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Reducing Embodied Carbon in Singapore's Specialty Chemicals Sector

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SYNOPSIS
The chemical industry is the third largest source of direct CO_2 emissions from industry worldwide and contributes to about 6 per cent of global greenhouse gas emissions. Singapore has a sizeable chemical industry and there is an ongoing shift towards specialty chemicals production. It is therefore of interest to study and evaluate the embodied carbon, or carbon footprint, of the specialty chemicals industry. By tracing the material supply chain and with the use of life cycle assessment tools, this policy brief evaluates the opportunities and challenges to the decarbonisation of the specialty chemicals sector and what it means for climate mitigation ambitions and trade.

KEY POINTS

- More than half of embodied carbon, or carbon footprint, of the specialty chemicals sector arises from direct emissions from processes in Singapore.
- While there have been efforts to green the sector, the reduction of embodied carbon in specialty chemicals industries faces significant technological and economic obstacles.
- The industries are heavily reliant on feedstocks that originate from fossil fuels, and these feedstocks as well as fuel sources cannot be easily substituted with low-carbon sources due to the unique nature of the industry and system constraints.
- To facilitate rapid decarbonisation in the specialty chemicals sector, end-of-pipe solutions such as carbon capture and storage, and market-based measures may be more cost-effective and can achieve emission reductions more easily.

INTRODUCTION

Globally, the chemicals sector is the third largest source of direct CO_2 emissions from the industry. According to Bloomberg estimates, the industry contributes to 6 per cent of global greenhouse gas (GHG) emissions. As demand for chemicals is on a rising trajectory, it is likely that emissions will rise in tandem if no action is taken globally. In its 2021 report titled *'Chemicals'*, the International Energy Agency (IEA) evaluated that to achieve net zero emissions by 2050, the chemicals sector needs to make significant reductions in coal use and enhance the energy intensity of processes used in chemicals production.

Singapore is the 8th largest exporter of chemicals globally. Companies in Singapore have been investing and shifting to higher value products, namely specialty chemicals. With industries focusing on moving up the value chain, more value-added processes will be carried out. As the industry is traditionally carbon-intensive, emissions from specialty chemicals manufacturing can influence both the direct GHG emissions domestically, as well as the overall carbon footprint of finished products considering the number of processes required to produce the specialty chemical from raw materials. It is therefore of interest to trace the sources of embodied carbon, which include direct emissions, as well as emissions arising from material extraction, processing, transportation and use. This can provide useful information to facilitate national decarbonisation efforts, and reveal any other considerations that may arise from the carbon footprint of finished products that may impact international trade flows.

ANALYSIS

Carbon Footprint of Specialty Chemicals

By tracing the material supply chain and estimating the embodied carbon, otherwise known as carbon footprint, through Life Cycle Assessment (LCA), our study estimated that the embodied carbon of the specialty chemicals sector in year 2019 was 5.67 Gg CO_2 equivalent (CO_2-eq). Although this does not seem large in comparison to Singapore's national emissions which was 51,570 Gg CO_2-eq in 2019, the share of embodied emissions arising from Singapore is notable. The study found that Singapore contributed to 78 per cent of embodied carbon in this sector. The finding is not surprising as Singapore is a manufacturing base for specialty chemicals. This means that the direct release of CO_2 from process emissions and energy use in the specialty chemicals sector contributes to a significant component of embodied carbon of specialty chemicals.

A large portion of embodied carbon of specialty chemicals arise from the raw material consumed. For example, propylene and methanol are heavily used as raw materials or solvents in twelve and eight downstream materials studied in our study respectively.

In light of the recent announcements that the carbon tax in Singapore could reach SGD50-SGD80/tonne of CO_2-eq by 2030, this would translate to between SGD220,000 to SGD353,000, based on the emissions in 2019. More importantly, with a significant portion of embodied carbon arising from processes in Singapore, decarbonisation of the specialty chemicals sector is critical for national climate mitigation efforts.

Singapore has a relatively cleaner specialty chemicals sector as coal is not used. Efforts have also been made to address the emissions from the sector. The Singapore Green Plan 2030 includes plans to transform Jurong Island into a sustainable energy and chemicals park. Besides transforming production processes, centralised utilities, greater system optimisation and smart grid technologies are components that are being explored to reduce process emissions and improve energy efficiency. Other solutions to reduce emissions that have been implemented include the use of pyrolysis oil and waste heat and gas recovery.

Greening the Power Grid?

The decarbonisation of the power grid can also reduce the embodied carbon of the specialty chemicals sector. Our study estimated that 11 per cent of total embodied carbon is influenced by electricity consumption, of which 9.5 per cent is due to domestic electricity consumption. Decarbonisation of the power sector in Singapore, as well as in countries where we import raw materials from, can improve the carbon footprint of specialty chemical products. This can be pursued as a low-hanging fruit, given the difficulties in decarbonisation of other processes within the industry.

Other Opportunities for Decarbonisation

The remaining embodied carbon generated domestically are from process emissions and emissions from fuel combustion on-site. Improvements in process efficiency or the adoption of more efficient equipment are low-hanging fruits for decarbonisation.

Recently, more measures to support the green transition were announced as part of Singapore's Budget 2022. For instance, the Energy Efficiency Fund (E2F) was enhanced and the maximum grant support cap was raised to 70 per cent from 50 per cent. Companies may adopt a more efficient technology/equipment to support their operations. For example, Pfizer Asia Pacific in Singapore saw an emission reduction of 17 per cent with the adoption of a trigeneration plant, as compared to a conventional system. A trigeneration plant provides chilled water, while producing electricity and steam. On the other hand, opportunities for substitution of feedstock are limited, given that they are more readily obtained from fossil fuels. Our study identified the top three feedstocks as methanol, ethylene glycol and styrene.

Furthermore, bio-based feedstocks cannot be easily utilised on an industrial scale. As an example, while methanol can be produced from non-fossil-based sources through chemical and biological processes, such processes may not be easily scalable. The same can be said for bio-based acetone. Ultimately, commercially viable and scalable substitutes are required for the green transition.

While there has been much chatter about the use of low or zero carbon fuels such as green hydrogen for fuel combustion in industrial processes, there are hurdles to the adoption at scale that need to be addressed. Considerations include safety, storage, and space constraints, especially in chemical plants in Singapore which face acute land constraints. There are also heating temperature requirements for manufacturing processes which may not be attainable by all types of low-carbon fuels (e.g. biomass).

Infrastructure for the use of green hydrogen including storage and transportation also need to be developed to support the industry's green transformation. There are also other considerations relating to cost and long-distance ocean transportation that need to be overcome to make green hydrogen a viable substitute for hydrogen that is produced from natural gas today.

These challenges to the adoption of low-carbon solutions suggest that we may need to look beyond the chemicals sector. Companies can adopt industrial symbiosis where waste heat/cooling water can be used by other processes within the vicinity. For instance, the use of liquefied natural gas (LNG) cooling which has been piloted for data centres in Singapore may be extended to the chemicals sector, particularly as a cooling energy source for chilled water system.

Rapid decarbonisation – a pipe dream?

It is unsurprising that there are significant challenges to the greening of industrial processes on a large scale for the specialty chemicals sector. Substitutes for feedstock and fuels also face certain constraints due to the unique needs and requirements of the manufacturing processes. In the medium term, one option to decarbonise the specialty chemicals sector would be to explore end-of-pipe technologies such as carbon capture and storage (CCS). CCS is often considered for sectors where emission reductions from other measures such as renewable energy adoption are difficult.

In its Clean Technology Scenario, the IEA estimates that more than 28 Gt of CO_2 needs to be captured up to 2060 from industrial processes globally, with the bulk coming from cement, steel and chemical sectors. Note that currently the use of CCS in the chemicals industry is still in a nascent phase as there are infrastructural, cost and social barriers to the implementation of CCS. It is also more challenging to implement CCS for specific industrial processes in comparison to the more general power sector due to the differing levels of CO_2 purity and end-of-pipe infrastructure requirements that may be unique to particular processes.

Another option is carbon capture and utilization (CCU). In its plan for a sustainable energy and chemicals sector, the Singapore Economic Development Board outlined plans to achieve at least 2 million tonnes of carbon capture potential. A CCU test-bedding facility is also in the works for Jurong Island and CCUS has also been included in support grants.

While our study showed that there are limited opportunities for CO_2 valorization – which refers to the chemical transformation of CO_2 for utilisation – in the specialty chemicals industry, there may be opportunities in other sectors. For instance, there is the potential for the development of synthetic fuels and feedstocks such as methanol and ethanol from captured CO_2 and green hydrogen. The demand depends on decarbonisation efforts, targets and regulations of other sectors such as aviation and shipping. In addition, methanol from CO_2 valorization can be further processed to form green propylene which is one of the commonly used materials based on our LCA study. CO_2 mineralisation for cement production is another solution. Greater demand is likely to lead to lower costs and more extensive adoption of such technologies.

Beyond technological solutions, another way to address the emissions from the sector is the implementation of a carbon price. The price signal can facilitate more rapid adoption of low-carbon and efficient technologies, as well as provide opportunities for access to carbon credits. Singapore has enhanced its carbon tax and there will be opportunities for emissions-intensive trade exposed (EITE) sectors to access high quality carbon credits to offset up to 5 per cent of taxable emissions. Revenue from the carbon tax can be used to support green innovations and decarbonisation in the sector.

In summary, to facilitate rapid decarbonisation in the specialty chemicals sector, end-of-pipe solutions and market-based measures may be more cost-effective and can achieve abatement more easily.

CONCLUSION

The reduction of embodied carbon in the specialty chemicals industries in Singapore faces significant obstacles for the following reasons: (1) the industries are heavily reliant on feedstocks that are obtained from a complex network that links back to fossil fuels, (2) feedstocks, and even fuel sources, cannot be easily replaced with low-carbon sources due to the unique nature and requirements of the industry, (3) emerging technologies for decarbonisation are not commercially available at the moment and the adoption of these technologies at scale remains challenging.

Besides pursuing the low-hanging fruits of energy efficiency improvements, industrial symbiosis and system optimisation, it is worthwhile to explore carbon capture, storage and utilisation, as well as market-based mechanisms so that a comprehensive suite of solutions are utilised for the sector. Given the high share of embodied carbon generated domestically and challenges to reducing embodied carbon, Singapore also needs to consider the impact of regulations and other market-based measures in other jurisdictions that it exports its products to as this may affect long-run economic competitiveness. An example would be the carbon border adjustment mechanism (CBAM) proposed by the European Union. Currently, the CBAM is slated to be applied to iron and steel, cement, fertiliser, aluminium and electricity when it is implemented in 2026. On a positive note, the large share of embodied carbon arising from processes in Singapore means that there are more domestic levers that can be explored to reduce the overall embodied carbon of specialty chemicals.

There are opportunities to explore research and development, pilot new technologies, processes and trial low-carbon alternatives. The eco-system in Singapore can facilitate such innovation and the green transition as the specialty chemicals sector is co-located on Jurong Island and the west of Singapore. Technological breakthroughs and mitigation measures for the sector will put Singapore at the forefront of innovation in this area and allow Singapore to enhance its competitiveness in low-carbon specialty chemical products.

WHAT TO LOOK OUT FOR

- Emerging technologies and processes to green the specialty chemicals industry.
- Implementation of Singapore's carbon tax.
- Implementation of carbon border adjustment tax on imports by other jurisdictions.

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