

URBAN SOLUTIONS AND SUSTAINABILITY R&D CONGRESS 2023

BUILDING SUSTAINABLE, RESILIENT, AND LIVEABLE CITIES OF TOMORROW

4TH - 5TH OCTOBER 2023

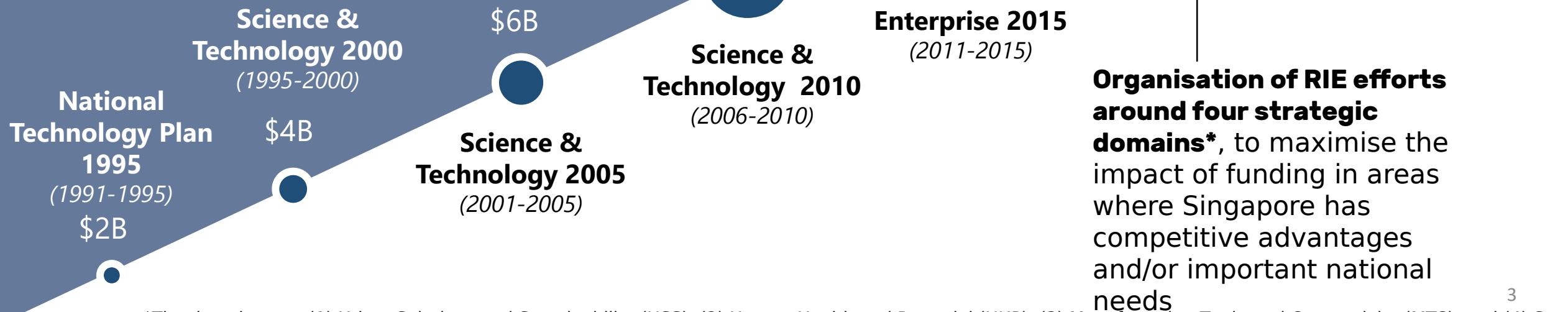


Overview of Urban Solutions & Sustainability : Focus Areas for Research and Innovation

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Background on Singapore's Research, Innovation and Enterprise (RIE) Plans

- Singapore's R&D journey started in 1991, with the first five-year National Technology Plan. These plans are refreshed every five years.
- In 2010, we expanded our R&D strategy to span Research, Innovation and Enterprise (RIE). Since then, our RIE plans include a strong focus on translation, commercialisation and innovation, to tap on the growing pipeline of promising research outputs and better support enterprises.



*The domains are: (1) Urban Solutions and Sustainability (USS), (2) Human Health and Potential (HHP), (3) Manufacturing Trade and Connectivity (MTC), and (4) Smart Manufacturing and Services (SMS)

Overview of USS Domain

USS began with investments in water and energy technologies which are critical resources to Singapore's survival. USS's mission expanded to address other resource constraints, and major urban systems needed for a sustainable and liveable city.

S&T2010



Water



Energy

RIE2015



Energy



Built Environment



Water

RIE2020/RIE2025



Energy



Built Environment



Water



Urban Mobility



Food



Closing the Resource Loop



Climate Change

US\$ R&D supports the Singapore Green Plan

5 Pillars of



- Whole-of-nation movement to advance Singapore’s agenda on sustainable development
- Charts ambitious and concrete targets over the next 10 years, strengthening Singapore’s commitments under the UN’s 2030 Sustainable Development Agenda and Paris Agreement, and positioning us to achieve net zero emissions by 2050.

Energy Reset

Use cleaner energy and increase our energy efficiency to lower our carbon footprint.

City in Nature

Create a green, liveable, and sustainable home for Singaporeans, and build up our carbon sinks by extending nature throughout our island.

Resilient Future

Build up Singapore’s climate defences and resilience, and enhance our food security.

Sustainable Living

Make reducing carbon emissions, keeping our environment clean, and saving resources and energy a way of life in Singapore.



Energy



Climate Change



Climate Change



Closing the Resource Loop



Climate Change



Built Environment



Food



Urban Mobility



Built Environment



Water

Green Economy

Seek green growth to create new jobs, transform our industries and harness sustainability as a competitive advantage.

Outline of 7 Topical Areas under USS

1  **Energy**

2  **Climate Change**

3  **Built Environment**

4  **Food**

5  **Closing the Resource Loop**

6  **Urban Mobility**

7  **Water**

(1) Energy/Decarbonisation – Background



As a small, resource-constrained country, Singapore imports almost all its energy needs, and has limited renewable energy options.

- Singapore is committed to reduce emissions to ~60 Mt in 2030 after peaking emissions earlier.
- Achieve net zero emissions by 2050.
- Deploy at least 2 gigawatt-peak of solar energy by 2030.

Lead Agencies



Key Achievements thus far

- ✓ **Enhanced energy resilience** – Singapore's solar photovoltaic capacity reached 630 MWp in 2021 (100x increase from 6MWp since 2011), on track towards 2GWp of solar photovoltaic capacity by 2030 (3% of projected power demand in 2030).
- ✓ Additional \$129 million set aside under Phase 2 of the Low Carbon Energy Research (LCER) Programme as part of the National Hydrogen Strategy to develop hydrogen as a major decarbonization pathway for our power and industry sectors.

(1) Energy/Decarbonisation – Background

Singapore's Energy Story

- The Singapore's Energy Story is a national strategy to ensure a reliable, affordable, and sustainable energy supply.
- The strategy focuses on four switches: (1) natural gas, (2) solar, (3) regional power grids, and (4) emerging low-carbon alternatives, to achieve a cleaner and more efficient energy future
- Our R&D focus areas are targeted at switches (1), (2) and (4)

Four Switches to Power Singapore's Future

Natural Gas

Power Systems Competitive Research & Test-bedding Programme (led by EMA)

- Test-bed energy efficient solutions at power plants
- Improve plant performance & reliability through digitalisation
- Develop digital twin platform for the grid

1

Solar

Solar Research Programme (led by EMA)

- Develop ultra-high efficiency PV technologies to maximise solar output
- Develop and customise innovative urban solar deployments for use in Singapore's unique environment

2

Regional Power Grids

Electricity imports will likely be predominately policy efforts but R&D will be conducted to facilitate this

3

Low-Carbon Alternatives

Low Carbon Energy Research Programme (led by MTI)

- R&D and test-bed of carbon capture, utilisation and storage and hydrogen technologies. E.g. CO₂ capture, CO₂ to fuels, CO₂ to aggregates, H₂ supply technologies, liquified H₂ storage technologies

4



Focus Areas under the Directed Hydrogen Programme for LCER Phase 2

Ammonia Utilisation

- Understand and address technical limitations associated with direct ammonia utilisation in Singapore's context, such as ways to tackle high NOx emissions and ammonia slippage, and fuel changeover requirements for ammonia combustion, feasibility of ammonia fuel cells and other technologies for direct ammonia utilisation

Ammonia Cracking

- Develop more energy-, space-, and cost-efficient solution to liberate hydrogen from ammonia, for applications where hydrogen molecules are required

Hydrogen Transport and Distribution

- Understanding the infrastructure deployment needs for transporting and storing ammonia and hydrogen within Singapore while considering our unique land use and space constraints

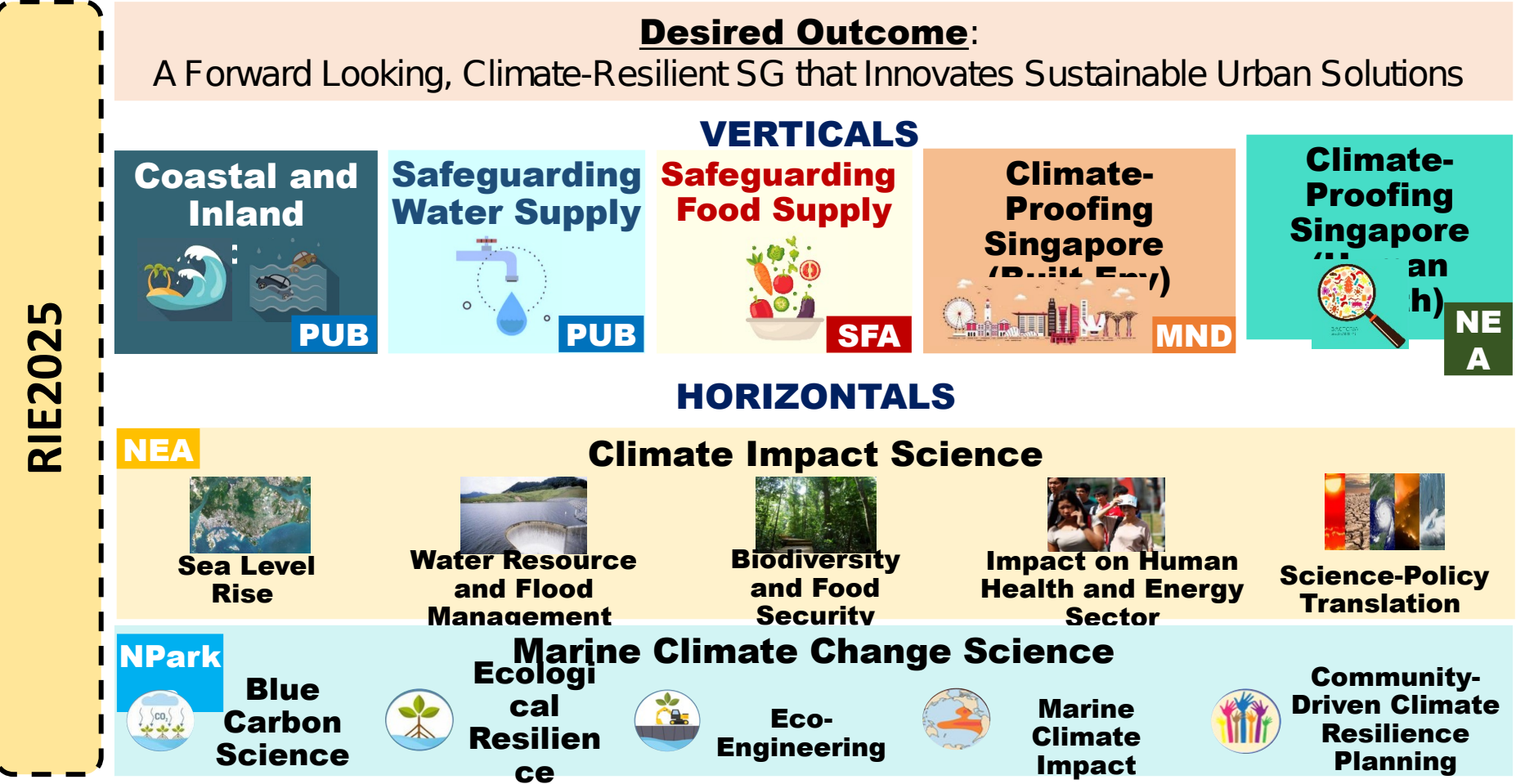
Safety and Regulatory Standards

- Address the knowledge gap of safely handling, transporting, storing and combusting ammonia/hydrogen so as to support the deployment of new hydrogen and hydrogen carrier technologies and scale up of infrastructure

(2) Climate Change – Background

As a highly urbanized, densely populated and low-lying island city-state, climate change poses complex existential challenges to Singapore.

- Singapore is heating up twice as fast as the global average temperature (at 0.25 degrees per decade).
- Sea levels are projected to rise by ~1m by end of the century (30% of the island lies <5m above Singapore Height Datum).



(2) Climate Change

R&D Focus Areas under Marine Climate Change Science Programme

Blue Carbon Science

- To provide solutions that will reduce Singapore's carbon footprint while conserving our coastal and marine ecosystems through building a foundational science for developing a marine carbon credits economy in Singapore

Ecological Resilience

- To better understand the impact of climate change on marine species, habitats, ecosystems and connectivity, so as to inform measures to enhance marine ecosystem resilience against climate change induced

Eco-Engineering

- To protect our coasts against sea level rise and extreme storm events via sustainable engineering measures, while incorporating nature-based solutions which will also enhance our marine environment and create new

Marine Climate Impact

- Develop predictive models for projecting how climate change may alter existing biogeochemical processes in Singapore's marine environment, so as to inform the formulation of interventions and relevant strategies

Community-Driven Climate Resilience Planning

- Explore how the social sciences can add important methods and perspectives towards climate change mitigation and adaptation efforts in our marine environment

(3) Built Environment – USS RIE2025



To build a resilient, sustainable, and liveable city through innovative urban solutions

- Resource and space constraints, ageing infrastructure, ageing population, climate change → Pressing and long-term challenges to address for the BE
- Support BE ITM's aim to improve the construction industry's productivity and use of technology
- Singapore imports most of its building materials → highly susceptible to supply chain disruptions.

Lead Agencies



RIE2025 Objectives

- To develop innovative solutions to address tightening resource constraints, ageing infrastructure, greater densification and climate change, for a liveable, sustainable and resilient city.
- Support the Built Environment Industry Transformation Map (ITM) goal of evolving the built environment sector into a smart and sustainable industry through the development of solutions in integrated planning and design, advanced manufacturing and assembly, and sustainable urban systems.

(3) Built Environment – USS RIE2025



Priority Areas under RIE2025

- Continued emphasis on advanced construction and resilient infrastructure, to accelerate productivity drive
- Augmented I&E strategy to strengthen industry partnerships through more targeted approach to drive value capture.
- Step up efforts to support Singapore Green Plan by strengthening our ecological, climate and social resilience:
 - a) Included ‘City in Nature’ as a new pillar under the Cities of Tomorrow R&D program, and started the Marine Climate Change Science (MCCS) research program to tap on nature solutions and address climate change challenges.
 - b) Enhanced Green Building Innovation Cluster (GBIC) program to push boundaries for developing energy efficient building technologies.
- Beyond existing efforts to improve urban planning and enhance liveability/ living comfort, started developing ‘Healthy Cities’ R&D plan to improve population health and ageing-in-place through BE interventions.

(3) Built Environment – USS RIE2025



Adv Construction and Resilient Infra.

- Novel robotics and automation solutions in construction sites
- Additive manufacturing i.e. 3D concrete printing
- Pre-emptive inspection and repair
- Advanced materials to improve durability of infra
- Smart and advanced facilities management

Urban Analytics & Complexity Science

- Evidence-based urban planning methodologies.
- Adopt Science of Cities approach to enhance understanding of interactions in urban systems.

Greater Sustainability

- Solutions to mitigate disamenities and enhance liveability and well-being of citizens (e.g. noise, thermal comfort)
- BE adaptation to Climate Change, e.g. coastal protection structure and materials, solutions to address UHI effect

Space Creation/Optimisation

- Innovative mooring solutions to reduce anchorage footprint.
- Cost-effective underground construction & maintenance

City in Nature

- Nature-based solutions for climate change mitigation and adaptation.
- Resilient, sustainable, and multi-functional greenery
- Biodiversity monitoring to support habitat restoration and species recovery
- Managing human-nature relationships.

Healthy Cities (*with HHP*)

- Explore implementation research at living labs to (i) improve health outcomes through BE interventions, and (ii) validate/ evaluate/ improve its effectiveness through longitudinal studies to inform policy & planning for public housing.

(4) Food – Background

To ensure Singapore's food security, SFA launched the Singapore Food Story to produce 30% of Singapore's nutritional needs locally and sustainably by 2030.

- > 90% of Singapore's food is imported → susceptible to supply chain risks.
- < 1% of Singapore's land space is available for farming.
- In 2019, local farms produced 14% of leafy vegetables, 26% of eggs, and 10% of fish consumed locally.

Lead Agency (SFA)



Key Achievements

- ✓ Generated interest in **new R&D areas in aquaculture, agriculture and alternative proteins** through grant calls, resulting in more than 30 awarded projects in Sustainable Urban Food Production and Future Foods: Advanced Biotech-based Protein Production.
- ✓ Established Future Ready Food Safety Hub, a tripartite collaboration between A*STAR, SFA and NTU, which aims to **plug scientific gaps in food safety & risk assessment for new ingredients & novel food safety development.**

(4) Food – USS RIE2025

RIE2025 Objectives

- To support the national agenda of strengthening Singapore’s food security and achieving capability and capacity to produce 30% of Singapore’s nutritional needs locally and sustainably by 2030, while reaping economic benefits.

R&D Focus Areas

Security and Resiliency

- Leverage genetics and breeding to improve productivity and nutritional qualities, increase climate change resistance and reduce resources to grow crops/fish.
- Improve process development to enable future manufacturing of Alternative Proteins.

Sustainability

- Develop resource-efficient solutions to improve sustainability and lower carbon emissions of local food production, e.g. from urban farms.

Food Safety

- Develop new analytical methods for food safety assessment, to address (i) slow turnaround time for conventional animal testing methods, (ii) need for human physiologically relevant models and (iii) unexpected hazards from food innovations.

Economic Value Capture

- Enhance R&D translation through facilitating commercialisation pathways for promising R&D projects.
- Anchor companies and grow Singapore’s agri-food tech capabilities.

(5) Closing the Resource Loop - Background

Lead Agency



As a small, resource-scarce and densely populated urban city-state, climate change and mounting waste are increasingly pressing and complex environmental issues.

- Reduce the daily per-capita waste sent to Semakau landfill by 20% by 2026, with the goal of reaching 30% reduction by 2030.

Key Achievements thus far

- ✓ Singapore Polytechnic (SP) has successfully developed environment-friendly solutions for recovery of precious metals (e.g. gold, silver and palladium) where its yield is on par with industry standards.
- ✓ NTU Singapore-CEA* Alliance for Research in Circular Economy have used orange peel with citric acid to dissolve and **recover 90% by weight of valuable metals from spent lithium-ion batteries**. The technology has been licensed to a local e-waste recycling company, Se-cure Waste Management Pte Ltd for further evaluation in a 1,000L hydro(organic) metallurgical pilot plant.

(5) Closing the Resource Loop – USS RIE2025

Priority Areas under RIE2025

- Stronger focus on technology translation and test-bedding efforts: Digitalisation, data analytics, social behavioural studies and material flow analysis incorporated as enablers to better understand the levers to effectively close the resource loop.
- Waste-to-Energy area has been expanded beyond electrical efficiency enhancement to increase energy recovery options for waste treatment (e.g. waste → syngas → hydrogen conversion) and to reduce carbon emissions.

(5) Closing the Resource Loop – USS RIE2025

RIE2025 Objectives

- Achieve 70% overall recycling rate by 2030.
- **Increase landfill lifespan:** To reduce the daily per-capita amount of waste sent to landfill by 20% by 2026, and 30% by 2030 and a stretch target of 65% beyond 2030.
- **Increase energy recovery options** from waste treatment and reduce carbon emissions of thermal waste processes.
- **Robotics and Automation** in Environment Services to shift away from labour-intensive processes.

R&D Focus Areas

Resource Recovery from Key Waste Streams

- Recover valuable metals from e-waste, food to fish feed, plastic to fuels.
- Optimise the management of other large waste streams such as paper, horticulture, and wood.
- Translate lab-scale proof-of-concept (PoC) into pilot and test-bedding projects.

Residues to Resources

- Incineration Bottom Ash into base or sub-base material for road construction projects, and Non-incinerable waste into value-added products, e.g. expansive agent and silica.
- R&D into methods to investigate, remediate and restore closed landfills.

Rethinking Energy from Waste

- Increase energy recovery options and minimise carbon footprint.
- Test-bed / demonstrate thermal waste treatment technologies developed from earlier PoC projects.

(6) Urban Mobility – Background



Singapore's urban transport system faces the pressing challenge of meeting rising demand with limited land, labour and fiscal resources.

Lead Agency



Key Achievements

- ✓ Successful demonstration of a **3-month autonomous vehicle (AV) on-demand trial** on Sentosa and R&D work on autonomous bus trials have informed and enabled a limited commercial AV deployment at Science Park 2 from Jan 2021 to Apr 2021. AV bus companies are considering plans for deployment and trials in other locations, e.g. NTU is planning to do a shuttle service trial at one-north while ST has planned to conduct further trials at Jurong Island to advance their AV developments.

(6) Urban Mobility – Background

Priority Areas under RIE2025

- Sustainable land transport commitment to peak emissions earlier and reduce emissions to ~60 million tonnes of CO₂ in 2030.
- Support a well-connected and fast transport network that is also cost effective and environmentally sustainable to operate and maintain; and a transport ecosystem characterized by gracious behaviour and inclusive infrastructure that contributes to better health and safer journeys.
- Support the shift towards cleaner-energy vehicles with the main thrust on electrification.

(6) Urban Mobility – USS RIE2025

RIE2025 Objectives

- To co-innovate with ecosystem partners to solve land transport challenges of reliability, cost-effectiveness, productivity and safety, in alignment with RIE2025's focus on economic value capture.

Digitalising our Rail System

- **Increased use of automation, smart equipment and use of digitalized processes** to achieve 20% reduction in rail O&M manpower and 30% reduction in life cycle cost
- Workstreams focusing on **improving productivity, reducing costs, achieving carbon-neutral operations and enhancing safety and security**

Sustainable and Cost-Effective Road Asset Management

- **Reduce maintenance costs** and improve sustainability for road assets management
- Leveraging technology to **reduce manpower requirements** by 50%, and overall maintenance costs by 20%

Future Urban Mobility with AV

- Develop capabilities in **testing and certification for AVs in Singapore's unique operating environment**
- Develop a regulatory framework to facilitate deployment of AVs

Enhancing Road/Path Safety with Connected Commuters

- Enhancing road safety through V2X or other IoT sensors by increasing awareness among road users
- **Establishing a common standard for V2X or other IoT sensors in Singapore**
- Reduce active mobility related road traffic accidents and conflicts towards a "Vision Zero" environment

Electrification of Land Transport

- Support EV adoption
- Focus on chargers and charging infrastructure, batteries related technologies, social and behavioural research of EV users, safety and security

Behavioural Sciences in WCR

- Understanding and **leveraging the psychological determinants of PT loyalty**
- Sustaining the shift to off-peak travel
- Strengthening our caring commuter culture
- Enhancing end-to-end navigation at PT nodes for commuters in need

(7) Water – Background

PUB and MSE have supported the development of a vibrant and comprehensive water research ecosystem. Singapore has developed R&D strengths in areas such as membranes for seawater desalination and water reuse.

To ensure future water sustainability, Singapore will increasingly depend on weather-resilient water sources¹ which will be balanced with continued efforts in managing water demand.

- Water demand is expected to almost double by 2065.
- Limited expansion of our reservoirs due to land constraints + extreme weather events associated with climate change → further reduce the reliability of rainwater supply.

Key Achievements thus far

- ✓ **Enhanced water supply resilience** – In the long run, majority of Singapore's water needs can be met by wastewater recycling and desalination, through advances in membrane technologies.
- ✓ **Established Singapore as a global hydrohub** with 200 water companies and 25 company research centers.

¹ e.g. NEWater and Desalination

Lead Agency



(7) Water – USS RIE2025

RIE2025 Objectives

- To meet national water needs – water security, sustainability and resilience, while **pre-positioning for future challenges brought about by climate change**.
- Concurrent push to promote wider adoption of developed technologies by enhancing the industry’s capacity to commercialise new technologies and making them suitable for regional markets.

R&D Focus Areas	Desired Outcomes
Desalination and Water Reuse	Reducing the energy consumption of desalination
Used Water Treatment	Improving treatment energy self-sufficiency
Industrial Water Solutions	Reducing water consumption by industries
Coastal Protection & Climate Change Adaptation <i>e.g. RIE2025 Coastal Protection and Flood Management Research Programme</i>	(a) Laying the foundation for implementing coastal protection works around Singapore’s coastline to adapt to sea level rise and (b) understanding the science, quantifying the potential impacts, and formulating future adaptation strategies.
Waste Reduction and Resource Recovery	Reducing the amount of dewatered sludge to be incinerated, from the current 0.16 to 0.11 kg dry solids/m ³ used water.

(7) Water – USS RIE2025

Coastal Protection (CP) and Flood Management (FM) Research Programme

Coastal Science Research

Coastal processes (Wave , Current , Storm Surge, Sediment transport) • Extreme event (Coupling of intense rainfall runoff and extreme sea levels, Joint probability, Events attribution)

Engineering for CP & FM

Technologies for integrated infrastructure • Construction techniques in deep waters • Structural Integrity

Integrated Nature-based Solutions for CP

Adaptive “green-grey” hybrid solutions and large scale testbed • Framework for Long-term monitoring • Design criteria

Sustainable Infra Solutions for CP & FM

Low carbon materials • Lightweight, high-strength, corrosion-resistant materials • Sustainable Construction methods

Smart Management Solutions for CP & FM

Smart ops & emergency response • Predictive ops of tidal gates and pumping stations • Smart system for structural health monitoring

Monitoring, Prediction and Digitalization of Coastal Environment

Next generation sensing technology • AI, machine learning and physics-informed analytics to process data streams • Cyber-physical predictive systems to couple advanced numerical simulation research

Integrated and Adaptive Planning

Integrated coastal and urban planning tools • Systems level planning framework • Social Science Research • Flood loss curves • Risk quantification



Thank You