

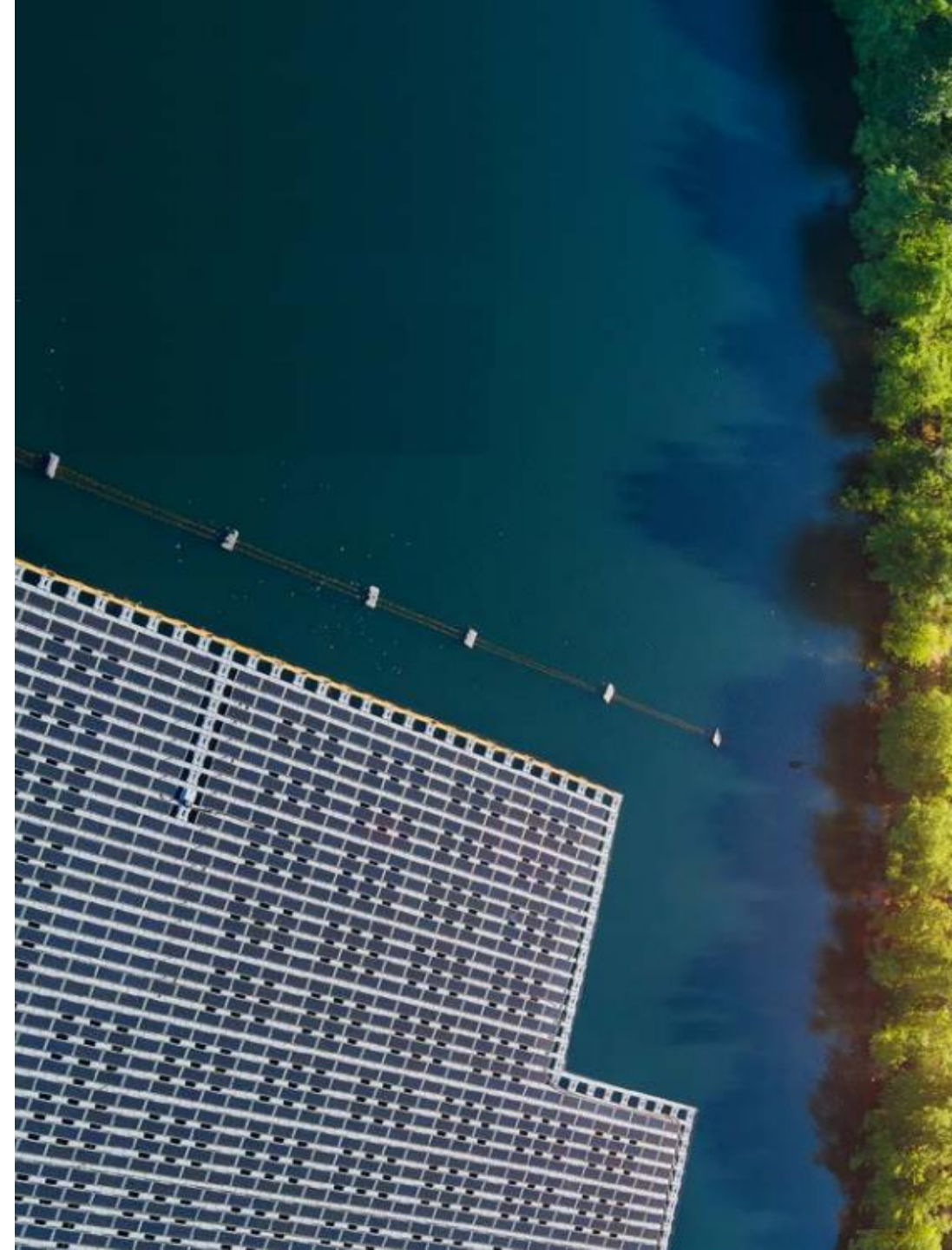
Singapore's National Hydrogen Strategy

39th IPHE Steering Committee Meeting
27 April 2023



Singapore's Journey towards Net Zero

- Singapore has committed to achieving net zero emissions by 2050, as part of our contribution to global climate action
- As a small and densely populated city-state, Singapore faces significant limitations in harnessing alternative energies
 - Limited land for solar deployment
 - No access to wind and hydropower at a meaningful scale
- Low carbon hydrogen is a promising broad-based and scalable decarbonisation pathway, which can also enhance our energy security



Power Sector

- Singapore's power sector accounts for 40% of our emissions; demand will grow with increasing electrification, and growth of electricity-intensive sectors
- Low-carbon hydrogen has the potential to decarbonise Singapore's power sector, by making up a significant component (up to ~50%) of our energy mix by 2050
- Key technological progress needed before large-scale deployment is feasible:
 - Hydrogen supply chain development to enable cost-competitive hydrogen transport and storage, as well as conversion/reconversion from carriers such as ammonia
 - Utility-scale hydrogen-compatible Combined Cycle Gas Turbines
 - Hydrogen import, storage facilities, and distribution network
- In the nearer-term, prioritising effort on ammonia which already has existing supply chains and other applications e.g. maritime bunkering
 - Direct combustion of ammonia in power plants (40-60MW)
 - Cracking of ammonia to hydrogen – but currently energy-intensive

FOUR SWITCHES TO POWER SINGAPORE'S FUTURE



NATURAL GAS

Natural gas has allowed us to significantly reduce emissions by switching away from fuel oil, and will remain a key source of fuel in the decades to come. We will continue to diversify our natural gas sources and improve the efficiency of power generation.



SOLAR

We will maximise solar deployment paired with the use of Energy Storage Systems.



REGIONAL POWER GRIDS

Regional power grids will allow Singapore to import cleaner electricity from neighbouring countries and promote the development of renewable energy in the region.



LOW-CARBON ALTERNATIVES

The remaining supply could be met by Low-carbon alternatives such as hydrogen to bring the power sector to net zero. Carbon Capture, Utilisation and Storage (CCUS) and geothermal are also being explored as potential solutions.

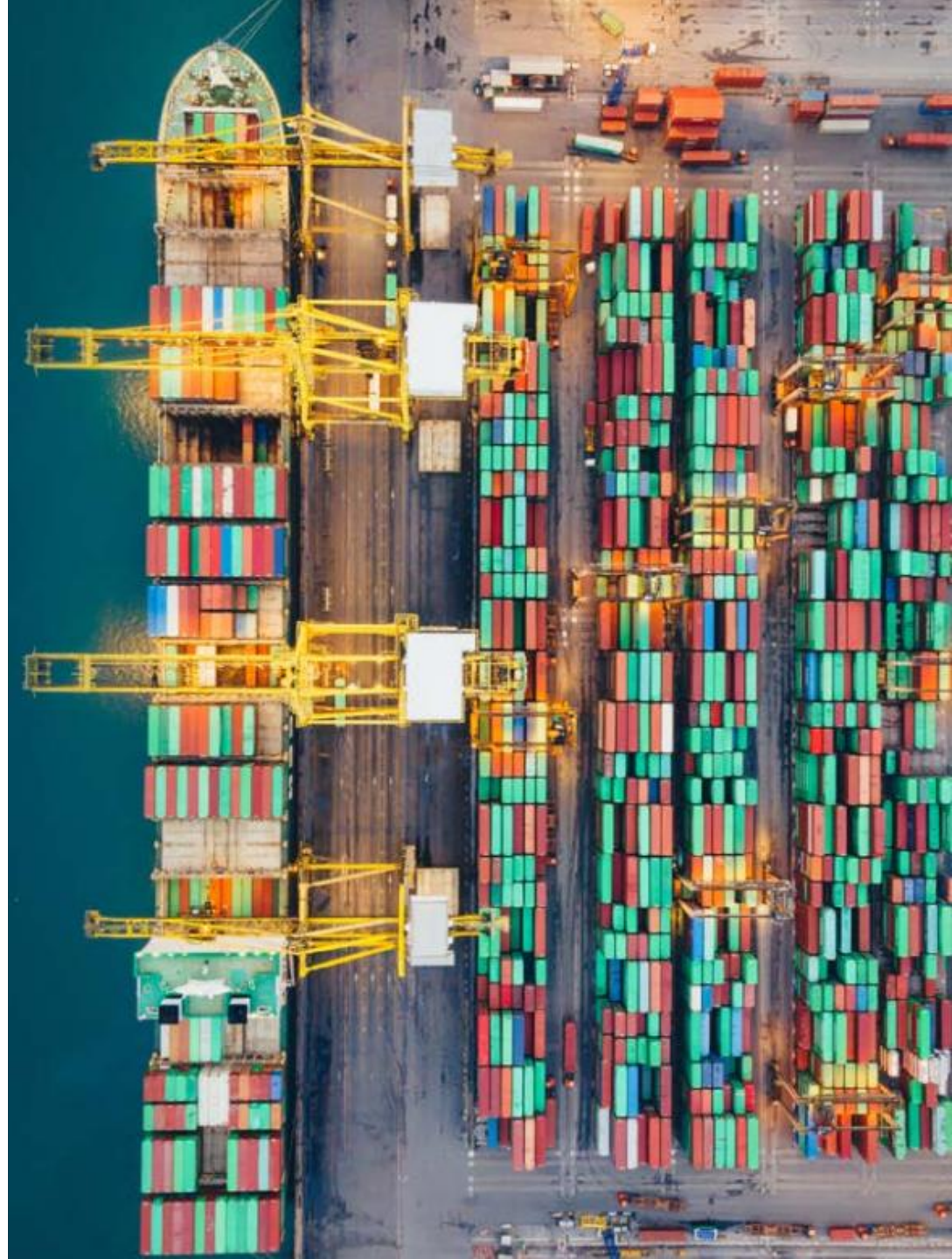
Industry

- The manufacturing sector is a significant contributor to Singapore's economy, but also the largest contributor to Singapore's carbon emissions (~44% in 2020)
- Low-carbon hydrogen is one of the key pathways to bring down industrial emissions, as
 - Feedstock for industrial processes; or
 - Fuel for heat, power, and steam generation
- Demand for low-carbon hydrogen is also expected to increase as companies produce more sustainable products



Maritime

- As a major global maritime hub, Singapore can play an important role in the sector's decarbonisation
- Industry outlook for international maritime is for a **multi-fuel transition**, with oil progressively replaced by lower-carbon fuels
 - Hydrogen-based fuels, in particular, ammonia and e-methanol, are considered to be the most promising carbon-neutral fuels in the long-run
- Singapore has been taking steps to ensure that we can be an early mover in the transition towards ammonia bunkering
 - Developing green shipping corridors with a network of leading ports to catalyse global low-carbon marine fuel supply chains
 - Already working with industry and research institutes to study safety regulations for ammonia bunkering
- PSA International will also decarbonise port operations and the domestic harbourcraft fleet through electrification and low-carbon fuels



Aviation

- In the near term, hydrogen can support the production of Sustainable Aviation Fuels
- In the medium term, hydrogen fuel cells could be used for air-side ground vehicles and aircraft propulsion
- In the longer-term, liquefied hydrogen could be a potential fuel source



Land Transport

- While encouraging the transition to electric vehicles, we will continue to monitor developments in clean energy alternatives including hydrogen fuel cells which can decarbonise vehicle segments that require higher power and mileage



Preparing Singapore for a Hydrogen Future

- Our approach is to progressively build up domestic capabilities, starting with hydrogen carriers or applications that are more technologically ready, while continuing to monitor market development, so that we can scale up deployment when the time is right

TO BEGIN OUR JOURNEY,
WE WILL ORGANISE OUR
EFFORTS AROUND
FIVE KEY THRUSTS:

Experiment with the use of advanced hydrogen technologies at the cusp of commercial readiness through pathfinder projects

Redouble efforts in R&D to unlock key technological bottlenecks

Pursue international collaborations to enable low-carbon hydrogen supply chains

Undertake long-term land and infrastructure planning

Support workforce training and development of broader hydrogen economy

Thrust 1: We have launched an Expression of Interest to use low/zero carbon ammonia for power generation and marine bunkering

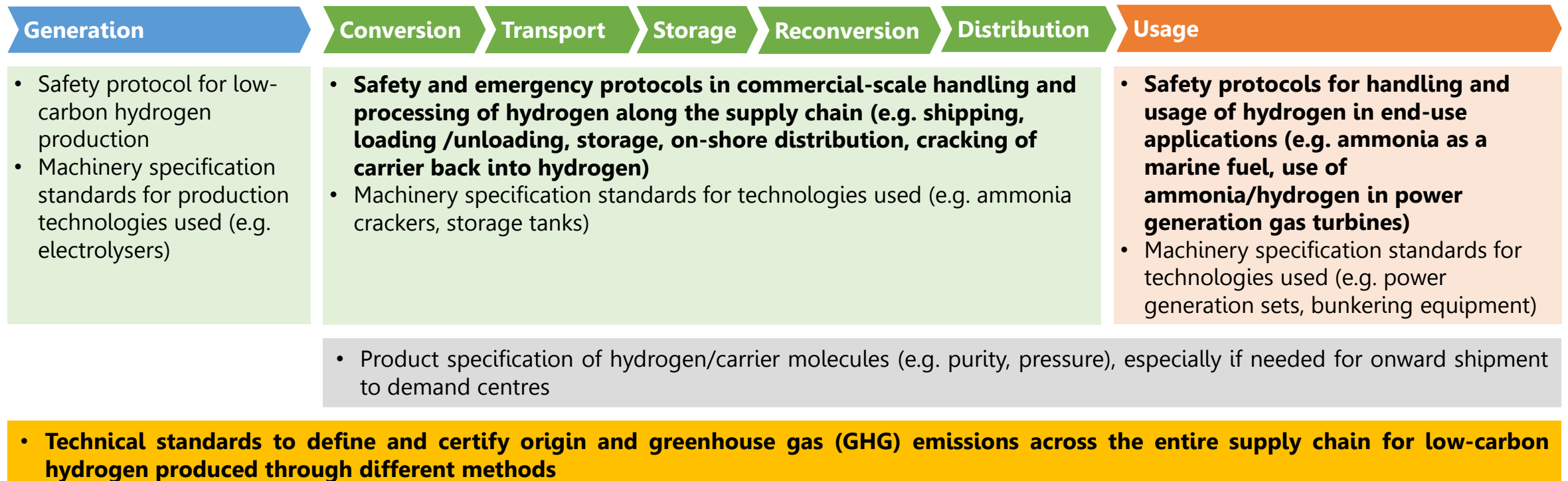
- Ammonia is currently the hydrogen carrier with the most established supply chain
- While ammonia has been used and transported around the world for decades, it has thus far been handled on a small scale in Singapore, with only a single import and storage provider supporting a few industrial users
- To kickstart the development of the ammonia supply chain, **our Energy Market Authority and Maritime Port Authority launched an EOI in Dec 2022 to solicit proposals to develop end to end solutions for low/zero carbon ammonia power generation and bunkering.** The EOI will close in Apr 2023
 - The EOI aims to achieve at least 50MW of power generation and 0.1 million tonnes per annum (MTPA) for marine bunkering by 2027
 - We designed the EOI to be pathway agnostic (i.e. can be direct ammonia firing, or extracting hydrogen from ammonia and burning it in hydrogen-compatible turbines)
- Concurrently, we are studying the safety standards and regulations for ammonia to support the EOI, as well as future scale up infrastructure and end use
- In parallel, we will continue to monitor market and technology developments, and stand ready to launch new pathfinder projects when suitable

Thrust 2: We are launching Phase 2 of the Low Carbon Energy Research (LCER) Programme

- As a likely net-importer of hydrogen, ability to transport, handle, and utilise hydrogen safely, economically and at scale is critical for Singapore
- In 2021, we awarded 12 projects under our Low-Carbon Energy Research (LCER) Funding Initiative that aimed to improve the technoeconomic viability of low-carbon technologies
 - Includes projects in the areas of methylcyclohexane dehydrogenation, hydrogen leakage sensors, ammonia cracking
- We will be setting aside another S\$129 million under LCER Phase 2
 - Directed Hydrogen R&D Programme focusing on our key R&D priority areas to address key technological bottlenecks on the safety of handling and utilising hydrogen in new applications, i.e. hydrogen and ammonia safety, ammonia cracking, ammonia handling and utilisation, and liquefied hydrogen transport and distribution
 - Develop novel solutions that has potential to be commercialised
 - Research community and industry are involved to shape the research direction

Thrust 3: We are pursuing international collaborations to facilitate development of global hydrogen supply chains

- Global trade in low-carbon hydrogen is nascent, and mutually-recognised and interoperable standards and certification across multiple areas will be important to enable large-scale hydrogen supply chains
 - Methodologies or standards for carbon accounting and its certifications
 - Use of hydrogen at scale also requires new or updated policies, e.g. safety in handling
- IPHE is an important platform to advance the developments of such standards



Thrust 4: We are planning for our long term land and infrastructure needs to meet our energy requirements

- Singapore's extremely limited land and sea space could be the biggest limitation to large-scale hydrogen adoption
 - Space is required to site new facilities such as import terminals and storage facilities, many of which require significant safety buffer zones
- Experience from pathfinder projects will inform long-term planning, by deepening our understanding on areas such as land requirements for storage, safety buffer zones, and hazard mitigation measures

Thrust 5: We will be enabling our companies to be hydrogen ready to be in a position of strength when the hydrogen economy takes off

- Domestic deployment of hydrogen and a large global hydrogen economy will open up economic opportunities for Singapore enterprises and workers
 - These could span across the value chain, in areas such as financing, trading, carbon certification, transportation, storage and end-use applications
 - Singapore's strong innovation ecosystem can support companies looking to provide hydrogen technological solutions
- We will work with industry and the education sector to support workforce development
 - Workers in sectors impacted by the hydrogen transition will need to acquire new skills to handle hydrogen and its derivatives
 - Experience from pathfinder projects will inform job skills and workforce capabilities needed

In parallel, we will work through the Singapore Green Economy Regulatory Initiative (GERI) to identify and solve regulatory issues regarding hydrogen

- GERI is a whole-of-government effort to accelerate innovation in the green economy facing regulatory impediments
- Projects in key areas (one of which is hydrogen) may be trialed on an **expedited timeline** through regulatory sandboxes
- GERI benefits businesses by:
 - a) Streamlining processes
 - b) Gaining early indication of agencies' assessment to help businesses better manage resources
 - c) Accelerating timeline to trial
 - d) Mitigating risks for businesses

Thank you