THE ROLE OF INDUSTRIAL DECARBONISATION TOWARDS SINGAPORE'S NET ZERO AMBITION

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EXECUTIVE SUMMARY

The world is facing its biggest challenge yet: climate change. Around the world, governments and industry players are stepping up decarbonisation efforts to accelerate the move to net zero. There is increasing pressure for transformative change in our economies and society, to lay the foundations for a cleaner, better, more sustainable future.

In this transition, industry has an important role due to its immense value to the economy and contribution to carbon emissions, but there are also significant challenges to overcome. Singapore and Jurong Island have taken some initial steps with the launch of Sustainable Jurong Island Plan in 2021. However, more would need to be done for Jurong Island to maintain its future competitiveness as the region's leading sustainable chemicals and petrochemicals hub.

At present, Jurong Island accounts for more than half of Singapore's total carbon emissions. In terms of emissions intensity, Jurong island's contribution is disproportionately high when considering the GDP contribution is only about 3% to the total while contribution to Singapore's total manufacturing output is about 25%. On the other hand, Jurong Island is strategically important for Singapore's industrial policy and considerations around safeguarding the country's energy security given Jurong Island's regional role in petroleum refining.

With that in mind, we believe it is critical that Jurong Island urgently focus on more ambitious implementation of net zero technologies integrated at scale, to supercharge the next phase of Jurong Island's growth and maintain its long-term competitiveness and role in the economy.

Systemic efficiency and circularity and clean electrification can be rapidly deployed in the short term to drive meaningful carbon emissions reduction before 2030. For initiatives around improving systemic efficiency and circularity, digital infrastructure to support resource sharing would further enhance and build upon the foundation of the plug-and-play ecosystem and existing integration of industries on Jurong Island. With regards to clean electrification, the focus should be on maximising solar rooftop capacity and the use of imported electricity from renewable generation sources on Jurong Island.

Immediate efforts to attract investments in carbon capture utilisation and storage (CCUS) and hydrogen are needed to ensure these technologies are scalable in the medium and long term. For CCUS, partnerships with neighbouring countries to find ways to utilise and store carbon will be key to ensure it can be deployed at scale, due to Singapore's own storage constraints stemming from lack of suitable geological sites with potential.

For green hydrogen, Singapore has the potential to become a regional hydrogen trading hub. However, lack of clear certification and policy frameworks for hydrogen classification present a major market barrier for sustainable hydrogen. While constraints around land and key resources including access to low-cost, abundant renewable energy and water mean that local production of green hydrogen will be challenging, Singapore's geographical position and excellent port infrastructure make it an appealing centre for hydrogen trade across Asia Pacific.

To support Singapore's net zero ambitions, Jurong Island should leverage the power of partnerships and ecosystem collaboration amongst all its players to deliver on these net zero technologies, by sharing data, investment and risk to help achieve a fair and just transition for everyone.

INDUSTRIAL DECARBONISATION: CRITICAL TO SINGAPORE'S PATH TO NET ZERO

The net zero challenge

Around the world, nations are rallying to the call for greater reforms to tackle the adverse effects of climate change. Singapore, as one of the world's most advanced city-states, is no exception. It aims "to halve emissions from its peak to 33 MTCO2e by 2050, with a view to achieving net zero emissions as soon as viable in the second half of the century."[1]

In September 2022, the Singapore government announced intentions to achieve net zero by 2050 and at the time of this paper's publication, is in the process of conducting public consultations on the target.[2]

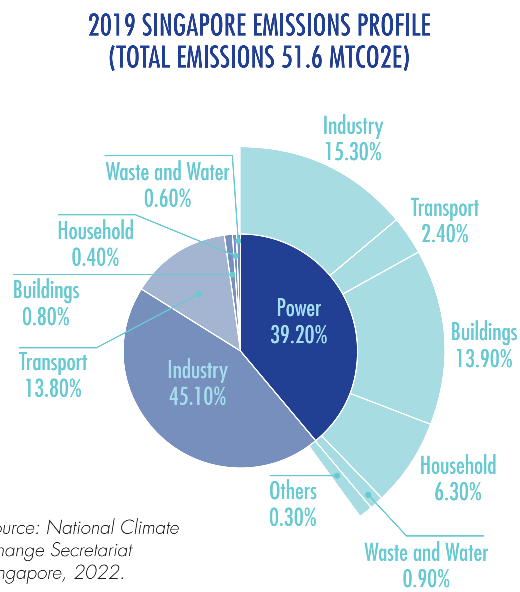
Achieving net zero means undertaking a fundamental transformation of the country's economy in key areas such as power, industry and transport while navigating the complex economical and societal challenges this entails.

Industrial clusters and its importance towards achieving net zero

Global industrial emissions account for an estimated 30% of total global CO2 emissions. Areas with industrial concentration, also known as industrial clusters, represent one of the most important focus areas for rapid, effective decarbonisation due to their significant carbon emissions contribution.[3]

In Singapore, the industrial sector is a major source of carbon emissions, accounting for 69% of total emissions, or about 35.9 MTCO2. Industry primary emissions contribute 54%, while secondary emissions contribute 15%.[4] Singapore's emissions profile by sector is presented in Figure 1.

Figure 1: Singapore's emissions profile.



Source: National Climate Change Secretariat Singapore, 2022.

1 National Climate Change Secretariat Singapore. (2021, April 10). Singapore's Long-Term Low-Emissions Development Strategy. Retrieved from National Climate Change Secretariat Singapore: https://www.nccs.gov.sg/media/publications/singapores-long-term-low-emissions-development-strategy
2 Tan, A. (2022, September 6). Singapore aiming to have emissions reach net zero by 2050; public feedback sought. Retrieved from The Straits Times.
3 Ollagnier, J.-M., & Jurgens, J. (2022, June 21). Decarbonizing industry: if industrial clusters win, we all win. Retrieved from World Economic Forum Web Site: https://www.weforum.org/agenda/2022/06/if-industrial-clusters-win-we-all-win
4 National Climate Change Secretariat Singapore. (2022, September 12). Singapore's Emissions Profile. Retrieved from National Climate Change Secretariat Singapore: https://www.nccs.gov.sg/singapores-climate-action/singapore-emissions-profile/

Jurong Island's decarbonisation is key to Singapore's industry net zero transformation

Efforts to decarbonise industrial activities on Jurong Island are critical for Singapore's net zero ambitions. According to a paper by the National University of Singapore (NUS), Jurong Island's carbon emissions is estimated at about 27 million tonnes or 54% of Singapore total carbon emissions in 2019.[5] This means the country's carbon emissions are highly concentrated in this area of about 30km^2. For context, Jurong Island accounts for 4% of Singapore's total land area, which measures around 728 km^2.

Jurong Island's high contribution to Singapore's carbon emissions is attributed to the concentration of industrial activities on the island, which includes petroleum refining and chemicals manufacturing. While these industries are typically considered difficult to abate, there are specific characteristics about Jurong Island and the wider Singapore ecosystem which supports the implementation and scaling of carbon abatement solutions.

This paper aims to explore the opportunities for Jurong Island to decarbonise, and to help Singapore achieve net zero.

1. JURONG ISLAND – THE KEY TO DELIVERING SINGAPORE'S NET ZERO AMBITION

1.1 JURONG ISLAND'S PRESENT AND FUTURE

Jurong Island is one of the world's leading Energy and Chemicals (E&C) hub. Located off the southwestern coast of Singapore, Jurong Island is formed through successive land reclamations and joining of smaller islands which were completed in stages over a 14-year period (1995-2009).

Jurong Island was envisioned as an integrated chemical hub with highly connected production chains. The concept of highly integrated infrastructure between plants, supported by common utilities and logistics, drove synergistic relationships that enabled savings for companies on capital outlay and transportation costs.

Today, Jurong Island is home to more than 100 leading global energy, petrochemical and specialty chemicals companies, with total assets invested worth over S$50 billion.[6] Singapore is the fifth-largest refinery export hub in the world and the eighth-largest chemical exporter by volume, with most of its E&C activities concentrated on Jurong Island, which has an important strategic role in ensuring Singapore's energy security.

In addition to refined petroleum products, Jurong Island produces a wide variety of chemicals used in essential consumer goods, such as alkoxylates, butyl rubber, ethylbenzene and many more. Industrial operations on the island are supported by many service providers including a liquified natural gas (LNG) terminal, underground oil storage facilities and power and utility companies which also supply around half of Singapore's total demand.[7]

Overall, Jurong Island's annual manufacturing output amounts to more than S$80 billion, contributing about a quarter of Singapore's total manufacturing output. Major industry players that have set up facilities on Jurong Island include the likes of BASF, Evonik, ExxonMobil, Singapore Refining Company, Solvay, Shell, Mitsui and Sumitomo.

Due to its general lack of natural resources and land scarcity, Singapore has had to strategise and develop a differentiated value proposition to attract global investments. Much of Jurong Island's current success is due to several key attributes, including world-class transport capabilities and a robust catalogue of supporting services which enables a plug-and-play model.

However, in a world focused on transitioning to net zero by 2050, what has worked well for Jurong Island so far will no longer be enough. It will be key for Jurong Island to start deploying and scaling net zero technologies from now on. This will enable it to continue playing a key role in the Southeast Asian industrial landscape, retain its competitiveness and become an example for others.

5 Hon, C., & et al. (2021, August 31). A Decarbonization Roadmap for Singapore and Its Energy Policy Implications. Retrieved from MDPI: https://www.mdpi.com/1996-1073/14/20/6455
6 JTC Corporation. (2022, September 9). Find Land for Long Term Development Jurong Island. Retrieved from JTC: https://www.jtc.gov.sg/find-land/land-for-long-term-development/jurong-island
7 Singapore Economic Development Board. (2021, November). Sustainable Jurong Island Publication . Retrieved from Singapore Economic Development Board Web site: https://www.edb.gov.sg/en/business-insights/market-and-industry-reports/sustainable-jurong-island.html

1.2 JURONG ISLAND – SUSTAINABILITY IN ACTION

Sustainable Jurong Island: Targets and aspirations

As Singapore aims to deliver its national carbon commitments, it has outlined initial plans to decarbonise Jurong Island. The Sustainable Jurong Island Plan will drive decarbonisation through improved circularity and higher carbon capture.[8] As government bodies implement new carbon regulatory policies, industry players are forming joint research efforts and piloting sustainability-themed technologies to futureproof their operations.

The current Sustainable Jurong Island Plan is centred around two key sustainability drivers: increased output of sustainable products and higher carbon abatement via renewable energy (RE) and carbon capture, storage and utilisation (CCUS).

Companies such as Neste, Shell and Evonik have already been deploying decarbonisation initiatives within Jurong Island; for example, in 2018 Neste made its biggest ever investment of €1.5 billion to expand renewable fuels production at its facilities on Jurong Island.[9] As part of Shell's goals to be carbon neutral by 2050, Shell Jurong Island production sites are focusing investments to deliver improved efficiencies for steam, water consumption and energy consumption under the 10-year plan it unveiled in 2021. Meanwhile, Evonik has adopted the use of an integrated digital platform to optimise production efficiency and material flows at its methionine production plant on Jurong Island.[10] The company is working towards their aim to reduce group Scope 1 and Scope 2 emissions by 25% and Scope 3 emissions by 11% by 2030.[11]

Foreseeable challenges to sustainable Jurong Island

Challenges to the implementation of sustainable initiatives vary depending on the project specifics. Due to the nature of Jurong Island's industries and Singapore's general characteristics, key challenges arise in three areas:

- **Space constraint** – Jurong Island, with a land area of 3,000 ha, already houses more than 100 companies and operating facilities. Projects will need to be selected carefully to ensure optimal use of its remaining land. Having said that, the clustering of industries also brings about opportunities for circularity and centralised hydrogen and CCUS services.
- **Inherent carbon-intensive processes of the industries** – Many of the processes and feedstocks used in the E&C sector are inherently carbon-intensive. Hard-to-abate sectors such as those on Jurong Island would potentially require CCS solutions for effective decarbonisation.
- **Existing energy mix that is predominantly natural gas** – 95% of Singapore's electricity is generated from natural gas, with the remaining 3% and 2% supplied by renewable sources (solar and waste-to-energy [WTE]) and carbon-based fuel (coal and petroleum products) respectively.[12] While lower in emission intensity in comparison to other carbon-based fuels, emissions from natural gas remain significant.

8 Singapore Economic Development Board. (2021, November). Sustainable Jurong Island Publication. Retrieved from Singapore Economic Development Board Web site: https://www.edb.gov.sg/en/business-insights/market-and-industry-reports/sustainable-jurong-island.html

9 Neste Corporation. (n.d.). Neste Singapore Expansion Project Information Page. Retrieved from Neste Singapore Web Site: https://www.neste.sg/neste-in-singapore-and-asia-pacific/journeytozerostories/singapore-expansion-project

10 Evonik. (2020, November 18). Press Release, Evonik Wins EuroCham's First Sustainability Award. Retrieved from Evonik Web Site: https://seaanz.evonik.com/en/evonik-wins-eurochams-first-sustainability-award-148088.html

11 Accenture conducted interview with Evonik, August 2022

12 Energy Market Authority Singapore. (2021). Singapore Energy Statistics, Chapter 02 Energy Transformation. Retrieved from Energy Market Authority Singapore's Web Site: https://www.ema.gov.sg/singapore-energy-statistics/Ch02/index2#:~:text=Fuel%20Mix%20for%20Electricity%20Generation,and%20Fuel%20Oil%20(0.6%25)

Despite its challenges, there remains a viable pathway for Singapore and Jurong Island to achieve net zero emissions. Several decarbonisation solutions have appeared in the past decade and are being explored as potential responses by industry for a sustainable future. These solutions, and how they can be applied for Singapore and Jurong Island, will be discussed in the next section.

Figure 2: Sustainable Jurong Island Targets and Aspirations.

By 2030	By 2050
Increase sustainable products output by 1.5 times from 2019 levels	Increase sustainable products output by 4 times from 2019 levels
Improve energy efficiency in refineries and crackers to be in the top quartile globally	Achieve more than 6 million tonnes of annual carbon abatement from low-carbon solutions
Achieve at least 2 million tonnes of carbon capture	

Source: Economic Development Board, 2021, Sustainable Jurong Island.

Figure 3: Key initiatives on Jurong Island.

Sustainable products	Sustainable production
High-value speciality chemicals and materials	Capturing carbon
Bio-based fuels and chemicals	Increasing renewables deployment on Jurong Island
Pyrolysis oil from plastics recycling	Improving industrial energy efficiency
Carbonated aggregates	Recycling chemicals and utilities

Source: Economic Development Board, 2021, Sustainable Jurong Island.

2. JURONG ISLAND INDUSTRIAL CLUSTER AND THE CRITICAL ENABLERS FOR A SUCCESSFUL LOW-CARBON TRANSITION

2.1 KEY CONSIDERATIONS

In our view, Jurong Island has established a good foundation that has worked well to support its impressive development for the past two decades. However, to maintain Jurong Island's position as a leading petrochemicals and chemicals hub into future decades, which contributes positively to Singapore and its people, significant challenges around sustainable transformation would need to be carefully navigated and decisive action taken to achieve net zero.

On the path to net zero, we see three key solution areas that should be given priority by stakeholders on Jurong Island:
1. Maximise efficiency in all aspects and invest in the digital infrastructure and storage that will scale the benefits of efficiency technologies that reduce waste, improve system efficiency and optimise demand.
2. Maximise the use of renewable energy through rooftop solar, green electricity imports and invest in the supporting grid and storage infrastructure.
3. Establishment of a CCS hub on Jurong Island.

This section explores key topics which are crucial for Jurong Island's low-carbon transition, namely:

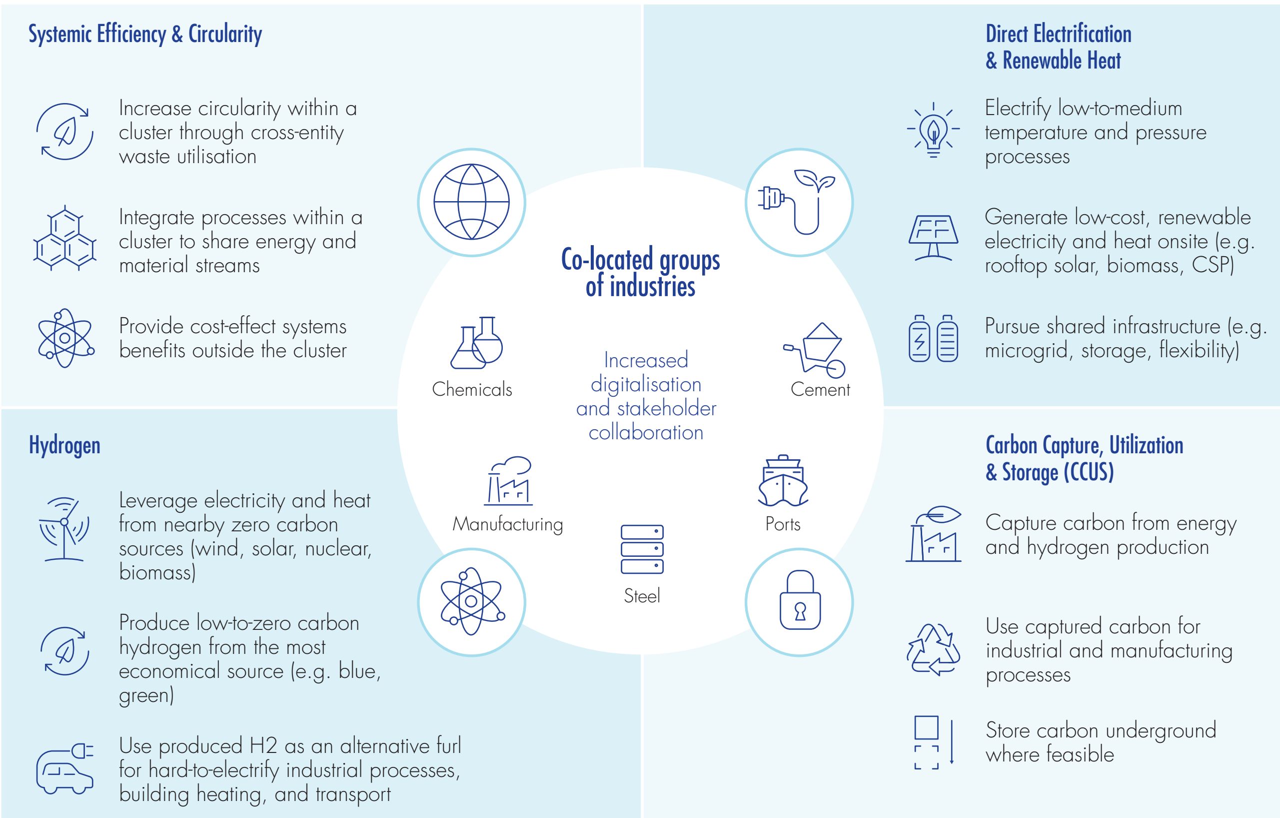
- **Integrated net zero solutions for Jurong Island** – Taking on an integrated approach allows parties on Jurong Island to achieve results greater than the sum of its parts. This approach is widely applicable in four solution areas, namely: systemic efficiency and circularity, direct electrification and renewable heat, CCUS and hydrogen.
- **Leveraging Singapore's strengths for net zero transition** – Singapore has made careful choices to set up Jurong Island for its success today. Many of these characteristics remain highly relevant in the decarbonisation discussion and tapping on these strengths can help organisations accelerate their net zero goals.

2.2 INTEGRATED NET ZERO SOLUTIONS FOR JURONG ISLAND

In identifying net zero solutions for Jurong Island, it is important to adopt a broader view that considers potential synergies for the entire cluster. This approach is well-aligned with Jurong Island's strategy emphasising synergistic opportunities for all stakeholders as seen in its network of shared essential services and utilities corridors.

To achieve the island's decarbonisation efforts, there is a menu of abatement opportunities that calls for a holistic approach towards optimising emissions solutions and creating an integrated industrial ecosystem. The World Economic Forum (WEF), in collaboration with Accenture, has proposed four key solution areas under its initiative "Transitioning Industrial Clusters towards Net Zero" Technology framework (see Figure 4) as also detailed in a WEF White Paper on Industrial Decarbonisation[13]. Accenture formulated the recommendations in this paper.

Figure 4: Net zero solutions area for industrial cluster.



Source: World Economic Forum and Accenture, 2022, Transitioning Industrial Clusters towards Net Zero: National Policy Enablement for Industrial Decarbonization.

Table 1 provides a summary of the net zero solutions and the decarbonisation opportunity it presents to Jurong Island.

13 *The World Economic Forum with support from Accenture developed this framework for the Net Zero Industrial Cluster Initiative. Retrieved from World Economic Forum White Papers Web Site: https://www.weforum.org/whitepapers/transitioning-industrial-clusters-towards-net-zero-national-policy-enablement-for-industrial-decarbonization/*

As previously mentioned, Jurong Island is already a model for integrated processes and co-products. There is an additional opportunity to convert Jurong Island's industrial process waste into feedstock for energy recovery or material input for manufacturing of sustainable products.

For CCUS, the proximity of industries and a well-integrated existing pipeline infrastructure present a foothold for organisations to accelerate carbon capture solutions.

While direct electrification technologies such as electric boilers and electric motor conversions are less applicable for the energy sector due to its higher operating temperatures, current electricity demand could be met with renewable generation. Hydrogen, though it is a highly promising decarbonisation solution, is less practical for Jurong Island since it lacks the availability of land and renewable energy sources to scale the solution and make it commercially viable.

The following sections provide a more detailed analysis of each net zero solution. The analysis explores each solution's unique applicability to Jurong Island and includes success stories from other industrial clusters including Humber, United Kingdom and Kalundborg, Denmark.

Table 1: Summary evaluation net zero industrial cluster solution areas (preliminary analysis by Accenture)

Solution area	Characteristics	Typical challenges	Opportunity for Jurong Island	Implementation time horizon
Systemic efficiency and circularity	Overall higher resource efficiency while introducing new revenue streams for companies.	Difficulty in matching supply and demand; process volumes will need to be modified to meet demand	**High** – Clustering of similar industries provide a steady supply of material for energy recovery and upcycling.	Short term
Direct electrification and renewable heat	Electrification enables industries to move away from carbon fuels and use renewable energy sources.	Electrification requires complex changes in technology and is limited to low- and medium- temperature processes.	**Medium** – E&C industries operate at higher temperatures which limit opportunities to introduce electrification. However, gas-fired electricity consumption makes up a significant portion of emissions and renewables can replace some of this generation.	Short - medium term
Carbon capture, utilization, and storage (CCUS)	Carbon capture presents a more straightforward solution for hard-to-abate heavy industries.	Cost for capturing carbon remains the highest barrier to CCUS adoption.	**High** – Proximity of industries helps lower logistics cost and existing pipeline infrastructures can be modified to enable CCUS.	Medium - long term
Hydrogen	Energy storage using hydrogen solves the intermittency of renewable energy sources.	Cheaper, abundant sources of renewable energy and water are integral to scaling green hydrogen.	**Low** – Singapore's land and water scarcity, and lack of renewable energy sources make it dependent on the import of green hydrogen.	Medium - long term

2.2.1 Systemic efficiency and circularity

Problem statement / opportunity for Jurong Island:

Singapore is an island city-state with limited arable land and freshwater sources. Jurong Island uses up to 40 million gallons of water daily, or 10% of Singapore's total water consumption, about 50% of which is imported.[14] Additionally, Singapore's sole waste landfill is expected to reach capacity by 2035.[15] As such, it is imperative for all stakeholders to make sure that natural resources are used efficiently to safeguard continuity of business operations on the island. One of the key focus areas for achieving resilience and continuity is improving waste and water circularity.

A key component to Jurong Island's net zero strategy is to improve industrial energy efficiency. As part of the Sustainable Jurong Island Plan, the cluster aims to ensure all refineries on the island are in the top global quartile in terms of energy efficiency. [16]

Proposed solution

Circularity and waste valorisation that entail combining or processing waste streams into useful products should be a focus area. On Jurong Island, this would include the direct use of captured flue gas to produce carbonated aggregates for land reclamation and road construction activities. To enable increased circularity, process integration across clusters including water recovery and recycling, treatment of chemical waste will require cluster symbiosis, the building of infrastructure for the recovery and shared utilisation of waste energy, water and materials streams that can reduce process input requirements and associated GHG emissions. Jurong Island's shared utilities infrastructure provides a good platform to enable further sharing of resources among companies.

Utilisation of waste heat can be implemented within individual facilities, supplying local heat demand, or across the industrial site to nearby plants via transfer of waste heat to other industries who could utilise the waste heat. Additionally, waste heat to power solutions could also be explored. On Jurong Island, companies can support similar initiatives by implementing flare gas recovery projects at existing facilities. In a separate project led by the Economic Development Board (EDB) and Singapore LNG (SLNG), the organisations' technologies were explored to harness cold energy released during LNG regasification and redirect it to local data centres for cooling purposes.[17]

Further, Singapore could consider utilising sustainable energy feedstock supplied from neighbouring major agricultural countries like Indonesia and Malaysia. In the long term, it can consider bringing in materials from agricultural and forestry residues or extend its waste-to-energy (WTE) capabilities to its neighbours which could help enable the manufacture of circular products.

The deployment of digital infrastructure to support the sharing of resources is a key enabler. A shared digital platform with a digital twin of the island's shared utilities/service corridors could allow various players on Jurong Island's manufacturing value chain to optimise energy use and production. Real-time data could allow players to access process by-products, steam or process heat and match supply to demand more precisely, opening opportunities for optimisation of the entire energy-chemicals industrial complex on Jurong Island in terms of production and energy use. The platform could provide accountability and transparency to users while helping suppliers reduce underutilisation and unlock hidden revenue in previously 'unwanted' process by-products.

Typical benefit

Enhanced integration between production facilities upstream and those downstream could scale-up efficiency gains and drive shared value across the cluster and the surrounding areas. Through symbiotic relationships with the support of digital technology, companies on Jurong Island could integrate their different production processes to realise optimisation and improve efficiency in the use of energy, water and materials.

Further, cross-company and cross-industry collaboration to utilise waste or by-products generated by plants upstream of a chemical value chain introduces ways to cut waste disposal costs and generate new revenue streams. This could effectively create additional new circular economies within Jurong Island itself and meet increasing demand for sustainable or circular chemicals in certain markets.

14 *Public Utilities Board Singapore. (2018, January). Our Water Our Future, Publication by PUB. Retrieved from https://www.pub.gov.sg/Documents/PUBOurWaterOurFuture.pdf*

15 *National Environment Agency Singapore (NEA). (2020). Envision Lite June-July 2020 publication by NEA. Retrieved from National Environment Agency Singapore Web Site: https://www.nea.gov.sg/corporate-functions/resources/publications/books-journals-and-magazines/envision-lite/june-july-2020/semakau-landfill-20th-anniversary#:~:text=Semakau%20Landfill's%20lifespan%20is%20getting,be%20fully%20filled%20by%202035.*

16 *Singapore Economic Development Board. (2021, November). Sustainable Jurong Island Publication . Retrieved from Singapore Economic Development Board Web Site: https://www.edb.gov.sg/en/business-insights/market-and-industry-reports/sustainable-jurong-island.html*

17 *Singapore LNG. (2019, October 21). Singapore LNG Press Release: NUS, Keppel And SLNG Join Forces To Develop New Energy-Efficient Cooling Technology For Data Centres. Retrieved from Singapore LNG Web Site: https://www.slng.com.sg/nus-keppel-and-slng-join-forces-develop-new-energy-efficient-cooling-technology-data-centres#:~:text=Cold%20energy%20generated%20from%20LNG,from%20the%20Singapore%20LNG%20Terminal.*

Challenges

The key to Jurong Island achieving island-wide circularity is close collaboration among players from different industry sectors. However, different interests and incentives among individual partners may impede the speed of joint decision-making process.

A multi-stakeholder scenario also presents difficulty when allocating capital cost due to differing financial positions. Adding to the complexity, companies on Jurong Island are mostly subsidiaries of multinationals which have limited ability to independently make major investment decisions.

There could also be technical challenges when integrating processes across the industrial cluster. Individual players may need to change production volume or production process to meet the volume obligations or desired output from receiving partners. This may disincentivise partners as it introduces process rigidity into their operations.

While Singapore could consider the use of bio-based or agricultural waste feedstock, there could be challenges in scaling up for wide adoption. Due to the large scale of the industry at Jurong Island, it could be necessary to import waste feedstock to meet the industries' production capacity. Availability and reliability of feedstock through imports from other markets is a factor that needs to be considered carefully when assessing the feasibility of scaling this solution.

Actions

Industry players could seek to formalise collaborations within the Jurong Island Industrial Cluster by establishing a clear pathway towards increased integration between facilities supported by a governance structure to facilitate the sharing of data and to find ways for waste streams to be valorised. When creating an island-wide consortium, partners need to agree on targets that align to individual interests. It is also critical to appoint decision-making groups with clear responsibilities.

The Singapore government could play an important role by leading and encouraging public-private partnerships for systemic efficiency projects on Jurong Island. The public-private partnership model has worked extremely well for Singapore in other sectors. The government could extend this to Jurong Island to reduce the capital outlay and de-risk investment.

Additionally, considering the business case for utilisation of waste or by-product stream and its potential implication on individual companies' processes and operations, commercial agreements on capacity for production and demand of waste streams should be put in place during the initial planning phase. Where possible, flexible arrangements should be developed to accommodate for demand variability and acceptable specifications of the waste or by-product stream.

Case study [18]

In Kalundborg, Denmark, partners from 25 different resource streams collaborated to create a close-loop system of material, water, and energy streams. From a holistic viewpoint, participants were able to minimise leakage and waste. In reducing resource consumption and waste disposal costs, players were able to effectively lower financial and environmental costs.

The cluster-wide initiative also promoted business model innovation. An example is Ørsted, a Danish power company that ran a biomass-fired cogeneration plant within the Kalundborg cluster. Instead of producing steam as a by-product of electricity generation, it has pivoted to supplying high-temperature steam to surrounding partners and has made it the primary product and revenue source of its operation.

18 *Accenture. (2021). Industrial clusters, Working together to achieve net zero. Retrieved from Accenture Web Site: https://www.accenture.com/_acnmedia/PDF-147/Accenture-WEF-Industrial-Clusters.pdf*

A key success factor for the Kalundborg industrial model is a shared sense of value and how benefits to the local environment translate to benefits for all players. This has led to successful public-private partnerships which started as far back as 1961. Applying this to the Jurong Island context, Singapore can continue to build on its close collaboration with international companies on Jurong Island to introduce projects that benefit stakeholders island-wide.

It is estimated that the Kalundborg project annually achieved €24 million in bottom line savings, reduced freshwater consumption by 3.6 million m^3 and recycled over 87,000 tonnes of materials.

2.2.2 Direct electrification and renewable heat

Problem statement / opportunity for Jurong Island

Jurong Island is composed of heavy industry with high-temperature processes that are difficult to electrify. Additionally, electricity generation, a large part of the energy mix is virtually all gas-fired.

Another challenge is the space limitations for deployment of large-scale renewable electricity generation capacity in Singapore such as utility-scale solar PV. A 2020 study showed that the total usable space for solar PV panels in Singapore amounted to just under 37 sq. km, with 62% of all panels on buildings, roof space, and facades with the balance shared between temporary land-based installations, floating installations on reservoirs and unused near-shore sea areas, and panels installed above land, canals and roads.[19]

Proposed solution

Clean electrification for industry involves firstly, direct electrification of industrial process heating and renewable heat use and secondly, the substitution of electricity from natural gas combustion with electricity generated from renewable sources. The use of large-scale heating coils and easily chargeable battery systems are some of the ways the chemicals industry can achieve direct electrification. Taking an integrated view, industrial cluster electrification enablers such as microgrids, shared renewable generation and storage, and demand optimisation—further powered by digital, data and visualisation technologies—will further drive the commercial viability of direct electrification technologies over other low-carbon solutions such as natural gas with CCUS.

Local solar PV generation could be maximised in Singapore and on Jurong Island by employing innovative use of available space such as rooftop solar, vertical installation (serving as facades of high- and medium-rise buildings), integration with other assets such as water reservoirs where feasible. This would enhance the energy mix with higher renewable electricity generation and overcome the constraints on land area. In support of higher renewable capacity, energy storage systems, with a focus on fast-response systems, and the combination of electrical and thermal storage such as in district cooling plants could provide mitigation for the impact of variable solar generation.

The cross-border import of low-carbon electricity from generation assets in the region could be a potential gamechanger for reducing the emissions intensity of Singapore's electricity supply. In 2022, Keppel and Electricite du Laos signed as power purchase agreement (PPA), pioneering cross-border power trade of up to 100 megawatts of (MW) renewable energy into Singapore.[20]

Additionally, waste-to-energy facilities in Singapore are extensively converting waste into energy, and Jurong Island could advance the effort by bringing in players using other forms of biofuel such as biomass and syngas to provide both electricity and steam.

With the solar resource available, concentrated solar heat could be used as a carbon-free, ultra-high temperature heat that serves as an alternative to traditional fossil fuel burning for industrial process heat. However, land scarcity in Singapore may pose challenges to implement this solution.

19 Consortium led by the Solar Energy Research Institute of Singapore. (2020). Update of the Solar Photovoltaic (PV) Roadmap for Singapore. Singapore: Solar Energy Research Institute of Singapore, National University of Singapore.

20 Ng, H. S. (2022, June 23). Singapore news, Singapore begins importing renewable energy from Laos through Thailand and Malaysia. Retrieved from Channel News Asia Web Site: https://www.channelnewsasia.com/singapore/singapore-import-hydropower-renewable-energy-laos-through-thailand-malaysia-2766251

Typical benefit

With carbon pricing and falling costs of renewables, electrification provides a lower-cost, technologically mature and more cost-efficient solution for decarbonisation. The technology is well-proven, cost-competitive with conventionally generated electricity and could be deployed in a relatively short time frame which could help accelerate decarbonisation efforts.

The electrification of processes generally leads to lower operating temperatures, which translates into longer continuous plant operation instead of annual technical shutdowns. This could potentially improve the plant productivity and up time.

Challenges

Constraints on available land for development could hinder the scaling of local renewable generation such as solar PV, requiring both government and industry to consider innovative use of available space to maximise Singapore's solar PV potential.

The transition to electric technology requires significant financial outlay and may require early retirement of long-life, carbon-based assets.

Moreover, many electrifiable processes provide limited productivity gains, which are the main drivers of technology adoption. The electrification of industrial processes also introduces complexity into operations as upskilling of operators and secondary process changes are required to accommodate the new technology.

Actions

Currently, Singapore's carbon pricing policy provides clear price signals to reduce investment uncertainty on direct electrification and use of renewable electricity. However, to reduce the relative cost of renewable electricity over carbon-based fuel for industrial processes, the government could continue to enhance policies that would incentivise the adoption of renewable generation.

The reliability of electricity supply and safeguarding the grid are important issues to address when there are higher levels of renewable generation. There is a need to ensure that "non-solar" assets can handle any high-variability situations. In this respect, Singapore could consider a capacity-based market system that is adequately priced to incentivise substantial stand-by reserves.

It is important for the industry to take the first steps in retrofitting electrification equipment and the use of hybrid technologies. This would provide a gradual transition for Jurong Island players and allow them to minimise fuel costs by having the option to switch between different energy vectors, whether electricity or fossil fuel.

Case study

Japan saw exponential growth in its solar PV installed capacity over the past few years, from about 6 GW in 2012 to 74 GW in 2021.[21] Despite land and solar resource scarcity, the island country rapidly increased its installed solar PV capacity and looks to be on track to achieve 150 GW of installed capacity by 2030 or more should existing policies continue or are enhanced.[22] This growth is largely driven by Japan's feed-in tariff policy and supported by technological advancements such as floating solar and bifacial solar PV modules, which help improve the financial feasibility of large-scale solar PV in Japan.

In China's Suzhou Industrial Park, a distributed clean energy microgrid Distributed Clean Energy Microgrid was implemented where it supplies up to 10% of the industrial area's energy consumption. The project includes two clean energy centers, 10 microgrid systems, 100 distributed energy systems including 25MW photovoltaic generation, 50MW wind generation, 22MW storage capacity and 1,000 electric vehicles, forming a clean energy system that is over 1 GWh.[23]

2.2.3 Carbon capture, utilisation and storage (CCUS)

Problem statement / opportunity for Jurong Island

CCUS is an integral pillar to Jurong Island's strategy towards achieving net zero. As outlined in the Sustainable Jurong Island plan, the island aims to capture two million tonnes in captured carbon dioxide by 2030.

Solution

CCUS solutions that utilise storage of CO2 beneath the ocean floor provide promising opportunities for proliferation of CCUS technology on Jurong Island. CCUS would be key to decarbonising unavoidable carbon emissions; for example, residual carbon emissions from industrial processes and product use that could not be avoided, even with other decarbonisation methods in place, such as increasing systemic efficiency and circularity and clean electrification.

A network of dedicated pipelines that connect and transport industry carbon emissions across Jurong Island to CCUS facilities could be developed in the existing Jurong Island services corridor for utilities. The potential of repurposing of existing gas pipelines for CO2 should also be investigated.

Apart from long-term storage of the CO2, industry players should collaborate on efforts to explore utilisation of captured CO2 for energy processes. There are various ways in which captured CO2 gas could be used beneficially. One example: captured carbon is highly viable as a working fluid in CO2-based steam cycles. When pressurized into its supercritical state, it can transfer heat more readily and require less energy for compression. Both these properties help achieve high power cycle efficiency.[24] The captured CO2 could also be used to extract geothermal energy by injecting it into geothermal reservoirs where it is heated and subsequently extracted to drive a turbine for electricity production.[25] Another well-developed use of CO2 includes enhanced oil recovery (EOR), where it is injected into an existing oil or gas field to increase recovery of oil and natural gas. The gas displaces the oil and is permanently stored in minute pore spaces. In the case of Jurong Island, government-related bodies like EDB and A*STAR are piloting the production of carbonated aggregates using captured CO2. These aggregates can then be used for land reclamation, road construction and coastal adaptation for climate change.

Typical benefit

CCUS technologies enables direct reduction of carbon emissions from industrial activities. When deployed appropriately, CCUS offer a highly viable pathway to decarbonise hard-to-abate sectors such as the energy and chemicals (E&C) industry on Jurong Island where there are inherent challenges with abating carbon emissions associated with industrial processes and product use during manufacturing.

21 *Klein, C. (2022, May 23). Generation capacity of Solar Japan 2012-2021. Retrieved from Statista: https://www.statista.com/statistics/814161/japan-generating-capacity-solar-energy/#:~:text=In%202021%2C%20the%20generation%20capacity,6.6%20thousand%20megawatt%20in%202012*

22 *Rai-Roche, S. (2022, June 10). PV Tech Project News, Japan set to reach 150GW+ of installed solar by 2030, rises to 180GW when more ambitious scenario pursued. Retrieved from PV Tech Web Site: https://www.pv-tech.org/japan-set-to-reach-150gw-of-installed-solar-by-2030-rises-to-180gw-when-more-ambitious-scenario-pursued/*

23 *Accenture. (2021). Industrial clusters, Working together to acheive net zero. Retrieved from Accenture Web Site: https://www.accenture.com/_acnmedia/PDF-147/Accenture-WEF-Industrial-Clusters.pdf*

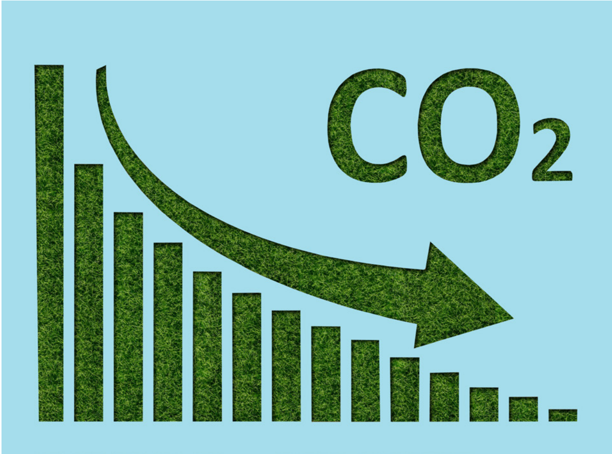
24 *Patel, S. (2019, April 1). POWER Magazine article, April 2019, What Are Supercritical CO2 Power Cycles? Retrieved from POWER Magazine Web Site: https://www.powermag.com/what-are-supercritical-co2-power-cycles/*

25 *Richter, A. (2021, May 19). Think Geoenergy, Technology News. Retrieved from Think Geoenergy Web Site: https://www.thinkgeoenergy.com/cpg-systems-storing-co2-for-geothermal-energy-production/#:~:text=CO2%20plume%20geothermal%20CPG%20technology,in%20motion%20to%20produce%20electricity.*

While the technology is presently at a nascent stage, CCUS could also enhance industry circularity by the utilisation of captured CO2 to produce valuable products.

Challenges

One of the biggest barriers to CCUS adoption is the cost to capture CO2. The cost may vary depending on the industry and the average capture cost for the petroleum refining industry is more than $100 per tonne.[26] For comparison, the current price on carbon imposed by the government on facilities that emit beyond 250,000 tCO2e per year is S$5/tonne. The government plans to increase this over the years to reach S$50-S$-$80/tonne which could improve the financial viability of CCUS.[27]



As the technology is in its early stages, investors are wary of the financial risks involved. Additionally, organisations will need to mitigate the risk of stranded assets with other ongoing projects.

On the technical aspects, the transport of condensed carbon dioxide would require specialised pipelines to maintain pressure and keep it in the liquid state. Existing oil and gas pipelines on Jurong Island will need to be renovated to be usable for CO2 transportation and calls for investment in such foundational infrastructure to enable CCUS.

Singapore currently lacks a suitable geological site for carbon storage, hence collaboration with neighbouring countries such as Indonesia and Malaysia becomes important for access to suitable carbon storage sites in the region. Also, any reservoir that is identified should ideally be closely located to Jurong Island as complexity and cost will increase as the distance increases between generation source and storage location.

Action

Considering the challenges for CCUS, the Singapore government's support of CCUS development by implementing policies that drive demand for carbon sequestration is important. For example, Singapore's Carbon Pricing Act is setting the marginal cost of abatement for companies on Jurong Island. The carbon tax policy should be continuously enhanced so that companies continue to invest and adopt CCUS technology.

Jurong Island industrial cluster is an ideal location for implementing CCUS as costs across the value chain can be driven down due to scale. Since multiple sources of carbon dioxide emitters are located nearby, emissions can be captured via a single capture, transport and storage system. Not only are transportation and storage costs reduced, but the shared facility also allows companies to reduce investment risk.

Case study [28]

UK's Zero Carbon Humber is a coalition of 12 entities collaborating on joint CCS infrastructure projects. The project will capture CO2 at scale from industrial sites via pipelines, which is then transported to compressor stations where it is readied for permanent storage.

The project is complemented by the Northern Endurance partnership which focuses on the development of offshore transport and storage infrastructure for carbon dioxide emissions in the North Sea. The UK government's "levelling up" agenda which aims to attract industry growth by deploying low-carbon technology to industrial regions has been critical to Humber's CCS success. The effort is further augmented by implementing low-carbon technology based on the geological and geographical advantages of each region.

26 Accenture. (2021). Industrial clusters, Working together to acheive net zero. Retrieved from Accenture Web Site: https://www.accenture.com/_acnmedia/PDF-147/Accenture-WEF-Industrial-Clusters.pdf

27 CNA. (2022). Budget 2022: Singapore to progressively raise carbon tax to reach net-zero target 'by or around mid-century'. Retrieved from https://www.channelnewsasia.com/singapore/carbon-tax-net-zero-target-emissions-singapore-green-plan-2506496#:~:text=SINGAPORE%3A%20Singapore%27s%20carbon%20tax%20will,18)%20in%20his%20Budget%20speech

28 Accenture. (2021). Industrial clusters, Working together to acheive net zero. Retrieved from Accenture Web Site: https://www.accenture.com/_acnmedia/PDF-147/Accenture-WEF-Industrial-Clusters.pdf

Zero Carbon Humber is aiming to capture up to 44 MtCO2 by 2040, accounting for approximately 30% of UK's total committed carbon dioxide capture.

The HyNet North West project is another UK industrial decarbonisation project featuring the use of CCS to decarbonise world-class energy intensive industries in North West England and North Wales, including chemicals, glass, ceramics, oil refining, food, paper and automotive.[29] The HyNet North West CCS project would see the transportation of CO2 to depleted gas reservoirs in Liverpool Bay for long term storage, the potential is abatement of 10 million tonnes of per year by 2030, equivalent to 100% of the UK government's 2030 target for CCS.[30]

As of February 2022, HyNet North West has signed 19 Memorandum of Understanding (MOU) with companies for the capture of carbon emissions.[31]

2.2.4 Clean energy focus – Clean Hydrogen

Challenges due to resources scarcity in Singapore

Clean hydrogen, while holding substantial promise for decarbonisation of hard-to-abate industrial activities, is less appropriate for Singapore at the present time mainly due to challenges with lack of abundant and cheap renewable electricity as well as access to water to support production of green hydrogen.

The lack of accepted certification standards for hydrogen is also a significant hurdle. This makes it difficult for producers to substantiate their green or blue credentials claim for hydrogen supplied,[32] while users/buyers may have doubts on the sustainability of hydrogen procured, the use of blockchain and digital technology for traceability across the hydrogen supply value chain could be valuable towards solving the challenges around certification and trust.

In addition, there are other significant techno-commercial challenges with clean hydrogen solutions. The technology is still in its nascent stage for scaled-up deployment and integration with existing industrial infrastructure and manufacturing processes. As projects are still being developed and built, there is at present a lack of proven application in large-scale efforts. Relatedly, the cost of clean hydrogen solutions is less competitive compared to other decarbonisation technologies such as electrification with renewable generation sources.

Longer-term play for Singapore: Regional hydrogen hub

Despite the relative lack of opportunity to produce green hydrogen, we believe Singapore is well-placed to position itself as a regional clean hydrogen hub in the longer term when the regional trade market develops, especially in East Asia.

To support this area of new growth, there may be a need to repurpose currently existing bulk liquids, and LNG storage facilities and terminals, building on its established position as a regional logistics and transportation hub. Taking the development in Europe as a reference, the government is heavily incentivising the development of the hydrogen economy in meeting their industrial decarbonisation goals.

Case study [33]

The Port of Rotterdam is undergoing a transformation towards into an international hydrogen hub with key projects planned from now until 2030. The Rotterdam Port Authority is collaborating with Gasunie, a Dutch natural gas network operator, on a hydrogen backbone public infrastructure that connects production and import tankers in the port area.

This hydrogen backbone, which is expected to begin operations as early as 2023, would be connected to Gasunie's national infrastructure throughout the Netherlands and to corridors leading to industrial areas in Chemelot in Limburg, and North Rhine-Westphalia, enabling the transformation of the Port of Rotterdam into an international hydrogen hub.[34]

29 HyNet North West. (n.d.). About Page. Retrieved from HyNet North West Project Web Site: https://hynet.co.uk/about/
30 HyNet North West. (n.d.). Carbon Capture Factsheet. Retrieved from HyNet North West Project Web Site: https://hynet.co.uk/wp-content/uploads/2021/06/HyNet-Factsheet-CCS.pdf
31 Eni UK. (2022, February 9). ENI UK: 19 AGREEMENTS SIGNED FOR CARBON, CAPTURE & STORAGE WITHIN HYNET. Retrieved from HyNet North West Project Web Site: https://hynet.co.uk/eni-uk-achieves-a-major-breakthrough-for-uks-decarbonisation-process-with-19-memorandums-of-understanding-mous-signed-for-carbon-capture-storage-within-the-hynet-north-west-project/
32 Hydrogen is categorised into various categories depending on its source. A breakdown of the categories, better known as the colours of hydrogen, is as follows. Green hydrogen: Uses renewable sources like wind and solar. Blue hydrogen: Produced from low-intensity processes e.g., natural gas where CO2 emissions are captured and stored.
33 Port of Rotterdam. (n.d.). Hydrogen in Rotterdam. Retrieved from Port of Rotterdam Web Site: https://www.portofrotterdam.com/en/port-future/energy-transition/ongoing-projects/hydrogen-rotterdam
34 Port of Rotterdam. (n.d.). Hydrogen Economy in Rotterdam. Retrieved from Port of Rotterdam Web Site: https://www.portofrotterdam.com/sites/default/files/2021-06/hydrogen-economy-in-rotterdam-handout.pdf

In developing the planned hydrogen network, Gasunie has estimated that 85% of the hydrogen network would consist of recycled natural gas pipelines, contributing significant cost savings for the project. In comparison to the option of laying completely new pipelines, the repurposing of natural gas pipelines is estimated to bring cost savings of about 25%.[35]

2.3 LEVERAGING SINGAPORE'S STRENGTHS FOR SUCCESSFUL NET ZERO TRANSITION

Singapore has continued to transform itself to become a leader in high value, specialised industries. A large part of its current success can be attributed to several key factors, including a mature technology landscape, a wide pool of talent, access to financing, and a robust transport network. Even as Jurong Island moves towards net zero, these factors continue to play a significant role in ensuring its future success.

Mature technology landscape

Singapore hosts many of the research and development (R&D) centres for the world's leading companies including the likes of Solvay, etc. In addition, there is strong support from government through its various grants into sustainability-based research conducted in local universities like National University of Singapore (NUS) and Nanyang Technological University (NTU). As such, it has early access to the latest in net zero technologies.

The critical pathway to carbon abatement relies on a host of digital capabilities to provide visibility and measurement of key emissions metrics, besides enabling better control over industry parameters which improve resource efficiency. Singapore is an early adopter of key digital and communications technologies like artificial intelligence (AI), internet of things (IoT) devices and 5G network. These technologies in turn enable net zero solutions including digital twins and smart grid solutions.

Building on these characteristics, the government has positioned Jurong Island as the leading choice for companies as a testbed for sustainability-focused projects, having provided a supporting ecosystem which maximises potential for success.

Highly skilled and specialised workforce in the areas of science, technology, engineering and math (STEM)

One of the key factors to Singapore's modern success is its continued ability to attract the brightest talents in the world globally to bolster its workforce. The country ranks number 2 on INSEAD's Global Talent Competitiveness Index, just behind Switzerland and ahead of the United States of America.[36] Singapore boasts a large pool of STEM talent, comprising both local and international residents. In addition, the government continues to invest in its people, providing various educational grants to upskill and retrain its workforce to serve new industries and meet new global demands for specialties in sustainability technologies.

As such, companies are attracted to invest in Singapore as it provides the opportunity to tap into its vast talent pool of specialised workforce. This is especially important when investing into nascent technologies where deep expertise may be difficult to acquire and retain due to its high demand.

Access to green financing

Singapore is Southeast Asia's financial hub with total assets under management reaching S$4.7 trillion in 2020.[37] A strong banking sector and progressive legal and regulatory systems make Singapore an ideal choice of destination for high net-worth individuals and family offices. This feature is further augmented by Singapore's Green Bond framework, which provides a robust governance structure for the investment and issuance of green funds. Its strong financial structure inspires confidence in both investors and investees to commit to large-scale decarbonisation initiatives.[38]

35 Gasunie. (2021, June 30). Press release, Gasunie decision on hydrogen infrastructure is milestone for energy transition. Retrieved from Gasunie Web Site: https://www.gasunie.nl/en/news/gasunie-decision-on-hydrogen-infrastructure-is-milestone-for-energy-transition

36 INSEAD. (2021, October 19). INSEAD Newsroom, 2021 Global Talent Competitiveness Index: Fostering green and digital jobs and skills crucial for talent competitiveness in times of COVID-19. Retrieved from INSEAD Web Site: https://www.insead.edu/newsroom/2021-global-talent-competitiveness-index-fostering-green-and-digital-jobs-and-skills-crucial-for-talent-competitiveness-in-times-of-covid-19

37 Koh, N. (2021, Jun 30). Assets under management in Singapore rises 17% to $3.5 trillion. Retrieved from Asian Investor Web Site: https://www.asianinvestor.net/article/assets-under-management-in-singapore-rises-17-to-3-5-trillion/470753

38 Ministry of Finance Singapore. (2022, August 29). Ministry of Finance Green, Fiscal Policies, Green Bonds Web Page. Retrieved from Ministry of Finance Singapore Web Site: https://www.mof.gov.sg/policies/fiscal/greenbon

Globally connected transport network

As Singapore is highly dependent on the import of goods to meet local consumption, it is continually developing its transport network and is epitomised by Changi Airport and more recently, Tuas Port. Its port connectivity is especially important in the context of decarbonisation as it will be facilitating the trading of key sustainability-based materials such as hydrogen and bio-based chemicals.

The newly inaugurated Tuas Port is set to become the world's largest fully automated port. Its 66 berths effectively double its handling capacity compared to its predecessor Pasir Panjang Terminal. On this note, Singapore is well-placed to be a key player in the future market for sustainable products and green hydrogen.

3. CHARTING JURONG ISLAND'S TRANSFORMATION GROWTH JOURNEY TOWARDS NET ZERO

3.1 COLLABORATIVE APPROACH TOWARDS NET ZERO IMPLEMENTATION

Emerging technologies like hydrogen and CCUS solutions have yet to prove their financial viability on an industrial scale and pose a risk to early adopters. However, organisations could navigate these uncertainties and mitigate some risks by adopting a collaborative approach and shared value mindset towards implementation.

At first glance, industries like chemical, energy, or manufacturing on Jurong Island are seen as siloed. However, each of them contains an ecosystem of diverse players that are part of their value chain. Cross-industry collaboration requires the building of trust among cluster partners. This could be achieved by forming working groups with representatives from all stakeholders such as industrial partners, government representatives, financiers, etc. The players could assess the concentration of industry within the geographic region and understand the diverse set of needs (e.g., fuel requirements for industrial processes) within the group.

83% of digital ecosystems have partners involved from three sectors.[39] With a system of interconnected elements, the multi-party system could become the digital backbone that builds not just new ecosystems, but also new business models for emerging companies, joint ventures (JVs) and consortiums, uncovering value for all partners.

Partnership and collaboration can also address Singapore's limitation of geological storage resources for CO2. Regarding CCUS implementation, Singapore could consider regional collaborative initiatives for CO2 storage. Regional approaches to CCUS infrastructure in Southeast Asia would likely incorporate CO2 transport by ship, which could be a lower-cost option for longer distances and smaller quantities of CO2.[40]

Jurong Island players could develop commercial models and risk-sharing initiatives such as JV formations, public-private partnerships, long-term PPAs, and take-or-pay agreements that help accelerate implementation of roadmaps.

3.2 MITIGATING RISKS AND ADVANCING THE SUSTAINABILITY AGENDA WITH CONFIDENCE

With its strategic location, favourable policies, and resilient financial system, Singapore is well placed to catalyse Southeast Asia's net zero development. It is key that the transition within Singapore is fair and just for all its people and stakeholders. As the country navigates the complex challenges of transitioning to net zero, it is imperative that the needs of all segments of society are considered

39 *Accenture Research. (2021). Future of Partner Relationships. Retrieved from https://www.accenture.com/_acnmedia/PDF-150/Accenture-Future-of-Partner-Relationships.pdf*

40 *International Energy Agency (IEA). (2021). Carbon capture, utilisation and storage: The opportunity in Southeast Asia. Retrieved from https://iea.blob.core.windows.net/assets/2c510792-7de5-458c-bc5c-95c7e2560738/CarbonCaptureUtilisationandStorage_TheOpportunityinSoutheastAsia.pdf*

and the potentially negative impacts stemming from the transition are appropriately addressed, to ensure that benefits and value created could be shared equitably and inclusively among all stakeholders.

The implementation of low carbon and sustainability solutions to the E&C industry on Jurong Island could catalyse efforts in reskilling of the country's workforce for new technologies and businesses, ensuring the safeguarding of jobs for the people, maintaining employability as well as the creation of new jobs. Through Jurong Island, Singapore in collaboration with industry players, can train critical green skills not only for the nation but for the whole region, becoming Southeast Asia's centre of excellence for developing its own sustainability workforce.

An Accenture report on green skills in Singapore finds that equipping the workforce across all sectors with green skills is fundamental in accelerating the speed of the country's transition to a green economy, which is identified as a potential driver of growth in the future. Despite pioneering sustainability efforts such as NEWater and Green Mark Scheme, a large part of Singapore's businesses represented by Small Medium Enterprises (SMEs) is lagging in implementation of sustainability. While leaders are mainly multinationals and some local companies, accounting for over 40% for employment demand for green skills despite employing less than 30% of the country's workforce. The report calls for a mindset shift and upskilling of the workforce so that Singapore is well positioned to make the best out of the sustainable transition, leaving no one behind.

Besides building the talent pipeline, government and investors will need to relook into existing strategies and navigate the common risks associated with net zero transitions.

Policy risk

The risk concerns potential changes in government and/or specific policies toward climate targets and associated regulations, which destabilises investor confidence and introduces uncertainty for the long-term financial viability for low-carbon investments.

To mitigate such risks, Singapore Budget 2022 has outlined the mid-term plan, which progressively increases the carbon tax to reach S$50 to S$80 per tonne of emissions by 2030.[41] To accelerate the transition, integration of low-carbon technologies into national energy and climate strategies could serve as an important policy signal for investors and public companies as has been demonstrated by the Singapore Government. For example, Singapore provided early indication of its approach in its Long-Term Low Emissions Development Strategy (LEDS), notably specifying CCUS as an important advanced technology for enabling the low-carbon transition.[42]

Investment risk

The risk includes the lack of clarity or suitability of sustainable business models (e.g., regulated asset base, contract for differences payments) for low-carbon technologies which often require scale and significant upfront infrastructure investment. This ambiguity could deter interest from private companies and delay the achievement of net zero emissions.

As a mitigation, governments could work together with international finance entities to create strong business cases for low-carbon investment. Increased engagement between industrial cluster players and the climate-finance community will be crucial to developing a common understanding and support for future sustainability projects.[43]

Various types of green financing products are now available, including grants and loans from development and climate finance institutions, emissions credit mechanisms, and climate-related debt financing. Several investment funds in Southeast Asia could be potential sources of financing, including Singapore's Temasek investment fund and a low-carbon investment partnership called Decarbonisation Partners formed by BlackRock.[44]

Stranded assets risk

This risk concerns how rapid changes in company policy—as opposed to a phased-out approach for older carbon-based assets that lack carbon mitigation potentials—could lead to an accumulation of stranded assets, which has wider economic consequences on jobs and the health of private industries and financial institutions. In response, businesses could consider building shorter-term

41 *CNA. (2022). Budget 2022: Singapore to progressively raise carbon tax to reach net-zero target 'by or around mid-century'. Retrieved from https://www.channelnewsasia.com/singapore/carbon-tax-net-zero-target-emissions-singapore-green-plan-2506496#:~:text=SINGAPORE%3A%20Singapore%27s%20carbon%20tax%20will,18)%20in%20his%20Budget%20speech.*

42 *International Energy Agency (IEA). (2021). Carbon capture, utilisation and storage: The opportunity in Southeast Asia. Retrieved from https://iea.blob.core.windows.net/assets/2c510792-7de5-458c-bc5c-95c7e2560738/CarbonCaptureUtilisationandStorage_TheOpportunityinSoutheastAsia.pdf*

43 *International Energy Agency (IEA). (2021). Carbon capture, utilisation and storage: The opportunity in Southeast Asia. Retrieved from https://iea.blob.core.windows.net/assets/2c510792-7de5-458c-bc5c-95c7e2560738/CarbonCaptureUtilisationandStorage_TheOpportunityinSoutheastAsia.pdf*

44 *International Energy Agency (IEA). (2021). Carbon capture, utilisation and storage: The opportunity in Southeast Asia. Retrieved from https://iea.blob.core.windows.net/assets/2c510792-7de5-458c-bc5c-95c7e2560738/CarbonCaptureUtilisationandStorage_TheOpportunityinSoutheastAsia.pdf*

projects that are more convertible and modular as well as quantifying project returns under stranding scenarios. These steps enable a more gradual and calculated transition towards net zero.

CONCLUSION

The paper looks at what net zero emissions growth means for Singapore—a transformation that is driven by industrial decarbonisation with Jurong Island at the frontier. There will be opportunities, as well as implications to businesses and government in approaches, capital spending and jobs for the island that produces up to 54% of Singapore's total carbon emissions.

Jurong Island has taken first steps towards achieving net zero, with a target of two million tonnes of carbon capture by 2030 and six million tonnes of carbon abatement by 2050.

However, more urgent action would be needed to supercharge Jurong Island's next phase of growth, driven by clear elaboration of country's net zero transformation ambitions including government policies, initiatives and implementation timeframe. All ecosystem players including industry players, investors, and governments should double down on their commitment to Singapore's carbon abatement and sustainable product output, drawing on the strengths of their technology, workforce, financing, and connected network.

The areas that should be of immediate priority, in view of the challenges around space constraints and hard-to-abate industry processes, are integrated net zero solutions which focus on:

- **Systemic efficiency and circularity** with increased sharing of resources such as feedstock, process heat and steam enabled by digital infrastructure. Industry players would need to collaborate and find ways to valorise waste streams while government could introduce policies that incentivise the use of waste products.
- **Clean electrification** by maximising deployment of rooftop solar where possible and increase the import of low-carbon electricity due to land constraints as current energy mix is predominantly generated using natural gas.
- **CCUS** for its hard-to-abate E&C sector processes. Efforts to attract international investments in piloting CCUS infrastructure, to enable the transportation, storage and utilisation of stored carbon emissions should be started immediately so that Jurong Island is well-placed for scaling the deployment of CCUS in the longer term.

Direct electrification of industrial processes is less applicable for the energy sector since it operates at higher temperatures. Hydrogen, though promising, stands less favourably for Singapore since it lacks the land and renewable energy sources for scale-up and commercialisation. However, in the longer term when the regional clean hydrogen trade market matures, we see that Singapore could potentially position itself as a clean hydrogen hub by repurposing its LNG and bulk liquids storage and logistics facilities.

One company alone cannot deliver on the decarbonisation of Jurong Island. Partnerships and collaboration between organisations would be crucial to facilitate the sharing of data and insights, investments, and risks to unlock shared value towards achieving net zero.

A collaborative approach promotes new opportunities in digital ecosystem, business models, and regional government-to-government (G2G) partnerships. Policies and financial risks are better navigated by businesses and government together, through mitigations in supportive policies, available financing, and cost-competitive technologies. In advancing the net zero agenda and for enabling a fair and just transition, taking an integrated industrial cluster approach with strong partnerships between government and industry would position Singapore to be a regional leader in sustainable transformation of the E&C industry. What could be achieved together is greater than that of companies and organisations working individually.

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