Power to Methanol/Power to Gasoline – Methanol/Gasoline Synthesis from H_2 and CO_2 by Using Water Electrolysis and Post-Combustion Capture

European Association for Storage of Energy

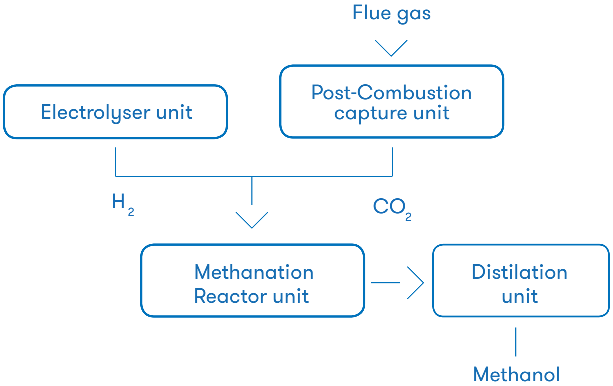
Chemical Energy Storage

1. Technical description

A. Physical principles

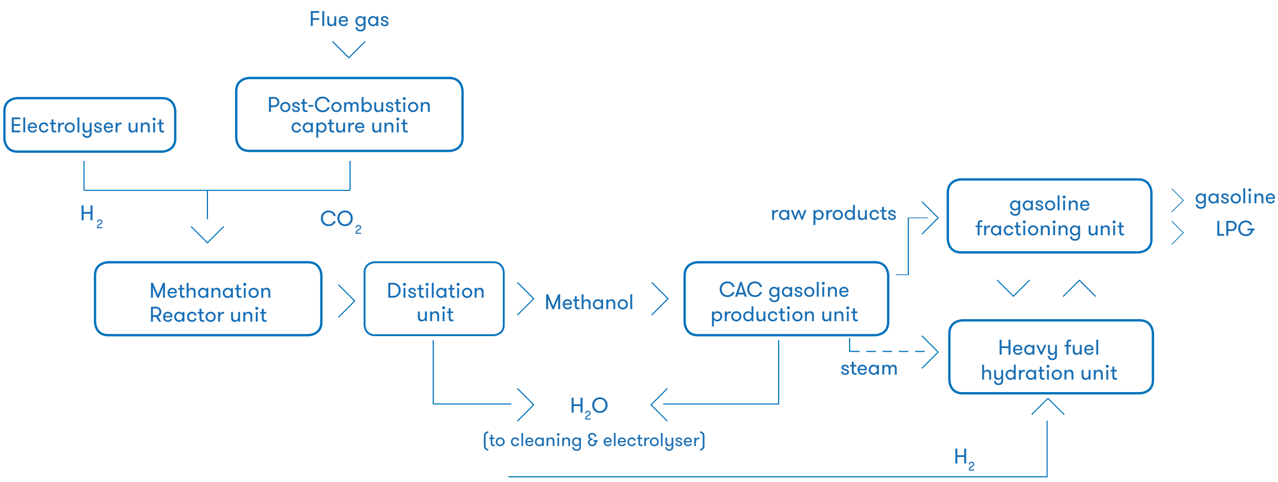
Power to methanol:

Hydrogen is produced by water electrolysis while carbon dioxide is captured from a flue gas via post-combustion capture. Both gases are converted to methanol by using a catalytic reactor. The needed product quality is ensured via a distillation process which is located downstream from the methanol conversion process. An additional high temperature heat pump utilises the waste heat from the electrolyser so the overall efficiency can be further increased. The efficiency is up to 50-55%.



Power to gasoline:

Gasoline can be produced by methanol conversion, e.g. using the CAC process. The efficiency is up to 93% (conversion of methanol and hydrogen to product fuels gasoline and LPG, LHV based). The efficiency of the whole process is up to 48-53%.



European Association for Storage of Energy

B. Important components

The main components are the following:

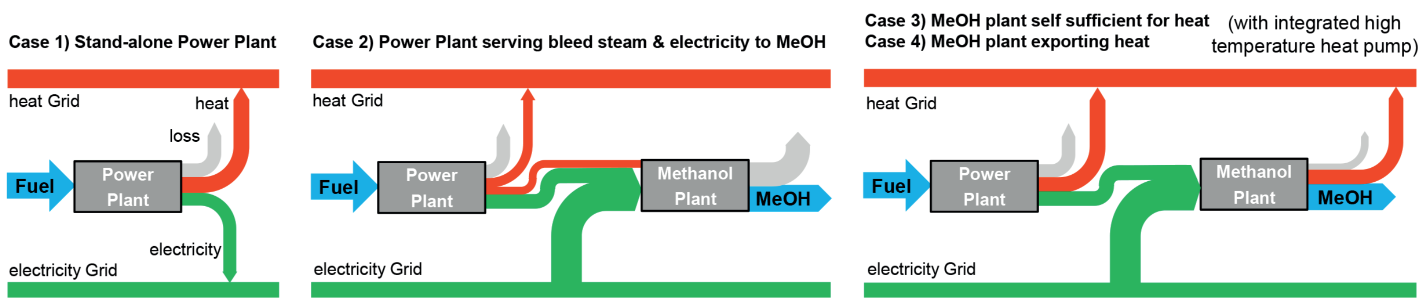
- Electrolyser unit:
  - Pressurised alkaline electrolyser, or
  - High-temperature solid oxide electrolyser, or
  - Proton exchange membrane (PEM) electrolyser
- Post-combustion capture unit:
  - Amine based absorption/desorption process as known from chemical processes
- Methanol reactor unit:
  - Catalytic conversion of hydrogen and carbon dioxide to methanol and water
- Methanol distillation unit:
  - Standard distillation process
- CAC gasoline production unit
  - Methanol is converted to gasoline
- Gasoline fractioning unit
  - Separates gasoline and LPG
- Heavy fuel hydration unit
  - Hydrates hydrogen with the steam from the CAC gasoline production unit

C. Key performance data

	Power to methanol	Power to gasoline
Power range	1MW-1GW	1MW-1GW
Energy range	1MWh-several GWh	1MWh-several GWh
Discharge time	n.a.	n.a.
Operating hours	8500h/year	8500h/year
Life Cycle	30 years	30 years
Reaction time	Sec	Sec
Efficiency	50-55%	48-53%
Energy density	5,5MWh/t	12,3MWh/t
CAPEX: energy	n.a. (storage size infinite)	n.a. (storage size infinite)
CAPEX: power	1,9-2,9 m€/MW	2,2-3,8 m€/MW

D. Design variants

Different design variants of the power to methanol process are mainly defined according to the on-site availabilities of the feed stocks hydrogen and carbon dioxide, respectively. The methanol reactor as well as the distillation process unit are core components and therefore always needed.

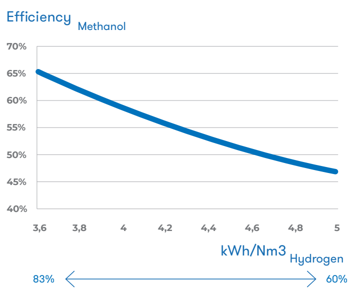


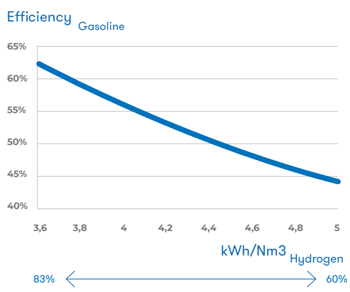
For the power to gasoline process there are three more important components, which are always necessary: the CAC gasoline production unit, the gasoline fractioning unit, and the heavy fuel hydration unit.

2. State of the art

The concept of hydrogen to methanol by using water electrolysis and post-combustion capture would be a first-of-its-kind plant. But it has to be noted that the technology is fully developed and almost all necessary sub-units have references at industrial scale with sufficient operational experience. The only unit which is not already in industrial operation related to the needed size for future plant designs is the methanol reactor. The availability of methanol reactors based on hydrogen and carbon dioxide in industrial operation is limited to a production size of at present 4,000 tons per year. Therefore and in order not to exceed established scale-up factors, the methanol reactor size is limited to 60,000 tons per year production. Consequently several reactor units have to be operated in parallel in order to achieve higher production rates.

So it can be stated that the technical risk can be reduced to a scale which is in the same range as it is normal for complex industrial plants. The efficiency of Methanol/Gasoline depends on the energy density of hydrogen:





Avenue Lacombé 59/8 - BE-1030 Brussels - tel: +32 02.743.29.82 - @EASE_ES - info@ease-storage.eu - www.ease-storage.eu

3. Future developments

- Methanol reactor unit: up-scaling and further development in order to achieve higher product capacities.
- Plant: build first-of-its-kind plant in order to achieve experience for future plants and improvement of the total process.
- Similar technology for gasification plants using biomass: Increasing the carbon conversion to nearly 100% by addition of hydrogen to raw syngas (Power to fuel as a sustainable business model for cross-sectoral energy storage in industry and power plants).
- Development of new reactor designs for process intensification, leading to improvements in reaction kinetics, energy efficiency and decrease in capital costs.
- Development of new catalysts for more durable and cost-effective processes.

4. Relevance in Europe

The EU has recently amended [i, ii] the Renewable Energy Directive (RED) and Fuel Quality Directive (FQD). The amended directives now include a new category of renewable fuels from "non-biological sources" other than biofuels. This category can cover synthetic, electrically derived fuels like hydrogen from water electrolysis or synthetic natural gas (SNG) from such hydrogen and captured CO_2, as well as low carbon intensity methanol derived from the combination of hydrogen and CO_2. Member States are each required to have at least 10% of their transport fuels come from renewable sources by 2020 according to the RED; the amended RED proposal made it possible for renewable fuels from "non-biological sources" as well as Carbon Capture and Utilisation (CCU) using renewable energy sources to count twice their energy content towards this target.

The FQD demands a 10% reduction of CO_2 emissions from fuels and electricity used in transport before 2020. Oil companies will have to source both fossil fuel as well as fuel from renewable sources with the lowest life cycle carbon based on the gasoline default value of 94.1 g CO_{2eq}/MJ. The mismatch between electricity demand and the supply of renewable electricity increases the pressure on regulators and generators to expand transmission grids, to transport electricity from regions with oversupply to regions with high demand or to implement energy storage in order to shift the supply of renewable energy from hours with excess supply to hours with excess demand.

5. Applications

Balance excess generation by RES and power plants, waste incineration or industry with existing technology.

Provide flexibility services to the grid through a smart management of process energy consumption.

Build power to methanol plants next to an existing industrial infrastructures.

Achieve the targets of the Renewable Energy Directive (RED) and Fuel Quality Directive (FQD).[i, ii]

Find the right fit between available power, utilisation factors, CO2 sources, infrastructure, and offtake distribution.

6. Sources of information

- Capturing of CO2 in Waste Incineration Plants towards Power2Fuel (Torsten Buddenberg, Christian Begins)
- Integrated Fuels and Vehicles, Roadmap to 2030+ (Roland Berger, April 27, 2016)
- Industry application of low carbon gasoline technology (S.Schmidt, M. Kuschel, J. Engelmann, T. Buddenberg)
- Production of fuels from hydropower and carbon dioxide from organic waste In Norway (Torsten Buddenberg, Christian Begins, Stephan Schmidt, Hans-Jörg Fell)
- Power to fuel as a sustainable business model for cross-sectoral energy storage in industry and power plants (Christian Begins, K.-C. Tran, Torsten Buddenberg, Benedikt Stefánson, Efthymia-Ioanna Koytsoumpa, Maria João Duarte)

i Council Directive (EU) 2015/652 of 20 April 2015 laying down calculation methods and reporting requirements pursuant to Directive 98/70/EC of the European Parliament and of the Council relating to the quality of petrol and diesel fuels

ii Directive (EU) 2015/1513 of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources