Despite these advantages in terms of volume and storage duration offered by energy storage by liquids, large applications such as scaled-up flow batteries, field-sized heat tanks, hydropower and Pumped Storage Hydroelectricity (or Pumped Hydroelectric Energy Storage) still suffer from some of the same limitations as electrical batteries – it is not quick or easy to add storage capacity; besides in some cases requiring the pouring of a lot of concrete, they require a lot of land area, and are not rapidly upwardly flexible in their storage capacity. If it takes time to build an energy storage facility, it is less likely to be part of the mainstream solutions to prevent dangerous climate change, that need to be implemented sooner rather than later. These concerns are mitigated in some cases – for example, hot water stored underground makes the storage of energy more efficient and longer-lasting. Despite this, underground energy storage of most kinds that use liquids still need a lot of construction, which is more complicated for underground sites. A better goal would be an energy storage technology suite that does not disturb the subsoil to a great extent.

Those energy storage technologies with the maximum scope, both for energy storage quantities, discharge duration, storage duration and compression, are the underground storage of gases, such as air and Renewable Gases, principally methane, hydrogen and carbon dioxide, in natural underground features, such as depleted Natural Gas caverns or natural aquifers. These gases can be compressed in order to store them; they can be safely stored for several seasons at a time without dissipating; and facilities can have a far larger capacity to store energy than other technologies of similar sizes. In terms of flexibility of operation, the locking away of energy as gas requires some lead time, as does calling on that energy again via some form of combustion. Currently, gas-to-power plants take anywhere between 20 minutes and 2 hours to spin up to operation. The ramp up could be improved with innovative designs, such as those to have startup phases that rely on the energy that can be harvested from the decompression of initially compressed gas in storage. This would also enhance the overall lifecycle efficiency of making and consuming gas, especially where the energy used to make the gas were spare Renewable Electricity, a set of processes commonly referred to as “power to gas”. Such improvements may even mean that gas energy storage and delivery solutions start to rank higher than electricity-only energy delivery solutions in overall efficiency. Although transforming power to gas to store, and then transforming gas to power again to make use of the energy, incurs losses; electricity also needs to be energy transformed when being utilised; for example, through electric motors in vehicles, and in radiative heaters. Whilst the use of electric heat pumps can significantly raise the efficiency of electricity-only energy delivery, new infrastructure, equipment and appliances for this will have to be installed in parallel or in series with other systems; and there is a materials efficiency loss owing to this. Electing to focus on developing Renewable Gases rather than batteries for energy storage, and keeping gas as an energy vector, delivered by the existing gas grids, and used in already existing appliances and equipment, reduces this asset investment overhead. Utilising the extant gas delivery networks means that an ordered transition from Natural Gas to Renewable Gases is made possible. This is particularly relevant, as the already-existing energy companies that process Natural Gas are ideally positioned to produce and supply Renewable Gas. Retaining their competency and making full use of their plant and other infrastructure assets is the optimal configuration for the introduction of Renewable Gases. Re-purposing themselves to be producers and suppliers of Renewable Gas will mean the least disruption to the systems of energy commerce and trade, and the investment structures centred on these energy companies. Of note, there are many gas processing plants and petroleum oil refineries where the technologies for industrial scale Renewable Gas making are already in use. Energy delivery via gas energy vectors is already highly efficient. To go further in optimising the use of gas, energy systems designers modelling the energy delivery chain will need to consider the advantageous role that different types of gas-fired and gas-refrigerant heat pumps could play in raising the overall energy efficiency of power-to-gas-to-storage-to-heat.

As it seems optimal to continue to use gas of different kinds to backup renewable power, it seems therefore that we will continue to need to understand how to burn things, only now we need to do it cleanly.

Objectives

As the scope of this research into Renewable Gas is so broad, results and outcomes are likely to be many years in the maturing/fermenting. The aim then is publication of study, references, data and analysis on a rolling basis, and made open access throughout; rather than through traditional, conventional programmes of academic activity. It is not expected that this project will be published in a traditional format, such as edited book, defended thesis, peer-reviewed article or conference paper. Instead, there will be a cycle of research and release, in the form of HTML and/or PDF, via upload to a website, where it can be freely downloaded.

The central task is to write a freely-available downloadable online digital resource about Renewable Gas, that is, low net carbon dioxide emissions gaseous phase energy vectors, including methane and hydrogen, made without the use of fossil fuels as feedstock, using non-fossil fuel energy to produce them.

Writing and Research Style

1. Flexible Structure and Content

The resource should be expandable, with the possibility to add new items to a menu structure or in categories, as they become available. This means that the resource will not be a standard fixed-content book. Neither will it be a loosely-written weblog, as each article added to the resource should be self-contained, evidence-based and referenced.

2. Communications-Friendly

The resource should be easy to access in style, in order to support a social media communications strategy - for example, uploading to a website that can be linked in Twitter. It should also be digestible - that is, in small enough pieces to absorb in stages, by those who are not concentrating or focused on the subject. The language should be simplified where it concerns engineering and other model-based or mathematics-based design.

3. Data-Supported Reasoning

Arguments should each have a foundation in publicly-available official or quasi-official data; or from peer-reviewed scientific research data. Research into relevant and well-recognised data should verify any claims made.

4. Signalling Rather Than Influencing

The aim is not to write persuasively, but to used different methods of observation of transitions in the energy sector. Since the overarching framework is the necessity for the global economy to undergo a step change to much lower carbon dioxide and methane emissions, this resource will signal activities and trends that comply/fit with this transition. In the Natural Philosophy of Physics, it is said that it is not possible to observe something without changing its course or outcome, and it is hoped that this resource contributes in a similar way. The aim is not to influence, but to record observations, in the recognition that information may alter behaviour through a variety of channels, not least, peer group involvement and networking.

5. Open Access Peer Review

This resource should consider different viewpoints, a range of data and a range of drivers for the global economy. To fully encompass this field, the writing needs to be open to comment and review as it progresses, so it will be Open Access and all feedback will be accepted.

6. Writer and Author

At the current time, there is only one author writing for this project : Jo Abbess. The project does not rule out including writing by others in future.

References

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Pellow et al. (2015) : "Hydrogen or batteries for grid storage? A net energy analysis", by Matthew A. Pellow, Christopher J. M. Emmott, Charles J. Barnhart and Sally M. Benson, in Energy and Environmental Science, 2015, Volume 8, Pages 1938-1952, Published by the Royal Society of Chemistry (RSC), http://dx.doi.org/10.1039/c4ee04041d, https://doi.org/10.1039/c4ee04041d