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A Joined-up Approach to Scope 1-3 Decarbonization

The hydrocarbon industries are major Scope 1-3 emitters and are coming under increased investor, consumer, and regulatory pressure to reduce emissions. Cumulative greenhouse gas (GHG) emissions from refineries worldwide reached approximately 34 gigatons (Gt) from 2000 to 2021 with an average annual increase in rate of 0.7%, making the global oil refining industry the third-largest contributor to greenhouse gas (GHG) emissions from stationary sources (Ma et al., 2022).

In response, most refineries have set ambitious reduction targets for 2030 and 2050 with net-zero Scope 1 and 2 emissions being the focus of the former and replacement products being the latter. Currently, emission reduction and energy efficiency are the focus of Scope 1 and 2, and companies worldwide are driven by either government regulations, subsidies, and/or incentives depending on the location. A lack of clarity on either can hamper the pace of investment and many companies find themselves locked in this boardroom debate.

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What it is and what it is not

Hydrocarbon operations must begin a journey of becoming energy complexes with an actionable plan to eliminate fugitive emissions, decrease carbon footprints in day-to-day activities, substitute products for lower carbon versions and, ultimately, replace carbon in favour of other molecules such as hydrogen, oxygen, and nitrogen. The United Nations Sustainability Development Goals and subsequent classification of Scopes 1-3 decarbonisation initiatives is helpful to establish common definitions and alignment. However, change needs to occur in upstream and downstream hydrocarbons to meet sustainability goals, which require a 45% reduction in global CO2 emissions by 2030 from 2010 levels, and net zero emissions by 2050.

Each operating asset is different and will require a dynamic roadmap charting the appropriate course. What it is not is 'Scope 1, 2 and possibly 3' it is 'Scopes 1-3,' and a joined-up approach is required that maps out the decarbonization journey. It draws on practical experiences, best practices, and current leading-edge technologies. Reducing Scope 1 emissions is a given, self-imposed next step, but how shall we proceed? Which option is the best choice – a

digital energy management system, a new gas turbine with furnace exhaust integration, a hydrogen or ammonia fired gas turbines, and/or the use of renewable power generation? While the choices are vast, the impacts from each are significantly different. So, how does an operator conduct a joined-up approach to Scopes 1-3 decarbonization and how can we transform a challenge into an opportunity that lasts decades?

Best practices

The best practice is to reflect on the big picture. Look across Scopes 1-3 today and out 10-20 years of operation. Then, construct a strategic roadmap that converts strategy into action by:

- Getting a clear view of the current situation.
- Identifying all drivers of GHG emissions.
- Brainstorming all the possible common and uncommon options prioritised by viable options.
- Developing a credible, technically rigorous tool kit to map potential paths to achieve emission reduction goals.
- Narrowing the wide range of potential solutions by evaluating the business attractiveness of each, then comparatively and assesses the risk both technically and financially to avoid the potential for regret capital.
- Understanding the optimal sequence of investments based on the capital outlays of many options and likely minimal returns and potential for change or regulatory uncertainty.

The roadmap extends beyond just managing emissions and efficiency. It also involves managing the risk of optionality in regulations, uncertainty in technology, and driving organization-wide change. The use of proven technology today enables detailed scenario planning ensuring a robust solution for an asset. KBC's approach for an individual facility is to build an Integrated Process, Energy, Emissions and Economics Model (IP3EM). The IP3EM illustrates the energy demand, supply, and consequential emissions of that energy supply, where we detail the following:

- Understand the actual Scope 1 and 2 emissions savings from mitigation or carbon capture alternatives.
- Identify initial quick wins to start the process and build momentum.
- Deploy a Digital Energy Management System to ensure process deviations are handled immediately and progress is sustained.
- Design an approach that can be extended to include the modelling and characterisation of bio feedstocks, other renewable feeds such as woody biomass, emerging technologies such as plastic recycling, and evaluate their integration into current systems and impact on Scope 3 emissions.

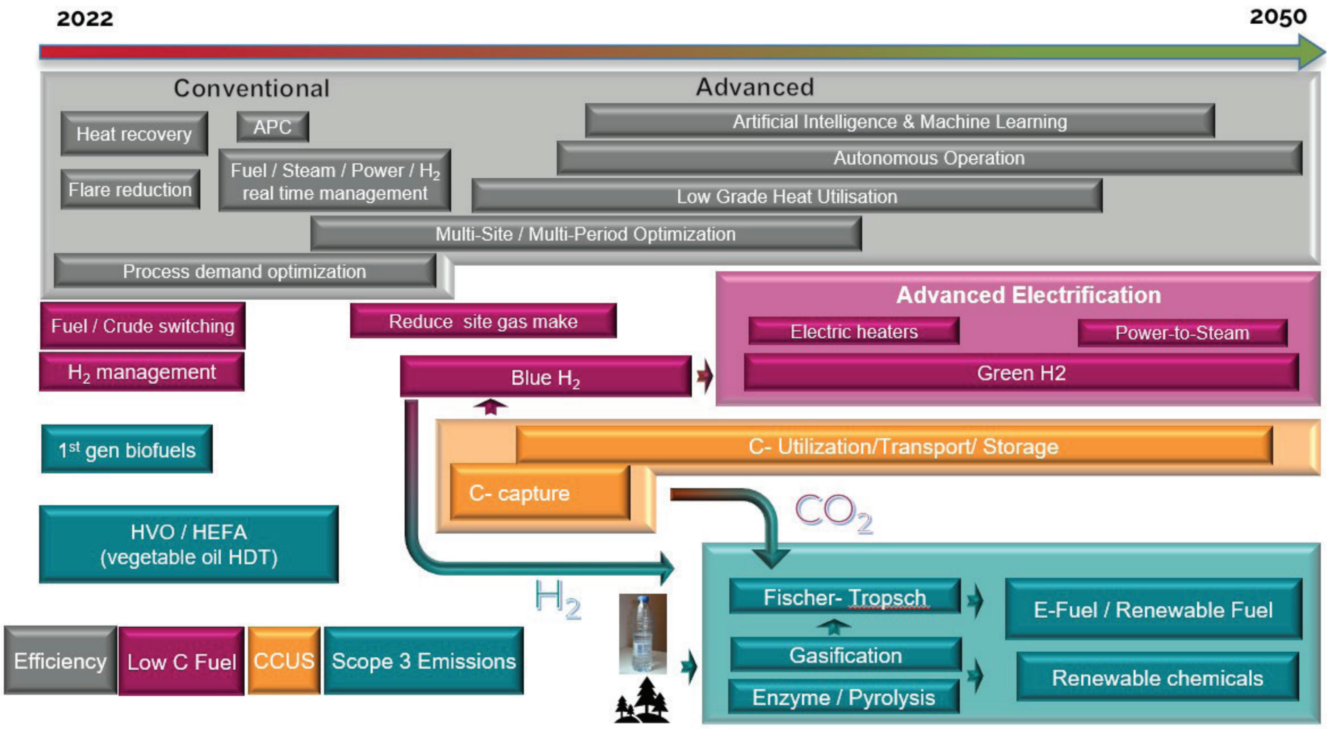

Figure 1: Examples of options in Scope 1-3 emissions reduction

- Joined-up approach to navigate the options of Scopes 1-3 emissions.

Figure 1 shows some of the options available and elements of the roadmap that must take place in a joined-up approach to reach net-zero emissions.

Explore New Territory

What got us here won't get us there. The only option is to change and change faster than ever before. Some unconventional thinking will be needed. We need to go outside our normal limits to significantly reduce Scope 1 and Scope 2 and will need to consider sources of low-carbon intensity electricity, hydrogen, other utilities, and CO2 sequestration. Some of the most exciting and emerging insights will be derived from the opportunities for emission reduction and energy optimisation between traditionally separate companies and industries co-operating in the future. Some, initial examples could be shared investment in carbon sequestration, or joint

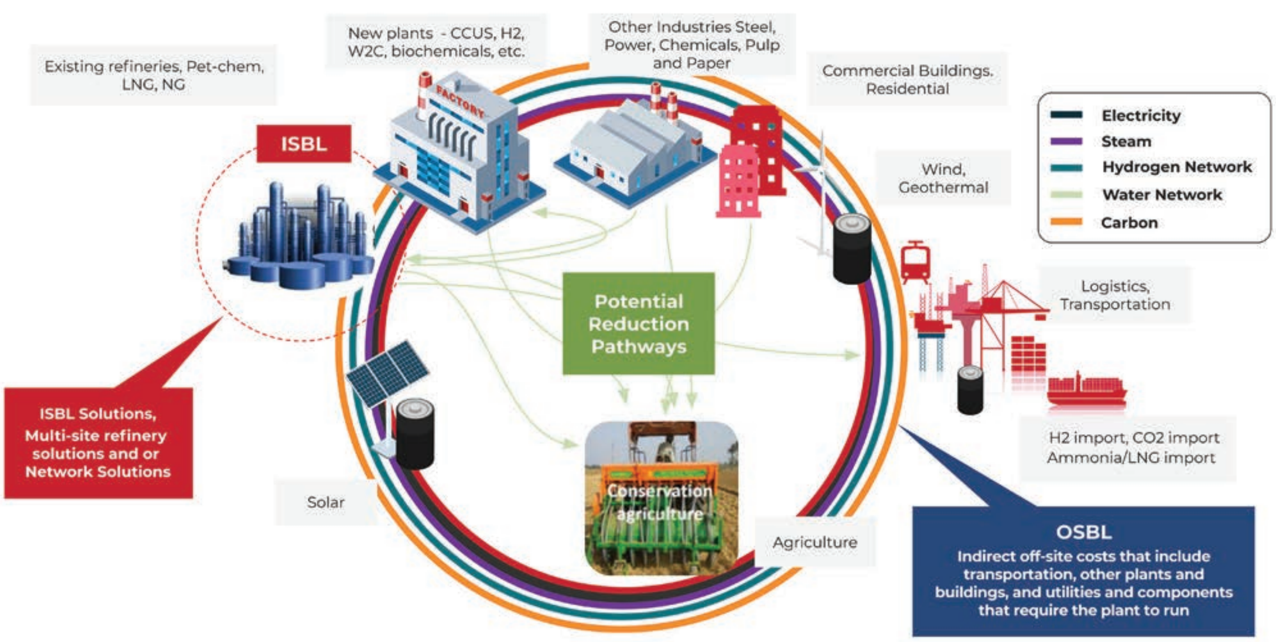

Figure 2: the industrial and local energy clusters of the future

#	Name	Main Product	Non CO_2 feeds
1	Methanation	Methane	H_2
2	Methanol	Methanol	H_2
3	Fischer-Tropsch	Syncrude / SAF	H_2
4	Oxo Synthesis	Butanal	Propylene, H_2
5	Carbonation	Building material	Steel slag
6	Xylenes	Mixed Xylenes	H_2
7	Urea	Urea	Ammonia (NH_3)
8	Polyols	Polyether carbonate polyol	Propylene oxide (PO)
9	Polymeric Carbonates	Polypropylene carbonate (PPC)	Propylene oxide

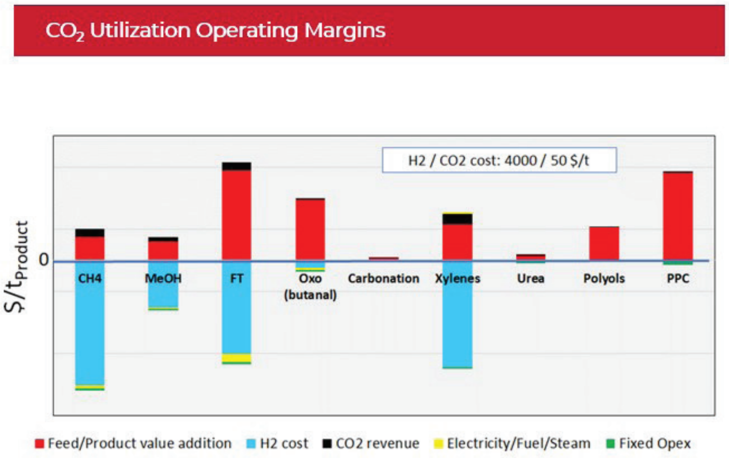

Figure 3: Carbon Dioxide uses, costs, and margins

development of low-carbon electricity or hydrogen by a cluster of co-located industries or even towns, cities, and residential estates. Our ultimate destination would be to design an industry network within which carbon is fully recycled, such as in Figure 2. Inside the Battery Limit (ISBL) refers to the area where the plant or the process plant and equipment are located while Outside the Battery Limit (OSBL) refers to the space outside the plant boundary and can affect the plant's operation. In the future, the line distinguishing the boundaries between ISBL and OSBL is expected to become more blurred and integrated. An oil and gas refinery or petrochemical complex will consist of many individual plants and units, integrated to outside utility plants, power generation units with shared process streams such as water, inter gases, hydrogen, ammonia, and steam. The shared infrastructure and emission reductions present a very large and exciting opportunity. The key to its success is more about new thinking, attitudes and execution than simply adopting novel technologies.

Bringing Decarbonization to Life™

To bring decarbonization to life, researchers show the operating margins must be understood today and in 10 years. For example, what is the cost and margin of CO2 use in industrial processes instead of emitting it? KBC has routinely looked and costed out nine potential carbon utilization technologies as shown in Figure 3.

The chart illustrates the operating margins associated with the various CU technologies based on the H2/CO2 price scenarios in 2030. Hydrogen, other utilities (electricity fuel, steam), and fixed operating costs are presented on the debit side, below the zero axis. In contrast, the revenue streams derived from the product/feed differential and CO2 utilisation are displayed as positive bars.

These economics may shift depending on the location, nearby industrial clusters, and potential for collaboration. This makes sense considering the Polyether Polyols Market size is forecast to reach USD $15 billion by 2025, and then grow at a CAGR of 5.5%.

Key take aways

A joined-up approach to reducing Scope 1-3 emissions is vital to successfully reaching net-zero emission objectives. Energy efficiency is a good start but can only go so far. Detailed modelling is required to thoroughly understand and rank the options available. Ultimately, significant reduction requires collaboration outside of the facility's battery limits. Significant Scope 1-3 reductions will require collaboration with new and existing industries, adoption of new technologies, and redesigning value chains.

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