EDB SINGAPORE

SG

SUSTAINABLE JURONG ISLAND

November 2021

Singapore's **Energy & Chemicals Sector** Today

3% of our Gross Domestic Product

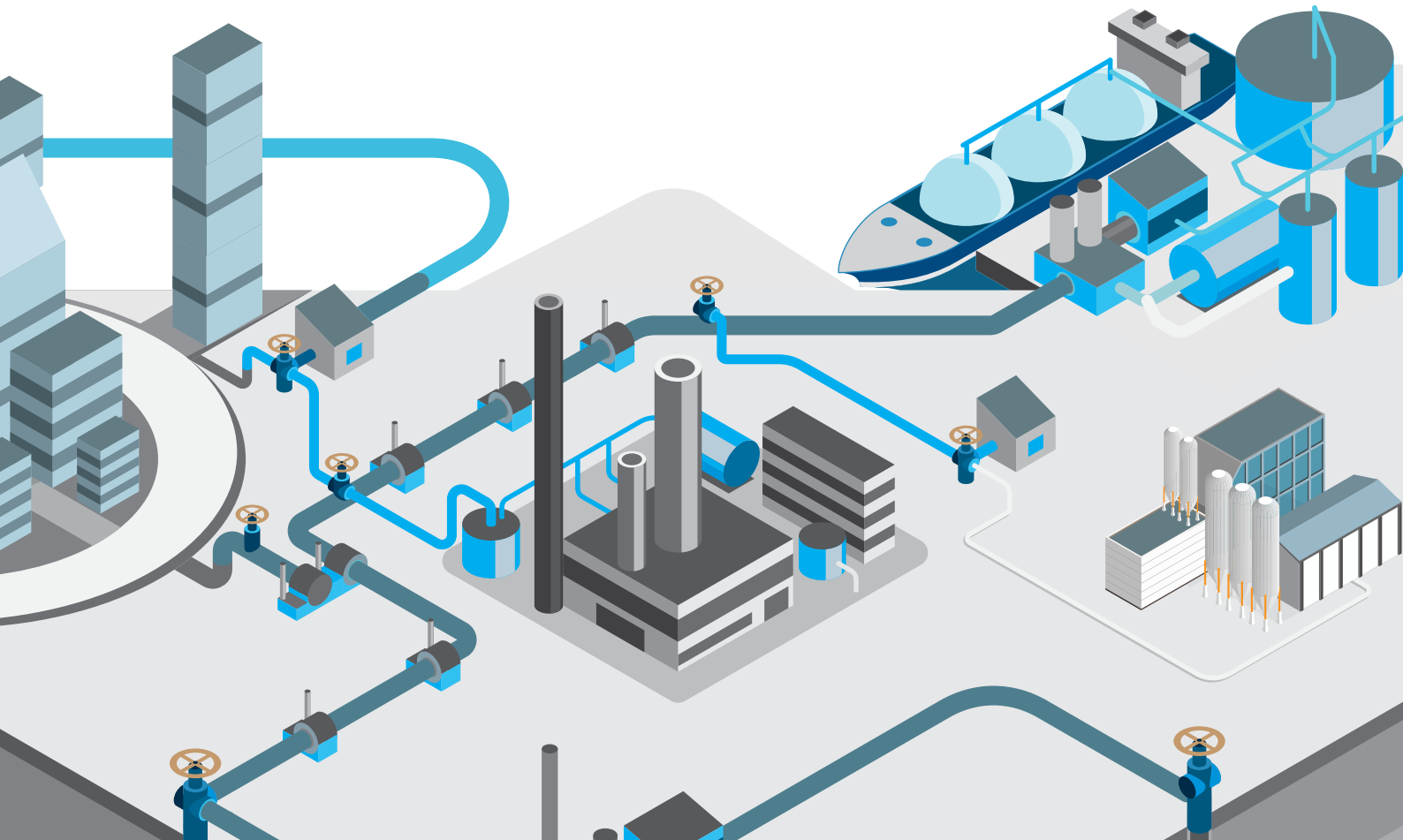
20.4% of our total output

27k people employed

8th largest exporter of chemicals globally

Singapore is one of the world's leading energy and chemicals hubs. The Energy and Chemicals (E&C) sector creates significant value for Singaporeans and the wider economy. In 2020, it contributed 3 per cent of our Gross Domestic Product, 20.4 per cent of our total output[1] and employed about 27,000 people[2]. The sector provides high-paying jobs with good career progression across technical, corporate and management roles. It also creates spin-offs to the rest of the economy, including trading companies, Small and Medium Enterprises (SMEs) and third-party contractors, to whom most plants tend to outsource critical maintenance work, logistics and warehousing services. Over the last decade, the sector has strengthened its global competitive position, ranking as the eighth largest exporter of chemicals globally in 2019 by the World Trade Organisation.[3]

[1] *Preliminary figures from the Singapore Economic Development Board (EDB)'s Research and Statistics Unit (EDB, 2021)*
[2] *Estimates from the Ministry of Manpower (MOM) (MOM, 2021)*
[3] *World Trade Statistical Review (World Trade Organisation, 2020)*



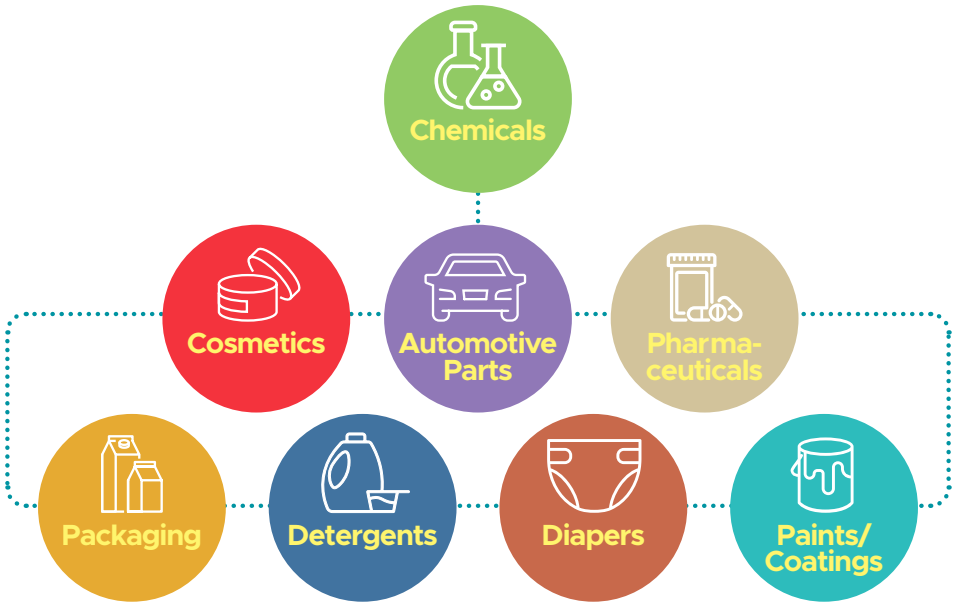
Jurong Island Today

Home to over 100 leading companies

from the global energy, petrochemical and specialty chemicals sectors, Singapore's Liquified Natural Gas (LNG) terminal, service providers, and power and utility companies that supply around 50% of Singapore's total domestic electricity demand.

At the heart of Singapore's E&C sector is Jurong Island (JI), a world-class chemicals park home to facilities of over 100 leading global energy, petrochemical and specialty chemicals companies, including ExxonMobil and Royal Dutch Shell ("Shell"). These companies carry out an integrated mix of refining, olefins production and chemicals manufacturing. Their products include fuels and lubricants, as well as petrochemicals and specialty chemicals, which are essential ingredients needed to produce a wide range of consumer goods, such as surgical masks and gloves, vehicle components and food flavours and fragrances. JI also hosts many service providers, our LNG terminal, as well as power and utility companies that supply around half of Singapore's total domestic electricity demand.

Producing a Wide Variety of Products Used in Essential Goods



JI's success today rests on past efforts to build a well-integrated value chain with supporting infrastructure and implement initiatives that bolster our competitiveness with an emphasis on safety and environment:

Plug and play infrastructure and integration

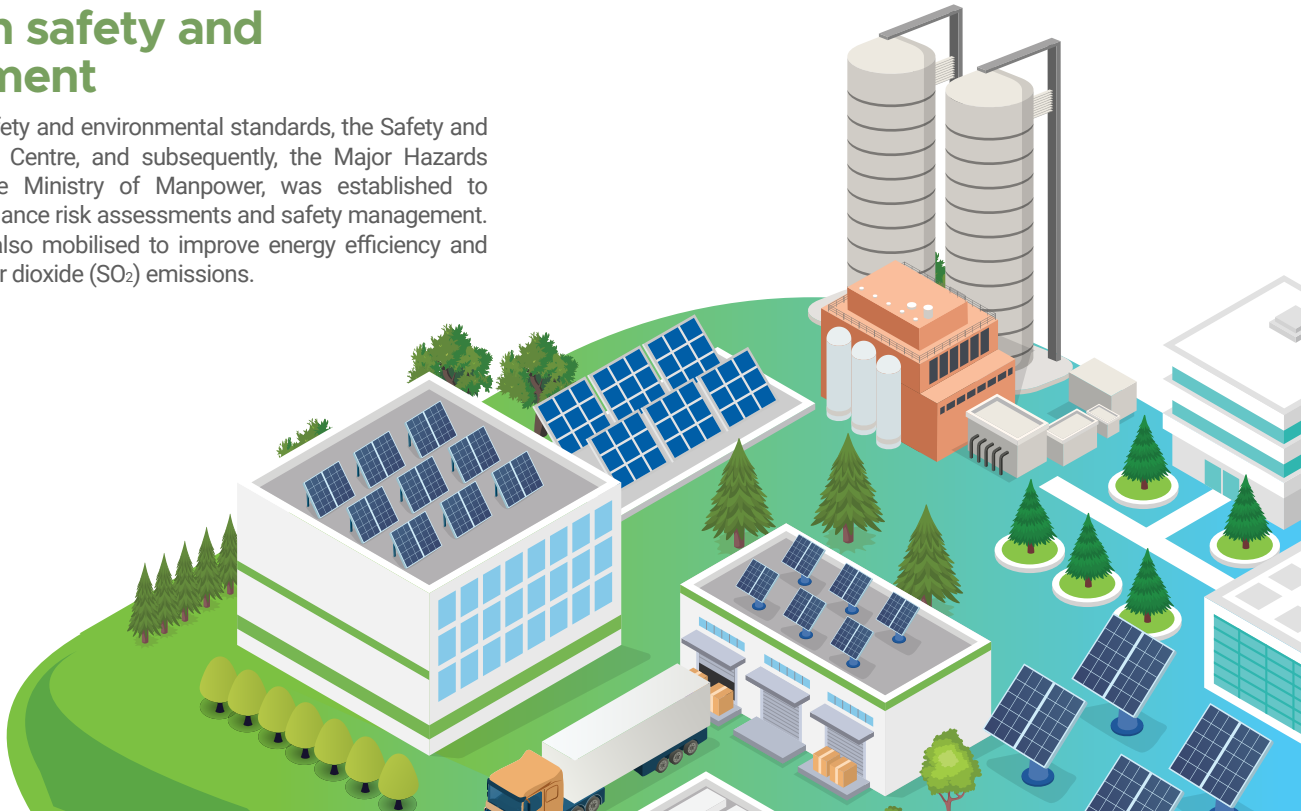
JI boasts an integrated ecosystem of seamlessly integrated infrastructure solutions including service corridors, logistics and warehousing, as well as shared third-party utilities and services. Companies can enjoy cost savings and build synergies through product integration. This 'plug and play' infrastructure and integration has been one of the main reasons for JI's success as a world-class chemicals hub despite Singapore's lack of oil and gas resources and limited land.

Continued improvements in competitiveness and resilience

In 2010, the Singapore Economic Development Board (EDB) developed the Jurong Island Version 2.0 (JIv2.0) Masterplan in light of rising global competition and Singapore's resource constraints. This brought government agencies together to partner with industry to drive the execution of initiatives across five core areas – energy, logistics and transportation, feedstock options, environment and water. Various projects have since been implemented to improve JI's competitiveness and resilience, including initiatives to improve feedstock diversification and enhance JI's logistics infrastructure.

Focus on safety and environment

To improve JI's safety and environmental standards, the Safety and Risk Management Centre, and subsequently, the Major Hazards Department in the Ministry of Manpower, was established to streamline and enhance risk assessments and safety management. Companies were also mobilised to improve energy efficiency and reduce their sulphur dioxide (SO_2) emissions.



Trends, Challenges And Opportunities

Globally, the landscape is evolving and this will have significant impact on the E&C sector. The United Nations has identified climate change as the biggest global threat. Across the world, international bodies and governments have stepped up their policies, frameworks and regulations in sustainability. 196 countries adopted the Paris Agreement at COP21 in Paris[4], and at least 44 countries have already submitted ambitious Low greenhouse gas Emission Development Strategies (LEDS) for 2050[5]. In 2021, the European Union (EU) Parliament also approved the inclusion of shipping into its Emissions Trading Scheme.[6]

Countries are looking towards low-carbon alternatives as enablers of future economic growth. For example, countries in the EU as well as Japan have committed significant investments in low-carbon hydrogen (H_2).[7] In 2020, Australia announced an AUD 1.9 billion investment package supporting future technologies to lower emissions.[8] These developments are changing the competitive landscape for new investments, especially for investors that are looking at green growth opportunities.

At the individual level, consumers are increasingly opting for and demanding sustainable products. In a survey of 6,000 consumers across North America, Europe and Asia, Accenture found that more than half believe it is important for companies to design products that are more sustainable and are willing to pay for it. This has implications for chemical companies, which will need to look into the sustainability of their products while maintaining price competitiveness.[9]

[4] *"The Paris Agreement" (United Nations Framework Convention on Climate Change (UNFCCC), accessed in Oct 2021) https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement*

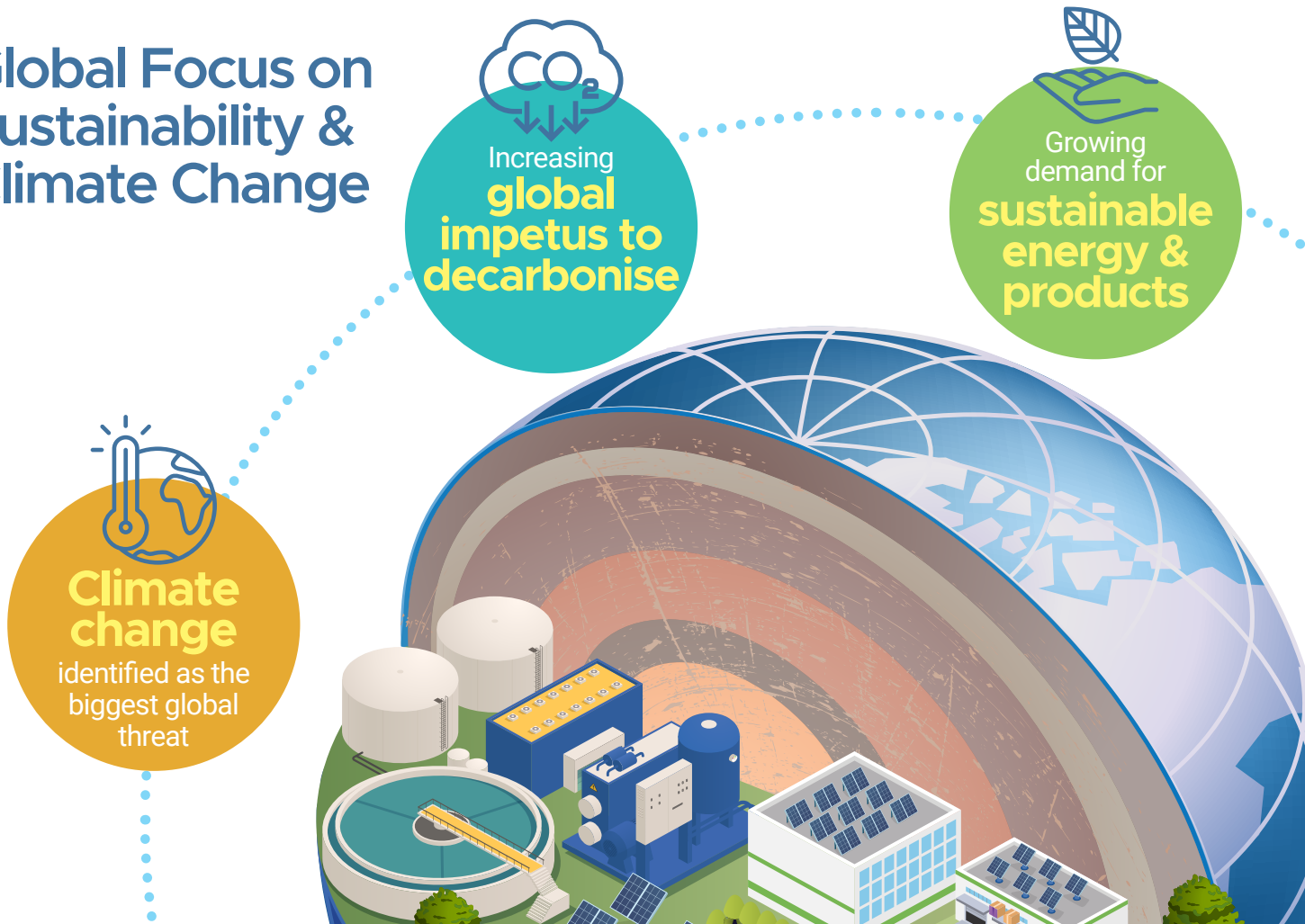
[5] *"Communication of long-term strategies" (UNFCCC, accessed in Nov 2021) https://unfccc.int/process/the-paris-agreement/long-term-strategies*

[6] *Other examples include the Carbon Offsetting Scheme for International Aviation (CORSIA); the International Maritime Organisation's (IMO) targets to halve absolute greenhouse gas emissions from maritime by at least 50 per cent by 2050; Sweden, U.K., France, Denmark, Italy and Australia with net-zero targets in law; and large Asian governments such as China, Japan and Korea committing to net-zero targets in 2020.*

[7] *Germany has committed at least €7 billion; Spain €8.9 billion; France €7.2 billion; Italy €4 billion; Austria €2 billion and Portugal €1 billion.*

[8] *"Investment in new energy technologies" (Department of Industry, Science, Energy and Resources, 17 Sep 2020) https://www.minister.industry.gov.au/ministers/taylor/media-releases/investment-new-energy-technologies*

[9] *"More than Half of Consumers Would Pay More for Sustainable Products Designed to Be Reused or Recycled, Accenture Survey Finds" (Accenture, 4 Jun 2019) https://newsroom.accenture.com/news/more-than-half-of-consumers-would-pay-more-for-sustainable-products-designed-to-be-reused-or-recycled-accenture-survey-finds.htm*



Given these shifts, the demand for carbon-intensive fossil fuels is expected to decline. This trend has been accelerated by the slowdown in travel and thus demand for transportation fuels amid the COVID-19 pandemic.[10] **Cleaner fossil fuels are still expected to play a major role in the medium term, even as the share of renewables in the global fuel mix grows.** BloombergNEF projected that natural gas will be the only fossil fuel to grow continuously by 0.5 per cent year-on-year to 2050, and fossil fuels will still provide between 28 to 70 per cent of the world's primary energy in 2050, depending on the extent of climate action measures.[11] **A broader transition to renewables entirely will likely take longer, in the post-2050 timeframe.**

The chemicals industry is also challenged by near-term pressures such as market imbalances and supply chain disruptions from geopolitical tensions and COVID-19. Despite these pressures, chemicals will continue to play an integral role across a wide-range of end-markets globally. Although the demand for chemicals from end markets such as automotive and construction has dropped due to COVID-19[12], McKinsey forecasts that even in its worst-case scenario, petrochemicals demand will return to 2019 levels by the first quarter of 2023. In particular, the sector's demand growth has been driven by emerging markets, especially in Asia, contributing to more than 40 per cent of the chemicals value growth from 2010 to 2018.[13] These markets will likely continue to drive the increasing demand for chemicals.

These global trends and the resulting demand shifts have the biggest impact on the E&C sector. At the corporate level, **E&C companies are restructuring their businesses and exploring low-carbon alternatives to prepare for a low-carbon future.** A portfolio of different approaches are being taken. These include:

a. **Increasing focus on transition fuels like natural gas, and renewables.** BP and Shell announced that they would write down up to US$17.5 billion and US$22 billion[14] from their oil and gas portfolios respectively, as an acknowledgement of the energy transition and anticipated fall in oil demand. In April 2020, Shell became the second major European oil company, after BP, to set a net-zero emissions target for 2050. To achieve this target, Shell is transforming its business and portfolio to offer customers more low-carbon energy products, ranging from renewable electricity, biofuels, to charging for electric vehicles and H_2.[15]

b. **Commercialising adoption of decarbonisation measures.** Oil and gas will be a key part of the future energy mix across all of IEA's assessed 2°C scenarios. ExxonMobil highlighted that increased energy efficiency and a shift to lower carbon energy sources will help curb CO_2 emissions, but not sufficiently to reach a 2°C pathway. Innovative technology solutions and supportive policies are still needed to reach society's aspirations.[16] In February 2021, it announced the creation of the ExxonMobil Low Carbon Solutions business unit to commercialise its low-carbon technology portfolio, starting with carbon capture and storage (CCS) opportunities.[17]

[10] *Global energy demand contracted by 4% in 2020, and the continued lockdowns and restrictions due to the COVID-19 pandemic will continue to damper demand. "Economic impacts of Covid-19" (International Energy Agency, 2021) https://www.iea.org/reports/global-energy-review-2021/economic-impacts-of-covid-19*

[11] *New Energy Outlook 2020 (BloombergNEF, 4 Nov 2020)*

[12] *There has been a global fall of 22 per cent in automotive production from 2019 to 2020. "Global commercial vehicle production expected to drop 22 percent" (IHS Markit, 17 Apr 2020) https://ihsmarkit.com/research-analysis/global-commercial-vehicle-production-expected-to-drop-22-perce.html*

[13] *"The impact of COVID-19 on the global petrochemical industry" (McKinsey & Company, 28 Oct 2020) https://www.mckinsey.com/industries/chemicals/our-insights/the-impact-of-covid-19-on-the-global-petrochemical-industry*

[14] *"Shell to write down as much as US$22b in wake of coronavirus" (The Business Times, 30 Jun 2020) https://www.businesstimes.com.sg/energy-commodities/shell-to-write-down-as-much-as-us22b-in-wake-of-coronavirus*

[15] *Shell has set carbon intensity reduction targets that not only cover emissions under its operational control, but also emissions associated with the end use of all the energy products the company sells to its customers. "Our climate target" (Shell, accessed in Nov 2021) https://www.shell.com/energy-and-innovation/the-energy-future/our-climate-target.html#iframe=L3dlYmFwcHMvY2xpbWF0ZV9hbWJpdGlvbi8*

[16] *"Outlook for Energy" (ExxonMobil, accessed in Nov 2021) https://corporate.exxonmobil.com/Energy-and-innovation/Outlook-for-Energy/*

[17] *"ExxonMobil Low Carbon Solutions to commercialize emission-reduction technology" (ExxonMobil, 1 Feb 2021) https://corporate.exxonmobil.com/News/Newsroom/News-releases/2021/0201_ExxonMobil-Low-Carbon-Solutions-to-commercialize-emission-reduction-technology*

Across the sector, companies are also investing in research and development (R&D) for carbon capture and utilisation (CCU) and low-carbon H_2 as longer-term pathways, in biochemicals to grow their portfolio of sustainable products, and in newer technologies such as crude-to-chemicals to improve carbon efficiency. For instance, Braskem announced plans to expand biopolymer production capacity[18], while BASF launched a Circular Economy Programme with the aim of doubling its sales volume of circular economy solutions to €17 billion by 2030; the programme includes initiatives such as its chemical recycling project ChemCycling™ to transform plastic waste into pyrolysis oil.[19]

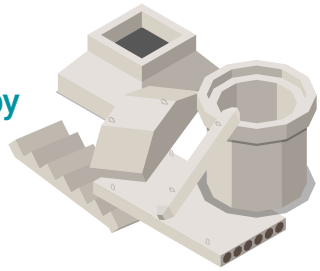
Finally, **COVID-19 has also increased pressures to reduce our E&C sector's reliance on foreign workers**, especially in the Process Construction and Maintenance (PCM) sector. Due to border closures and resultant manpower shortages, several projects were halted, incurring significant economic losses. This calls for measures to accelerate ongoing initiatives to improve digitalisation and workplace productivity, to strengthen the sector's competitiveness and resilience against unforeseen disruptions.

[18] "More Braskem biopolymers on the market" (Braskem, 22 Mar 2021) https://www.braskem.com.br/newsletter-carbon-neutral-detalhe-en/more-braskem-biopolymers-on-the-market
[19] BASF's other initiatives include its chemical recycling processes for used mattresses and lithium-ion battery "Circular Economy at BASF" (BASF, accessed in Oct 2021) https://www.basf.com/sg/en/who-we-are/sustainability-archiv/we-drive-sustainable-solutions/circular-economy-at-basf112.html

Targets and Aspirations for a **SUSTAINABLE JURONG ISLAND**

By 2030

Increase the output of sustainable products by **1.5 times** from 2019 levels



Ensure that the refineries and crackers are in the **top quartile** of the world in terms of energy efficiency

Realise at least **2 million tonnes** of carbon capture

By 2050

Increase the output of sustainable products by **4 times** from 2019 levels

Achieve more than **6 million tonnes** of carbon abatement per annum from low-carbon solutions

Against the backdrop of the global energy transition and Singapore's 2050 LEDS[20], which was submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2020[21], **our E&C sector must transform and play a key role in developing solutions for a global low-carbon future. Our aspiration is for the E&C sector to increase its output of sustainable products by four times from 2019 levels[22] and achieve more than six million tonnes of carbon abatement per annum from low-carbon solutions, by 2050.**

To reach this long-term goal, EDB will set out to achieve the following key targets[23] by 2030 to transform JI into a sustainable E&C park:

a. Increase the output of sustainable products such as bio-based fuels and chemicals by 1.5 times from 2019 levels, where sustainable products accounted for seven per cent of the sector's manufacturing output;
b. Ensure that the refineries and crackers in Singapore are in the top quartile of the world in terms of energy efficiency;
c. Realise at least two million tonnes of carbon capture potential.

The following section elaborates on the key initiatives the Government will embark on, in partnership with the industry, to grow the base of **Sustainable Products** and enable **Sustainable Production** in the E&C sector to meet our 2030 targets and longer-term 2050 aspirations.

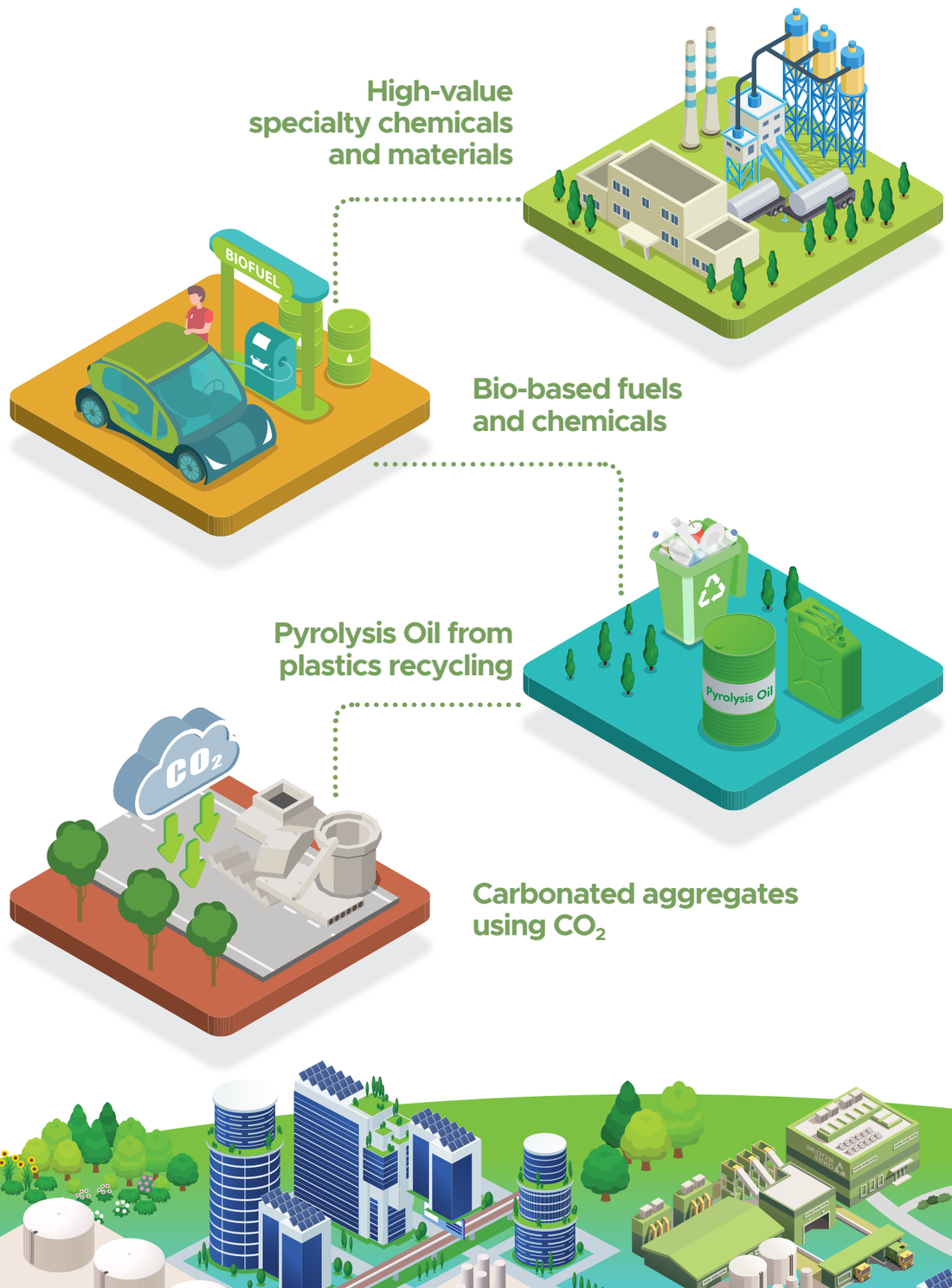
[20] *Singapore aims to halve emissions from its peak to 33 million tonnes of carbon dioxide emissions by 2050, with a view to achieving net zero emissions as soon as viable in the second half of the century, as part of its LEDS aspiration. "Singapore's Enhanced Nationally Determined Contribution and Long-Term Low-Emissions Development Strategy" (National Climate Change Secretariat (NCCS), 28 Feb 2020) https://www.nccs.gov.sg/media/press-release/singapores-enhanced-nationally-determined-contribution-and-long-term-low-emissions-development-strategy*

[21] *The UNFCCC is the parent treaty of the 2015 Paris Agreement, which aims to keep the global average temperature rise as close as possible to 1.5 degrees Celsius above pre-industrial levels in this century (UNFCCC, accessed in Oct 2021) https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement*

[22] *The baseline for our targets is 2019 data, given that 2020 data may not be a representative base due to the impact of COVID-19 on our E&C sector.*

[23] *These targets will apply to the E&C sector in general.*

Key Initiatives



Sustainable Products

We will seek to attract and anchor the manufacturing of **Sustainable Products**, which significantly reduce environmental impact in their use and/or are manufactured using recycled or renewable materials, such as:

High-value specialty chemicals and materials

We will look to grow highly valued specialty chemicals and materials manufacturing that is less dependent on JI's integrated feedstock. Such specialty chemicals include lubricant additives and long-lasting rubbers used in vehicles that improve fuel efficiency and reduce carbon emissions. This will moderate the demand for molecules from the refineries and crackers, which are the most emissions-intensive portions of the E&C value chain. JI's shared utilities and logistics infrastructure will continue to help E&C companies reap production synergies, while minimising health and safety implications to the mainland.

Bio-based fuels and chemicals

Biofuels, which are considered carbon neutral, are primarily used as transportation fuels by blending with fossil-based fuels such as gasoline and diesel. The aviation sector is exploring the use of sustainable aviation fuels (SAF) made from biogenic feedstock, starting with small percentage blends due to the significant cost premium.[24] All Nippon Airways (ANA), for instance, has signed a preliminary agreement to source for SAF from Neste's largest biorefinery based in Singapore[25], which will be more than doubling its output to meet the rising global demand for renewable energy[26]. In 2021, EDB, together with a group of government and industry stakeholders, completed a study on the operational and commercial viability of deploying SAF at Changi Airport and are looking into potential pilots. The marine sector is also looking at using biofuels as an interim alternative to conventional marine fuels, while exploring LNG and ammonia as longer-term alternatives to meet the International Marine Organization's 2030 and 2050 targets.[27] As a step towards this, GoodFuels, BHP and Oldendorff successfully completed their first ocean-going vessel biofuel bunkering trial in Singapore with the support of the Maritime and Port Authority of Singapore (MPA) in April 2021.[28]

Biochemicals are similarly considered carbon neutral and can replace fossil fuel-based chemicals.[29] We are keen to work with companies which are looking to manufacture bio-based chemicals for Singapore and the world. Arkema is one company with plans to invest in bio-based chemicals, and will be starting up a new biochemicals plant on JI in the first half of 2022 to meet the strong demand in the region.[30] However, the lack of available and accessible non-food or food waste-derived biomass feedstock in Singapore and the surrounding region remains a key impediment to widescale adoption, and we will need innovative solutions and partnerships to scale this.

EDB will continue to work closely with companies to facilitate the piloting and production of biofuels and biochemicals where viable. We are interested in exploring the development of novel biofuels and biochemicals with enhanced properties and functionality that give them a performance advantage over conventional fossil fuel-based alternatives. As novel bio-based products have lower technical maturity compared to petrochemical technologies, further R&D and testing will be vital to realising their potential.

Pyrolysis Oil from plastics recycling

Through pyrolysis, plastic waste is converted into pyrolysis oil, a higher-value product which can be used as feedstock for chemicals and materials. This allows domestic plastic waste to be diverted away from our incineration plants, which will reduce carbon emissions, extend the lifespan of our landfills and contribute to Singapore's recycling targets. The National Environment Agency (NEA) is working with Shell to study the feasibility of chemically recycling plastics in Singapore.[31]

Carbonated aggregates using CO_2

The carbonation of aggregate materials such as concrete waste and natural minerals is a potential way to use domestic carbon dioxide (CO_2) emissions permanently.[32] This pathway is applicable to Singapore's context for two main reasons. First, carbonated aggregates can be used to supply aggregates for land reclamation, road construction and coastal adaptation, allowing us to obtain sizable CO_2 abatement. Second, this process can make use of low concentrations of CO_2. CO_2 emissions from flue gas, which are in low CO_2 concentration and form a majority of our domestic CO_2 streams, can be directed to this pathway without the need for an additional step to concentrate the CO_2 before use. EDB, together with local research institutes such as the Institute of Chemical and Engineering Sciences (ICES) at A*STAR and relevant government agencies, will work with large CO_2 emitters and the local concrete industry to pilot and scale the production of carbonated aggregates in Singapore.

[24] Prices range from approximately US$1,500 to US$5,000 per metric tonnes of SAF, depending on production pathway, compared to US$450 to 600 per metric tonnes for conventional jet fuel.

[25] "Neste and All Nippon Airways (ANA) collaborate on first supply of Sustainable Aviation Fuel in Asia" (Neste, 26 Oct 2020) https://www.neste.com/releases-and-news/aviation/neste-and-all-nippon-airways-ana-collaborate-first-supply-sustainable-aviation-fuel-asia

[26] "Finland's Neste expands Singapore refinery as it taps renewable growth" (The Business Times, 31 Jul 2019) https://www.businesstimes.com.sg/energy-commodities/finlands-neste-expands-singapore-refinery-as-it-taps-renewable-growth

[27] By 2030, CO_2 emissions should be reduced by at least 40 per cent from 2008 levels, and by 50 per cent by 2050, under the IMO's targets.

[28] "Joint Media Release: BHP, Oldendorff and GoodFuels successfully complete first trial with biofuel supplied in Singapore" (Maritime and Port Authority of Singapore, 15 Apr 2021) https://www.mpa.gov.sg/web/portal/home/media-centre/news-releases/detail/81f61c24-e01a-4c0b-92ca-4927676da2f9

[29] For direct replacements, the bio-derived product and petroleum-derived product are chemically identical; for functional replacements, the bio-derived product and petroleum-derived product are chemically different but have similar functions or properties.

[30] Arkema's production of Amino 11 and its flagship Rilsan® polyamide 11 will be 100%-derived from renewable castor beans. "Arkema to start up new bio-based polyamide 11 plant in Singapore in the first half of 2022" (Arkema, 22 Apr 2021) https://www.arkema.com/global/en/media/newslist/news/global/corporate/2021/20210422-arkema-new-bio-based-polyamide-11-plant-singapore/

[31] "NEA And Shell To Jointly Explore New Chemical Recycling Value Chain To Turn Plastic Waste Into Chemicals" (National Environment Agency (NEA), 16 Oct 2020) https://www.nea.gov.sg/media/news/news/index/nea-and-shell-to-jointly-explore-new-chemical-recycling-value-chain-to-turn-plastic-waste-into-chemicals

[32] Mineralising industrial waste to produce aggregates for the construction sector is defined as a permanent technology to bind or store carbon, as it binds or stores carbon for more than a century before it is released back to the atmosphere (Navigant Report for EDB and NCCS, 2019)

There are other sustainable products that are applicable to Singapore but will require further R&D to improve their overall techno-economic viability. We will advance our capabilities in these areas to promote decarbonisation and sustainable growth beyond 2030. Such areas include:

Low-carbon H_2

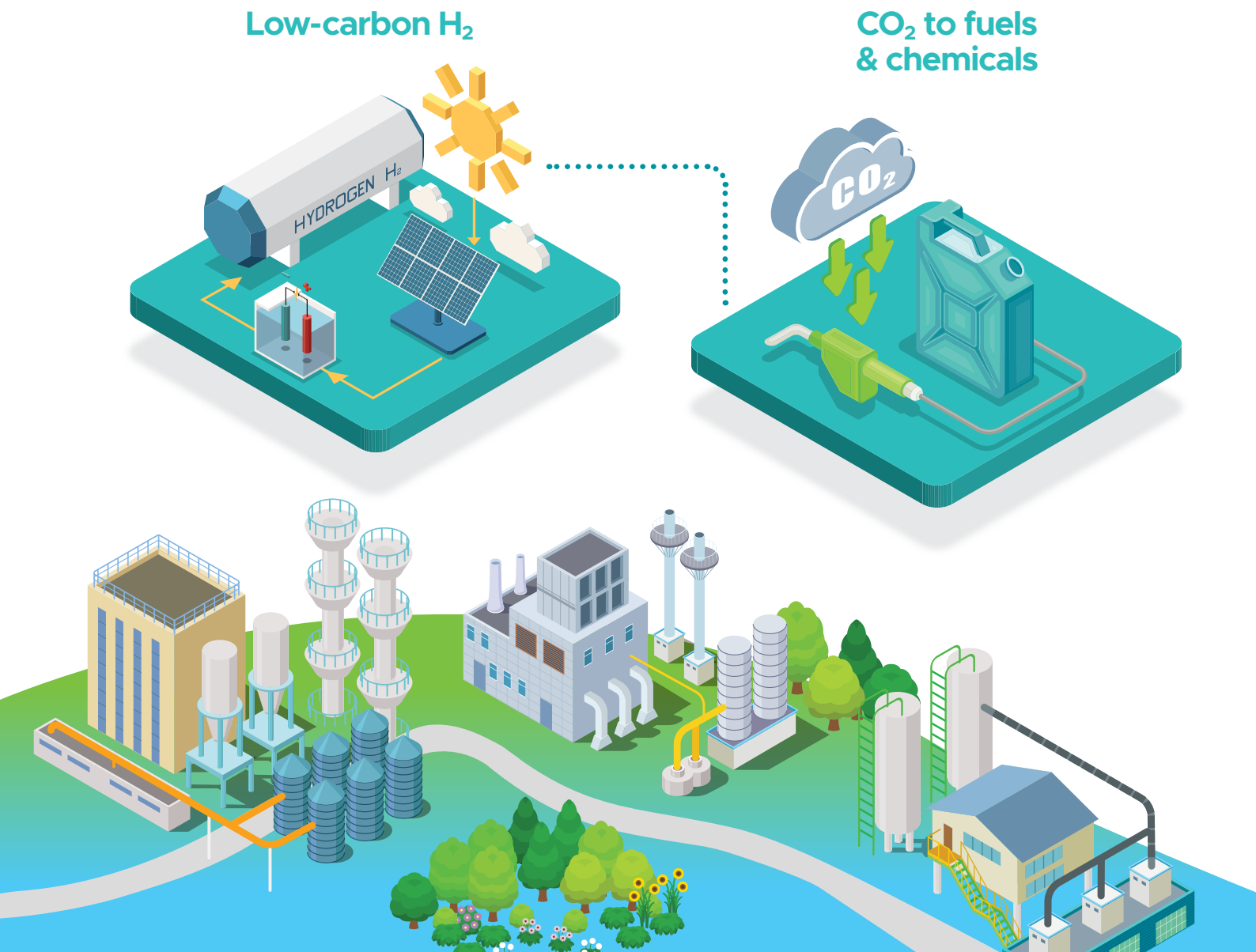
Low-carbon H_2 is both a fuel and feedstock alternative that can generate significant abatement for Singapore, potentially even fully decarbonising the power sector. However, there is a lack of access to cost-competitive low-carbon H_2 and the necessary supporting infrastructure; the technology is also not ready for wide-scale adoption. To advance its development, we will partner with E&C companies to enable low-carbon H_2 supply pathways, develop the necessary infrastructure and solutions, and address the key barriers to its deployment through further R&D and pilots. For example, in 2021, TechnipFMC signed a partnership with EDB to develop a Master Control Station in Singapore, focused on developing and implementing solutions for the production, storage and distribution of green H_2.

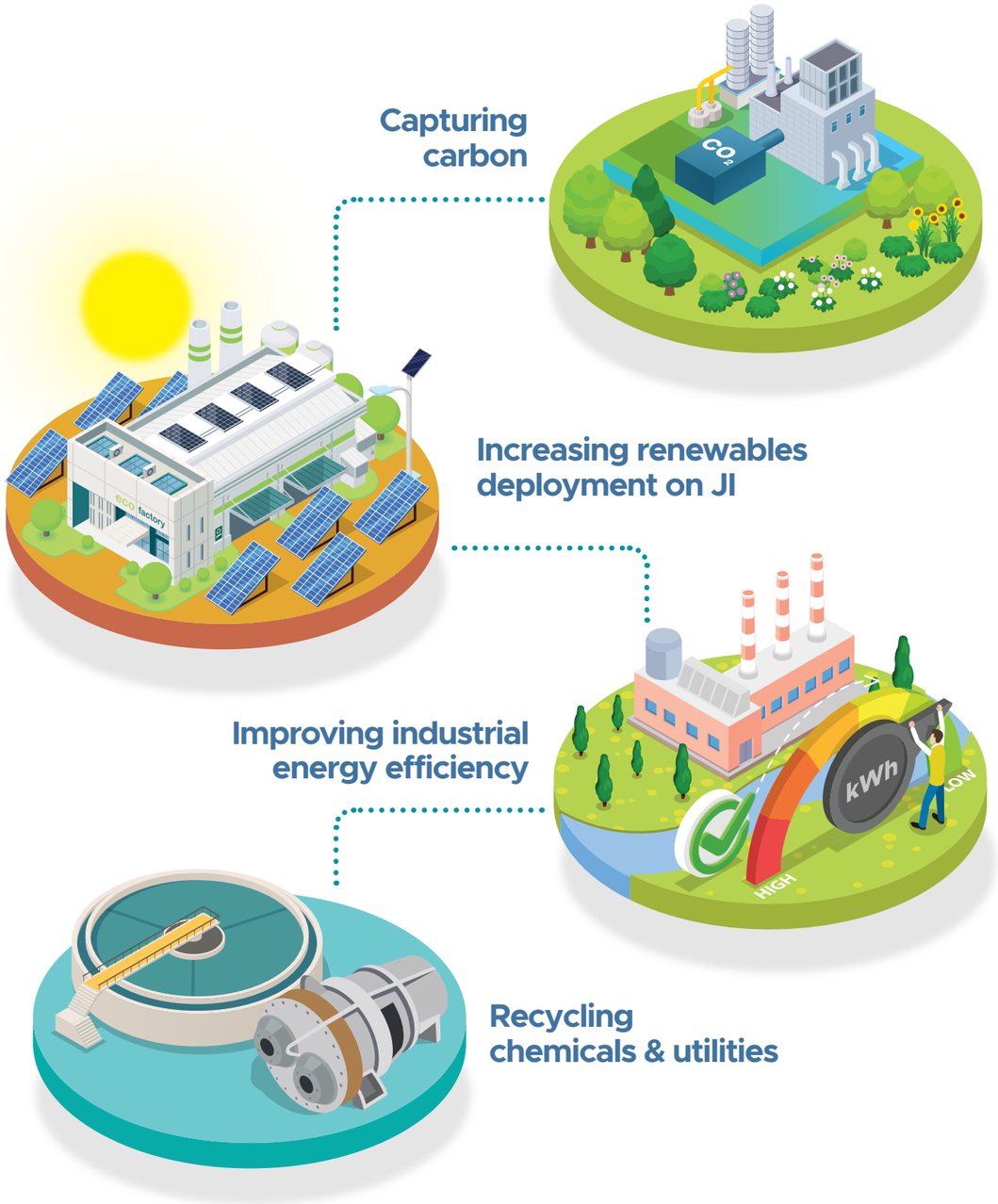
CO_2 to fuels and chemicals

Converting CO_2 to fuels and chemicals is another long-term abatement solution. This pathway is heavily dependent on access to abundant low-cost, low-carbon H_2 and is thermodynamically challenging, requiring significant R&D to overcome these barriers. We will continue to explore options for this pathway and partner with companies looking to develop and test-bed technologies for the conversion of CO_2 to fuels and chemicals in Singapore. For instance, EDB is supporting Sumitomo Chemical to explore combining its Propane Dehydrogenation technology, which converts propane gas into propylene, with CO_2-to-methanol locally.[33] Shell has also signed a S$4.6 million research agreement with the National University of Singapore (NUS), with support from the National Research Foundation (NRF), to jointly develop novel processes to use CO_2 to electrochemically produce ethanol and n-propanol that can be used to deliver cleaner fuels.[34]

[33] *"Sumitomo Chemical to Examine the Combination of Propane Dehydrogenation Technology with CO_2 Utilization Technology in Singapore, Aiming to Improve both Economic Activity and Eco-friendliness" (Sumitomo Chemical, 24 Dec 2020) https://www.sumitomo-chem.co.jp/english/news/detail/20201224e.html*

[34] *"NUS and Shell join hands to advance decarbonisation solutions" (National University of Singapore, 14 May 2021) https://news.nus.edu.sg/nus-and-shell-join-hands-to-advance-decarbonisation-solutions/*





Sustainable Production

In addition to unlocking the use of carbonated aggregates to reduce emissions, we will focus on the following **Sustainable Production** pathways, that will reduce domestic carbon emissions and pollution, or optimise resource use:

To achieve carbon abatement through carbon capture, utilisation and storage (CCUS) pathways, we will invest in the R&D and piloting of new **carbon capture technologies**, and **explore carbon utilisation and storage opportunities** to use or store the CO_2 captured. Such utilisation opportunities include the products mentioned under Sustainable Products such as carbonated aggregates and CO_2 to fuels and chemicals.

Capturing carbon

Carbon capture is a key component of CCUS; it involves separating CO_2 from other gases and concentrating it for subsequent transportation, utilisation or storage. Given the high costs of carbon capture from low concentration emissions (i.e. <30%), we will focus on the capture potential of higher concentration streams in the near term and explore technologies that can sequester carbon from low concentration streams directly. EDB and JTC will also plan for the necessary infrastructure on JI to support the capture and transportation of these streams for utilisation or storage.

To enable cost reductions in carbon capture, especially from lower CO_2 concentration streams, Singapore will invest in the R&D of emerging technologies such as membranes and solid adsorption materials, leveraging our strong local research capabilities in material science and chemical engineering. We invite industry players to collaborate with local Institutes of Higher Learning and to develop and test-bed their carbon capture technologies here. Some industry efforts are already ongoing. In July 2020, Keppel Data Centres, Chevron, Pan-United and Surbana Jurong, with the support of NRF, signed a Memorandum of Understanding to accelerate the development of a highly integrated clean and energy efficient CCUS system that can lead to a low-carbon economy and potential commercial developments for Singapore.[35]

CCS offers a potentially viable decarbonisation pathway for hard-to-abate sectors such as E&C and power. CCS technologies are already proven at commercial scale, have high abatement potential and can potentially deliver abatement at lower costs per ton of CO_2 compared to other commercial-scale abatement pathways. Companies have started to explore regional transboundary solutions. For example, ExxonMobil announced that they are planning a CCS hub concept in Singapore to capture, transport and permanently store CO_2 generated domestically into the APAC region in February 2021.[36]

Increasing renewables deployment on JI

JI can also play a role in our efforts to solarise Singapore. To increase the deployment of renewable energy on JI, JTC has launched the SolarLand programme to deploy portable solar PV systems on interim vacant land.[37] The Energy Market Authority (EMA) and JTC have launched an innovation call, the Jurong Island Renewable Energy Request For Proposals, at the Singapore International Energy Week 2021 to test-bed innovative energy solutions including renewable energy, energy storage systems and low-carbon solutions to reduce JI's carbon footprint.[38]

Improving industrial energy efficiency

To strengthen JI's position as a leading sustainable E&C export hub, we aim for JI companies to be global leaders in energy efficiency. Many companies have implemented energy efficiency projects over the last decade; ExxonMobil, for example, has improved the energy efficiency of its operations by over 25 per cent from 2002 to 2019 through process improvements and plant upgrading, avoiding CO_2 emissions equivalent to removing 600,000 cars off Singapore's roads over this period.[39] In the Energy Efficiency National Partnership Awards held in October 2021, CCD (Singapore) was given the "Best Practices" award for its efforts in reducing emissions through steam optimisation, with ExxonMobil, Afton Chemical and Petrochemical Corporation of Singapore (PCS) receiving an honourable mention for their respective energy efficiency improvement efforts.[40] Building on this momentum, EDB and NEA will continue working with industry players to identify and make further improvements in industrial energy efficiency and thus reduce emissions.

Recycling chemicals and utilities

There are also opportunities for circularity on JI. To lower carbon and other gas emissions (such as SO_2) from gas flaring during oil production, we will work with companies to explore the implementation of flare gas recovery projects to recycle these waste gases. EDB, EMA and JTC have been working with the Singapore LNG Corporation (SLNG) to explore how we can harness cold energy, released during the regasification of LNG, to reduce power consumption and associated carbon emissions.

Besides these initiatives, EDB will work towards **reducing other environmental impacts** from JI's operations, such as by building on our toxic industrial waste treatment capabilities. We will also continue our efforts with the industry and partner with government agencies to **improve the competitiveness and resilience** of JI. These include driving productivity improvements in the supporting PCM sector, as well as enabling system-level digitalisation on JI.

[35] *"Industry leaders collaborate to develop Singapore's first end-to-end decarbonisation process to mitigate climate change" (National Research Foundation, 2 Jul 2020) https://www.nrf.gov.sg/docs/default-source/modules/pressrelease/media-release-on-ccus*

[36] *"ExxonMobil Low Carbon Solutions to commercialise emissions-reduction technology" (ExxonMobil, 1 Feb 2021) https://corporate.exxonmobil.com/News/Newsroom/News-releases/2021/0201_ExxonMobil-Low-Carbon-Solutions-to-commercialize-emission-reduction-technology*

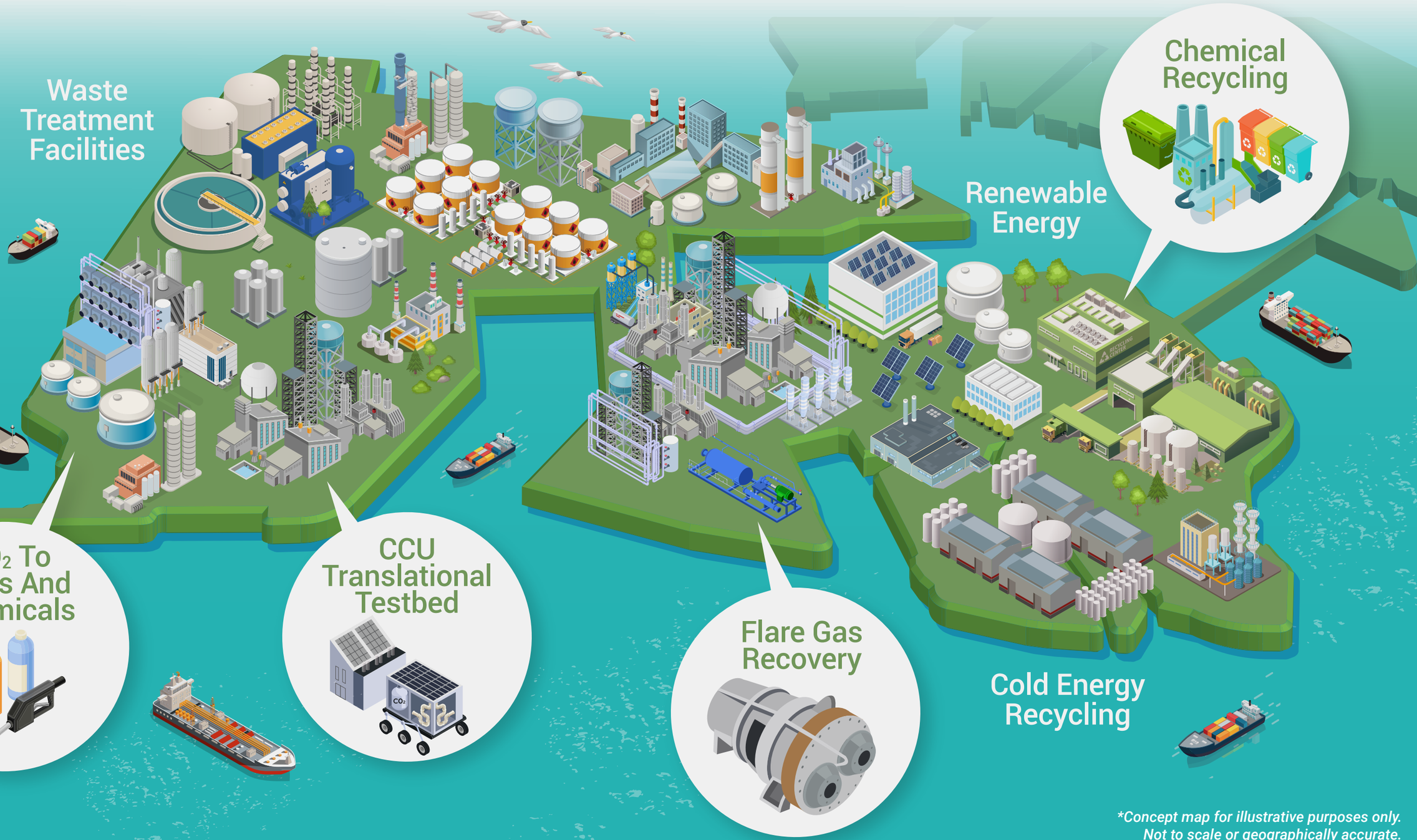
[37] *Portable systems provide flexibility for the relocation of the solar installation in the event of a need to recover the solar site for future E&C investments. "A Boost for Clean Energy in Singapore with SolarLand Programme" (JTC, 12 Jun 2019) https://www.jtc.gov.sg/news-and-publications/press-releases/Pages/20190613(PR1).aspx*

[38] *"EMA and JTC Launch $6 Million Open Call to Accelerate Clean Energy Innovations on Jurong Island" (Energy Market Authority (EMA), 25 Oct 2021) https://www.ema.gov.sg/media_release.aspx?news_sid=20211023YAxJKHOr0KaM*

[39] *"ExxonMobil Asia Pacific a Winner of the Best Practices Award" (The Business Times, 8 Oct 2020) https://www.businesstimes.com.sg/hub/energy-efficiency-national-partnership/exxonmobil-asia-pacific-a-winner-of-the-best-practices*

[40] *"13 Companies, Organisations And Individuals Recognised For Outstanding Achievements In Energy Management At The National Energy Efficiency Conference (NEEC) 2021" (NEA, 12 Oct 2021) https://www.nea.gov.sg/media/news/news/index/13-companies-organisations-and-individuals-recognised-for-outstanding-achievements-in-energy-management-at-the-national-energy-efficiency-conference-(neec)-2021*

Transforming for a **Low-Carbon Future**



**Concept map for illustrative purposes only. Not to scale or geographically accurate.*

Cross Cutting **Enablers**

To enable the initiatives above, the Government will work on **Infrastructure** and **Policies and Programmes** to support the ecosystem.

Infrastructure

Incorporating sustainability into the planning of greenfield sites and investments

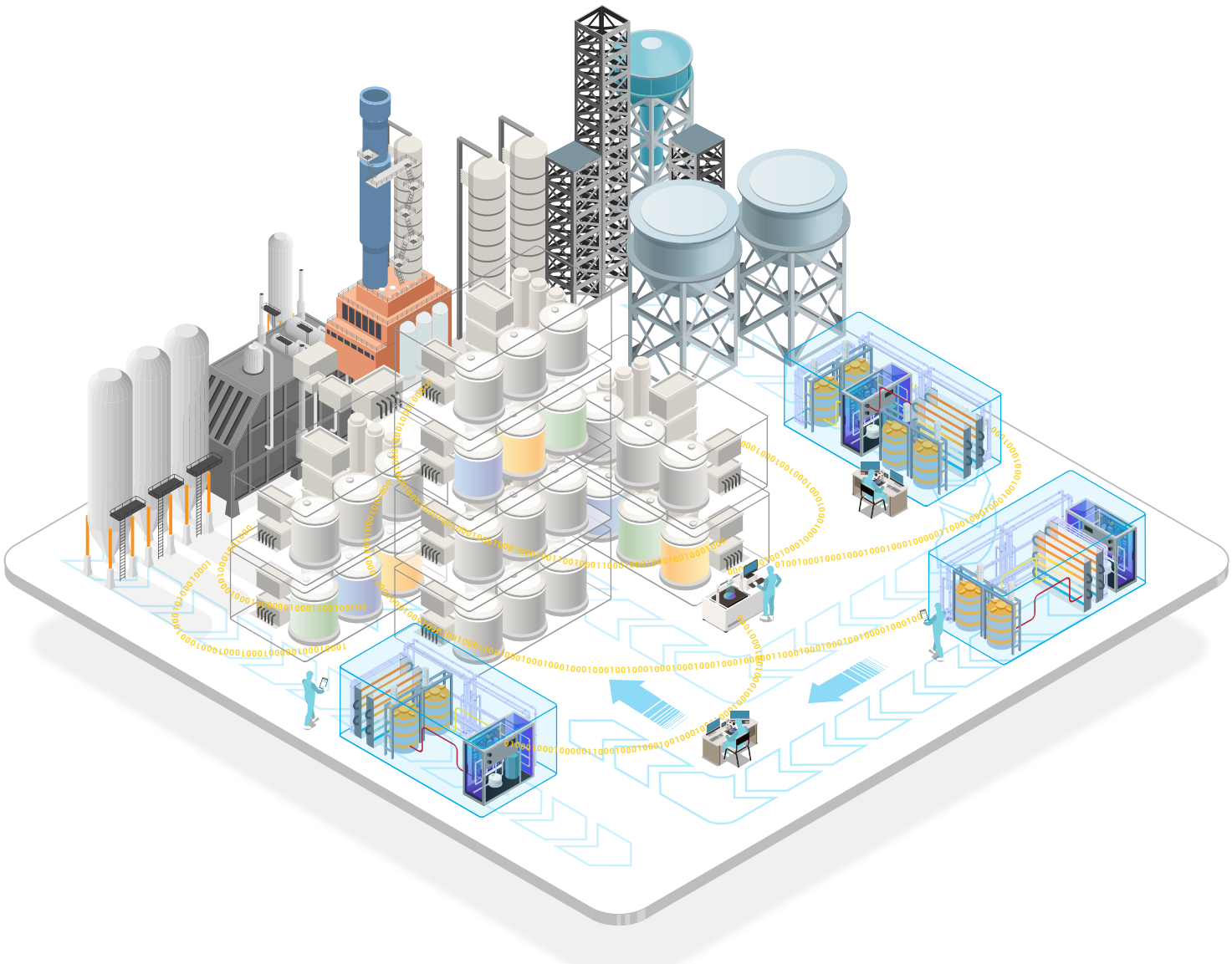
Efforts are ongoing to identify key areas for sustainability to be incorporated into the planning and design of greenfield sites on JI. We will explore how new plants can be designed upfront with sustainability in mind, to optimise resource use and reduce emissions when operational.

Building specialised or shared infrastructure

JI houses critical infrastructure that contribute to greater sustainability of our domestic energy use, such as the LNG terminal and advanced Combined Cycle Gas Turbine power plants that are designed for greater efficiency. Building on this, EDB and JTC will work with the industry to identify and plan for the necessary infrastructure to support the decarbonisation and energy transition needs of JI companies and Singapore's wider energy needs, such as specialised or shared infrastructure for carbon transportation and storage, and for future marine fuels such as ammonia and H_2.

Conceptualising the CCU Translational Testbed to accelerate the development of CCU technologies in Singapore

To accelerate the development and commercialisation of CCU technologies, A*STAR, EDB and JTC are working together to study the potential of a CCU test-bedding facility on JI, the CCU Translational Testbed. This facility will leverage the latest test bedding technologies – such as modularisation and digitalisation – to accelerate the development of CCU technologies from feasibility at lab scale to technology translation in industrial settings. Such infrastructure will help to support our research institutes and companies to develop and scale their technologies more quickly in Singapore.



Policies and Programmes

In recent years, Singapore has progressively put in place legislative tools to support national outcomes related to environmental sustainability. We have mandated the Energy Conservation Act, which will require energy intensive companies to assess how they can reduce their emissions and improve energy efficiency. Carbon Pricing was also introduced in 2019, which stands at S$5 per tonne of greenhouse gas emissions for large emitters. The Carbon Pricing Act will be reviewed by 2022, taking into consideration the appropriate price and design needed to spur further decarbonisation as well as its impact to competitiveness.

To complement these national efforts and support Singapore-based companies in the energy transition, the Government has introduced **incentive measures to help companies adopt decarbonisation and sustainability solutions**:

Adopting decarbonisation measures

EDB administers two incentives that support industry in reducing emissions, namely the Resource Efficiency Grant for Energy (REG(E)) and the Investment Allowance for Emissions Reduction (IA(ER)). REG(E) was introduced in 2019 to support companies in improving energy efficiency and reducing the use of non-CO_2 greenhouse gases. IA(ER) was introduced in 2010 as the Investment Allowance for Energy Efficiency to encourage companies to improve energy efficiency. In 2021, both schemes were enhanced to reflect the expanded scope that includes opportunities such as CCUS and flare gas recovery, beyond energy efficiency improvements and reduction of non-CO_2 greenhouse gases. The government will continue to review these incentive schemes periodically to ensure they remain targeted and effective in supporting industrial decarbonisation efforts.

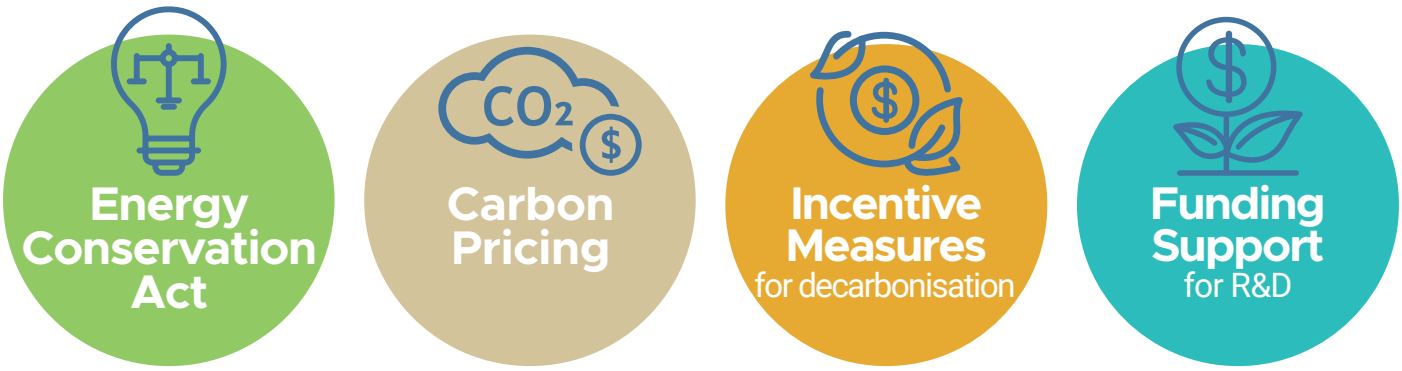
R&D in low-carbon solutions

To support R&D in CCUS and low-carbon H_2, the Government announced a new Low-Carbon Energy Research Funding Initiative (LCER FI) in October 2020. The LCER FI aims to develop low-carbon energy technologies in the domains of H_2 and CCUS over the next five years, to support the decarbonisation of the power and industry sectors in Singapore. Under the inaugural grant call, S$55 million was awarded in October 2021 to 12 projects spanning focus areas in novel carbon capture technologies, carbon utilisation in developing alternatives to sand and the production of commodity chemicals, as well as reducing costs and increasing efficiencies of H_2-related processes.[41]

Grant monies are also available for enterprises to create sustainability solutions for JI companies. JTC and Enterprise Singapore launched the Jurong Island Innovation Challenge in August 2021, to crowdsource innovative ideas from start-ups and SMEs to enhance the sustainability and circularity of resources on JI. Industry players such as SLNG, PCS, Shell, Chevron Oronite, and BASF submitted 10 challenge statements covering four key themes that will boost resource efficiency efforts: energy efficiency, emissions reduction, water management and chemical waste management.[42] We welcome new efforts by the industry to come together and partner with other enterprises to co-create innovative solutions.

[41] *"12 Projects Awarded $55 Million to Accelerate Decarbonisation in Singapore" (EMA, 25 Oct 2021) https://www.ema.gov.sg/media_release.aspx?news_sid=20211024M01pxaeHuLYZ#*

[42] *"51 companies including Chevron, ExxonMobil and Shell jointly support industry-first circular economy study by JTC to optimise resource use as Jurong Island transforms into a sustainable energy and chemicals park" (JTC, 19 Aug 2021) https://www.jtc.gov.sg/news-and-publications/press-releases/Pages/20210819.aspx*



Conclusion

Global shifts are creating an accelerated impetus for the E&C sector to decarbonise and transform its portfolio towards more sustainable products, including cleaner fossil fuels and sustainable chemicals. JI, the cornerstone of Singapore's E&C sector, must also pivot to remain competitive and spearhead the E&C transition to capture green growth opportunities.

As part of the Singapore Green Plan 2030, we will transform JI into a sustainable E&C park, that operates sustainably and makes sustainable products for the world. To achieve this, EDB, together with other government agencies, will embark on the various key initiatives to grow the base of Sustainable Products and enable Sustainable Production on JI.

The journey towards a Sustainable JI will require close collaboration with stakeholders across the public and private sectors. We welcome new and existing investors to partner with us in these initiatives and position themselves as regional leaders of low-carbon innovation and technology from Singapore.

Annex A
Other Key Initiatives

Reducing Environmental Impact

Enhancing toxic waste treatment

The Government has established an inter-agency working committee to monitor and increase our Toxic Industrial Waste (TIW) treatment capacity by partnering with TIW treatment companies to build and enhance their capabilities. This will help enable a sustainable and competitive TIW management ecosystem. An example of a TIW treatment company that has been upgrading their capabilities is ECO Special Waste Management. They launched Singapore's first activated carbon plant in 2020 to help a JI plant treat its waste for reuse, and their Rotary Kiln Incineration Plant also generates steam and electricity to power other processes.[43] Such technologies are examples of improvements TIW treatment companies can adopt to support JI's operations.

Diversifying Sources of Feedstock & Utilities

Utilising Rich LNG

To diversify the feedstock used in crackers, which is currently sourced from the refineries and imported Liquified Petroleum Gas, we are looking towards other sources such as Rich LNG. In particular, SLNG is collaborating with Keppel Infrastructure on the Front End Engineering Design for a Natural Gas Liquid (NGL) Extraction Facility at the SLNG Terminal on JI to extract ethane and propane from Rich LNG[44], which can be used as an alternative feedstock for the crackers on JI.[45]

Diversifying LNG imports

In 2021, EMA appointed 2 additional term LNG importers, ExxonMobil LNG Asia Pacific and Sembcorp Fuels (Singapore) Pte. Ltd.[46] This increases the total number of term LNG importers to 4, which will offer gas buyers in Singapore greater procurement choice and flexibility.

Improving utilities competitiveness

We will also work with the power sector to improve JI's utility infrastructure and facilities in line with baseload demand trends. For instance, EDB and JTC are actively exploring opportunities to enhance competitiveness of steam supply on JI, which is commonly used in E&C production processes.

Increasing Productivity & Efficiency

Improving productivity in supporting PCM sector

The PCM sector is an essential supporting sector for the E&C industry. Improving its productivity will enhance the E&C sector's competitiveness and reduce its reliance on migrant workers. We are working closely with the PCM Management Committee, which comprises both E&C plant owners and PCM companies, to improve productivity and reduce migrant worker reliance for the sector such as through introducing firm-level productivity standards, implementing best practices for productivity and mechanisation tools to automate manual processes.

Digitalising operations to improve efficiency and workplace safety

Digitalisation will drive the next wave of productivity and efficiency gains. Companies in the E&C sector can leverage Industrial Internet of Things solutions to improve operational efficiency and safety. All the refineries and crackers have started to adopt advanced manufacturing technologies in their JI operations. For example, Linde Group launched a S$30 million initiative in 2018 to set up an Asia Pacific Digitalization Hub in Singapore to develop digital technologies and has plans to digitally transform Linde's plant on Jurong Island into a "plant of the future".[47] Beyond the plant level, we will work towards enabling system level digitalisation across companies such as logistics providers, utility companies and plant owners, to improve operational efficiency and better manage energy consumption.

[43] *"Transforming Waste into Treasure: Local Firm Redefines Waste Management" (JTC, 7 Jan 2021) https://www.jtc.gov.sg/news-and-publications/featured-stories/Pages/Local-firm-redefines-waste-management.aspx*

[44] *Rich LNG has higher concentrations of ethane and propane vs lean LNG.*

[45] *"SLNG And Keppel To Collaborate On NGL Extraction Project To Further Strengthen Singapore's Position As An LNG And Chemicals Hub" (Singapore LNG, 28 Jul 2021) https://www.slng.com.sg/node/305*

[46] *"ExxonMobil LNG Asia Pacific and Sembcorp Fuels (Singapore) Pte Ltd Appointed as Term Liquefied Natural Gas Importers for Singapore" (EMA, 25 Mar 2021) https://www.ema.gov.sg/media_release.aspx?news_sid=20210325M0UUEbYpthaR*

[47] *"German gas giant Linde to invest S$30m in Singapore digital technologies hub" (The Straits Times, 5 Feb 2018) https://www.straitstimes.com/business/companies-markets/linde-to-invest-s30m-in-singapore-digital-technologies-hub*

EDB SINGAPORE

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