The State of Industrial Decarbonisation

Decarbonisation, simply put, is the process of reducing human-caused carbon emissions. As governments, businesses, and communities worldwide seek to reduce their dependence on fossil fuels, they realize that achieving decarbonization is a principal challenge. Why? Because over the years, many decarbonization initiatives have been implemented and produced both good and bad outcomes. The purpose of this article is to share what has been learned about decarbonisation initiatives that maximize economic and environmental benefits while minimizing social and financial costs.

Decarbonisation is the buzz these days but where did it start, where are we now, and what lies ahead?

The Past

The European Emission Trading System (EU ETS), launched in 2005, was the first large scale initiative attempt to put a price on industrial CO2 emissions. Other schemes followed in various countries ranging from Canada and the USA to China and South Korea. Despite these efforts, the impact was limited. The initiatives failed to provide a high carbon price signal to generate significant action. As far as the EU ETS is concerned, this was due to an oversupply of emission permits in the market and the fact that nearly all emissions permits were distributed at no cost, basically rendering the system obsolete. According to Emissions Trading Extra, the EU ETS main beneficiaries were the financial sector and some of the polluting industries (Ref. 2). Refineries were granted emission permits at no cost between 2008 and 2010 that exceeded actual emissions by about 14 million tonnes (Refs. 3, 7). Some actors in the highly carbon intensive steel sector extracted even higher benefits from the EU ETS, which ultimately were funded by the households' electricity bills. The European Commission realised its credibility was at stake and reduced the volume of emission

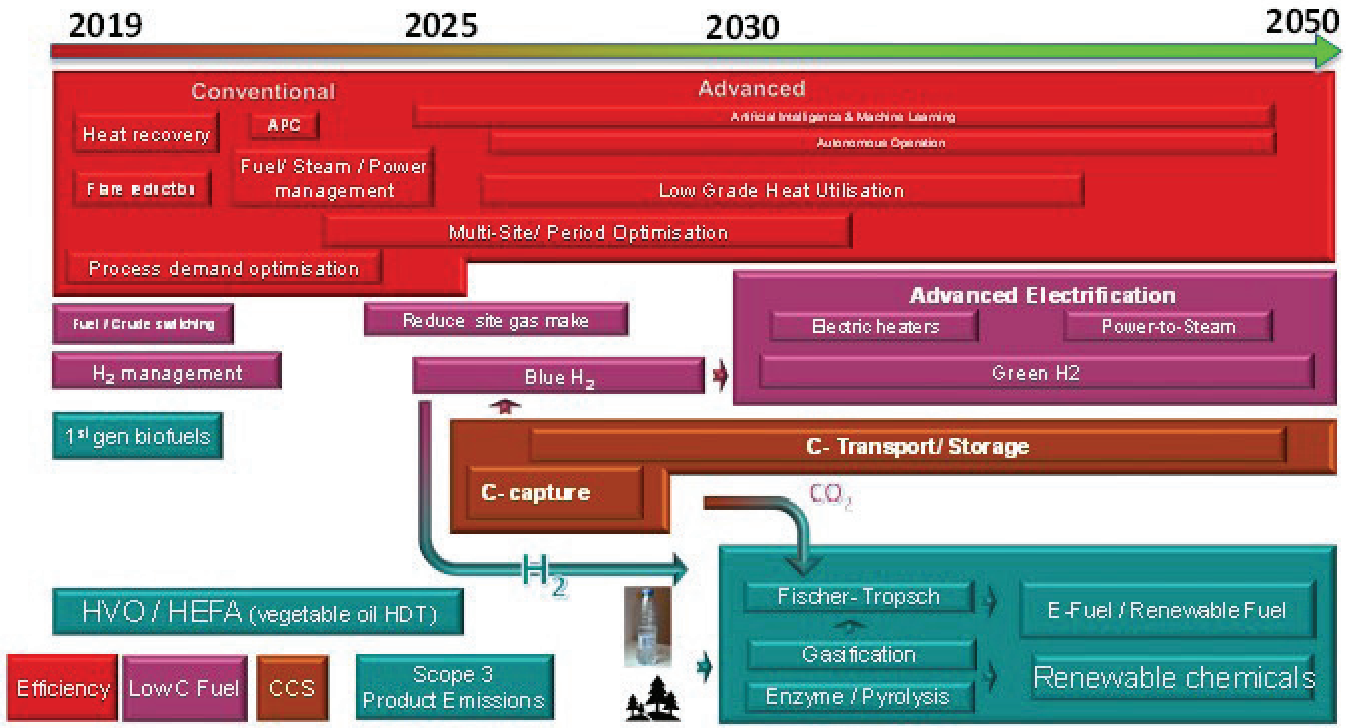

Figure 1. Decarbonisation technologies

permits in the market, which began having an impact on the European carbon price from 2017 onwards.

So far, the scope of industrial climate action was largely limited to the Scope 1, or direct, emissions. Scope 3 emissions caused by road fuels have been addressed to some extent during that period by the first-generation biofuels – ethanol and FAME- which, however, were generally not produced by traditional oil refineries.

The Present

SCOPE I to SCOPE III

Although the 2015 Paris Agreement does not force countries to submit and abide by a clearly defined decarbonisation roadmap, the accord does catalyse action. The ensuing plans submitted, and pledges made since 2019 have moved decarbonisation to the forefront of the industrial debate. According to the European Council, the EU's Fit for 55 package, for example, bundles more ambitious versions of existing climate initiatives with new initiatives such as developing a hydrogen economy (Ref. 1).

In 2019, KBC compiled the decarbonisation technologies shown in Figure 1. The challenge lies in choosing which of these to implement and how fast to do it. Energy efficiency is the first driver. A refinery in

SCOPE I Emission Reduction		
Strategies	High Performance Hardware Digitalisation Energy Management Systems	Economically justifiable & Technically developed
Emission reduction achieved	**3% per quartile**	
SCOPE I Emission Reduction Beyond 3% per quartile		
Strategies	CCUS Low level heat recovery Electrification	Economically unjustifiable & Technically undeveloped (as of now)

the 4th quartile emits 65% more CO2 than similar plants in the 1st quartile. If the refinery drops one quartile, emissions have been shown to decrease by roughly 15% percent.

Most industries have already been working on this initiative for several decades. In the case of best-in-class sites with high performance hardware, digitalisation with an energy management system that connects the management of different energy-carrying utilities such as steam, electricity, fuel and hydrogen, and CO2 can be expected to further reduce emissions by 3% per quartile.

Further reductions of Scope 1 site emissions will require investments that have been historically either economically unjustifiable or technically undeveloped, such as CCUS, low level heat recovery, and electrification.

International institutions and nations are primarily driving industry's decarbonisation, for example by setting road and aviation fuel emission standards. Focusing on technological solutions risks overlooking the fact that gasoline and diesel demand will decline substantially, especially in more prosperous regions with plans to decarbonise road fuels by 2050. Combine this with the International Maritime Organisation plans for decarbonisation, and the refinery carbon intake could drop by 60%, leaving only a demand for petrochemical feedstocks, heavy duty vehicles, and aviation fuel unaffected. That forecast could prove to be optimistic with legislation in place in the EU and USA to also displace fossil jet fuel with sustainable aviation fuel (SAF) and initiatives related to petrochemical feedstocks and products.

Market assessment companies predict

that global annual plastics production will increase from nearly 400 million tonnes to over one billion tonnes per year by 2050. Considering most plastics end up in the environment, this is an unsustainable industrial model. Despite the lack of concrete regulation regarding petrochemicals, the industry actively looks at means to recycle waste plastics and reduce the carbon intensity of its products.

Strict Scope 3 product emission targets will severely disrupt the operating model of the refining industry and, in the longer run, the petrochemical industry (Ref. 6). SAF production is gradually taking second generation biodiesel as refinery Scope 3 investment focus. Pacesetters in the petrochemical industry are exploring the possibility of recycling plastics through gasification combined with synthesis, or pyrolysis. In 2019, KBC expected this would not become significant until at least 2030, but the first plants are now under construction, albeit not uncontested (Ref. 8). Currently, the use of lignocellulosic material as feedstock seems to be less intensely investigated, possibly because it does not contribute to the plastics pollution issue.

KBC assessed nine carbon utilisation technologies during the strategic decarbonisation study of the Goi industrial area in the Chiba Prefecture at Tokyo Bay (Ref. 9). Figure 2 shows a cash flow breakdown for the nine technologies in a scenario where green hydrogen is inexpensive, and CO2 usage generates high revenues (Refs. 4, 5). The economically viable options at high hydrogen costs will be limited to those technologies that consume little or no hydrogen, unless low carbon chemicals can be sold at significantly higher prices than their fossil fuel counterparts, as is already

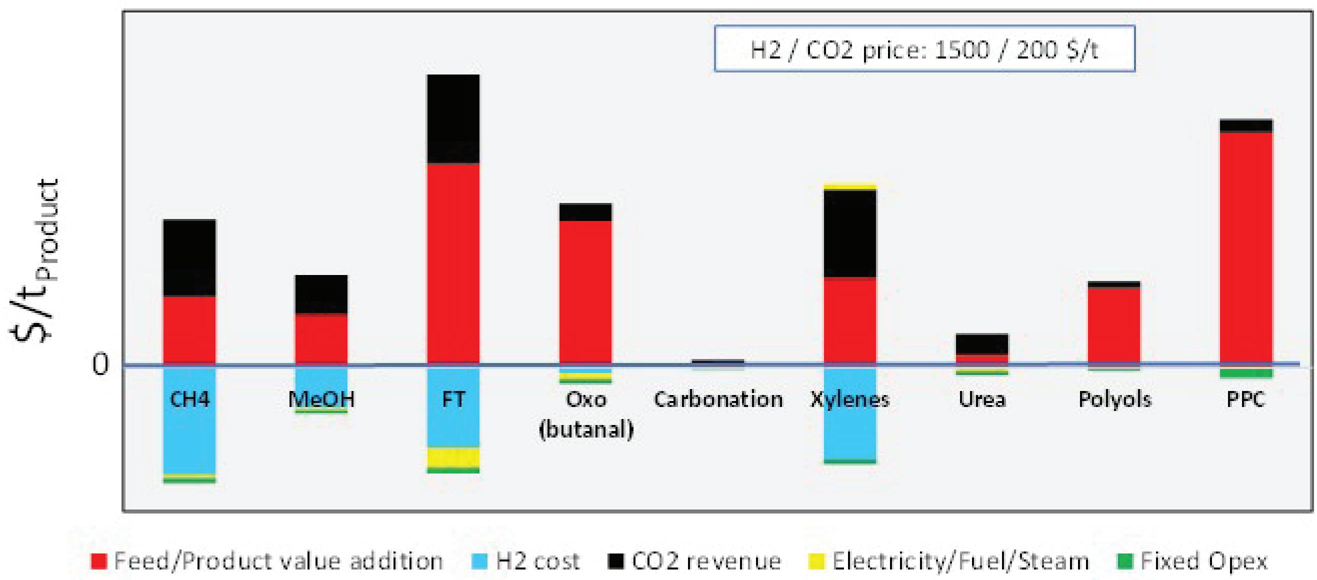

Figure 2: Carbon utilisation technology cash flow comparison

the case for SAF, which results in favourable economics for the Fischer Tropsch (FT) path. Clearly, regulation plays a crucial role in establishing separate markets for low carbon intensity chemicals and fuels.

In summary, development of a decarbonisation investment strategy requires process and utility simulation capacities, high level cost estimating capabilities, and a vision for how market and economics will evolve. Compared to the current economy, a low carbon economy will be more constrained by resource availability and logistics. Green electricity and hydrogen will be available less abundantly and the supply more perturbed than fossil feeds. The availability of biomethane and lignocellulosic feeds sourced from wastes will also be limited, while low carbon lipid feeds are already in short supply.

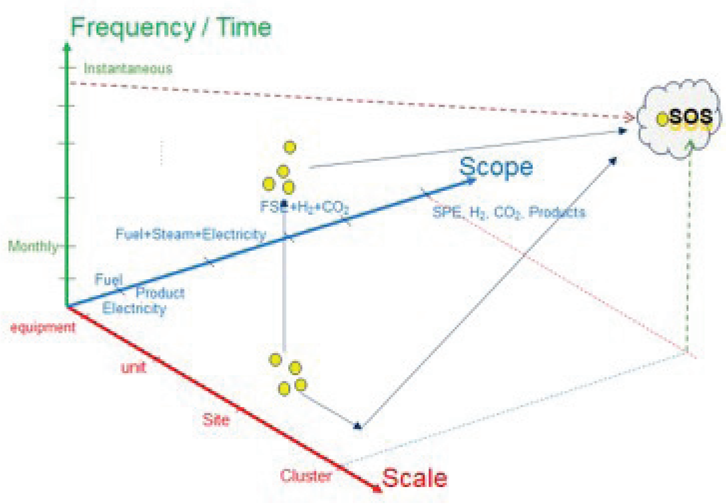

Figure 3: System of System optimisation

The Future

Industrial symbiosis

Clusters of different industrial sites owned by different operators are better positioned to successfully decarbonise because of their higher potential to optimise the use of the scarce and fluctuating low carbon resources.

System optimisation has three dimensions: frequency, scale, and scope. Each dimension indicates a higher optimisation potential as it moves up the scale. Minimising capital and operating costs while optimising resources of industrial clusters can be achieved by creating a System of Systems (SOS), where select operational information sourced from various industrial sites is shared in a safe environment to optimise the overall flexibility. To accomplish this, the infrastructure could either be a centralised structure or an information backbone that connects different subsystems.

Yokogawa and KBC are jointly involved in transforming this conceptual model into reality in the Goi/Chiba industrial cluster (Refs. 4, 5) and are also conducting a conceptual study for an industrial cluster in Europe. We believe that these studies will set a standard for industrial cluster decarbonisation worldwide.

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