Hong Kong

Heating and cooking with hydrogen-rich 'town gas'

A case study by **Stephen B. Harrison, sbh4 consulting**

Town gas, a mixture of hydrogen, carbon monoxide (CO) and carbon dioxide (CO_2) was first produced by William Murdoch in 1794 in a coal gasification retort. The gas was used in his house and office in Redruth, Cornwall. Many cities relied on town gas for heat and light during the industrial revolution.

In the US, the Seattle Gas Light Company operated a coal gasification facility from 1906 which could produce up to 170,000 cubic metres per day of town gas. The rusted remains of the plant can still be seen in Gas Works Park, on the north shore of Lake Union.

Over time, gas holders and pipeline distribution networks were converted from town gas to natural gas. Discoveries of natural gas in the North Sea and North America enabled these regions to convert from coal gasification to the direct use of natural gas. The avoidance of emissions from coal gasification plants contributed to an improvement in air quality.

In Asia, Hong Kong has been using town gas for heating, cooking and industrial applications since 1864. At that time, coal gasification was the source of town gas. In 1967, the feedstock was changed to heavy fuel oil and in 1973 naphtha became the main feedstock.

Tai Po Towngas

The modern Tai Po Towngas plant commenced operation in 1986, producing hydrogen-rich town gas on four catalytic-rich gas (CRG) trains. It was upgraded with an additional four CRG trains in 1992 to triple the town gas production capacity. Landfill gas was introduced as feedstock in 1999.

The site received an additional 15% capacity upgrade in 2006, at which time pipeline natural gas was added to the feed mix. Today, the plant can generate more than 12 million cubic metres per day of town gas – 70 times more than the aged Seattle coal gasification facility.

Natural gas now forms around 60% of the feed to the CRG process. The switch from pure naphtha-fed operation to the mix of naphtha and natural gas resulted in 20% less CO_2 emissions from the process. SOx and NOx emissions reductions of 30% and 50% were also achieved.

The CRG plant operates in the bay area of Tai Po, on the mainland to the north of the city. Hydrogen-rich town gas is distributed by pipeline network to consumers on Hong Kong Island, Lantau Island, and the New Territories. Town gas remains the dominant heating and cooking heat source in Hong Kong.

Catalytic-rich gas reformer

Hong Kong is reliant on energy imports and there are several refined products terminals around the city. A floating LNG import terminal commenced operations in 2023 to increase the availability of natural gas for power generation. LNG will support the transition away from oil and coal-fired power plants and reduce the carbon intensity of power generation in Hong Kong.

A naphtha import terminal close to the Tai Po CRG plant unloads cargos to three storage tanks at the town gas production facility. The gas supply to the Tai Po Towngas plant is regasified LNG, which is transported by a submarine pipeline from the Guandong Dapeng LNG terminal. The submarine pipeline runs for 34km to Tai Po in twin pipes, each of 450mm diameter at a maximum working pressure of 90 bar.

Landfill gas is also captured from several waste management sites around Hong Kong to be fed to the reformer. Use of landfill gas in the CRG plant reduces the need for fossil fuels and avoids harmful methane greenhouse gas (GHG) emissions from the landfill sites.

Each train of the Tai Po Towngas facility has a CRG reactor (pre-reformer), and a tubular steam methane reformer at its heart. Upstream of these reformers there is a desulphurisation unit to purify the feedstock and protect the reformer catalyst. Naphtha typically represents 40% of the feed to the process and may contain up to 100pm of sulfur. The natural gas feed is also desulfurised.

Downstream of the tubular steam reformer, carbon monoxide in the reformate gas is reacted with additional steam in a water gas shift reactor (referred to as a CO converter) to enrich the hydrogen content of the town gas.

Integrated carbon capture

Leaving the CO converters, the town gas is rich in hydrogen and CO_2 but contains less than 3% carbon monoxide. However, at this point in the process the CO_2 concentration is higher than would be desirable when the town gas is burned to produce a flame for heating or cooking.

The next stage in the process is therefore CO_2 removal using a hot potassium carbonate solution as a solvent.

The CO_2 capture equipment is a twin tower process that operates like a SELEXOL™, or amine-based CO_2 capture unit. In the first absorber tower, much of the moisture and CO_2 is removed from the town gas stream as it is captured in the potassium carbonate solution. In the second tower, known as the CO_2 stripper or carbonate regenerator, the CO_2-rich potassium carbonate solution is boiled to release water vapour and CO_2.

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At present, the CO_2 loaded gas stream from the stripper tower is emitted to atmosphere. However, in the future, this flue gas stream could be dried and the remaining CO_2 could be liquefied to be utilised or sequestered. This enhancement would significantly reduce the carbon intensity of Hong Kong's energy system.

The final stage of syngas preparation is drying. This is important to avoid the combined presence of moisture, CO, and CO_2 in the town gas distribution pipeline. Drying minimises the potential safety risks associated with steel corrosion and cracking. The final town gas product, containing around 50% hydrogen, 30% methane and 18% CO_2 and 2% CO at around 30 bar pressure is then distributed throughout Hong Kong in a pipeline network.

Town gas distribution to industrial and commercial consumers

A network of 3,700km underground pipes distributes town gas to more than one million domestic, commercial, and industrial end-user locations in Hong Kong.

In 2021, Towngas developed an internal pipeline conditioning robot that can grind and apply a protective surface finish to steel pipeline weld seams. This innovation enhances corrosion protection and ensures safe operations and can extend pipeline infrastructure life.

As with natural gas distribution, the Hong Kong town gas is stenched with an odorant called THT (TetraHydroThiophene). This is a sulfur compound with a very strong smell which allows minor leaks to be detected

The Tai Po Towngas plant in Hong Kong

by the human nose to minimise the risk of gas explosion accidents.

When the natural gas pipeline from the LNG terminal at Guandong was built, consideration was given to converting Hong Kong to natural gas and shutting down the CRG town gas plant. However, the costs and disruption associated with such a transition were regarded as excessive. For example, town gas consumers would have needed to purchase new cookers and heating boilers to run on methane rather than town gas. Each of these two energy vectors burns with different flame characteristics and heating equipment is therefore not interchangeable.

The issues discussed when the change from town gas to natural gas was considered in Hong Kong are like those that several cities are debating today as they consider converting natural gas pipelines to pure hydrogen, or admixing hydrogen into natural gas grids.

Pure hydrogen on-tap

Blending hydrogen into gas distribution networks has been proposed in several countries. When blending hydrogen and natural gas together, the question arises whether to use the combined gas mixture for heating, cooking and other applications or to separate the hydrogen from the natural gas prior to use.

Separation allows the hydrogen to be used as a zero-emission fuel in mobility and other applications but incurs an additional CAPEX and OPEX penalty due to the requirement to purchase and operate equipment to achieve the gas separation.

Separating hydrogen from methane is achieved as the final stage of most steam methane reforming processes using a pressure swing adsorption (PSA) unit. However, the Tai Po CRG facility does not perform this PSA purification stage. When low concentration of hydrogen is recovered from an admixed natural gas pipeline, a membrane can be used upstream of the PSA unit to achieve a low-cost first stage of hydrogen enrichment prior to the PSA unit.


Hong Kong cuisine

During a visit to the Tai Po facility in December 2022, Mr Tse Chin-wan, the Secretary for Environment and Ecology of the Hong Kong Government, toured the town gas production facility. He was shown the newly installed hydrogen extraction system which can puritfy hydrogen from the town gas. To achieve high purity hydrogen on-tap, all around Hong Kong, small PSA units, such as the one he observed, could be implemented at locations where hydrogen is required.

And, if the CO_2 emissions from the stripper at the CRG facility were to be permanently sequestered, the resulting hydrogen could carry a 'blue' tag or an official 'low carbon' guarantee of origin certification. The path to this major decarbonisation milestone in Hong Kong is clear. gw

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Close-up: The Tai Po Towngas plant in Hong Kong