Gasification of waste and biomass to hydrogen

Decentralised, low-carbon intensity hydrogen production

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It is hard to imagine what could derail the development of the emerging hydrogen economy. Positive sentiment and momentum related to the use of hydrogen as a renewable energy vector are at an all-time high. Many industrial, energy and transport applications will pull for significantly more hydrogen to displace fossil fuels.

At present, compressed hydrogen gas is moved from centralised production facilities to the point of utilisation on trucks in high pressure cylinders. Regional liquid hydrogen storage and distribution networks will also emerge.

Unfortunately, this kind of hydrogen distribution is costly and inefficient. For example, a 40 tonne truck with steel cylinders for compressed hydrogen distribution at 200 bar will contain only 300kg of hydrogen: less than 1% of the total vehicle weight is the valuable hydrogen payload. Liquid hydrogen distribution is not much better. A 40 tonne liquid tanker will contain around 3.5 tonnes of hydrogen – less than 10% of the vehicle weight is the payload.

Increasing conviction to use hydrogen will stimulate major national infrastructure investments. The European Hydrogen Backbone is good example of a proposed hydrogen transmission pipeline network. However, in no country is the pipeline hydrogen transmission and storage infrastructure yet in place. Localised hydrogen generation close to markets is therefore essential to bridge the time until large-scale pipeline infrastructure is in place. Localised hydrogen production and utilisation can jump-start the hydrogen economy.

Low-carbon hydrogen production from waste

More than 95% of the hydrogen produced worldwide today is derived from thermolysis of fossil fuels. Reforming of natural gas is by far the largest source of hydrogen, accounting for around 80% of hydrogen production. In this category, steam methane reformers (SMRs) lead the way and auto thermal reformers (ATRs) play a supporting role. Gasification of coal and petcoke is the second-largest hydrogen production pathway. POX, or partial oxidation of natural gas, a process that is like gasification, is also a significant thermal process to produce hydrogen.

Electrolysers are being built at an increasing pace and on an ever-larger scale. When fed with renewable electricity from sources such as wind, hydropower or PV solar panels, 'green' hydrogen is the result. Hydrogen production on electrolysers is growing at around 50% per year. From a low base, this kind of growth is not surprising. A benefit of electrolysers is that they can use water and electricity, which are available in many locations to generate hydrogen at the point of application. This avoids the expense and complexity of hydrogen distribution.

To meet the need for additional hydrogen that will be required to support decarbonisation of industry, transportation, and the energy sector, low-carbon hydrogen production from thermolysis of waste-to-hydrogen will also grow. Since municipal waste and agricultural wastes are universally available resources, this technology has relevance to developed and developing nations.

An affordable solution

Energy poverty is often concentrated in rural communities and exists over numerous levels. According to the Centre for Global Equality, around 38% of the global population is living without clean cooking facilities and 34% of hospitals are operating separately from main-grid electricity.

Long hours collecting fuel can be hazardous for individuals from these communities and cooking over inefficient stoves prevents the women and girls in these regions from pursuing an education or from having an independent source of income, thus perpetrating the poverty cycle. A viable solution to this problem would be to supply rural communities in developing countries with energy in the form of hydrogen and methane from the gasification of waste.

In 2016, Hybrid Gasification Ltd (HGL), based in UK and Green Sands Engineering (GSE), based in Pakistan developed a novel Hybrid Gasification technology to convert biomass to syngas. The process consists of solar-assisted gasification using village combustible residues to produce hydrogen and methane. The pilot project was led by Dr. Abdullah Malik, who worked in Pakistan as part of the regulatory body OGRA (Oil & Gas Regulatory Authority) for three years and served under the administration of Prime Minister Imran Khan for over a year.

After years of development, Hybrid Gasification is now ready for

"Pakistan has a total installed power generation capacity of around 40,000 MW"

Sugar cane waste is ideal for gasification to produce hydrogen commercial demonstration, perhaps in a rural location in Pakistan or a similar remote location, with a highly agricultural economy.

Empowering off-grid rural communities

According to Dr. Malik, "The project will be novel in tackling issues of biomass and other combustible household residues that have no use. In Pakistan, this kind of waste could produce around 10 mega tonnes of oil equivalent per year."

The natural gas market of Pakistan is amongst the biggest in Asia and the country was gas self-sufficient until 2005; from then on, gas production has not been able to keep up with the gas demand of the country and LNG imports through terminals in the Karachi region have been implemented to fill the gap. Discussions are ongoing about the construction of a natural gas pipeline that would run from Turkmenistan through Afghanistan to Pakistan and then on to India. However, difficulties in securing finance for fossil fuel projects and security issues have delayed the project. Local gas production is therefore a short-term imperative.

> $0.5m
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> CAPEX in a solar-assisted hybrid gasification plant could be just $0.5m

Pakistan has a large amount of agricultural and biomass resources, which have not been utilised due to difficulties with collection and transportation to centralised energy facilities. Pakistan has a total installed power generation capacity of around 40,000 MW, including more than 40 bagasse (sugar cane waste) fired power stations. This type of hybrid gasification plant offers a solution that can build on the established use of agricultural wastes for power generation, and these biomass resources can decrease the requirement for imported LNG.

The perfect community for this project to thrive in, is one which is off the gas grid, has access to solar power and bio-wastes and a culture of burning biomass for heating. Rural economies around the world, such as India, Bangladesh, Iran, and other Southern Asian countries that have a similar profile to Pakistan, could equally benefit from the solar-assisted hybrid gasification of biomass wastes.

There is great potential for distributed hydrogen applications in rural areas, such as heating water for overnight hot water bottles in winter, cooking on an open flame, fuel cell buses, and fuel cell tractors. Hydrogen storage for back-up power generation via fuel cells will also be important in remote areas as dependence on electricity increases, because distributed off-grid solar energy is limited to the daytime.

Avoiding air pollution and deforestation

A benefit of the Hybrid Gasification process is its simplicity, as it combines proven technologies. Firstly, the bio-waste is manually dried in the sun, then a ball mill is used to grind it to pieces of approximately 1 to 2cm in size. These are fed to a vertical pyrolysis unit where they are heated for around one minute. The feedstock is then forced through a horizontal pyrolysis auger, for around 1-2 minutes.

The resultant ash is emitted from the auger and the produced gases are then purified to recover hydrogen and methane for heating, cooking, and fuel cell applications. The residual gas, which includes flammable components such as carbon monoxide and ethylene, can be utilised to generate power on a gas engine.

The system is designed to operate for 6-8 hours per day, when sun is usually guaranteed. It can use crop stubble in a constructive way, as opposed to being burnt irresponsibly. This also enables the produced gases to be cleaned using a chemical scrubbing technique, so that people won't be exposed to hazardous vapours, such as carbon monoxide and sulfur dioxide when using their stoves.

The gasification plant is designed to operate with most types of biomass and farm residue, such as animal wastes, peanut or rice husks, bagasse, straw, cotton seeds or corn cobs. Additionally, other combustible domestic and urban wastes such as, vegetable residues, sludge from drains, plastics, spent fats and oils can also be gasified easily.

According to Dr. Malik, "Pakistan's primary energy supply mix clearly shows natural gas as playing a major role in the country's economic development by accounting for nearly 50% of its total primary energy supply."

This therefore poses a huge obstacle towards reaching carbon neutrality, which is where solar-assisted gasification comes in. The project outcome is deemed to benefit the Pakistan Government's policy to reduce greenhouse gas (GHG) emissions, helping to meet The Paris Agreement requirements to limit climate change and carbon dioxide emissions.

The plant is designed to run for more than 20 years, with solar energy as the main source of electricity. For a typical small-scale village, with about 100 households, the initial capex would be around $0.5m, with the ability to process four tonnes of feedstock per day and providing sufficient gas to meet the needs of that community for cooking and heating applications.