Energy Transition: Decarbonization and Hydrogen

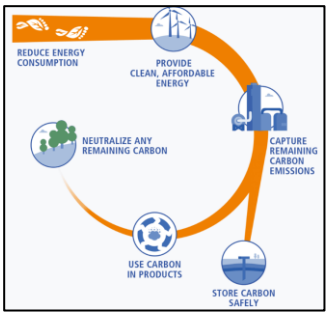
Introduction

The world is going through significant social, economic, environmental, and public health challenges right now but we have some opportunities in the energy sector. Technologies and tools are increasingly available to help achieve improvements in energy efficiency, reduce carbon footprints, and move to more sustainable sources of clean energy. Disrupted energy markets over the past six months have made it difficult to achieve acceptable economic returns for some conventional energy developments. Environmental considerations (regulations and social awareness) means that most companies want to do better with respect to the stewardship of our natural world. Carbon intensive industries are being challenged to reduce emissions and carbon pricing is one policy to attempt to incentivize them to seek lowest cost abatement options for their industries. Upstream industries can help with carbon capture (both their and other industries') and storage in depleted geological reservoirs. But carbon pricing is only part of the solution and should be viewed in the context of several other complementary policies including (1) reduction of emissions by increases in efficiency; (2) switch of energy generation from carbon intensive fuels to clean sources; and (3) transformation of energy applications across Mobility, Residential, Power Generation, and Industrial sectors.

Decarbonization

Reducing Carbon Dioxide (CO_2) and Carbon Monoxide (CO) emissions is part of what is sometimes referred to as Decarbonization, but it also includes "Carbon Equivalent" (CO_2-eq)reduction considerations which means that emissions of other greenhouse gases like methane (CH_4) should be reduced also.

A group of twelve (12) large oil & gas companies representing ~32% of Upstream energy production formed the Oil and Gas Climate Initiative[1] and they represent a portion of the industry perspective on Energy Transition. In addition to internal and cooperative progress towards Energy Transition, they are investing in third party technologies and R&D to facilitate the drive towards low carbon. Three of OGCI's objectives are as follows: (1) reduce methane emissions; (2) reduce CO_2 emissions; and (3) recycle and store CO_2. Reducing methane emissions during production, delivery, and use of oil and gas could involve more efficient processing and transportation such as minimising any leaks (including fugitive emissions) and eliminating flaring. Reducing CO_2 emissions could involve cleaner combustion and reducing unnecessary operations and logistics. Recycling and storing CO_2 could involve isolating sources of CO_2 so that it could be captured, stored, transported, and reinjected downhole into depleted reservoirs or aquifers.



The Oil and Gas Climate Initiative has just, for the first time, announced a set of joint targets to cut their combined greenhouse gas emissions as a proportion of production[2] - reducing the average carbon intensity of their aggregated upstream oil and gas operations to between 20 kg and 21 kg of CO_2 equivalent per barrel of oil equivalent (CO_2e/boe) by 2025, from a collective baseline of 23 kg CO_2e/boe in 2017 – about a 10-15% reduction. It was described as a "near term target", not the end of their efforts to continue reducing. Some of the individual European members including Shell, BP, and Total have higher percentage targets – and Equinor is already significantly below the target. This is the first time Exxon has announced such a target. EY will review and report the data annually. Note that the carbon equivalent terminology means that methane emission reductions are included.

Other oil and gas companies have announced various decarbonisation initiatives including Hess, Neptune Energy, Premier Oil, OMV, Energean, Lundin Energy, and Kosmos Energy. A key challenge for all oil companies is to reduce methane leakage emissions which are significantly worse green house gases for the environment than CO_2. We have the technologies and tools to monitor for and detect these kinds of emissions and we need to take positive actions to improve the integrity of our facilities. Leaking methane is a safety risk, a loss of value, and a serious environmental failure – so there should be no excuse to not resolve these emissions.

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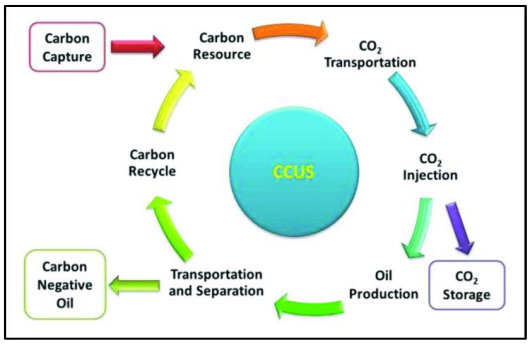
[1] https://oilandgasclimateinitiative.com/

[2] https://oilandgasclimateinitiative.com/carbon-intensity-target-pr/

Carbon Capture and Storage

As part of the Energy Transition, the Upstream energy industry can take positive steps both for themselves and in support of other industries. Carbon Capture (CC) is possible: (1) from flue (waste) gases at power plants; (2) from industrial production processes; and the easiest method (3) separated from natural gas during processing. Transportation of CO_2 can be by pipeline or ship and the most economic solution is storage location is close geologically aquifers or depleted reservoirs. CO_2 Stored[3] is a UK database compiled by a consortium of academic, public and private sector organisations for potential offshore geological storage. Norwegian Petroleum Directorate has a database on possible Norwegian North Sea reservoirs for CO_2 storage[4].



Over the past 40 years, CO_2 has been used onshore for Enhanced Oil Recovery (EOR), but was usually from CO_2 reservoirs not CC – but the technology to handle, transport, and reinject CO_2 is well proven. CC is increasingly being studied and implemented. The world's first full-scale facility for capturing CO_2 from coal-fired power production was opened in Canada in October 2014.

The North Sea area has been very active for CC. Norway has done a number of schemes over the years: (1) for almost 20 years CO_2 has been extracted from Sleipner field natural gas and injected subsurface; (2) from 2008 to 2011, gas from Snøhvit had CO_2 separated in the LNG plant and it was transported back offshore to be injected subsurface[5]; and (3) Equinor/Shell/Total are working with the Norwegian government to capture CO_2 from a cluster of industrial facilities and reinject offshore in a project called Northern Lights[6] –the investment decision is planned within the next year but rising costs are challenging the project. The UK has some CC schemes in various stages of study and development: (1) Equinor is studying a CCS scheme for the Saltend Chemical Park near Hull combined with a 600 MW autothermal reformer (ATR) to convert natural gas to hydrogen with the resultant CO_2 emissions captured and stored[7]; and (2) a Carbon Capture Utilisation and Storage (CCUS) project by AECOM called Net Zero Teesside is being progressed to decarbonise a group of carbon-intensive industries there by 2030 – storage will be through a CO_2 pipeline to offshore North Sea[8]. Pipeline economics are a challenge, so shorter distances help.

Some other international CC/EOR schemes exist[9] or have been studied[10]: (1) Petrobras has been doing CO_2 EOR in the Lula Field, offshore Santos Basin Brazil; (2) Vietnam and Malaysia have conducted offshore CO_2-EOR pilot programs; (3) ADNOC has planned a CO_2-flood in the Lower Zakum oil field using CO_2 emissions from a steel plant; and (4) various international basins and reservoirs have been identified for the application of CC and EOR.

A really intriguing concept which has been studied by NPD- Norway and trialled by ConocoPhillips-Alaska[11] was for CO_2 to be stored downhole in gas hydrates where solid exchange of CO_2 for methane CH_4 meant CO_2 was sequestered into thermodynamically stable hydrates and free methane was released to produce to surface.

A technical challenge is CO_2 related corrosion, so gas treatment (dry), material selection (CRA), chemical inhibition[12], and dehydration are important for improved transportation (pipeline) and storage (wells) integrity.

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[3] http://www.co2stored.co.uk/home/index
[4] https://www.npd.no/en/facts/publications/co2-atlases/co2-storage-atlas-norwegian-north-sea/
[5] https://www.equinor.com/en/news/archive/2008/04/23/CarbonStorageStartedOnSnhvit.html
[6] https://www.equinor.com/en/news/2020-05-northern-lights.html
[7] https://www.equinor.com/en/news/plan-for-world-leading-clean-hydrogen-plant-in-the-uk.html
[8] https://www.newcivilengineer.com/latest/teesside-carbon-capture-project-reaches-second-public-consultation-stage-09-07-2020/
[9] https://res.mdpi.com/d_attachment/energies/energies-12-01945/article_deploy/energies-12-01945.pdf
[10] https://www.netl.doe.gov/projects/files/FY14_CO2-EOROffshoreResourceAssessment_060114.pdf
[11] https://netl.doe.gov/sites/default/files/netl-file/nt0006553-final-report-hydrates.pdf
[12] https://www.researchgate.net/publication/321136427_Carbon_Dioxide_Corrosion_Inhibitors_A_review

Hydrogen (Grey, Blue, Turquoise, and Green)

Hydrogen is an important energy source for the Energy Transition since its combustion produces only water – but the production process needs to be considered. Popular terms of the method of production involve the colours grey, blue, turquoise, and green:

Grey Hydrogen	Blue Hydrogen	Turquoise Hydrogen	Green Hydrogen
Split natural gas into hydrogen and CO_2	Split natural gas into hydrogen and CO_2	Split natural gas into hydrogen and solid C	Split water into hydrogen and O_2 by renewable energy (i.e. solar or wind)
Energy Required: Steam methane reforming= 252 kJ/mol H_2	Energy Required: Steam methane reforming= 252 kJ/mol H_2 +Energy for CCUS	Energy Required: Pyrolysis= 38 kJ/mol H_2	Energy Required: Electrolysis= 285 kJ/mol H_2
CO_2 emitted to atmosphere	CO_2 captured and stored	No CO_2 emitted from process	No CO_2 emitted

Hydrogen can be produced from natural gas in a process called "grey hydrogen" which involves thermal processes such as steam-methane reformation[13] or electrolysis powered by gas-fired power generation. These methods of production have been used commonly, but CO_2 is produced in this process, so some improvements are necessary.

To be classified as "blue hydrogen" the CO_2 needs to be captured, stored, and reinjected downhole (sequestered). Peter Coleman-Woodside CEO has stated "Blue hydrogen is the key to building scale and lowering costs in hydrogen transport and distribution, which will enable an earlier transition to renewable green hydrogen, produced through electrolysis of water, powered by renewables. The earlier we can shift, the faster we can reduce emissions."[14]

Another type of low-carbon hydrogen produced from natural gas is called "turquoise hydrogen" and it involves pyrolysis which is a family of technologies being scaled up now. One production route to hydrogen is "catalytic thermal decomposition" where natural gas is heated up in a vertical reactor to high temperatures in order to generate hydrogen whilst valuable nanostructured carbon black particles are simultaneously produced. Other pyrolysis production routes include "thermal and non-thermal plasma", "thermal non-catalytic", and "liquid metal" (passing methane through a bubble column reactor of molten liquid metal (>1000°C)). In all pyrolysis production routes there are no CO_2 emissions associated with the processes. The carbon intensity of these process is dependent on the details of methane production and the source of energy for the reactors. But because energy potential is released from the four hydrogen atoms (e.g. CH_4) during processing, much less energy is required than splitting water (H_2O) during electrolysis (since its hydrogen atoms are already oxidized). This means pyrolysis is a very energy efficient means to produce hydrogen.

"Green hydrogen" is the production of hydrogen through electrolysis powered by renewables power generation (wind or solar) – this is the most popular and environmentally compliant current manifestation of hydrogen today. Some electrolysis technologies need purified water, but other technologies using seawater are advancing rapidly, as well as more efficient catalytic technologies for the electrodes.

Using surplus electrical power (from whatever source) to generate hydrogen through electrolysis is currently being trialled as a form of energy storage for later use (analogous to off peak pumped water energy storage schemes).

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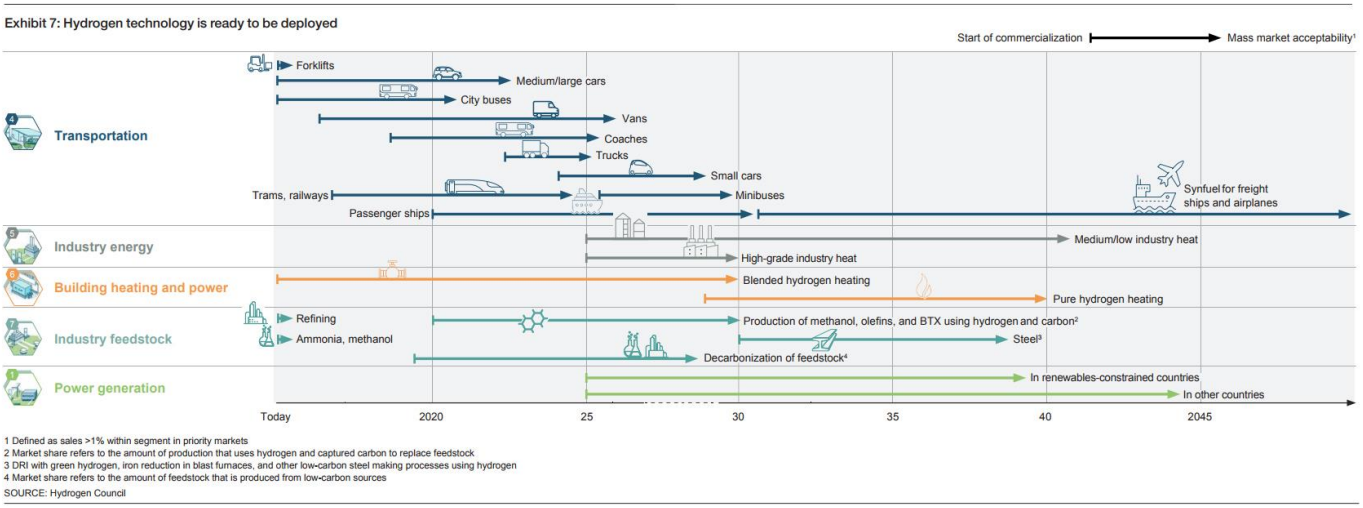
[13] https://www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming

[14] https://www.theguardian.com/environment/2019/apr/08/the-perfect-storm-woodside-energy-and-siemens-invest-in-australias-hydrogen-economy

Energy Transition: Decarbonization and Hydrogen

Hydrogen technology is being deployed on a timeline from today (transportation and building power) over the next 20-25 years through industrial energy and feedstock to power generation:

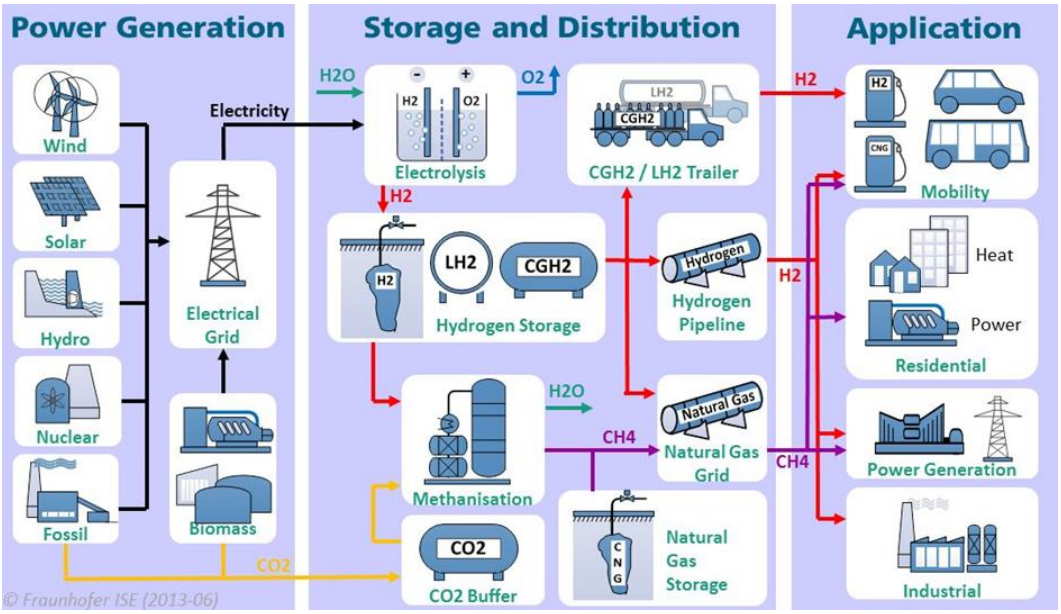


Technical challenges remain for the risk to some steels of Hydrogen-Induced Stress Corrosion Cracking (HISCC). Under certain conditions hydrogen can degrade the fracture behaviour of many structural alloys, including many stainless steels, by causing brittle failure to occur caused by interface separation of grain boundaries. The use of HISSC resistant steel as a construction material would be the preferred way to reduce this risk, but some existing legacy pipelines may not be suitable. There are however more than 4500km of hydrogen specific pipelines already in use. Some blending of hydrogen has been used (5-15%) into natural gas without substantial negative impact on the pipelines, valves, or equipment infrastructure. The latest European recommendation is <6% compositional blending now, with targets on infrastructure materials to rise to <10% by 2030 and <30% eventually. Some technical advice on the use of conventional steel pipelines has recommended limiting operating pressure stresses to <30 SMYS or <20% SMUTS for blended natural gas + hydrogen transportation.

The energy density of blended natural gas + hydrogen also needs to be considered in calculating CO_2 emission "savings":

- 1 cubic metre of natural gas will provide 35.8 million Joules of energy;
- 1 cubic metre of hydrogen will provide 10.8 million Joules of energy;
- A 70%/30% blend will therefore have 28.3 million Joules of energy so 1.26 cubic metres of <u>blended</u> gas will have to be combusted to get the same energy release as <u>pure</u> natural gas;
- So natural gas combusted will be 1.26 x 0.7 = 0.88 cubic meters which is a 12% reduction in CO_2 not 30%.

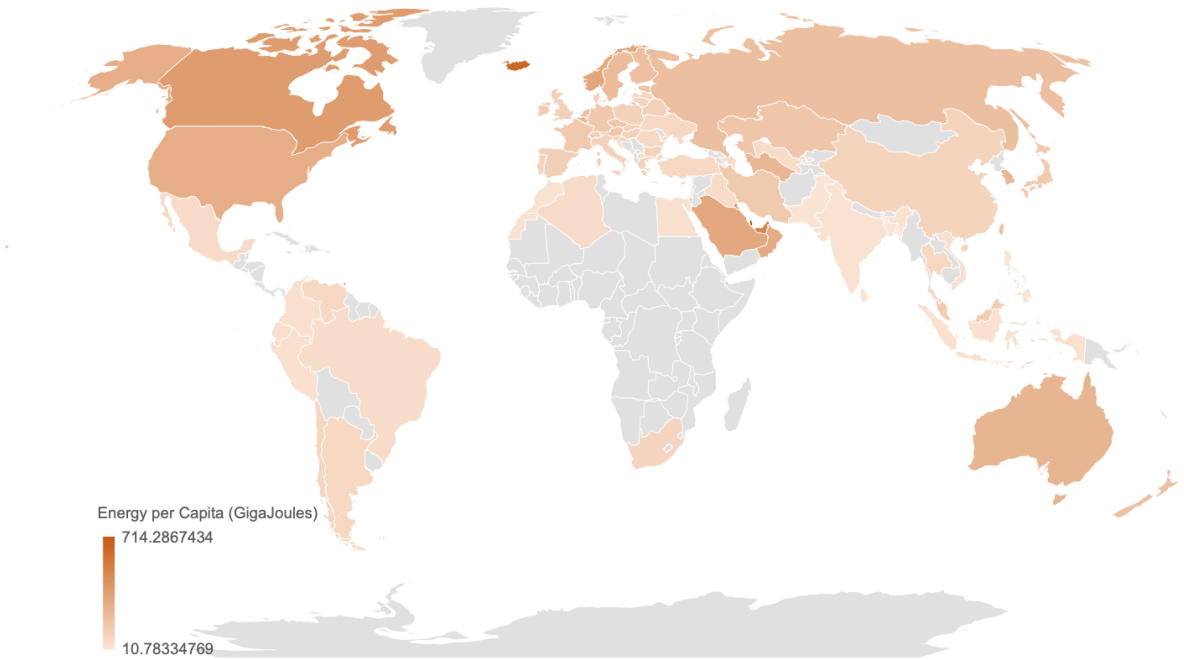
We have multiple sources of power generation to produce electricity, multiple means of both energy and CO_2 storage and distribution, and multiple applications for hydrogen to support increased decarbonisation:



Energy Transition: Decarbonization and Hydrogen

World View of the Energy Transition (Decarbonisation and Hydrogen)

Developed countries are well positioned to progress the Energy Transition and the growth of renewables connected to the existing grid infrastructure is easy and economic, so decarbonisation is increasing. Developing and undeveloped countries with existing subsurface hydrocarbon resources are likely to develop these as efficiently as possibly whilst improving their economies and living standards to the point where increased consideration of decarbonisation and the use of renewables is more widespread. Energy per capita has to be more fairly distributed.



~1B population of North America and Europe are proceeding well towards Energy Transition but ~5B population elsewhere have mixed progress – countries with good electricity access already are different to those with poor electricity access. For example only ~50% of Africa has electricity access and this needs to improve by using their existing hydrocarbon resources as efficiently as possible before environmental priorities are able to be significantly increased. Hydrogen may provide a significant positive contribution to the energy mix of developed and developing countries.

Upstream companies have an important role to play in the Energy Transition – with their technical, commercial, operational and logistical resources they are well positioned to serve a positive role in the world's energy future. We are seeing significant improvements worldwide with multiple sources of renewable and sustainable power generation, storage and distribution alternatives, and diversified energy applications across all sectors of society and the economy.