Hydrogen Gas Grid Share

Hydrogen possesses the highest heating value compared to other commercially available petroleum-based fuels, and significantly, its combustion product is only water. Approximately 95% of hydrogen has been produced using fossil fuels, where natural gas reforming claims the highest share of around 68% due to its cost-effectiveness. Only less than 5% of hydrogen has been produced from renewable energy sources using water electrolysers.

The concept of blending hydrogen into the existing Natural gas (NG) pipeline network has been initiated to address the high risk of electrical grid instability due to the intermittent nature of renewable resources. The hydrogen blending with natural gas provides a smooth and cost-effective way to transform fossil fuel into a hydrogen-based economy by utilising the existing pipeline network. The hydrogen blending will improve the combustion efficiency of various end-use equipment and processes and help decarbonise the demand sectors such as the transportation and heating industry. The hydrogen roadmap targeted a blending of 5–15% hydrogen with NG and distributed through the national pipeline network by 2030 and increases further to 50% blending by 2050. Malaysia expected to establish a 100% carbon-free gas pipeline network and integrate solar PV or wind resources with the electrical grid by 2060.

In 2016, about 281GWh of natural gas was supplied through the transmission and distribution gas grid. Processes currently running on natural gas, such as commercial buildings boilers, will require modification or replacement to run on hydrogen.

In the Calculator, the hydrogen economy facilities are expected to start in 2030 and be completed in 2050 by phases.

Level 1
None of the gas grid is converted to hydrogen

Level 2
Pilot projects and none is commercialised.

Level 3
10% of hydrogen blended in the gas grid.

Level 4
By 2050, 25% of the gas grid is converted to 100% hydrogen.

Biomethane Gas Grid Share

Biomethane is made up of methane produced from biological sources and is very similar to natural gas (which is mostly methane) and hence can be directly substituted for natural gas in existing gas grid infrastructure. Increasing the share of biomethane in the gas grid is therefore a way to reduce emissions as it requires no new network infrastructure and causes no disruption to the end user.

The achievable share of biomethane in the gas grid is driven primarily by availability and sustainability of biomethane supply. Currently there is no biomethane of the gas grid supply

(Key interaction) Biomethane is supplied by anaerobic digestion (AD) of waste and gasification of biomass. Biofuels can be created from waste and biomass, but these have limited availability. Any demand not met by local biomass is satisfied by imports. However, dependency on large quantities of imported biomass may not be possible in reality and would results in a less robust energy system. Malaysia bioenergy production can be controlled through the Land Use & Biofuels levers. Biomethane is below Hydrogen in the priority order, should ambition for gas grid share exceed 100%.

Level 1
There is no Biomethane injection at Level 1 by 2050.

Level 2
Development of biomethane technology continue but there is biomethane share in the gas grid for Level 2 by 2050.

Level 3
The biomethane share of the gas grid rises to 10%, using AD of waste and gasification of biomass.

Level 4
Huge advances in methods of sustainability and securely generating biomethane lead to 25% injection of biomethane to the gas grid.

Hydrogen – Biomass CCS

Gasification is the partial combustion of a material to produce syngas – a mixture of carbon monoxide and hydrogen. Syngas can be used to produce biomethane, hydrogen or liquid biofuels. Hydrogen does not emit CO2 when it is combusted to produce heat or power. By using biomass gasification in combination with carbon capture and storage (CCS), there is the potential to remove CO2 from the atmosphere resulting in negative emissions. CCS processes have an energy demand of their own, which will add to the amount of CO2 that must be stored.

Gasification of biomass has been achieved at small scales, but it has not yet been combined with CCS. Hydrogen can be used to heat building via the Hydrogen Gas Grid Share lever. In 2016, the consumption of natural gas for industry (excluding electricity generation) was about 0.07 TWh (5989 ktoe)

(Key Interaction) The total demand for H2 is determined by the level of gas grid conversion to H2, the demand for gaseous fuels in buildings and industry and demand from transport.

The CCS Capture Rate lever determines how much of the CO2 from the gasification process can be captured and prevented from entering atmosphere. If electrolysis is needed to supply enough H2 to meet demand, then sufficient low-carbon electricity is needed to ensure the H2 conversion results in decarbonization.

Level 1
There is no hydrogen produced from biomass gasification with CCS.

Level 2
Hydrogen from biomass gasification with CCS rises to 4 TWh/year.

Level 3
Hydrogen from biomass gasification with CCS rises to 12.5 TWh/year

Level 4
Hydrogen from biomass gasification with CCS rises to 23 TWh/year and, in 2050.

Hydrogen – Methane CCS

Fossil fuels such as methane contain carbon and hydrogen atoms. In methane, four hydrogen atoms are bonded to a single carbon atom (CH4). Steam methane reformation (SMR) breaks apart these bonds and allows the hydrogen to be separated. High temperature stream is reached with methane in the presence of a catalyst to produce hydrogen and carbon monoxide. The carbon monoxide can be reacted further using the water gas shift process to produce more hydrogen and CO2. If CCS (carbon capture and storage) is applied to the process, this CO2 can be captured and stored and the hydrogen produced can be considered to be low carbon.

SMR is the most common method of producing bulk hydrogen in the world today. However, it has not yet been combined with CCS.

Hydrogen can be used for heating via the Hydrogen Gas Grid Share lever. In 2016, the consumption of natural gas for industry (excluding electricity generation) was about 0.07 TWh (5989 ktoe)

Key Interaction The total demand for H2 is determined by the level of gas grid conversion to H2, the demand for gaseous fuels in buildings and industry and demand from transport.

The CCS Capture Rate lever determines how much of the CO2 from the SMR process can be captured and prevented from entering atmosphere.

If electrolysis is needed to supply enough H2 to meet demand, then sufficient low-carbon electricity is needed to ensure the H2 conversion results in decarbonisation.

Level 1
There is no hydrogen produced from SMR with CCS.

Level 2
Hydrogen from SMR with CCS rises to 15.75 TWh/year.

Level 3
Hydrogen from SMR with CCS rises to 48 TWh/year (half of Level 4)

Level 4
Hydrogen from SMR with CCS rises to 87 TWh/year. This represents a quantity of energy approximately sufficient to meet all light transport demand assuming full conversion to hydrogen in the future.

Hydrogen - Imports

An alternative to producing hydrogen in the XXX would be to import zero-carbon hydrogen from countries with resources better suited for its production.

Hydrogen production is a major industry and currently around 50 million tonnes of hydrogen are produced each year worldwide. This is predominantly produced by steam methane reformation without carbon capture and storage (CCS) and so is not currently zero-carbon.

Key Interaction. The total demand for H2 is determined by the level of gas grid conversion to H2, the demand for gaseous fuels in buildings and industry and demand from transport.

If electrolysis is needed to supply enough H2 to meet demand, then sufficient low-carbon electricity is needed to ensure the H2 conversion results in decarbonization.

Level 1
There is no zero-carbon hydrogen imported

Level 2
Zero-carbon hydrogen imports rise to 11.8 TWh/year.

Level 3

Zero-carbon hydrogen imports rise to 35 TWh/year

Level 4
Zero-carbon hydrogen imports rise to 69.6 TWh/year.

Greenhouse Gas Removal

Whilst CCS allows the emissions from combustion and other transformation processes to be captured before they are emitted to atmosphere, there are methods by which CO2 can be removed directly from the atmosphere. These include afforestation (controlled by the Forestry lever) and direct air capture and enhanced weathering (controlled by this lever).

Direct air capture (DAC) envisages using a chemical process to absorb CO2 directly from the atmosphere. DAC requires energy to separate the CO2 from the chemicals it has bonded to. To capture and store one tonne of CO2, approximately 7GJ (or 2MWh) of energy is required. Storage infrastructure is required to permanently remove this CO2 from the atmosphere.

Enhanced weathering involves adding silicon-based minerals (silicates) to soils, which dissolve and in doing so, take up CO2. Silicates occur naturally at the surface of igneous rocks, but are also found in mine waste, cements, ashes and slags.

Key Interaction. Afforestation is controlled by the Forestry lever.
Deployment increases electricity demand which should be generated from a low carbon source to maximize emissions reductions.

Level 1
No DAC systems are installed and no enhanced weathering techniques are applied.

Level 2
No DAC systems are installed and no enhanced weathering techniques are applied.

Level 3
Approximately DAC captures 10 MtCO_2e & Enhanced Weathering controls 3 MtCO_2e

Level 4
Ambition level proposed DAC captures 48 MtCO_2e & Enhanced Weathering controlled 10 MtCO_2e

Bio-Conversion with CCS

The conversion of biogenic resources into different fuels requires energy and so results in CO2 emissions. Carbon is present in the biomass and waste resources used in biomethane and biofuel production; some of this remains in the biomethane and liquid biofuel (and is released on combustion of these products), but a portion of this is released during the transformation process. Direct combustion of waste to produce electricity also releases CO2.

By applying carbon capture and storage (CCS) to bio transformations, there is the potential to remove CO2 from the atmosphere resulting in negative emissions. This happens because biomass contains CO2 absorbed during its growth (removal of CO2). Ordinarily this is released back into the atmosphere during conversion to biofuels (net zero CO2). If these emissions are captured, they are prevented from re-entering the atmosphere (removal of CO2).

Bio-Conversion process suitable for CCS:
-Biomass gasification to produce biomethane;
-Liquid biofuel production from used cooking oil, wet waste and solid biomass;
-Energy-from-waste involving direct conversion to electricity by incinerating waste products (dry/wet waste, used cooking oil, landfill gas)
In the case of liquid biofuels production, CO2 emissions are fairly small, but emissions of nitrous oxide (a greenhouse gas) as a result of biomass processing may be more significant. Currently, there is no CCS applied to bio-methane, biofuel or energy from waste plants.

Key Interaction. This lever controls how much CCS is applied across bio-conversion processes. The amount of CO2 captured and stored is dependent on the capture rate (CCS Capture Rate lever) and the demand for biomethane (biomethane gas grid share lever) and liquid biofuels (transport biofuel levers).

Level 1
No CCS is applied to bio transformation processes.

Level 2
One third of bio-conversion processes have CCS applied.

Level 3
Two-thirds of bio-conversion processes have CCS applied.

Level 4
All bio transformation processes have CCS applied.

CCS Capture Rate

Despite the speed of maturity in renewable technologies, we still rely on fossil-based fuels to generate the energy demand needed globally. While waiting for renewable energy technologies to mature enough and replace fossil-based fuel, carbon capture storage and utilisation of fossil-based emissions are removal options as a transition state. The three main technologies of carbon capture, storage and utilisation: pre-combustion, post-combustion and oxy-fuel combustion which comes along with the carbon storage and utilisation technologies. Oil and Gas companies have been making important investments in CCUS. These technologies are at research and pilot stage in Malaysia.

Moving towards cleaner power generation such as advanced efficient coal and gas power plant (i.ecal boiler for coal power plant and H-Frame turbine for gas power plant technologies) with carbon capture and storage technology has been one of the CCS technology option.

There is the potential to remove CO2 from the atmosphere resulting in negative emissions by using biomass in combination with carbon capture and storage (CCS), known as BECCS (bioenergy with carbon capture and storage). This happens because biomass contains CO2 absorbed during its growth. Ordinarily this is released back into the atmosphere during combustion (net zero emissions). If these emissions are captured, they are prevented from re-entering the atmosphere (negative emissions).

In the calculator, it is expected that the facilities to support the hydrogen economy will be completed by phases in 2050.

In the calculator, the CCUS technology is expected to start in 2025 and be completed in 2050 by phases.

The capture rate of a CCS process determines what proportion of the total CO2 emissions can be captured. A capture rate of 100% means that all of the carbon emitted by a process fitted with CCS is captured.

Applying CCS to a process can reduce its efficiency as the process of capturing and storing carbon requires energy. In the Calulator, higher capture rates may result in a greater loss of efficiency.

Key Interaction This lever controls the proportion of CO2 captured by CCS processes. The level of CCS deployment is controlled by the levers for Industry CCS, Bio-Conversion with CCS, Hydrogen (Biomass or Methane) CCS and electricity from Biomass CCS. If no CCS is deployed, then the CCS capture rate has no effect.

Level 1
For most applications a capture rate of up to 85% is the minimum expected. Industry CCS capture rates are those achievable for key industrial processes within the sector.

Level 2
For most applications a capture rate of 90% is achieved.

Level 3
For most applications, a capture rate of 95% is achieved.

Level 4
All emissions are captured by CCS processes.

CCS Capture Rate by 2050 for Level 1-4		
BioSNG CCS Biofuel Plant CCS Energy to Waste CCS H2 -Bio Gassification CCS H2 - SMR CCS Electricity Generation Gas CCS	Level 1	85%
	Level 2	90%
	Level 3	95%
	Level 4	100%

Biomass & Biogas Power Plants using CCS

By using biomass in combination with carbon capture and storage (CCS), known as BECCS (bioenergy with carbon capture and storage), there is the potential to remove CO2 from the atmosphere resulting in negative emissions. This happens because biomass contains CO2 absorbed during its growth. Ordinarily this is released back into the atmosphere during combustion (net zero emissions). If these emissions are captured, they are prevented from re-entering the atmosphere (negative emissions).

Level 1
No Biomass & Biogas plant with CCS

Level 2
By 2050, 50% plants are with CCS.

Level 3
By 2050, 80% plants are with CCS.

Level 4
All plants are with 100% CCS