PRIME MINISTER'S DEPARTMENT
ECONOMIC PLANNING UNIT

AKADEMI SAINS MALAYSIA

WST 2040

WATER SECTOR TRANSFORMATION

WATER AS AN ECONOMIC SECTOR (WES)

(VOLUME IX)

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SUB-SECTORAL FINAL REPORT

WATER AS AN ECONOMIC SECTOR (WES)

(VOLUME IX)

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Foreword

The Economic Planning Unit (EPU), on 3rd April 2020, appointed the Academy of Sciences Malaysia (ASM) as its strategic partner to undertake the Study on Water Sector Transformation Agenda 2040 (WST2040), to transform the water sector from an enabler to becoming a dynamic growth engine by 2040, as stated in the 12th Malaysia Plan (12th MP). This standalone Volume 9, "Water as an Economic Sector (WES)", forms part of 9 compendia of reports. Volume 1, the Main Report, summarised the output of Volume 2 to Volume 9. The details in Volume 1 can be found in each of the 8 standalone reports.

The emphasis in all these reports is to achieve a secure, sustainable, and vibrant water industry in Malaysia, to forge it into a dynamic, efficient, sustainable, and revenue-generating industry. The five focused areas of WST2040 are empowering people as the drivers of the transformation, strengthening governance, enhancing data-driven decision-making, ensuring sustainable financing, and developing sustainable and cost-effective infrastructure. Implementing WST2040 and following the recommendations made by the study will contribute significantly to the national gross domestic product (GDP), create new job opportunities and facilitate the development of science, technology, innovation, and economy (STIE), which in turn will enhance the research, development, innovation, and commercialisation (RDIC) of indigenous new products for both the national and global platforms. This transformation agenda is planned over 2 decades and 4 phases of four 5-year Malaysia Plans (MP), starting with the 12th MP.

The WES Sub-Sector study proposes an ecosystem approach that matches the 8i-ecosystem framework of *infrastructure*, *infostructure*, *intellectual-capital*, *integrity systems*, *incentives*, *institutions*, *interaction*, and *internationalisation* to the five focused areas of WST2040. It assesses the current contribution of the water sector to the economy and highlights several areas of the water sector that can increase its contribution to the Malaysian economy. The study also highlights several gaps in the enablers of the water ecosystem. Several strategies are being proposed to increase civic consciousness on water resource management among all stakeholders and to strengthen water sector governance by adopting a "Whole-of-Government & Whole-of-Society" approach.

To achieve this ambition, we have partnered with expert advisors and researchers from the Sunway Institute for Global Strategy and Competitiveness at Sunway University. By leveraging their knowledge and expertise, we have been able to produce findings and holistic recommendations that we believe, are greatly relevant to the current water landscape of the country. On behalf of ASM, I would like to take this opportunity to thank the WES team led by Professor Mahendhiran Sanggaran Nair FASc for all their dedication, hard work, and commitment.

Thank you.

Ir. Dr. Salmah Zakaria FASc,
Chairperson, Project Management Committee WST2040,
Water Sector Transformation (WST2040) Study Team, EPU-ASM,
2021-2015 ,Chairperson, ASM Water Committee

Preface

This report is a culmination of a series of other studies led by the Academy of Sciences Malaysia (ASM) on Integrated Water Resources Management. This report provides a comprehensive analysis of key factors that contribute to the development of a dynamic water ecosystem. The study proposes an ecosystem approach, in particular, the adoption of the 8i-ecosystem framework to characterise the national water ecosystem. The eight enablers of the water ecosystem include *infrastructure* (physical and natural infrastructure); *infostructure* (digital infrastructure); *intellectual-capital* (talent), *integrity systems* (governance systems); *incentives* (fiscal and non-fiscal); *institutions* (key players in the water sector); *interaction* (collaboration and smart partnerships) and *internationalisation* (adherence to global best practices and engagement with global knowledge networks and supply chains).

This report assesses how well the national water ecosystem adheres to the *8R-water philosophy* (respect, rethink, reduce, re-use, recharge, recycle, repurpose and regenerate water) and the current contribution of the water sector to the economy. The report highlights that several strengths in the water sector can increase its contribution to the Malaysian economy. The study also highlights several gaps among the enablers of the water ecosystem that prevent adherence to the 8R water philosophy. Hence, hindering its transformation into a dynamic economic sector. Weakness in the supply-side and demand-side of the water sector management, on the other hand, impedes the water sector from increasing its contribution to the gross domestic product (GDP) of the country.

The study proposes several strategies to strengthen the eight enablers of the water ecosystem, which entail the following: increasing civic consciousness about water resource management among all stakeholders in the ecosystem; increasing the talent stock in the water sector; strengthening water sector governance by adopting a "Whole-of-Government & Whole-of-Society" approach; embedding the 8R-water philosophy and 'Circular Economy' framework; introducing water tariff system and increasing investment in water-related R&D; accelerate digital transformation of the water sector; establish a water sector centre of excellence, which becomes a 'one-stop' centre for all stakeholders in the water sector; establish neutral water sector agency that facilitate strong public-private partnerships, including institutions of learning and research centres to create strong network externalities and multiplier-effect; and adopt a staged approach to develop a national water grid infrastructure that utilises advanced technology to effectively manage the water sector, including pre-empting and mitigating any risks that adversely impact the quantum and quality of water supply to all stakeholders across the country.

The report also highlights that a sound water ecosystem will be able to nurture the next generation of water-related technologies aligned with the 10-10*My*STIE outlined in the 12th MP, creating a strong water-related high-technology sector and supply chain. These locally developed technologies will be critical to modernising the water sector, ensuring undisrupted water supply, and increasing the quality of water. The latter is critical in attracting high-end industries to Malaysia, in search of a high-quality and stable water supply.

The use of advanced technology in the water sector will also enable suppliers to manage the water demand and ensure the water resources meet the needs of all stakeholders in the economy. Careful management of the supply-side and demand-side of water will be critical to ensure stable water prices, sustainable growth of the sector, and transformation of the sector into a dynamic knowledge-driven economic sector, thus contributing to high-income jobs and GDP of the country. The development of the water sector as a dynamic economic sector will set the stage for it to play a more dominant role as a water sector hub in the ASEAN region.

It is with great pleasure, that I would like to express my deepest appreciation to all the Taskforce chairpersons and members, experts from various government agencies, industries, community organisations, and institutions of learning for their invaluable contributions to the team in undertaking this study. I would also like to thank the ASM Secretariat for all the administrative support. Last, but not least, I would like to express my gratitude to all members of the WES task force and the other taskforces for painstakingly working as a team to complete this study for the nation.

Professor Mahendhiran Sanggaran Nair FASc
Chairperson
Water as an Economic Sector (WES) Sub-sector

List of Acronyms

AACB	Advocacy, Awareness, and Capacity Building
AI	Artificial intelligence
ASM	Akademi Sains Malaysia
CAPEX	Capital expenditures
CBS	Statistics Netherlands
CBWM	Community-based water monitoring
CC	Climate change
COE	Center of Excellence
CREST	The Collaborative Research in Engineering, Science and Technology Centre
DCS	District cooling system
DEBC	Direct economic benefits coefficient
DOSM	Department of Statistics Malaysia
DRM	Disaster risk management
DWUC	Direct water use coefficient
EC	Edge computing
EPU	Economics Planning Unit
ESG	Environmental, social, and governance
ETP	Economic Transformation Programme
FOMCA	Federation of Malaysian Consumers Association
GDP	Gross domestic product
GVA	Gross value-added
ICT	Information and communication technologies
ILBM	Integrated lake basin management
IP	Intellectual property
IRBM	Integrated river basin management
IWK	Indah Water Konsortium
IWRM	Integrated water resources management
IWRM	Integrated water resources management
KASA	Kementerian Alam Sekitar dan Air
LCD	Litres per capita per day
LUAS	Lembaga Urus Air Selangor
MAGI	Malaysian Global Innovation and Creative Centre
MDEC	Malaysian Digital Economy Corporation
MIGHT	Malaysian Industry-Government Group for High Technology
MITI	Ministry of International Trade and Industry
MOE	Ministry of Education
MOHE	Ministry of Higher Education
MOHR	Ministry of Human Resources
MOSTI	Ministry of Science, Technology, and Innovation
MP	Malaysia Plan
MW	Magnetic water
MWT	Magnetic water treatment
NAHRIM	National Water Research Institute of Malaysia

NBS	Nature-based solutions
NGO	Non-governmental organisation
NIWRM	National integrated water resource management
NKEA	National Key Economic Area
NKPA	National key priority area
NMC	National Management Committee
NRW	Non-revenue water
NTIS	National Technology and Innovation Sandbox
NTIS	National Technology and Innovation Sandbox
OECD	Organisation for Economic Co-operation and Development
OPEX	Operating expenditures
PAAB	Pengurusan Aset Air Berhad
PBC	Performance-based contract
PBL	Project-based learning
PES	Payment for ecosystem services
PPP	Public-Private Partnerships
PUB	Public Utilities Board
RDIC	Research, Development, Innovation, and Commercialisation
ROI	Return on investment
ROV	Return of value
SEM	Structural equation modelling
SINGSTAT	Singapore Department of Statistics
SME	Small and medium-sized enterprises
SPAN	Suruhanjaya Perkhidmatan Air Negara
STEM	Science, technology, engineering, and mathematics
STIE	Science, technology, innovation, and economy
TEBC	Total economic benefits coefficient
TES	Thermal energy storage
TSM	Tariff setting mechanism
TVET	Technical and vocational education and training
TWUC	Total water use coefficient
UN	United Nations
WDM	Water demand management
WES	Water as an Economic Sector
WF	Water footprint
WRC	Water Resources Council
WST	Water Sector Transformation
WSWM	Water supply and wastewater management
WWF	World Wildlife Fund

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SME Corp
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Lembaga Urus Air Selangor (LUAS)
Ministry of Utilities Sarawak (MOU Sarawak)
Jabatan Pengairan dan Saliran Sarawak (JPS Sarawak)
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Federation of Malaysian Manufacturers (FMM)
ROCKWOOL Malaysia Sdn. Bhd.
Top Glove Corporation Berhad
Showa Denko Carbon Malaysia Sdn. Bhd.
Mega Fortris (M) Sdn. Bhd.
FMM Secretariat
Federation of Malaysian Manufacturers Malaysian Food Manufacturing Group (FMM MAFMAG)
Etika Holdings
Nestle Malaysia
FMM Secretariat
Malaysia Shopping Mall Association (PPK Malaysia)
See Hoy Chan Holdings Group
Hektar Real Estate Investment Trust
PPK Malaysia Secretariat
Malaysian Plastics Manufacturers Association (MPMA)
Piping Technology Sdn. Bhd.
Federation of Malaysian Consumers Associations (FOMCA)

1.0 Executive Summary

Water shortages and lack of access to quality water supplies are major concerns in many developing countries. While Malaysia gets abundant rainfall, the water sources are vulnerable to increasingly erratic weather patterns. Coupled with ageing water infrastructure and under-resourced water management systems, there has been an increasing trend of water supply shortages and disruptions. The problems of the country's water system have major implications on the health and well-being of citizens. These disruptions also harm local industries and may impact foreign investments into the country if not controlled accordingly. Hence, better management of the country's water sources is critical to ensure the development of a vibrant water industry that becomes a major revenue earner for the nation and a key enabler for ensuring the competitiveness of other sectors of the economy where water is an important input. While the Malaysian government recognises the importance of the water industry, past policies merely mention broad goals without a clear framework with hard targets and timelines. Comparison of policies against highly developed water sectors in other countries also shows that a holistic multi-sectoral approach with strong stakeholder collaboration is vital for a dynamic water ecosystem. To achieve this, an assessment has shown that there are systemic issues within the enablers of the water ecosystem that need to be addressed and are outlined below:

1. People

- × There is a general lack of civic consciousness on the importance of water amongst the public and a lack of specialised and technical knowledge within the water supply sector.
- ✓ The way forward is to establish a strong water centre of excellence that leads research and education institutes to nurture the next-generation talent and awareness for the water industry.
- ✓ The water centre of excellence has the potential to provide leadership in talent development in Malaysia, the region, and other developing countries; fostering strong multilateral technology and knowledge transfers that will strengthen the position of the Malaysian water sector in the region.

2. Governance

- × The water sector has been plagued by a lack of coordination and harmony in policy direction, planning, and execution due to the inconsistent quality of institutions. There often exists overlapping roles, and collaboration among stakeholders is patchy and fragmented.
- ✓ The way forward is to establish an integrated water management institutional framework that embraces a "Whole-of-Government & Whole-of-Society" approach, incorporating a Circular Economy Framework that embeds the *8R Water Philosophy* in every facet of policy development and implementation.
- ✓ A strong collaborative framework among all stakeholders will lead to more cohesive and effective policy and implementation mechanisms that will enhance the return-of-value for all stakeholders in the ecosystem (i.e., Federal, states, local governments; community organisations, civil society; industry, and communities living near the water basins).
- ✓ An integrated water ecosystem will ensure a sustainable supply of water and effective water demand management; both of which will lead to stable prices for water. Gains from improved water supply and demand management will render the sector to be affordable and profitable.

3. Finance

- × The lack of incentives and the ability to foster R&D has led to low levels of adoption and development of new technology and innovation by local firms.

- × The water tariff system is neither competitive to attract the private sector nor is it sufficient to cover operating and development costs.
- ✓ The way forward is to align R&D funding for water-related research to the 10-10 MySTIE framework.
- ✓ Developing a multi-tiered water tariff model is also critical to attracting private and foreign investments for the sustainability of the water sector.

4. Information and RDIC

- × The lack of a national RDIC collaborative platform has resulted in a "knowledge chasm" between the R&D undertaken by academic institutions and the industry needs.
- × The digital transformation of the water sector has been slow. The lack of data-enabled insights and decision-making has led to minimal knowledge sharing. This further weakens the sector's access to R&D funding and commercialisation of water technology.
- ✓ The way forward is to align national development funding to accelerate the digital transformation of the water sector. This will also strengthen engagements with higher learning institutes and industry players to develop local technologies.
- ✓ The establishment of a water centre of excellence can play a key role as a one-stop end-to-end centre working in partnership with the National Technology and Innovation Sandbox (NTIS) and i-Connect initiatives to foster strong collaborative partnerships in the water sector.
- ✓ Establish a neutral water sector equivalent agency such as The Collaborative Research in Engineering, Science and Technology Centre (CREST) for the electronic & electrical sector (E&E) to foster trust and knowledge sharing among industry players, research institutions, and institutions of learning.

5. Infrastructure and Technology

- × The ageing infrastructure and low adoption of new technology threaten the water security of the nation.
- × Lack of an integrated smart water grid system leads to high non-revenue water and low reserve margins in many states.
- ✓ The way forward is to adopt a staged upgrade of the water grid infrastructure that uses advanced technology which allows the water sector to continuously monitor, pre-empt risks associated with pollution, manage, and improve the quality of service, thus reducing the percentage of non-revenue water, frequency of disruptions, and increasing the state water reserve margins.

By strengthening these enablers of the water ecosystem, the sector can achieve a much higher value-added amount to the economy and transform into a dynamic economic sector, increasing its contribution to the national GDP from 0.3% in 2017 (RM4.5bil) to as much as 0.5% by 2040 (RM13.3bil).

2.0 Introduction

Water is an important commodity for sustaining life and economies across the globe. Water shortages and access to quality water supply are major concerns for policymakers (World Economic Forum, 2019). While Malaysia gets abundant rainfall, the distribution of water across the different states varies. Some states experience an over-supply of water, while others are in a deficit position. Furthermore, the water reserves in the country are impacted by weather patterns. For instance, during the monsoon season, an abundance of rainfall causes annual flooding in many areas of the country. On the other hand, during the dry spell, many of the major dams experience low water levels, which causes water shortages and disruptions during severe times. A more concerning recent trend is when the water systems in the country started to experience constant disruption due to contamination of rivers and water sources. Such problems regarding the country's water system have major implications on the health and well-being of citizens and the economic development of local industries. Hence, better management of the water sources of the country will go a long way to ensure water security. Importantly good management of the water supply is critical in ensuring the development of a vibrant water industry that becomes a major revenue earner for the nation and a key enabler for ensuring the competitiveness of other sectors of the economy where water is an important input.

Increasing population and economic activities have raised the demands for water in the last few years. Based on data from DOSM[1] for the years 2015 and 2019, the water collection, treatment, and supply sector have experienced a growth of 31 per cent in gross output from RM6.1 billion in 2015 to RM7.9 billion in 2019. The value-added of the water sector has increased from RM3.5 billion in 2015 to RM4.5 billion in 2019 (a 29 per cent growth); the intermediate input in this sector increased from RM2.6 billion in 2015 to RM3.4 billion in 2019. The sector also increased employment from 16,113 in 2015 to 18,662 in 2019; and the salary bill jumped from RM633 million to RM749 million for the same period, respectively. While the nation has an abundant supply of water, the water industry experiences regular water disruptions due to old infrastructure and pipeline networks across the country. Many of the water pipelines date back to the 1960s and close to 44,000km of pipes today are due for replacement as a result of leakage of over 4.2 billion litres of treated water every day[2].

Moreover, unfettered industrial development, especially new industries polluting rivers caused major water disruptions due to contamination of the water supply[3]. Floods due to the annual monsoon seasons, water pollution due to intensive industrial activities, rapid urbanisation, and climate change[4] continue to pose significant challenges to the nation's water supply, especially in rural and remote communities. Many of the challenges are attributed to the fragmentation of the water supply networks and institutions, leakages in the system, and uncoordinated management of the water ecosystem. The problems are exacerbated by heavy reliance on old infrastructure and the lack of modern technology to monitor the upstream water supply and the development of effective water distribution networks to strengthen the downstream water subsectors. As such, the water industry in Malaysia continues to operate below its full potential and its real impact on economic development is underestimated.

Increasing demand for high-quality and secured water, escalating water supply issues, and mounting pressure to reduce government burden in water management have warranted the consideration of revamping the country's water ecosystem. This necessitates a re-examination of gaps in the current water ecosystem and the development of strategies and policies to create a sound and agile water ecosystem; one that can meet the changing needs of the population and the Malaysian economy. This study also examines key drivers both in the supply-side and demand-side of water strategies that are required to bolster existing industries, spawn new ones, and stimulate high-end water demand. All of which will result in the water sector contributing to the economic growth of the country.

1 Annual Economic Survey – Water Supply, Sewerage, Waste Management & Remediation Activities
2 Refer to Bernama (2018), Malay Mail (2016), and The Straits Times (2014)
3 Refer to Benjamin (2017), Bernama (2020), Hyde (2018), and Sharip et al. (2014}
4 Cosgrove and Loucks (2015)

3.0 Objectives

Managing the water resources as an economic sector will go a long way toward ensuring that this vital natural resource of the country is managed more effectively and efficiently to create optimal economic value for the nation. Effective management of water resources of the country will have a significant impact on the overall economic growth of the country. Water is an important revenue earner for the country and an essential driver of productivity for other key economic sectors of the nation. It also has the potential of creating jobs, especially high-income jobs, as the sectors move up the innovation value chain. Hence, this study will examine the water ecosystem that will raise the Return of Value (ROV[5]) to the Malaysian economy in a more holistic way. The objectives of the study are as follows:

- To examine the economic value of water to the Malaysian economy. In this context, we will estimate the economic value of this vital resource as a final product for the domestic and international markets; input for production processes for key economic sectors; and as a source of employment.

- To examine key challenges of transforming the water resources of the nation into a vibrant and value-adding economic driver for the Malaysian economy.

- To examine key strategies and policies that will transform the water sector into an important source of economic growth as a key revenue generator and enabler for other sectors to move up the global economic value chain (improve productivity and efficiency). In this context, this study will examine global best practices and case studies that will provide valuable insights into the formulation of a vibrant and competitive water sector.

4.0 Scope of the Sub-Sectoral Study

The scope of our study is developed based on the Terms of Reference for the EPU Study. Description of the scope and the related deliverables are outlined in the table below:

- **Scope 1**: Review and analyse current policies with a focus on improvement

  Deliverable 1: Using the 8i-framework for the water system, this study assessed both upstream and downstream industries. These include assessing the current state of the ecosystems and key blueprints of the ecosystem, that facilitate seamless integration of the different water ecosystems. A review and synthesis of past water-related studies and policies conducted by ASM will also be done as part of this deliverable.

- **Scope 2**: Undertake comparative strategy analysis/business models with other nations

  Deliverable 2: Detailed case studies documenting the water ecosystem of selected developed countries will be conducted and developed; focusing on the technologies, legislation, regulatory framework, and institutional arrangements supporting the water sector.

[5] ROV (Return on Value) is the value an organisation gains as a result of continuous improvement using new technology, systems, processes and new business models. The return on investment (ROI) is hence a function of ROV.

- **Scope 3**: Study the potential for the nation's water sector industry with consideration to current global markets trends in making the water sector a dynamic new economic sector capable of driving the nation's GDP growth in the future.

  Deliverable 3: Economic performance of Malaysia's water sector will be compared against those of major developed countries taking into consideration key factors including water quality and demographics profile.

- **Scope 4**: Prepare a transformation strategy and initiative implementation framework for each of the 4 Phases including the implementing agencies, estimated budgets, and main target achievements based on the analyses undertaken and expert reviews.

  Deliverable 4: In this deliverable, the 8i Framework characterising the water ecosystem in Malaysia and those countries included as part of the case studies will be re-mapped into the five pillars of integrated water resources management (IWRM).

- **Scope 5:** Undertake consultations with stakeholders and experts to finalise the proposed strategies and initiatives of the nation's water sector transformation

  Deliverable 5: Focus group discussions and interviews with stakeholders and development of case studies to examine key best practices in the water industry in Malaysia and across the globe will inform future strategies and policies that will enable the sector to move up the innovation and economic value chain.

- **Scope 6**: Prepare a complete roadmap for the national agenda on the Water Sector Transformation 2040 for the various ministries' and agencies' information and guide for the implementation of programmes and activities towards achieving the targeted transformation objectives

  Deliverable 6: Preparation of an integrated WST2040 roadmap towards achieving the targeted transformations which comprises detailed elaboration on the strategies, initiatives, programmes, and projects with the expected economic outcome.

5.0 Conceptual Framework to Characterise the Water Ecosystem and its Impact on the Economy

The water industry is characterised by multiple players and value chain and is outlined as follows:

- Upstream – supply of raw water from river, underground, and seawater

- Downstream – consists of the following:
  - o Primary sector – water extraction and harvesting (river, underground, and sea)
  - o Secondary sector (end-users of water) - which includes raw water and treated water that is used by food, energy, manufacturing, and agriculture sectors.
  - o Service sector – which includes water treatment, plants, and distribution network.

The tangible value and intangible value of the upstream and downstream sectors are assessed in this study. The tangible value includes economic value, while the intangibles include job creation, investment, development of networks, and other spill-over impacts that contribute to increasing economic value to the economy. The inter-linkages between the downstream industries are also examined in this study. In this context, the state of the upstream and downstream industries is assessed using the 8i-innovation framework, where key blueprints of the ecosystem include the following (as shown in Figure 1)[6] :

- *Infrastructure* – is the state of the physical infrastructure (treatment plants, dams, pipelines, logistic supply chains, and transportation) & natural infrastructure (rivers, oceans, lakes, and other groundwater sources) of the water supply and distribution network to deliver quality water supply to the various stakeholders in the economy.

- *Infostructure* – is the state of the digital infrastructure in the water sector that is, the use of advanced ICT, big data, and industry 4.0 technologies, and seamless integration of multiple digital and data analytic systems to manage the water resources efficiently.

- *Intellectual-capital* – is the state of the talent stock (general and specialised skills set and core competencies) in the water industry to transform the sector into a technology- and knowledge-driven sector, to enhance the ROV of the downstream and upstream of the water subsectors.

- *Integrity* – is the state of the governance systems at the federal, state, and municipal level that ensure seamlessly integrated implementation of strategic policies and initiatives to enhance efficiency and maximum economic value for all stakeholders in the economy. These governance systems ensure transparency and accountability.

- *Incentives* – is the level of fiscal and non-fiscal incentives to not only ensure water security but also maintain it as an important source of economic wealth for the country. These include support for research and development, innovation grants, access to state-of-the-art research facilities, tax incentives and subsidies, and other incentives to spur incremental and radical home-grown innovations in the water sector to enhance the competitiveness of the water sector, including competitive pricing systems.

- *Institutions* – is the availability of quality institutions at the federal, state, and local council levels (government, industry associations, community organisations, institutions of learning, and research institutions) that act as key enablers for the water industry to move up the innovation and economic value chain. These include the existence of sound regulatory architecture and standard boards that manage the water resources of the country efficiently and ensure transparency and accountability. These institutions use advanced technologies to manage complex relationships in the water sector.

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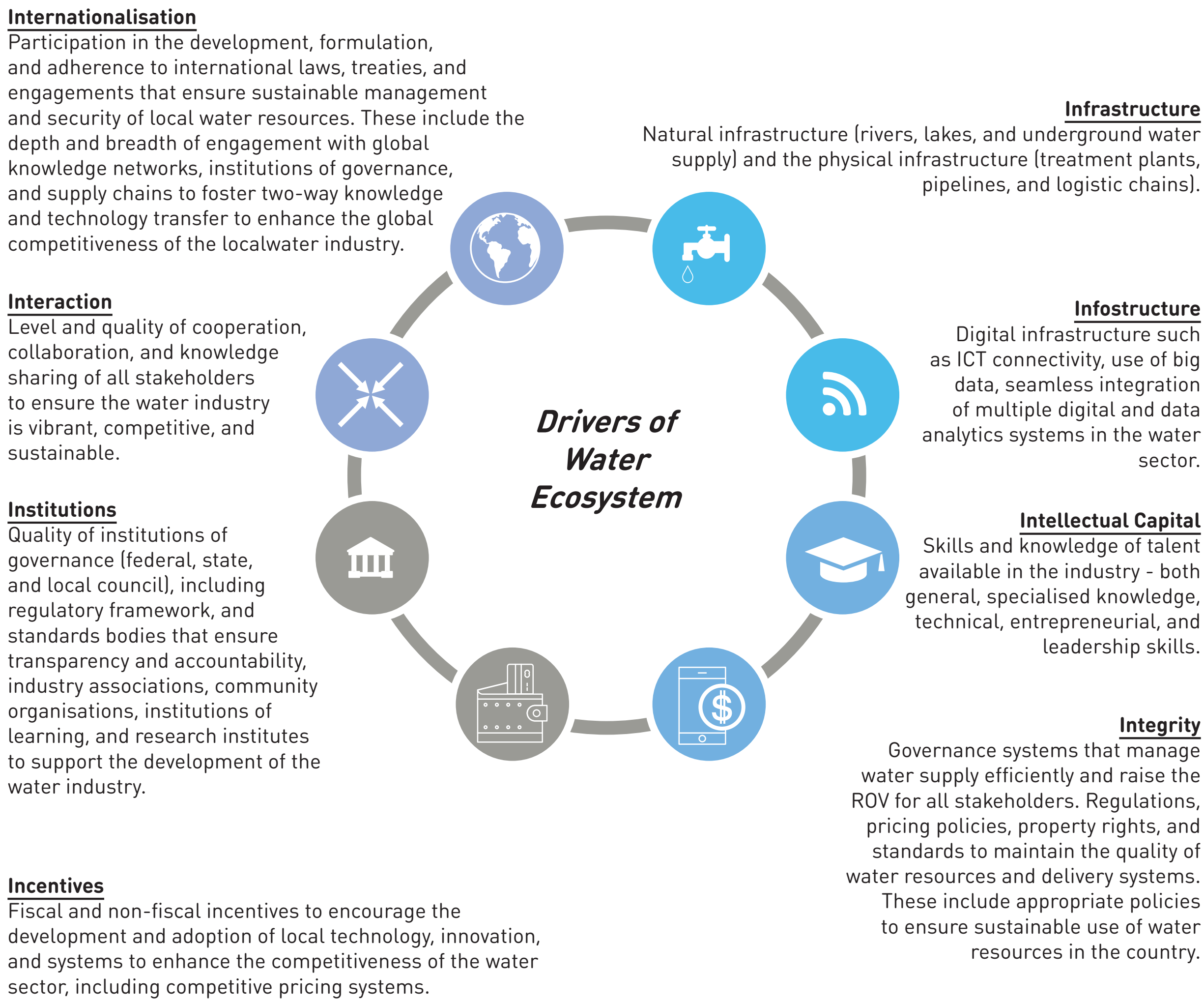
6 The 8i-framework was adopted for the water industry from Nair (2011).

- *Interaction (smart partnerships)* – is the level and quality of cooperation, collaboration, and knowledge sharing among the key institutions (federal, state, local councils, and community organisations) and economic agents (industry and industry associations), to continuously innovate and adopt new technology and systems to ensure economic value and competitiveness of the water industry.

- *Internationalisation* – International cooperation and collaboration to foster multi-lateral technology and knowledge transfer, expansion of market share, and being part of the global knowledge networks and supply chains. This includes participation in the development, formulation, and adherence to global best practices, international laws, treaties, and engagements that ensure sustainable management and security of local water resources.



Source: Framework by Sunway Institute for Global Strategy and Competitiveness (2021)

Figure 1: Framework to characterise the water ecosystem

Using the 8i-framework for the water system, this study assessed both upstream and downstream industries. These include assessing the current state of the ecosystems and key blueprints of the ecosystem, that facilitate seamless integration of the different water ecosystems. Identifying key factors that hinder the integration of the multiple water ecosystem and taking measures to close these gaps in these ecosystems will be critical for increasing the ROV of the water sector to all stakeholders in the economy and increasing economic value. Infusing the *8R-Water Philosophy* [7] in every facet of the *8i-innovation framework*, the national water plans and national development plans that utilise water as an enabler to move the current weak and fragmented water ecosystem to a vibrant and dynamic one:

Respect water;
Rethink the value of water;
Reduce wastage of water;
Re-Use used water;
Recharge groundwater;
Recycle waste-water;
Repurpose water for higher-value use; and
Regenerate water.

Thus, integrating the *8i-innovation framework*, which examines the importance of the enablers, and their endogenous interaction, interlinkages, partnerships, and collaborations will depend on the strength of the multiple players (Ai, Aj, and Ak[8]) in the ecosystem (see Figure 3). The transmission mechanism as shown in Figure 3 in terms of how the ecosystem has an impact on socio-economic development is highlighted and it shows that the enablers and inter-connection between the stakeholders are weak and fragmented, as shown in Figure 3.

Figure 2 shows that a sound water ecosystem will trigger the following transmission mechanisms that create systemic and sustainable development of the water ecosystem, reducing non-revenue water, improving the quantum and quality of water (reserve margins), and improving socio-economic development and economic growth potential of the country. A staged transmission approach is provided as the conceptual model to capture the linkages between the *8i-innovation framework, multiple stakeholder interaction, 8R-Water Philosophy,* and 10-10 MySTIE to move the current water ecosystem into a vibrant and sustainable water ecosystem.

STEP 1: Strengthening the institutional governance of the water sector at all levels (federal, state, and local council levels). This includes adopting a Whole-of-Government and Whole-of-Society approach to accelerate the implementation of the IWRM framework.

STEP 2: Foster a strong collaborative partnership among all stakeholders in the water ecosystem, which includes government agencies (federal, state, and local councils), industries, community organisations, civil societies, citizen scientists, and institutions of learning.

STEP 3: Strengthen the regulatory architecture, implementation mechanisms, tracking and monitoring, and ensuring a continuous improvement cycle is in place, including adherence to global best practices and outcomes reported transparently regularly.

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7 Adapted from the 8Rs of Recycling (Siegle, 2019)

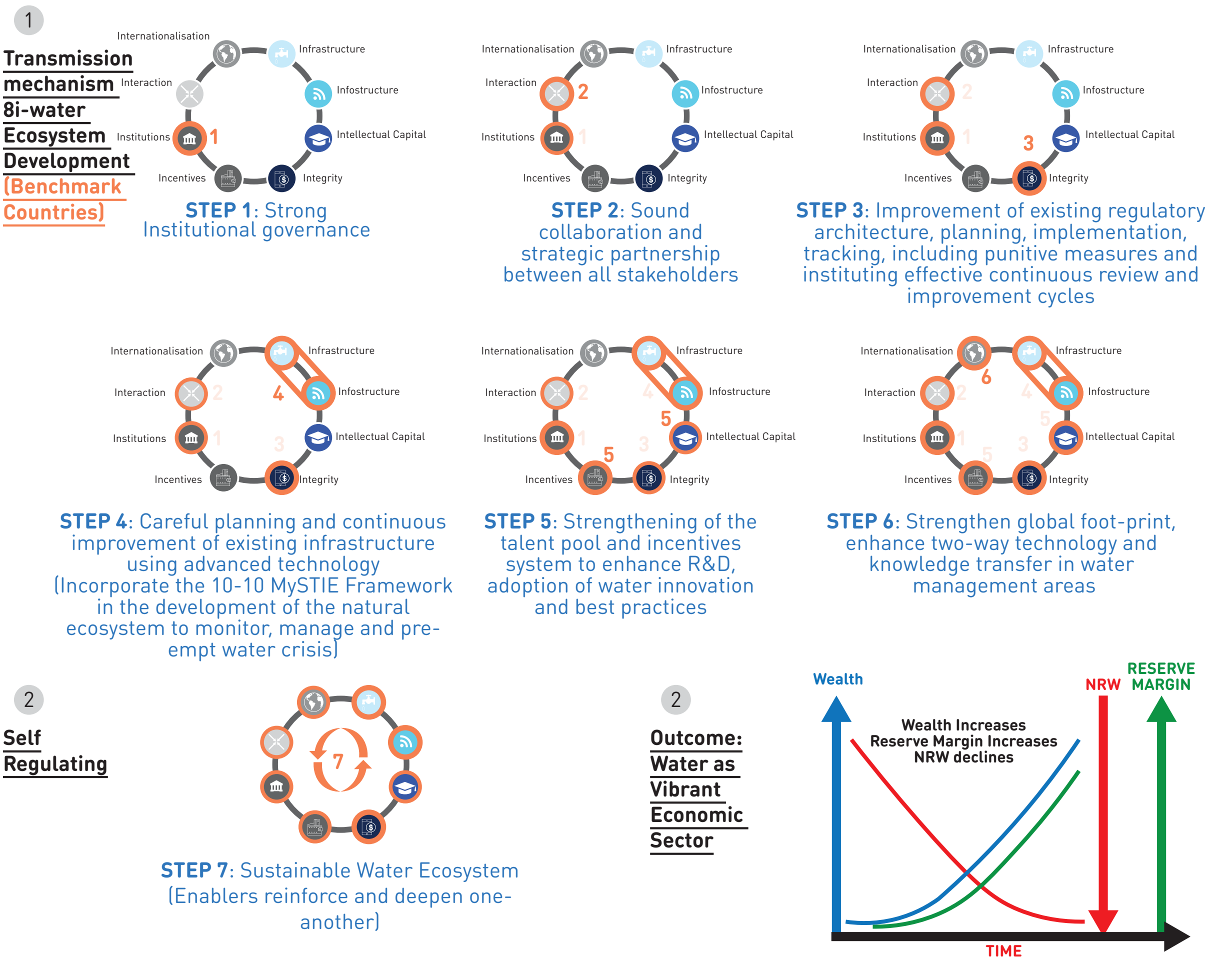
8 A_i, A_j, and A_k represent the different stakeholders within the water ecosystem

STEP 4: Careful planning and development of the water infrastructure using advanced technology and nature-based technology to ensure effective management of the water resources and supply chain across the country aligned to the 10-10 MySTIE framework.

STEP 5: Strengthening the talent pool and incentives for RDIC to be aligned to the technology development strategy, and ensure the continuous development of talent and incentive system to deepen the infrastructure development and vice-versa.

STEP 6: A strong water ecosystem due to the implementation of STEPS 1 to 5 will place the water ecosystem in a good position to strengthen international collaboration and partnerships that will foster two-way knowledge- and technology transfer, enabling the water sector to move up the regional and global water supply chain.

STEP 7: Continuous development of the enablers of the water ecosystem (8i-enablers) will lead to a sustainable and dynamic water sector that will reduce non-revenue water (NRW), increase reserve margin, and increase the contribution of the water sector to the Malaysian economy.



Source: Framework by Sunway Institute for Global Strategy and Competitiveness (2021)

Figure 2: Systemic Sustainable Water Ecosystem Transformation

With the establishment of the first 6 steps, a self-generating and self-sustaining water ecosystem has the high potential to allow public-private partnerships to be achieved. At this stage, sustainable development of the water sector will increase the competitiveness of other sectors of the economy that is dependent on water. Underpinning the water ecosystem transformation are the 5Ss which needs to emphasise the following:

Safety – implies the technology used is per global best practices, standards, and regulations that ensure safe use for all stakeholders.

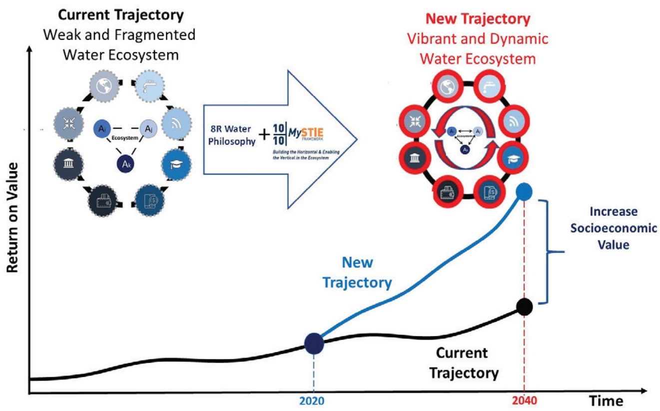
Security – where the nation needs to secure water as a resource and as a livelihood that satisfies basic community needs, economic opportunities, and advanced industry needs. Appropriate security protocols and measures need to be in place. Water security is designed to ensure safe use in all aspects of water, ranging from everyday water use to transboundary water-related conflicts that may arise over water with water scarcity becoming one of the greatest challenges globally.

Safeguards – where water resources are managed properly to ensure sustainable water supply for future generations.

Seamless integration: to ensure strong seamless institutional governance is in place, complemented with a comprehensive regulatory architecture to ensure sustainable development of the water sector. This means that there should be a collaborative common platform where people and stakeholders can work together towards incorporating the 8R water philosophy, thus fostering public-private-community partnerships.

Sustainable: implies the use of our water resources in a balanced manner to provide adequate water quantity and quality for multiple needs without compromising on future needs. The enablers of the water ecosystem are developed to create positive spillover across the different sectors of the economy and regions in the country.

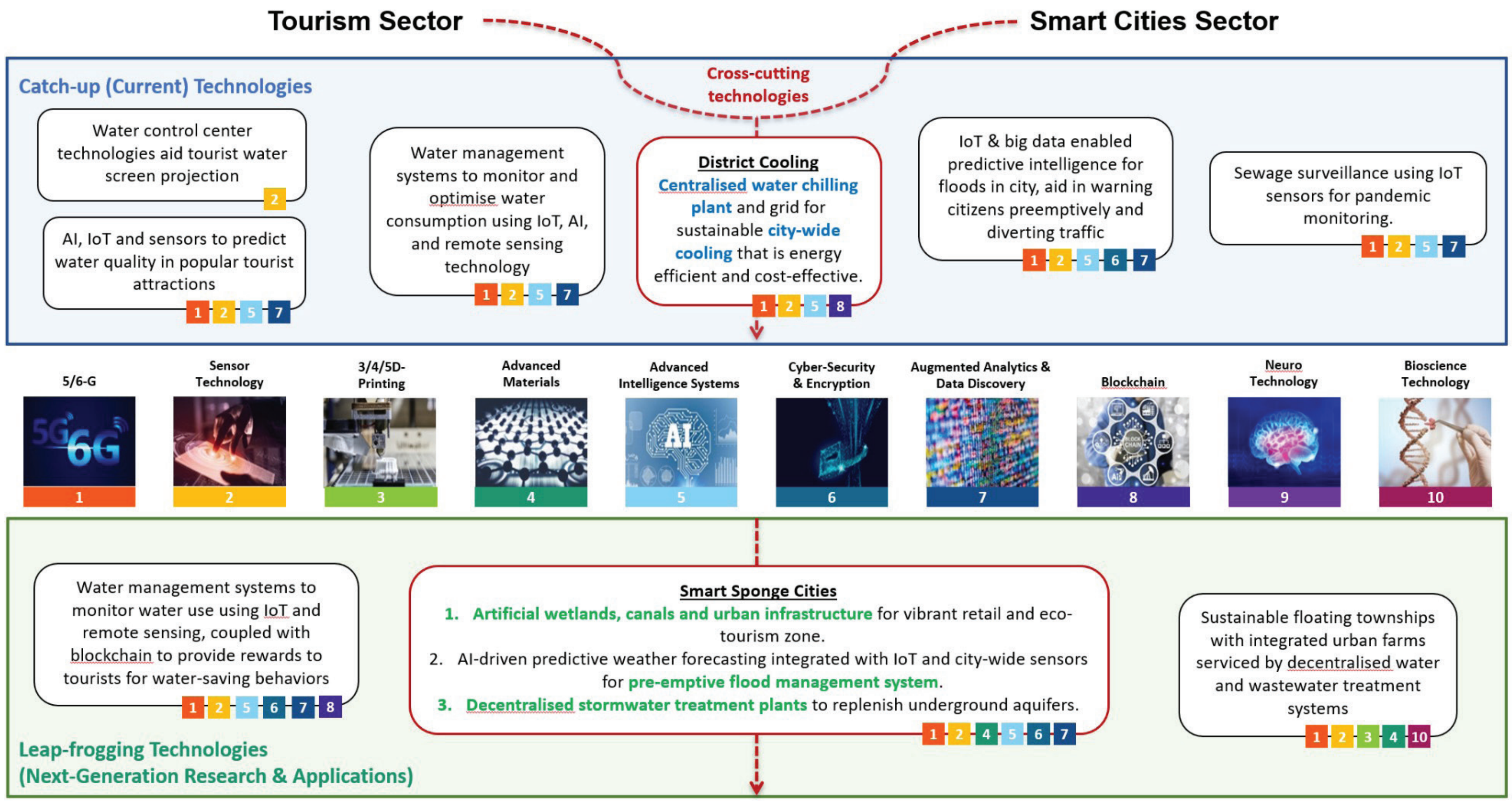
The above 5Ss are critical for a dynamic water sector that is driven by the **STIE Ecosystem Approach** (8R Water Philosophy and 10-10 MySTIE Framework).



Source: Framework by Sunway Institute for Global Strategy and Competitiveness (2021)
Notes: The ecosystem entails various economic agents that are represented by the Ai, Aj, and Ak and the interaction between them is denoted by the connecting lines. In the case of the weak and fragmented ecosystem, the interconnecting line between these economic agents is denoted as dotted lines. Whereas the vibrant and dynamic ecosystem is represented by solid lines. In the context of the weak and fragmented ecosystem, the interactions between the economic agents are weak and this results in weak inter-connectivity between the eight enablers, hence the ecosystem is unable to derive a multiplier effect to the water ecosystem. On the other hand, in the vibrant and dynamic ecosystem, the inter-linkages between the economic agents and enablers are strong, resulting in sustainable development in the water ecosystem. This will lead to an increase in the socio-economic value of the water sector.

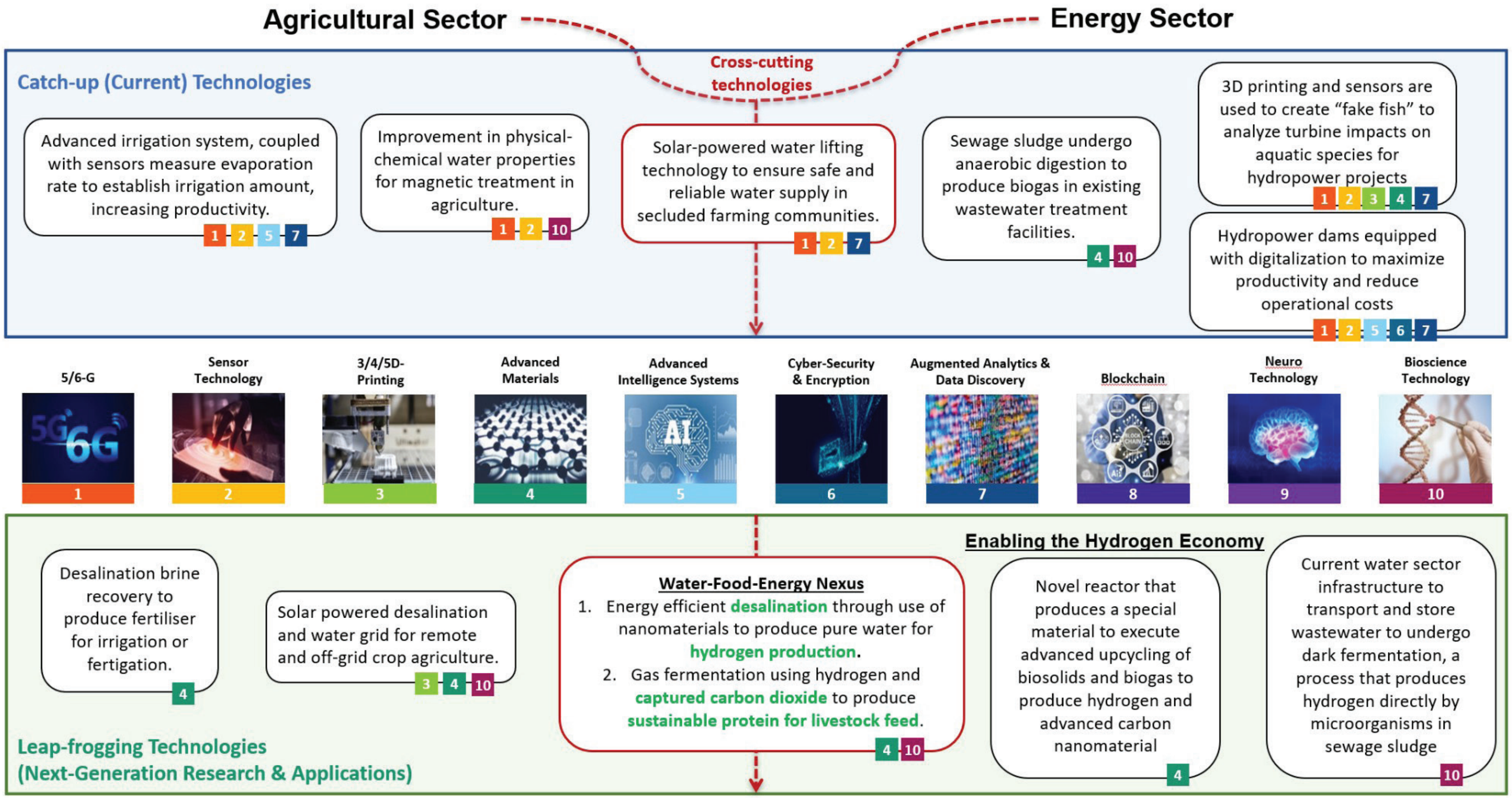
Figure 3: WST2040 - Transition Towards a Vibrant & Dynamic Water Sector

The 10-10 MySTIE ecosystem provides a blueprint for the application of technologies in key socioeconomic drivers of Malaysia. In Figures 4 and 5, the potential technologies in use and development in advanced countries have been mapped out to illustrate the impact of a technology-enabled water sector. These applications can have significant cross-sectoral synergies as well, enhancing the economic and welfare value of other socioeconomic drivers.



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021)

Figure 4: Application of the 10-10 MySTIE Framework corresponding to the Water Sector, for Tourism and Smart Cities Sector



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021)

Figure 5: Application of the 10-10 MySTIE Framework corresponding to the Water Sector, for Agricultural and Energy Sector

Agricultural Sector

Catch-up Technology

1. Advanced irrigation system, coupled with sensors to measure evaporation rate to establish irrigation amount, increasing productivity

Utilising digital technologies to monitor micro-climate and soil moisture provides a simple and effective solution to enhance irrigation efficiency. The enhancement of irrigation efficiency not only conserves water and energy but also improves the amount and quality of yield (Tabarelli, 2020). Specifically, sensor technologies are used to obtain information such as water infiltration rate (i.e., to ensure adequate drainage), crop water uptake (i.e., measured by soil moisture sensors), and evapotranspiration rate (i.e., tracked and calculated by the weather station, which record measurements of temperature, wind speed, humidity, and solar radiation sensors; see Croptracker [2021] for more information on weather station mechanisms). Combined with a clean water source and conveyance system, irrigation scheduling can then be performed.

With access to important information such as daily water balance (i.e., derived from inputs such as precipitation, evapotranspiration, and irrigation data) and weather information from satellites, crop yields can be maximised (Tabarelli, 2020). For instance, corn requires ample moisture and minimal water stress within the active root zone to produce maximum yield – i.e., studies have shown that diminishing root zone moisture stress can improve corn yield by 10 to 25%. Hence, to produce optimal results from irrigated crop production, irrigators must be able to calculate water loss amounts from the root zone (Tabarelli, 2020). This is to deduce the optimum volume of water to be applied at the subsequent irrigation. With the ability to obtain, calculate, model, properly time, and execute irrigation schedules, crop productivity can be maximised.

2. Improvement in physical-chemical water properties for magnetic treatment in agriculture

Besides reducing the amount of irrigation water needed, magnetic water treatment (MWT) is effective in improving crop yield, as well as enhancing soil quality and controlling erosion rate (Ali, Samaneh, Kavakebain, 2014). In essence, the magnetic treatment of water restructures water molecules into smaller clusters (i.e., into six symmetrical organised molecules), which is vastly different from the original form (i.e., a looser and more chaotic organisation form). In addition to enabling an easier passageway into plant cell membranes, magnetic water (MW) is a bio-friendly compound for plant cells as its packed structure does not allow the entry of toxic agents.

These benefits have been demonstrated in empirical studies – for instance, in addition to promoting water productivity, studies have shown that MWT has beneficial impacts on plant growth, especially at the rate and yield of seed germination (Ali et al., 2014). For example, MWT was found to increase both celery yield and water productivity by 12%. In addition, due to its magnetic susceptibility, soil with MW has a higher amount of soil phosphorus content. Phosphorus is a vital nutrient in plant health and growth, promoting important aspects such as root development, stalk, stem strength, resistance to plant diseases, etc (Mosaic, 2021).

3. **Solar-powered water lifting technology to ensure safe and reliable water supply in secluded farming communities**

Solar-powered water lifting technology allows communities in the most secluded areas to access water for both daily and agricultural uses in both a sustainable and affordable manner (Practical Action, 2021). Solar-powered pumps to transport water from rivers to solar-equipped local reservoirs. Solar energy is then converted into electrical energy via generators, powering electric motors in water pumps to carry out water lifting.

The importance of solar-powered water-lifting is reflected in the rural farming communities in Nepal (Practical Action, 2021). Even in the most remote, off-grid mountainous regions in Nepal, these pumps enable the distribution of water to community reservoirs, which is critical to ensure the survival of crops, especially during the dry season. To ensure the proper functioning of the water pumps, a committee is established for each set of solar pumps to carry out continuous monitoring (Practical Action, 2021). In addition, each local community is engaged in the "Pay for Water Scheme", where every household provides a small fee to maintain the water pumps.

Leap-frogging Technologies

4. **Solar-powered desalination and water grid for remote and off-grid crop agriculture**

Enhancement of performance and efficiency of solar-powered desalination will greatly benefit agricultural activities in developing regions, especially in remote areas where electricity is scant, but seawater and sunlight are ample (Chandler, 2020). With the severe decline of water resources around the globe, seawater desalination has gained increasing popularity as it is regarded as one of the most effective solutions to address water scarcity (Xu et al., 2020). Coupled with simple configuration and the flexibility of off-grid operations, Passive solar desalination systems are especially attractive to developing regions with abundant sunlight and seawater. Nonetheless, the high costs involved in the desalination infrastructure, as well as the large area requirements from low conversion efficiency (approximately 35% from solar energy to water) pose a great hindrance to the adoption of such technologies in developing regions. Using inexpensive and readily available materials (e.g., paper towels as a capillary wick to get water into contact with solar absorbers), researchers from MIT and Shanghai Jiao Tong University in China are developing a highly efficient solar desalination plant (Chandler, 2020). As the system utilises each stage to desalinate water – i.e., the heat released at each stage is harnessed instead of waste, the device can demonstrate a solar-to-vapour conversion efficiency of 385% (Xu et al., 2020). This project shows great promise as it exhibits great possibility in elevating the performance of existing passive solar desalination, which produces affordable water that can be utilised for irrigation.

5. **Desalination brine recovery to produce fertiliser for irrigation or fertigation**

In the face of an emerging freshwater crisis, the use of desalination technology to produce potable water is becoming an increasingly common usage (El Zayat, Nasr, & Sewilam, 2021). Nonetheless, a significant drawback of desalination is the production of residual brine as a by-product, which can comprise up to one-fourth of the total collected water (European Commissions, 2021). Brine is a saline solution that has chemical compositions and concentrations that differ based on the water source and quality, as well as plant recovery; however, most brine consists of toxic contaminations such as high concentration nitrates and pathogens (Bello, Zouari, Da'ana, Hahladakis, & Al-Ghouti, 2021; European Commissions, 2021). Using the double reverse osmosis process, the EU-funded LIFE DESIROWS project aims to eliminate nitrates in water to be reused for irrigation, as well as recycle brine salts to be used as fertilisers in agricultural activities (HRS Heat Exchangers, 2021; Life Desirows, n.d.). In addition to contributing to a circular economy, the entire process will be carried out using photovoltaic solar energy and biomass energy, both of which are renewable resources (Life Desirows, n.d.).

Energy Sector

Catch-up Technologies

6. Sewage sludge undergoes anaerobic digestion to produce biogas in existing wastewater treatment facilities

Anaerobic digestion is an integral process of waste management. This technology is oftentimes integrated within existing wastewater treatment facilities, where microorganisms break down wastewater solids (i.e., sewage sludge, manure, and food) to produce biogas (i.e., the mixture of gases such as methane and carbon dioxide; United States Environmental Protection Agency, 2021a, 2021b; University of Florida, 2019). Biogas is an important resource used to generate electricity; not only is it environmental-friendly because it does not contribute to greenhouse emissions, but the use of biogas also reduces energy costs as the electricity-powered is re-used for operations at the facility (University of Florida, 2019). In addition, a portion of the energy produced is sold to the utility grid to generate profits (the United States Environmental Protection Agency, 2021a).

7. Hydropower dams equipped with digitalisation to maximise productivity and reduce operational costs

Digitalisation is becoming an integral element in the hydropower industry, as it greatly aids in maximising performance, reducing costs, and optimising asset management (International Water Power, 2020). Hydropower is currently the largest renewable source, generating two-thirds of global renewable electricity (Agostini, Corbetti, Ogbonna, & Stark, 2020). There are a few areas where AI, IoT, advanced analytics, and remote sensors are aiding to maximise the potential of hydropower plants: (i) automation of generation planning calculations using data on external (e.g., forecasts on water inflow and weather) and internal factors (e.g., reservoirs level) to optimise energy production and bidding, (ii) automation and enhancement of operations and management processes (e.g., maintenance automation and asset monitoring) to reduce maintenance costs and maximise efficiency gains, as well as (iii) real-time monitoring and inspection of remote areas within hydropower plants to elevate defence from possible attackers (Agostini et al., 2020; Alarcon, Malagon, & Snyder, 2018).

8. 3D printing and sensors are used to create "fake fish" to analyse turbine impacts on aquatic species for hydropower projects

Sensors and 3D printing technologies play useful roles in aiding the conservation of aquatic lives at hydropower dams. While hydroelectric energy is an extremely valuable resource, the change in water pressure, turbulence, as well as blades on turbines may result in injuries to the nearby aquatic population, especially when the fishes pass through the dams (Oak Ridge National Laboratory, 2020). To analyse the impact of hydroelectric dams on nearby fishes, scientists from the Pacific Northwest National Laboratory have designed plastic "sensor fish" to measure the fishes' stresses and strains when swimming through dam machinery (McCormick, 2014). Licensed in 2019, the manufacturing process of the sensor fish is streamlined, enabling access and utilisation from more hydropower operators and researchers (Mraz, 2019). In 2020, researchers from Oak Ridge National Laboratory have incorporated the use of 3D printing into the design of sensor fishes, as it is a fast and inexpensive option to allow the creation of diverse fish models within a short period (Oak Ridge Laboratory, 2020).

Leap-frogging Technologies

9. Novel reactor that produces a special material to execute advanced upcycling of biosolids and biogas to produce hydrogen and advanced carbon nanomaterial

This novel process not only provides an efficient, sustainable, and cost-effective approach to hydrogen production but also supports the formation of a circular economy. Researchers from RMIT University have invented a technology that utilises a special material derived from biosolids (i.e., solid organic matter recovered during the wastewater treatment process) to spark chemical reactions that convert biogas into hydrogen (RMIT University, 2020; the United States Environmental Protection Agency, 2021). In this process, the reactor invented and patented by RMIT University catalyses biosolids into a carbon nanomaterial-coated biochar (RMIT University, 2020). In addition to being an efficient catalyst in decomposing hydrogen from biogas, the special carbon-nanomaterial-coated biochar can be converted into high-value advanced carbon nanomaterials, which can be used to boost agricultural soils, as well as for energy storage. As a whole, this process provides several benefits: (i) it enables the upcycling of unlimited waste resources into high-value products (i.e., circular economy), (ii) avoids the need for pricey metal-oxide based catalyst, (iii) as well as supports the production of hydrogen, a clean and renewable energy source (Patel et al., 2020). As of 2020, the process was undergoing trial in a pilot plant supported by RMIT's Enabling Capability Platforms and South East Water (RMIT University, 2020).

10. Current water sector infrastructure to transport and store wastewater to undergo dark fermentation, a process that produces hydrogen directly by microorganisms in sewage sludge

In the dark-fermentation method, bacteria such as Clostridium thermocellum decomposes organic matter to produce hydrogen (Aquatech, 2020). This is different from the other green hydrogen production processes – while the aforementioned processes typically entail a metal catalyst (e.g., iron ore) in the decomposition process, the current method utilises microorganisms to directly produce hydrogen, without the aid of any metal catalysts (Aquatech, 2020). As of 2020, research efforts were still ongoing to optimise this process – e.g., establish the types of bacteria that would best suit this fermentation process and the optimal conditions to promote hydrogen production. While the processes and dynamics of dark fermentation are considerably complex, it is deemed as a promising alternative technique to produce hydrogen from sewage sludge (Detman et al., 2021).

Tourism Sector

Catch-up Technologies

11. Water control centre technologies aid tourist water screen projection

Water control centres can be used as platforms to aid water screen projections in tourist destinations (Laservision, 2020). With the main screen size of close to 900 square meters, the water screen projection in Dubai City Festival set the Guinness World Record for the "largest water screen projection" in 2017. The floating platform that houses the water screen projection is the principal location for water technology pumps, filtration, sanitation, and control systems (Laservision, 2020). Besides the utilisation of LED lighting, laser system, projectors, and audio technologies, water screen projections also utilise optical sensors, a technology that converts light rays into electronic signals (Elprocus, n.d.; Water Show, 2020).

12. Water management systems to monitor and optimise water consumption using IoT, AI, and remote sensing technology

Water management systems aided with IoT, AI, and remote sensing technology can greatly assist in reducing water consumption, whilst decreasing cost, and contributing to environmental sustainability . In addition to IoT-equipped water meters, smart bathrooms with smart showers are used to monitor water consumption and provide tailored water flow control that generates significant utility savings (Global Banking and Finance Review, n.d.; John, 2019; Youssef & Zeqiri, 2020). IoT and machine learning algorithms are also used to identify users' showering behaviours, who are then notified and nudged to reduce showering duration (Youssef & Zeqiri, 2020). A study on the aforementioned technology has indicated a reduction in real-time showering duration by 12.06% or 6.14 litres of water (Pereira et al., 2019, as cited in Youssef & Zeqiri, 2020). This is important as showering is the principal source of water consumption – approximately one-fourth of the total water consumed in hotels per month can be attributed to showering (Youssef & Zeqiri, 2020). In addition to being the largest consumer of water in tourism accommodations, showering and bathing are also extremely energy-intensive. Overall, these technologies are useful in aiding the reduction of overall utility costs for hotel operators.

13. AI, IoT, and sensors to ensure high water quality in tourist destinations

Currently, the Wadden Sea coast is almost entirely preserved as a national park and nature reserve; with the aid of digitalisation, the Wadden Sea serves as an example of a well-managed tourist destination – it generates vital income for the local population while simultaneously contributing to sustainable tourism (Prokosch & Luczak, 2016; Wadden Sea World Heritage, n.d.a). Home to various plants and animal species, the Wadden Sea in Denmark is the final remaining large-scale, intertidal marine system where natural processes remain largely undisturbed (UNESCO, 2021). Due to its unique structure (e.g., wetlands and mudflats) and the various flora and fauna available (i.e., over 10,000 species), the Wadden Sea is a popular destination for tourists around the world (Wadden Sea World Heritage, n.d.b). According to Prokosch and Luczak (2016), the Wadden Sea has approximately 10 million tourists and 50 million overnight stays per

[9] Some Malaysian firms have started incorporating sustainability practices into their operations. However, adoption rates are still low and there are still issues with incentives and regulatory consistency (WES Focus Group Discussions, 2021)

year, generating three to five billion euros in a year. However, as the rise of tourism often leads to pollution and waste problems, the use of interventions to monitor and protect the Wadden Sea and its nearby environment is imperative (The World Counts, 2021).

To accurately monitor the water quality of the Wadden Sea, IoT, sensors, and AI are deployed in Citclops Data Explorer to predict optical water quality indicators (Cecaaroni et al., 2018). Optical water quality indicator (i.e., detect water quality change through visual appearance of water bodies) enables larger areas of water bodies can be monitored in repeated time intervals, which in addition to reducing cost, also provides good potential for automation (Graf, 2020). In Citclops Data Explorer, the AI technique of inductive learning is used to analyse data from Earth-observation systems, citizens, scientists, coastal planners to generate tailored predictions of watercolour seven days ahead (Cecaaroni et al., 2018). Specifically, decision trees are used in the learning process. With this AI-induced technology, prompt mitigation actions can be taken; this way, not only can the negative environmental effects be reduced, but tourists' experience and satisfaction can also be maximised, especially in activities such as recreational boating and diving (Cecaaroni et al., 2018).

14. District cooling: centralised water chilling plant and grid for sustainable city-wide cooling that is energy efficient and cost-effective

With the rapid climate change, not only are summers getting hotter, but also more enduring – for instance, according to a recent study, summers in the Northern Hemisphere could persist up to 6 months by 2100 if global warming continues to develop at the current rate (Chow, 2021). As hotter weather is simultaneously accompanied by enhanced air conditioning demand and usage, there is an acute need to turn away from traditional air conditioning technology, as it is a major contributor to greenhouse gases (Perla, 2021). Furthermore, in addition to day-to-day lives, the rise of tourism also entails higher consumption of energy (Nepal, Irsyad, & Nepal, 2018). Thus, district cooling is rapidly adopted in countries around the globe – for instance, the use of district cooling in Europe is projected to escalate by 72% between 2016 and 2030 (Al-Noaimi, Khir, & Haouari, 2019). As an example, Munich utility Stadtwerke München in Germany has recently invested EUR 87 million to expand its district cooling network in Sendling to the inner-city (Radowitz, 2020).

A district cooling system (DCS) is a sustainable, efficient, and cost-effective method of supplying air conditioning. In essence, a DCS comprises three components: central chiller plants (also houses water and treatment system to carry out water circulation, which is important to prevent equipment fouling), a chilled water distribution network, and consumers' substations; cool thermal energy is distributed from central production plants – where cooling medium such as chilled water is generated – to consumer buildings through a piping network (Al-Noaimi et al., 2019; Araner, 2021). The cooling energy is then withdrawn using an energy transfer station to enable space cooling (Al-Noaimi et al., 2019). Cooling grid further extends the functionality of district cooling system: with thermal energy storage (TES) technologies, a variety of renewable or clean energy can be used to power the district cooling system, ensuring sustainability and flexibility based on the availability of energy sources (Al-Noaimi et al., 2019; Perla, 2021). By effectively harnessing the newest TES, DCS can diminish power demand for cooling during peak hours by up to 40% (i.e., compared to conventional systems; Perla, 2021). As clusters of the building are usually incorporated within a DCS, it makes it more energy and cost-efficient (Energy Land, 2021). Importantly, it also supports a circular economy, like seawater, river water, and even treated sewage effluent can be used to execute the heat rejection process (Araner, 2021; Perla, 2021).

Leap-frogging Technologies

15. Water management systems to monitor water use via IoT and remote sensing, coupled with blockchain to provide rewards to tourists for water-saving behaviours

With the aid of IoT and sensors, blockchain technology holds great potential in ensuring sustainability in tourism. A study by Thakur and colleagues (2021) proposed a blockchain-based incentive model with soft computing techniques (i.e., artificial neutral networks) to minimise water wastage among house owners. Specifically, this framework entails the use of blockchain with edge computing (EC). In essence, EC is a process of collecting, filtering, processing, and analysing data that is executed closer to [or ideally, at] the location where data is generated instead of the client endpoint (Bigelow, 2021). The benefits of EC not only include a faster and more effective response compared to the traditional computing paradigm, but also the ability to provide more autonomy (e.g., restricted connectivity at remote sites) and better data sovereignty. Nonetheless, as IoT devices can be relatively insecure, EC deployment with proper device management such as security in computing and storage resources with emphasis on encryption is cardinal (Bigelow, 2021). By paring EC with blockchain, which is oftentimes described as an "immutable database" where a central authority and third-party verification is not warranted, the issue of security can be resolved while the benefits of EC can be reaped simultaneously (Knirsch, Unterweger, & Engel, 2019, p. 2; Luo, Xu, Li, & Wu, 2020). Thus, these technologies allow sensors and IoT devices at the house nodes themselves to compute rewards based on the preceding time series data and act as a secure predictive reward system for water-saving behaviours. In a similar vein, a concept paper by Tyan, Yagiie, and Guevara-Plaza (2020) proposed the use of blockchain technology to support the creation of a cryptocurrency-based reward system. The goal of this proposed system is to allocate rewards to tourists for sustainable behaviours (e.g., the act of saving water and energy in accommodation premises) within a predetermined period (Tyan et al., 2020). While this study did not further elaborate on the mechanisms to carry out the reward system, further research could be carried out to examine ways to incorporate the process suggested by Thakur and colleagues (2021) in hotel accommodations, which can promote water-saving behaviours among tourists, as described by Tyan and colleagues (2020).

Smart Cities Sector

Catch-up Technologies

16. IoT and big data-enabled predictive intelligence for floods, aid in warning citizens preemptively and diverting traffic

Smart water technologies are a critical component in building a strong and resilient community. With the utilisation of technologies such as IoT-enabled sensors, smart water technologies or systems enable the collection, dissemination, and analysis of water equipment and networks (Miller, 2020). In Virginia Beach, the collection and sharing of sensor data allow the forecasting of floods – using street-level hydrodynamic modelling, information collected from sensors and crowdsourcing enable city officials to forecast floods from storm surges, rain, and sea tides up to 36 hours beforehand. This allows transport departments to pre-emptively provide warnings about forthcoming inundation and divert traffic accordingly (Hitachi, 2021).

17. Sewage surveillance using IoT sensors for pandemic monitoring

The benefits of smart water technologies extend to the epidemiology field, providing valuable resources to health officials in addressing public health challenges (Goldfarb, 2020). Specifically, IoT-enabled sensors allow the detection of anomalies in municipal systems – in addition to leaks and pollutants, these technologies can be utilised to detect traces of viruses in wastewater. For instance, through these technologies in sewers, Italian scientists were able to discern the arrival time of the COVID-19 virus – through the sewage samples gathered from Turin and Milan, they found that the virus was already present in Italy in December 2019, which is much earlier than previously presumed (Goldfarb, 2020). Not only can these technologies in sewers assist health officials in discerning the full degree of an outbreak; by identifying infection hotspots, they enable a targeted and localised response, which can potentially avoid the implementation of sweeping lockdown measures (Goldfarb, 2020; Minsky, 2020).

Leap-frogging Technologies

18. Sponge cities (e.g., China)

Sponge Cities were initiated in 2014 by the central government of China, with the central aim of reducing the risk of natural disasters and improving water availability in urban settlements and – i.e., to achieve the goal for "70% of rainwater [to]… be soaked into the underground instead of … discharged into the nearest rivers and lakes" (Winkless, 2021, para. 8). In essence, this project combines the use of nature-based solutions and grey infrastructure to retain run-off, which would be reused subsequently (Local Governments for Sustainability, 2017). In particular, nature-based solutions such as green roofs, pervious pavements, bioremediation, urban and peri-urban wetlands are utilised to improve water permeation, retention, storage, purification, and drainage. Importantly, these enhanced greenery sceneries also serve as attractive tourists destinations, which further promote tourism within the city (Zhou & Penning-Rowsell, 2021). As of 2017, 30 sponge cities were piloted across the country (Gill, 2021). These pilot programmes demonstrated several implementation challenges that may impede its implementation, such as governance issues, uncertain financing, and difficulty in implementing some of the proposed designs. However, this is understandable as sponge cities are a concept ahead of their time; with proper solutions, this concept will resolve some of the major water challenges in the present time (Gill, 2021).

19. Sustainable floating townships with integrated urban farms serviced by decentralised water and wastewater treatment systems

The concept of floating townships is proposed as one of the innovative solutions in the face of rapid population growth, as well as climate change, and rising sea levels, especially in coastal cities and low-lying countries (Allen, 2021). The conception of these townships rests on self-sufficiency and sustainability – to enable individuals "to live sustainably across the nexus of energy, water, food, and waste" (Oceanix, 2018a, p. 1). For instance, a variety of renewable energy sources will be employed to fulfil the energy needs of floating townships, such as solar panels, tidal/current generators, and wind turbines (Oceanix, 2018c). In addition, residents would produce their food both above (e.g., using aquaponics and aeroponics) and below the surface (e.g., underwater cages to grow kelp and capture seafood; James, 2019; Oceanix, 2018b). To combat the issue of freshwater scarcity, SeaPods by Oceanix will utilise desalination to produce potable water (Oceanbuilders, n.d.a). Moreover, a solid waste incinerator is in the midst of development; the function of this incinerator is to convert toilet waste into non-toxic ash, while the liquids will be sent to a blackwater storage tank for additional treatment or periodic removal (Oceanbuilders, n.d.b). Finally, to reduce excess water consumption during showers, the team at Oceanbuilders are working with ShowerLoop to develop a continuous 3-step water filtration process, which would reduce water usage during showers by up to 90% (Oceanbuilders, n.d.c.).

The innovations discussed above leverage discoveries made by local scientists in the bioscience technology and intelligent systems of these natural ecosystems across their respective countries. While the list of technologies provided in Figures 4 and 5 are not exhaustive, the 10-10 MySTIE provides opportunities for the development of a wide range of recombinant innovations that can value-add to the water sector, and spawn new local tech industries in the water and aqua sectors.

These new recombinant technologies have the potential of raising the dynamic capabilities (absorptive, adaptive, and innovative capabilities) of the water sector, which in turn will raise process improvements and product developments within the sector, including the adoption of the home-grown innovations. This will also increase the competitiveness of the water sector and enhance economic spillover the impact to other sectors such as the food sector, culture arts & tourism, smart cities, and transportation. All of which are dependent on the water sector. To harness the full potential of the advanced technology in deepening the impact of the water ecosystem on the socio-economic development of the country, the enablers of the water ecosystem need to be carefully curated and developed.

An additional key aspect of water sector transformations in other countries is the exploration and experimentation with nature-based solutions. It is crucial to balance the transformation of the water sector into a dynamic economic sector with the health and sustainability of the water ecosystem. As highlighted in the Science Outlook 2020 report (ASM 2021), Malaysia has historically prioritised economic progress over environmental and societal progress. To protect, restore, and promote the health of the water ecosystem and the communities dependent on it, it is important to promote the utilisation of natural and community-based solutions.

Nature-based solutions (NBS)

There has been a growing convergence of interests around NBS in the past decades across the globe, especially in developed countries. NBS plays an important role in preserving, managing, and restoring the health of water and the environmental ecosystem. Specifically, they utilise natural processes to address contemporary water management challenges such as water quality and availability, as well as water-related disasters and climate change. A key feature of NBS is that they tend to deliver groups of ecosystem services in tandem, despite only one being targeted specifically by the intervention, hence oftentimes addressing several challenges simultaneously. In many developed countries, advanced technology and innovations as outlined in the 10-10 MySTIE are used to enhance the NBS to derive a better return on value (ROV) from the natural ecosystems. The following examples will illustrate some of the NBS carried out in different countries.

Gorla Maggiore Water Park, Italy. Inaugurated in 2013, the Gorla Maggiore Water Park located in Gorla Maggiore, Lombardy is an urban wetland developed based on NBS (Urban Nature Atlas, 2020). Its main goals are to shield the city against flooding, improve water quality, expand biodiversity, as well as to derive some social co-benefits (Oral et al., 2020). The park comprises of three different sections that serve distinct functions: (i) area with water grid, sedimentation tank, and vertical subsurface flow wetlands to remove pollutants, (ii) surface flow wetland that serves as pollution retention, flood buffer, and recreational zone, and (iii) a recreational park with restored riparian trees, beautiful green open spaces, cycling paths among others. Extensive use of bioscience technology and intelligent technology outlined in the 10-10MySTIE framework have been used to address some of the natural disasters and embellish the value of this ecosystem to society and the economy. A study has shown that the outcomes (i.e., costs and performance) of the park are close to or even more superior than those of grey infrastructure (Masi et al., 2017, as cited in Oral et al., 2020).

Sponge Cities, China is an NBS that was initiated by the Chinese government to address issues related to water access to urban communities and at the same time mitigate risks to the water sector due to natural disasters. The initiative provides major infrastructural transformation in the urban and peri-urban wetlands underpinned by strong bioscience technology and intelligent systems of these natural ecosystems across the country. For more details on the case study refer to the previous section on leap-frogging technologies - Smart Cities Sector.

Mangrove restoration, Senegal. Launched by the Livelihoods Funds and Senegalese NGO Océanium and validated by the United Nations Framework Convention on Climate Change Board in 2011, the mangrove restoration programme in Senegal is the largest mangrove restoration programme (Livelihood Funds, 2020). Mangrove forests are an important tool for climate mitigation (e.g., through carbon sequestration from the atmosphere), coastal protection, preservation of water quality (e.g., by trapping sediments and filtering pollutants) as well as fishery resources, which is critical for food security. According to a study by the UN Food and Agriculture Organisation, around 133,000 acres of coastal mangrove forest have disappeared in Senegal between 1980 and 2005, which heavily impacted the soil quality and aquatic resources in the coastal area (Bilskil, 2018). To mitigate this issue, Océanium and the Livelihoods Funds have provided support to carry out the mangrove restoration project, with the involvement of 250 local villages and 100,000 other individuals. Starting with 173 hectares in 2008, the plantation area has now expanded to more than 10,000 hectares; more than 79 million mangrove trees are now planted, providing 500,000 million tonnes of expected carbon offsets for its investors over 20 years (Fleming, 2019). These projects and initiatives leverage major discoveries made in bioscience and smart engineering technologies outlined in the 10-10 MySTIE.

Community-based water monitoring (CBWM)

In essence, CBWM involves the participation of local communities in tracking and monitoring water quality and availability. In recent decades, it has expanded rapidly across different countries; while CBWM is especially popular in Europe and North America (including Canada), countries such as Australia, Brazil, and China have also partaken in this initiative (Carlson & Cohen, 2018). This growth in popularity can be attributed to several factors such as (i) the finite ability of monitoring by government agencies and scientists, (ii) invention of inexpensive and easily-manoeuvred technologies to undertake accurate water monitoring and crowdsourcing data, as well as (iii) the emerging concerns of local communities concerning the health of their environment. Increasingly advanced technology, in particular, the technologies in the 10-10My STIE are being deployed by many of the countries to manage the natural ecosystem and water basins. The following examples will illustrate the use of CBWM in different countries.

The Lake Windermere Project, Canada. Lake Windermere is the most extensively utilised water source across the entire Columbia Valley. In recent decades, however, its ecology has undergone profound deterioration. For instance, the population of burbot collapsed, and over 50% of its shoreline was degraded (Living Lakes Canada, 2021). In face of these challenges, the 2005 Lake Windermere Project was initiated as a water stewardship programme that involved the government, local community, as well as First Nations residents to resurrect the health and ecosystem of the lake. Some measures of its education and outreach programmes included the Door-to-door Outreach Campaign (i.e., to increase residents' awareness on the project and ways to participate) and Lakekeepers Workshop (i.e., provided knowledge to residents on basic lake functions and sampling protocols). The initial training for water collection samples was provided by government staff and other lake stewardship societies (Kanu et al., 2016). As the coordinator obtained the lake stewardship certification and became qualified, new community volunteers were trained to become project coordinators.

In 2010, this project was chosen as the "best practices" example for community-based environmental monitoring by the research project executed by the Environment Assessment Agency and N.T. Yap Environmental Assessment Agency (Living Lakes Canada, 2021). The stewardship of the lake has since been handed over to the local community through the Lake Windemere Ambassadors Society to enable the active and full participation of residents (Waterbuckets eNews, 2021). This was also the inception of Living Lakes Canada – a group that builds capacity through CBWM to restore and protect the watersheds across Canada (Waterbuckets eNews, 2021).

Futaleufú community-based water monitoring, Chile. The Futaleufú River and one of its principal tributaries, the Espolón River are exposed to environmental threats at an escalating rate (Waterkeeper Alliance, 2021). Examples of environmental threats include the contamination from the nearby water treatment plant and the proliferation of invasive algae (i.e., didymo) as a result of the extensive gravel extraction from the riverbanks (Futaleufú Riverkeeper, n.d.). Due to the lack of monitoring efforts from the public institutions, a community-based water monitoring programme was spearheaded by the Futaleufú Riverkeeper, an NGO established by the green energy company Enel (Futaleufú Riverkeeper, 2020). Volunteers from the local community are provided with training workshops and certifications to carry out water quality sampling at predetermined sites (i.e., physical-chemical aspects such as pH and alkalinity; Blanchet & Gonzalez, 2020). In addition to cost reduction, CBWM is an excellent method to educate and engage the local community in the water management of the country, which is especially important given that it is the only country in the world with fully privatised water rights.

A successful transformation of the water sector hinges on effective management of both the supply and demand aspects of the water sector, where both aspects are governed by the 8i and circular economy framework that embeds the 8R philosophy of water. This transformation will be driven by the 10-10 MySTIE framework which links the technological development of the water sector with local community empowerment.

5.1 The Supply and Demand of the Water Sector

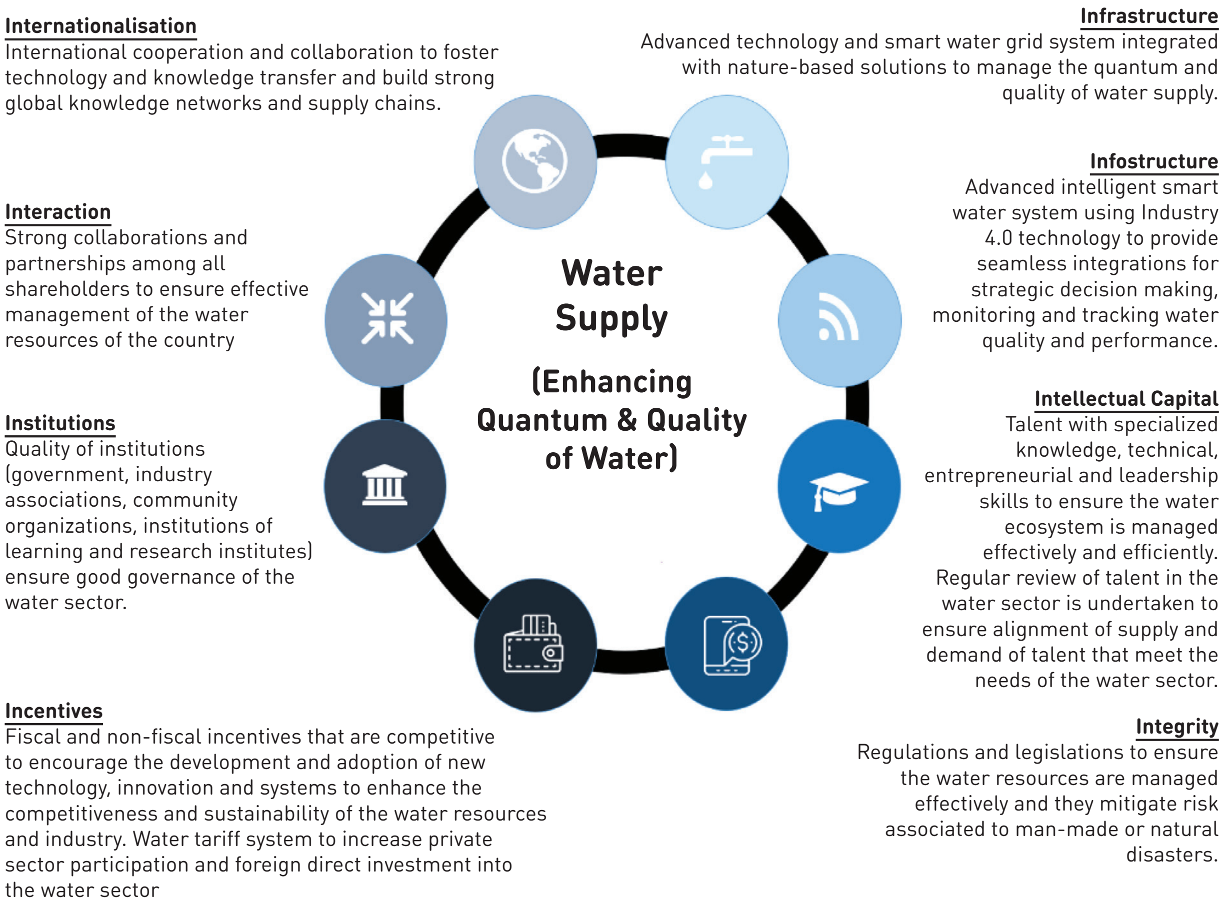
The concept of water as an economic good, which has important value to multiple stakeholders (users) is outlined in this study. Like any other goods, it is assumed that users are willing to pay a particular price for the water, from which they derive a benefit, and there is a cost for using the water. This cost should reflect the cost of extracting, treating, and distributing water.

The water quality needs for different stakeholders varies, hence a sound water industry will need a flexible and agile water ecosystem (allocative and productive capacities) that have highly developed enablers –

the 8i (infrastructure, infostructure, intellectual capital, integrity systems, incentive systems, institutions of governance and internationalisation strategy), as defined in Figure 1 above. A highly evolved water ecosystem will increase the overall productivity of the sector, keep the cost of production low using the best technology and capabilities and create adequate high-income jobs. Further, a highly evolved water ecosystem will also be able to manage the demand side of the water by ensuring that water is used in a sustainable way to meet the basic needs and higher-order economic value creation. A brief discussion on the characteristics of the supply and demand functions for the water ecosystem to transform the sector into a vibrant economic sector that contributes to the country's wealth is provided in this section.

5.1.1 Characterising the Water Supply Function

The supply of water is assumed to depend on the enablers of the water ecosystem, which consists of the 8i-ecosystem enablers and the tariff price of water. Figure 6 characterises the enablers of the supply function. The supply function measures the marginal cost of producing the water at different levels of water production. A well-managed water ecosystem increases both the quantum and quality of the water supply. Second, the strength of the enablers of the water ecosystem determines the dynamic capabilities (absorptive, adaptive, and innovative capabilities), competitiveness, and wealth creation opportunities of the industry.



Source: Framework by Sunway Institute for Global Strategy and Competitiveness (2021)

Figure 6: 8i-Framework for Water Supply

A highly evolved water ecosystem powered by high technology will enable water operators to pursue economies of scale and economic scope in the water industry. The former will keep the cost of production of water low, while the latter will increase the range of water services to the market. For example, from raw water in the agriculture sector to more high-quality water with a reasonable cost for high-end users and industries. This will increase the water demand, increase revenue and profitability of the industry. A supply-side analysis for the Malaysian water sector is provided in Section 7.3.

5.1.2 Characterising the Water Demand Function

On the other hand, the demand function is characterised in Figure 7, where the ecosystem enables the effective management of water consumption and sustainable use by end-users. The water demand is assumed to be a function of the water tariff rates and the 8i enablers that enhances the market reach and richness in the consumption of water by the end-users. The reach entails the use of advanced infrastructure and technology to expand the water coverage to a wider segment of the population, and innovative business models and incentive systems to effectively serve wider economic sectors that are dependent on water. The richness entails the adoption of better technology, knowledge systems, collaborative platforms, and internationalization strategies that will increase the demand for value-added water resources. For example, a well-managed water ecosystem will be able to attract high-end industries that are willing to pay a premium for water resources. This may provide opportunities for the Malaysian water ecosystem to nurture a very strong regional virtual market that can increase the demand for water resources and increase the income streams by the water sector. The demand measures the marginal benefits of water. The demand side analysis for the Malaysian water ecosystem is discussed in section 6.3.

Source: Framework by Sunway Institute for Global Strategy and Competitiveness (2021)

Figure 7: 8i-Framework for Water Demand

5.1.3 The Dynamics between the Supply and Demand for Water

The water sector comprises both the supply and demand which determine the equilibrium price (market price) and level of production by the sector. Significant investments in the 8i-enablers of the water ecosystem will increase the supply and demand of water. This has the potential for the water industry to break away from the cycle of loss and unsustainability to one that can meet the needs of all stakeholders in the economy. Thus, transitioning to a trajectory of economic sustainability and becoming an important revenue earner for the nation.

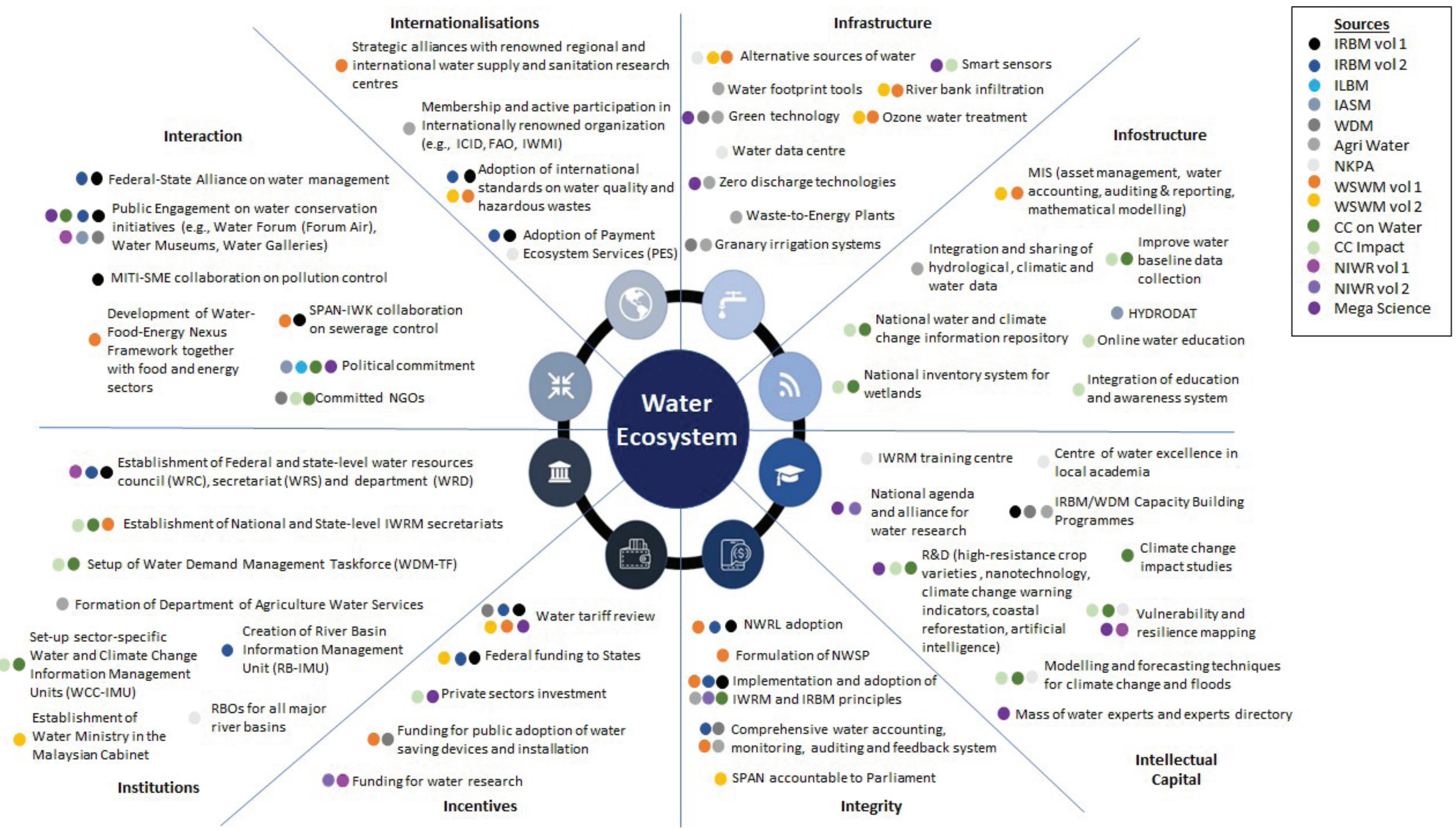
6.0 Sub-Sectoral Findings

6.1 Review of Scientific Literature and Policies (Scope 1)

Since 2008, the Academy of Sciences Malaysia and the relevant agencies have completed key studies related to the water sector and its importance of water as a resource and livelihood in supporting all sectors of the economy. In this section, a detailed review of the current plans and policies (see Table 1) of transforming the water sector into a vibrant ecosystem, contributing to the wealth of the country is undertaken. Figure 8 highlights the key policies in these reports that are grouped according to the 8 enablers of the 8i water ecosystem framework discussed in Section 5.0.

Table 1: Integrated River Basin Model Studies and Water-Related Studies

- IRBM vol 1: Academy of Sciences Malaysia. (2015, March). *Strategic Plan for Integrated River Basin Management (IRBM) In Malaysia Volume 1.*
- IRBM vol 2: Academy of Sciences Malaysia. (2014, February). *A Study on the Status and Issues on Strategic Plan for Integrated River Basin Management (IRBM) In Malaysia Volume 2.*
- ILBM: Academy of Sciences Malaysia. (2019, April). *Strategies for the Development and Management of Lakes and Reservoirs in Malaysia.*
- IASM: Academy of Sciences Malaysia. (2011, April). *Strategies for the Sustainable Development and Management of Groundwater in Malaysia.*
- WDM: Academy of Sciences Malaysia. (2015, June). *Strategies to Enhance Water Demand Management in Malaysia.*
- Agri Water: Academy of Sciences Malaysia. (2016, September). *Agriculture Water Services for Agribusiness.*
- NKPA: Academy of Sciences Malaysia. (2015, January). *A National Key Priority Area (Nkpa) On Water.*
- WSWM vol 1: Academy of Sciences Malaysia. (2015, May). *Strategies for the Improvement of Water Supply and Wastewater Management Services in Malaysia (Volume 1)*
- WSWM vol 2: Academy of Sciences Malaysia. (2014, February). *Study on the Current Issues and Needs for Water Supply and Wastewater Management Services in Malaysia (Volume 2)*
- CC on Water: Academy of Sciences Malaysia. (2014, January). *Strategic Plan for Addressing the Impacts of Climate Change on Water-related Issues in Malaysia*
- CC Impact: Academy of Sciences Malaysia. (2010, December). *Study on the Status of Climate Change Impac on Water related Issues*
- NIWR vol 1: Academy of Sciences Malaysia. (2014, February). *Setting A National Agenda for Integrated Water Research VOLUME 1*
- NIWR vol 2: Academy of Sciences Malaysia. (2014, February). *A Study on the Current Status and Needs Assessment of Water Resources Research in Malaysia VOLUME 2*
- Mega Science: Academy of Sciences Malaysia. (2010, December). *Sustaining Malaysia's Future: The Mega Science Agenda.*



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021)

Figure 8: Policy Review of the Integrated River Basin Studies and Water-Related Studies

The Malaysian government recognises the importance of the water industry not only to meet the basic needs of people but also its' potential role as a major contributor to the economic development of the nation. Towards this agenda, a comprehensive strategy referred to as the National Integrated Water Resources Management (NIWRM) Plan was developed to achieve greater sustainability of the industry and for the industry to create a higher economic multiplier effect in the economy (ASM, 2016).

Water resources cover the primary, secondary and service sectors. The NIWRM and several other policies refer to the various initiatives that impact the water industry and potentially transform it into a viable economic sector. Table 2 below shows some of the major initiatives undertaken in the three subsectors of the water industry.

A key feature of the NIWRM is its emphasis on the importance of research and development (R&D) activities to transform the water sector to be sustainable. In this context, the NIWRM lists 21 research themes (refer to Table 3) comprising 97 research topics (Ismail & Yusop, 2016). The research topics are aligned to the primary, secondary, and service sectors in the water industry as given in Table 4. The list was developed through a study commissioned by ASM in 2012 to assess the current and future needs of water resources research to 2020.

Table 2: Findings on Policies and Strategies that Address Water-related Issues

Primary Sector	Secondary Sector	Service Sector
• Groundwater mapping and abstraction	• Water reuse and recycling systems for agriculture and aquaculture	• Tertiary treatment for sewage to reduce eutrophication in public waters
• Rainwater harvesting	• Urban farming	• Smart water network monitoring systems for non-revenue water reduction
• Desalination of brackish / saline water	• Livestock waste treatment system	
	• Hydropower development	
• Alternative water	• Water-efficient design and buildings	• Improve stormwater management
	• Water transportation	• Pollution monitoring and control at source
	• Water and ecotourism	
	• Commercialisation of technology and expertise	• Flood mitigation and forecasting

Research	Institutional and Legal Framework
• Establish a: o Water Research Consortium	• Review, update, and introduction of existing/new policies: o Optimisation of government bodies and agencies
o National Water Research and Development Centre	o Institutionalising IWRM
o Centres of Excellence or research institutes for water, green technology, tropical biological diversity, timber,	o Toughened regulation and enforcement of IWRM
o Global Warming Research Centre	o Privatisation / Corporatisation of the water supply sector
• Conduct and fund water research into 21 themes and 96 research topics	
• Encourage research into water and water-related sectors (i.e., energy, agriculture, tourism, urban development)	

Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021)

Table 3: 21 Research Themes from the NIWRM Plan

NIWRM Plan Research Themes	
1. Hydrological Cycle and Meteorology	11. Conflict resolution
2. Policy and Regulation	12. Climate Change
3. Hydrology, limnology and associated mathematical modelling	13. Sustainable water supply development and management for multi-purpose use
4. Hydrogeology and groundwater modelling	14. Resource for wealth creation
5. Eco-Hydrology and relevant IWRM subsets	15. Sustainable water supply development and management for multi-purpose use
6. Ecosystem services — resource provision, environmental flows, and regulation	16. Integrated Water Demand Management
7. Biodiversity and natural products of terrestrial and aquatic ecosystems	17. Wastewater Management and Reuse
	18. Agricultural Drainage
8. Coastal Systems	19. Green Technology
9. Water Quality and Pollution	20. Water-Energy-Food Nexus
10. Participatory Management	21. Products and services for wealth creation

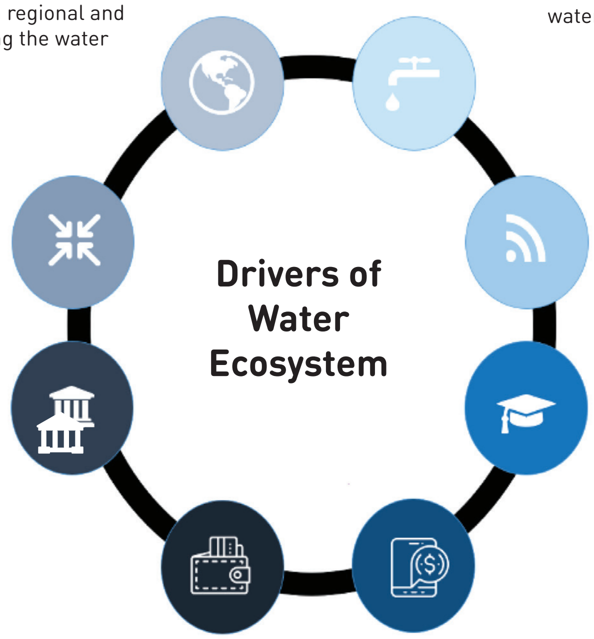
Table 4: NIWRM Plan Research Topics Categorised into Key Areas

Primary Sector	Secondary Sector	Service Sector
• Stormwater management • Alternative water resources	• Advanced dam technology and dam modelling construction • Improved and innovative irrigation technology • Rainwater harvesting for irrigation purposes • Water use efficiency • Phyto- and bioremediation technology for industrial wastewater treatment • Agricultural drainage design discharge, and practices • Green technology	• Advanced water treatment process • Low carbon and energy-efficient treatment system • Water demand projection and forecasting • Decentralised and unconventional urban sanitation system • Integrated urban water management • Flood management and mitigation • Water quality and wastewater reuse
Water Resources	**Enviromental Protection**	**Community Engagement**
• Hydrological cycle and meteorology • Surface water, rural and urban hydrology • Resource management • Water quality information management and modelling • Erosion and sedimentation	• Climate change and rainfall modelling • Eutrophication • Conservation, preservation and restoration of water sources and marine biodiversity • Technologies for monitoring, controlling, and removing diffuse, point source and non-point source pollution • Newly emerging water pollutants • Carbon and water footprint	• Public participation and awareness in water resources management and conservation

One of the key findings of the study was the ad hoc and fragmented nature of local water-related research initiatives, primarily driven by academia with very little translational impact on the water sector. Furthermore, water research was previously not listed as a research priority area for MOSTI and MOE Funds. Additionally, the annual budgets for R&D activities under NAHRIM were curtailed over the years. To address these compounding issues, ASM subsequently submitted an advisory report in 2014 entitled

Setting a 'National Agenda for Integrated Water Research Volume 1'. The report consisted of institutional recommendations – some of which were outlined in the NIWRM Plan – including the setup of a national centre and consortium for water research, a national agenda for integrated water research, and a launching grant of RM100 million to support translational R&D activities in the water industry (Ismail & Yusop, 2016).

Based on an aggregation of the selected research topics in the NIWRM Plan (as seen in Table 4), there is a preference towards the secondary and service sector, environmental protection and understanding of water resources. The findings show research in the primary sector is sourcing for alternative water, indicating a shift from traditional water abstraction. Currently, Malaysia is almost entirely subsisting on surface water for its raw water supply (at 97%) (Yusop, 2016), making the supply vulnerable to rainfall variability and surface water pollution. Recent pollution events (e.g., Sungai Kim-Kim, Sungai Semenyih) have further underscored these vulnerabilities and the threat it poses to water security. A study by ASM in 2011 on groundwater resource development advocates for the abstraction of groundwater to complement current surface water usage to improve water supply reliability. However, groundwater abstraction poses its own set of risks. Overexploitation of groundwater can lead to diminishing groundwater levels, disturb the hydraulic connection between surface and groundwater, and affect stream flow during low flow periods (Fendekova et al., 2005). This is coupled with the uncertainty of water quality with groundwater being susceptible to soil contamination by leaks from underground storage tanks, landfills, manufacturing facilities and agricultural sites (Atmadja & Bagtzoglou, 2001).



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021)

Figure 9: Proposed recommendations in the NIWRM Plan based on the 8i Water Ecosystem Framework

There is recognition in the NIWRM plan that the above issues can be addressed by sound R&D activities by the various research centres within the country. Through these endeavours, the economic potential from water can be expanded by developing emerging technologies to improve the efficiencies in the extraction, production, and management of water. These include ensuring innovations from R&D, generating both water savings as well as productivity gains across industries. With just the application of real-time water pollution prevention and predictive maintenance of the water pipeline grid alone, it is envisaged that significant improvements in water efficiency can be achieved if more advanced technology and innovations are used in the water industry. The plan highlights that a targeted water research approach could generate both multiplier and spillover effects across multiple sectors of the economy.

While the broad goals are mentioned in the NIWRM plan, a clear framework and hard targets and timelines to achieve the objective of transforming the water sector into a vibrant economic sector were not clearly articulated. A breakdown of the NIWRM Plan based on the 8i Model framework (referring to Figure 9) provides a summary of the current challenges in developing an IWRM. Some of the gaps within the water ecosystem include a poor funding situation; a weak legal framework and enforcement, particularly in water pollution; necessary investment in targeted research; and the need for national policies to reflect contemporary demands of society in a fast-changing economy.

A preliminary global benchmark comparison (as seen in Table 5.) makes clear that a holistic multisectoral approach with strong stakeholder collaboration is vital for the success of NIWRM and water-related initiatives. In Singapore, water and environmental policy and institutional review are done in tandem due to the intertwining of the two resources. As quoted, "what pollutes the land pollutes water" (Tortajada & Joshi, 2014), it is clear that efforts will need to be synchronous, not just across these two aspects, but also in adjacent sectors that both rely on and affect water resources and services. This is the case in the Netherlands, whereby water-related policies are reviewed together with a broad range of sectors including energy, agriculture, housing, shipping, nature, and recreation in conjunction with water tasking (I&W & EZK, 2015).

At the status quo, water demand will inevitably exceed supply at the current development rate, making water efficiency much more critical in the pursuit of continued economic growth. However, the water pricing paradox comes into play, whereby "its price rarely equals its value and rarely covers its costs" (Grafton et al., 2020, p. 90). Some nations such as Singapore, Australia and Scotland conduct revisions on water prices and tariffs to cover not just operational costs but also future development, be it capital expenditure or research. This ensures that future water supply may be guaranteed through financial stability. However, the motion for water rate hikes remains a contentious issue within Malaysia, with the country reporting some of the lowest water prices globally (Muhairwe, 2019), and tariffs have seen only marginal change over years – some even decades (SPAN, 2017) – leaving water concessionaires operating at a loss. This has led to disputes over operational costs and price increases, one of many reasons for the failure of water privatisation (Lobina et al., 2014).

The review of the policies was undertaken in the context of the 8i-framework, identifying some of the key gaps in the enablers of the water ecosystem. The review shows that while there are great aspirations of transforming the water sector into an economic driver for the country, many of the plans and policies lack hard targets and timelines. Of particular concern is the lack of integration of the NIWRM Plan with the economic sector plans that overlap with the water sector.

Aspirational targets by NIWRM are calling for the following approaches to achieve their goals:

- *Infrastructure* – The natural infrastructure including the water basins should be managed well to ramp up environmental protection and to meet the needs of the people and industry. In this context, effective tools such as the Water footprint tools using new technologies is necessary to improve water resource management. Emerging technologies using green technologies and other technologies for example smart grids and sensors to increase efficiency in the water sector and reduce water footprints and greenhouse gas emissions so that upstream-water basins are managed effectively. Real-time water pollution prevention and predictive maintenance of the water pipeline grid alone is envisaged to have significant improvements in water efficiency if more advanced technology and innovations are used in the water industry. The physical infrastructure should be managed properly and have access to good treatment plants, pipelines, and other physical infrastructure (such as dams, logistic supply chains and transportation). Improved water supply and distribution networks can reduce water leakages and deliver quality water supply to the various stakeholders in the economy.

- *Infostructure* – is the state of the digital infrastructure in the water sector such as ICT connectivity, the use of advanced ICT and big data for seamless integration of multiple digital systems to manage the water resources efficiently. NIWRM emphasises an integrated data centre and an information repository to enhance data sharing. Asset management, water accounting, auditing and reporting, and mathematical modelling should involve using these advanced data analytics.

- *Intellectual-capital* – NIWRM discusses talent development and the state of the talent stock (general and specialised skills set and core competencies) in the water industry to transform the sector into a technology- and knowledge-driven sector, to enhance the ROV of the downstream and upstream of the water subsectors. Dedicated training centres and water research & development for effective capacity building programmes that include information programmes, laws and standards, wastewater reclamation, coupled with public involvement in decision making, would ensure sustainable water management for communities. These training centres should develop training modules for different target groups. Establish centres of excellence among the local academia for capacity building and to have a pool of water experts and experts' directory.

- *Integrity- systems* – is the state of the governance systems at the federal, state, and municipal level that ensure seamlessly integrated implementation of strategic policies and strategies to enhance efficiency and maximum economic value for all stakeholders in the economy. Comprehensive accounting and accountability; implementation of IWRM and IRBM principles for continuous water accounting monitoring, auditing, and feedback system. All water agencies such as SPAN become responsible to parliament to ensure transparency and accountability.

- *Incentives* – is the level of fiscal and non-fiscal incentives to not only ensure water security but also as an important source of economic wealth for the country. These include support for research and development, innovation grants, access the state-of-the-art research facilities, tax incentives and subsidies, and other incentives to spur incremental and radical home-grown innovations in the water sector. To attract private sector participation in the water sector, there is a need to review the water tariff to ensure that the rates are competitive. Equitable tariff settings with provisions for targeted subsidies access to federal funding to States; incentive schemes/funding to encourage both suppliers of water and end-users to use water-saving devices/systems should be considered.

- *Institutions* – is the availability of quality institutions at the federal, state, and local council levels (government, industry associations, institutions of learning and research institutions and community organisations) that act as key enablers for the water industry to move up the innovation and economic value chain. Institutional coordination and institutional arrangements are required to facilitate cooperation and conflict arising due to multiple institutions at the federal, state, and local council levels. Establishment of Federal and State-level water resources council (WRC) to facilitate cooperation and conflict between the multi-stakeholders, for example, federal and state conflicts. These include the existence of sound regulatory architecture and standard boards that manage the water resources of the country efficiently and ensure transparency and accountability. These institutions use advanced technologies to manage complex relationships in the water sector.

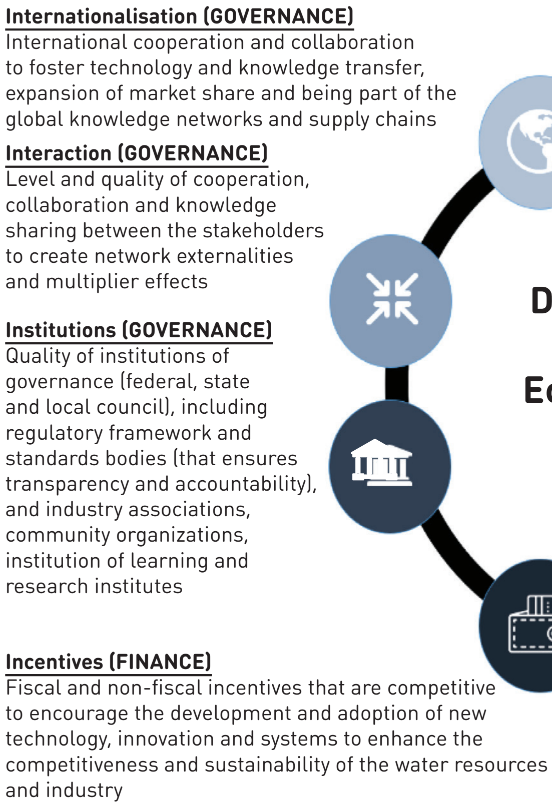
- *Interaction (smart partnerships)* – is the state of cooperation, collaboration and knowledge sharing among the key institutions and economic agents to continuously innovate and adopt new technology and systems to economic value and competitiveness of the water industry. There is a need for Federal-State Alliance on water management. Partnership and collaboration with different agencies, for example, SPAN-IWK collaboration on sewerage control; MITI-SME collaboration on pollution control etc.

- *Internationalisation* – International cooperation and collaboration to foster technology and knowledge transfer, expansion of market share and being part of the global knowledge networks and supply chains. This includes adherence to global best practices and the adoption of international standards on water quality and hazardous waste. It is important to build strategic alliances with a renowned regional and international water supply and sanitation research centres.

6.2 Comparative Analysis (Scope 2)

The IWRM identified 5 Focus areas to characterise the water ecosystem namely People (the driver), and 4 enablers – Governance, Information & RDIC, Finance and Infrastructure & Technology. These 5 focus areas are broad categories. The 8 enablers in the 8i framework are a more granular version that better represents the water ecosystem as a viable water market that trades in international markets. The 8 enablers in this framework are mapped to these 5 focus areas as shown in Figure 11.

4 focus areas that map to 4 of the enablers in the 8i framework have similar characteristics: People represented by Intellectual Capital; Information & RDIC as Infostructure; Finance is represented by Incentives; and Infrastructure & technology is represented as Infrastructure. However, the focus area on Governance, an enabler in the IWRM focus area that broadly describes governance encompasses 4 dimensions (Integrity, Institutions, Interaction, and Internationalisation) in the 8i framework. These 4 dimensions represent the granular level of governance and better measure the distinct aspects of governance (such as the governance systems, quality of institutions of governance, collaboration between the multi-stakeholders and adherence to international standards).



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021)

Figure 10: A Model of the Water Ecosystem: 8i-Ecosystem Analysis and the IWRM Focus Areas

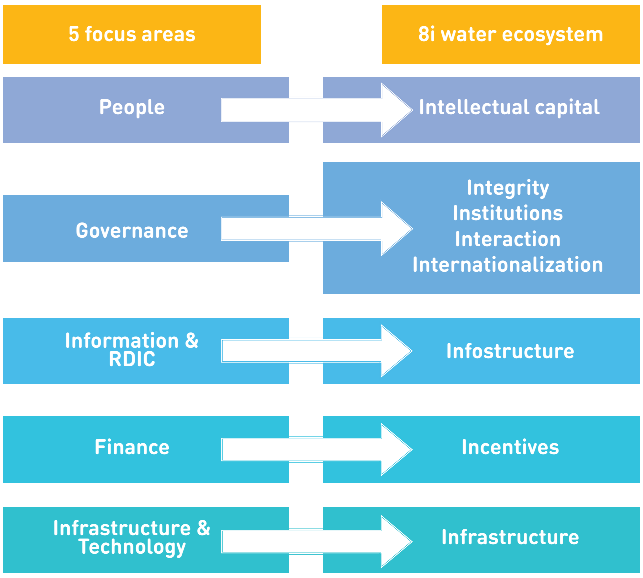


Figure 11: How the IWRM Focus Areas Map onto the 8i Framework

Figure 10 shows the components of a dynamic water ecosystem from benchmark countries. Compared to that of Malaysia, there is a stronger focus on ensuring the water ecosystem is future-ready. This includes continuous infrastructure upgrades and alternative investments to fund these upgrades to prevent a systemic failure of the water supply systems due to long-term neglect. There is also a commitment to thought-leadership and cutting-edge research into water and water-related knowledge, which is then leveraged into market pacesetters and expansions. The policy review summary of benchmark countries' dynamic water ecosystems is shown in Figure 12. This observation is more clearly defined in Table 5 where policy strategies of the benchmark countries are compared with Malaysia based on the 5 Focus Areas (as shown in Table 6).

Upon inspection of each of the 5 Focus Areas (Table 5), benchmark countries tackle IWRM through a strategic approach comprising strong capacity and knowledge building; highly coordinated governance structure; targeted fiscal and non-fiscal instruments; financially sustainable pricing structure; and sector modernisation through physical and digital infrastructure investment. These key aspects are foundational drivers to a holistic IWRM and sustainable water sector that creates strong economic impact and global outreach and is outlined below:

Governance: Many benchmark[10] countries approached national plans and policy design with a Whole-of-Government or Whole-of-Society approach. These countries displayed early foresight with the incorporation of environmental and sustainability targets within policies, as well as high coordination between implementing agencies. For instance, Singapore's Public Utilities Board (PUB) is responsible for the country's water supply, was highly proactive in implementing projects and coordinating between ministries to ensure water security became an important facet of Singapore's overall growth (Jensen & Nair, 2019; Tortajada et al., 2013a; Tortajada & Joshi, 2014a). Meanwhile, Australia is a strong proponent of the Whole-of-Society approach, having conducted some of the highest number of citizen participation programmes (e.g., citizen jury) among OECD countries (OECD, 2020c). This incorporation of society in policy design and decision making allows for more holistic policy decisions that encompass the perspectives of different demographics, is contextual, and provides novel solutions that the government may not have thought possible.

Strong integrity systems are present in benchmark countries to ensure accountability and transparency to gain consumer trust. Water operators (public or privatised) publish annual reports detailing project progress, financials, and future investments that are publicly accessible. In some countries, such as in Australia and the UK, water operators publish their business plans for the next coming years outlining future investments and targets. This ensures consumers are kept abreast of how water tariffs are being invested. Similar to the polluter-pays principle, should water operators fail to meet targets or breach regulations, they are held accountable and in turn penalised for any shortfalls. Additionally, again in Australia and the UK, water operators are regulated by independent regulators (Cathryn Ross, 2017; Horne, 2020). This ensures political agendas are kept separate from judgement.

Finance: Benchmark countries have shown to use cost-reflective pricing and polluter-pays principle as a means of ensuring water operators remain financially sustainable and as a part of water demand management strategies employed. In the UK, water supply for businesses is non-monopolistic, thus incentivising suppliers to improve in terms of efficiency, price competitiveness and service quality (Government of the United Kingdom, 2017; Loveday, 2016b). In Australia, water prices are tied to license targets that may range from service quality to environmental goals (Horne, 2020). Singapore sets a water conservation tax on top of cost-reflective prices (in addition to other non-fiscal initiatives) to manage water consumption levels.

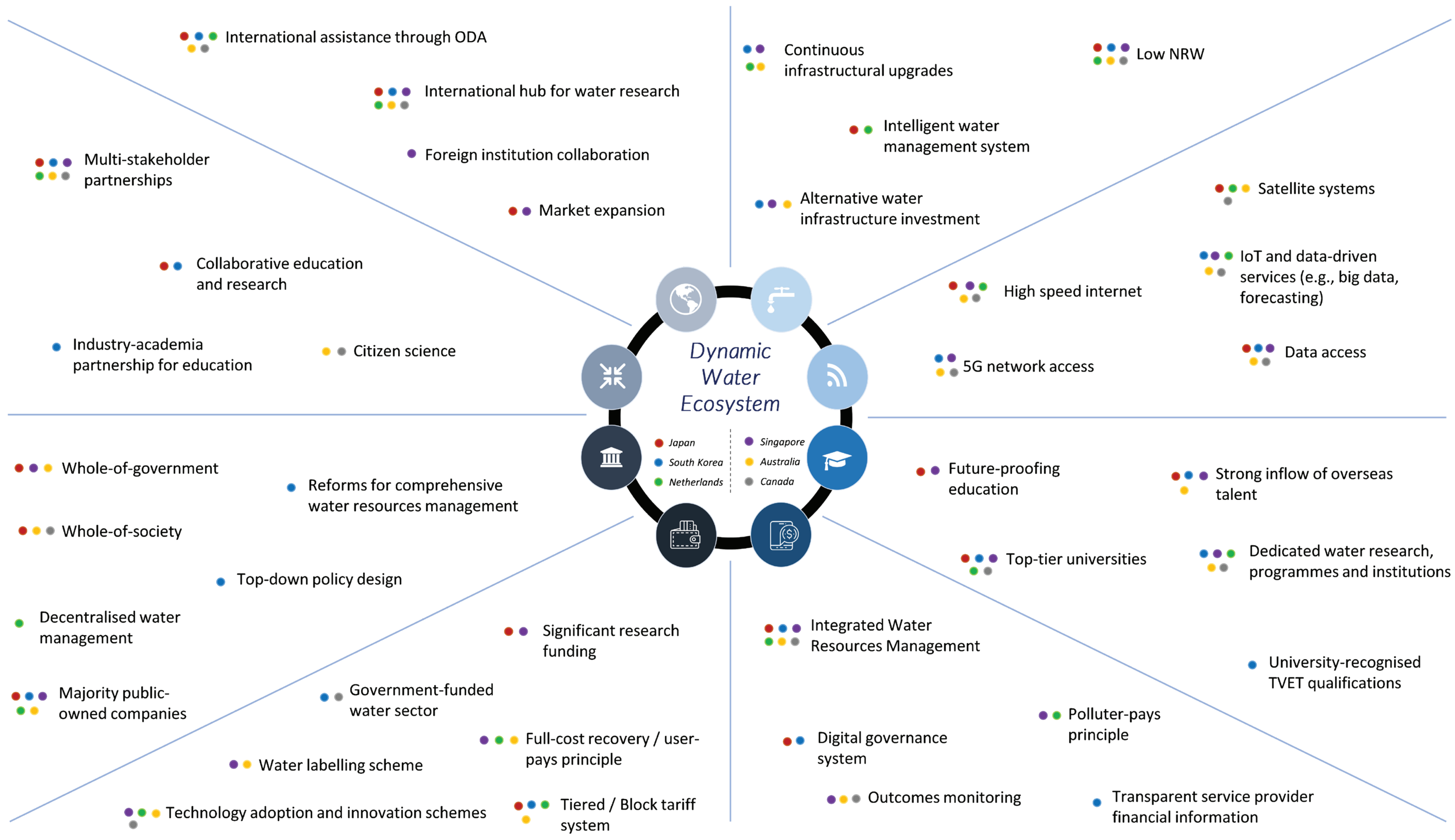
[10] Benchmark countries are Japan, South Korea, Singapore, Netherlands, Australia, Canada, and selected OECD countries where appropriate

Benchmark countries show strong public investment as mechanisms for spurring research, innovation, and collaboration. Public support (in this context, financially) is important in encouraging business R&D, as the risky and uncertain nature of R&D presents a large barrier, especially for young firms and SMEs (OECD, 2021). Findings from an OECD study suggest that generous innovation-specific policies encourage private sector innovative activity, such as R&D tax incentives, and direct government support for private R&D increased business R&D expenditure (Westmore, 2014). However, the converse effect was found when policies were frequently reversed, indicating that a stable and predictable policy environment was key for positive outcomes. In Singapore, fiscal and non-fiscal incentives help drive local and foreign direct investments into research and innovation, while also supporting local SME globalisation, and providing safety nets to encourage private sector participation in water Public-Private Partnerships (PPPs) (S. Ho, 2015; Jensen, 2017; PUB, 2018a). In the UK, research councils fund more than £120 million in public sector water research annually (Government of the United Kingdom, 2015), while in Canada and the Netherlands, fiscal incentives help drive investment and research into water technologies (Canadian Water Network, 2018; Government of the Netherlands, n.d.; Natural Sciences and Engineering Research Council of Canada, 2019; OECD, 2020b). To promote state and local government adoption of water technologies and infrastructure, Australia's federal government provides co-investment schemes (DITRDC, 2021; OECD, 2019).

People: Dedicated water education institutions, emphasise STEM education, and sometimes citizen science programmes are common mainstays in benchmark countries. Other strong enablers are their strong indigenous tertiary education institutions and tech industries that help create that inflow and retention of foreign talent (i.e., students, researchers, and workforce). Additionally, some countries, such as Australia, create tailored visa programmes like its Global Talent Visa Programme that targets growth in innovation and tech economies in key areas including resources and circular economy (Department of Home Affairs, 2021). Citizen science and community-based water monitoring are some approaches used in Australia, Canada and the UK to not only improve water literacy amongst society but also shared water management and provide cost-effective and accurate scientific data (ACSA, 2021a, 2021b; Sandford et al., 2018).

Infrastructure and Technology: Benchmark countries have a relatively low NRW (15% or less) which is aided by strong investments into improving and upgrading ageing infrastructure. Additionally, some countries have made infrastructure investments that are highly contextualised, such as Singapore's NEWater plants and urban-integrated water catchment zones (e.g., Marina Barrage) and the Netherland's many massive flood barriers to increase land availability even with a third of the country lying below sea level.

Information and RDIC: Benchmark countries have shown support for open-data access, data-driven solutions, and high-speed internet (i.e., broadband, 5G network). Australia and the Netherlands are among the top countries in terms of open-data access (Hisham, 2015; Open Knowledge Foundation, 2016; Speedtest, 2021a, 2021c; World Wide Web Foundation, 2017). Further, the Netherlands in particular has a strong space sector and makes data-driven solutions and digital technologies as its international water solutions (Government of the Netherlands, 2021; Kingdom of the Netherlands, 2017). South Korea incorporates technologies such as IoT, sensors and data analytics into its water supply chain as seen in its Smart Water City projects where remote leak monitoring, smart metering, and predictive maintenance are some that have been implemented to improve efficiency and transparency (Lee, 2019). Additionally, benchmark digital-based solutions are further enabled by strong investments into digital infrastructures such as strong 5G rollout and high-speed broadband coverage (Speedtest, 2021a, 2021c).



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021)

Figure 12: Policy Review of Benchmark Countries' Dynamic Water Ecosystems

Table 5: Policy Strategies to Target the Five Focus Areas of the Water Ecosystem

WES				
Implementation of a strategic programme towards positioning the water sector as a new national economic sector (WES)				
People	**Governance**	**Finance**	**Information and RDIC**	**Infrastructure and Technology**
• Adequate talent with specialised knowledge, technical, entrepreneurial and leadership skills. • Continuous upgrading and reskilling in place. • Strong awareness and acculturation of care for water basins and civic consciousness on the value of natural water resources. • Incorporate the **8Rs of water philosophy**: Respect water; **Rethink** the value of water; **Reduce** wastage; **Re-Use** used water; **Recharge** groundwater (rain harvesting); **Recycle** wastewater, **Repurpose** water for higher-value use; and **Regenerate** water. • Strong training centres in the water areas that meet the talent needs of the industry and provide training to other countries.	• Adopt a **"Whole of Government and Whole of Society"** Approach to operationalise Integrated Water Resource Management (IWRM) model. • Continuous improvement of institutions in place – the adoption of new technology, knowledge systems and capability development. • A strong **"Champion with Clout"** (Federal Government) orchestrating the development of the water ecosystem – a good 'Conductor.' • Level and quality of cooperation among all stakeholders good – the ability to harness **economic multiplier & spillover effects**. • Strong International cooperation that fosters two-way technology and knowledge transfer – continuously moving up the global value chain. • Strong adherence to global best practices; in some cases, setting new standards.	• Competitive fiscal incentives to encourage continuous modernisation of the water sector via the adoption of new technology, innovation, and systems to enhance the competitiveness and the sustainability of the water resources and industry. • Strong incentives for fundamental & translational R&D and commercialisation of R&D in the water sector. • **Tariff rates are competitive** to attract private sector participation in the water sector. • Attractive economic incentives schemes, financial instruments, and support systems to encourage **private sector participation** in the water sector. • Strong fiscal and non-fiscal incentives to encourage **foreign direct investments** (FDIs) into the water sector	• Extensive use of digital infrastructure, blockchain, big data, data analytic tools to seamlessly integrate multiple information and data system in the water sector. • Strong use of digital governance systems to enhance stakeholder relationships and effective management of the water ecosystems, including prevention of rent-seeking and moral hazard behaviour. • Digital technology is used to monitor water quality, water supply and potential risks of climate change and other natural disasters on the water basins. • Digital technology enables the gathering of market intelligence (water usage & demand conditions). • Development of a strong local **water-tech/aqua-tech industry.**	• The upstream and downstream water system incorporates an intelligent water management system, which enables **traceability** (ability to trace the source of water and contaminants), **harmony** (balanced use among householders, industry, and the environment), **sustainability** (safe and reliable water services) and **self-reliance** (energy-efficient systems). • Continuous upgrading of the infrastructure to reduce the Non-Revenue Water (NRW), increase reserve margin rate, quantity & quality of water and contribution to GDP.

Table 6: Targeting the Five Focus Areas of the Water Ecosystem – Policy Strategies Comparison between Malaysia and the Benchmark Countries

Country	People	Governance	Finance	Information and RDIC	Infrastructure and Technology	Economic Impact
Malaysia	• Weak knowledge sharing culture. • TVET enhancement roles are divided among institutions but poor coordination has created silos (Beschel et al., 2018). • Lack of awareness on the 8R water philosophy • Lack of next-generation talent in specialised areas with inter-and multi-disciplinary skills set to foster strong nexus between the water sector and other sectors.	• Weak implementation of IWRM due to lack of a strong "Champion with Clout" and low usage of digital governance systems. • Poor cohesion in government policy and weak, patchy and territorial water governance (Lee, 2005). • Institutions operate in silos due to poor coordination. Lack of effective stakeholder involvement in water resource management. • Use of traditional water management systems that are inadequate in addressing water resources in multiple jurisdictions/ states and ensuring seamless flow of information for strategic decision making.	• Low investment in R&D for the water industry. • Tariff rates have not been reviewed regularly incorporating the current costing structures • The current tariff rates are inadequate to cover operational and capital expenditure to meet the increasing needs of society and industry(SPAN, 2017). • Water service provision is primarily government-funded. Low private sector and FDIs into the water sector	• Low ICT literacy. • Low adoption of advanced ICT systems in the water industry (Ali, 2019). • Low impact research results from high quantity but low impact publications and low technology transfer rate (World Bank, 2020)	• Water infrastructure does not utilise advanced technology and cost-effective nature-based technology. • Lack of basic water infrastructure in several rural and island communities. • High NRW due to ageing infrastructure and primary use of mild steel (29.1%), asbestos-cement (27.1%) and polyethylene pipes (19.0%) (Jones et al., 2021; MWA, 2018; Rishyakaran, 2016)	• Gaps and weaknesses in the enablers in the ecosystem (in the 5 focus areas) has resulted in disruptions in the quantum and quality of the water supply. This has had a significant impact on the water and other economic sectors and quality of life. • Inadequate investment in the five enablers to stimulate strong demand-side water management (water conservation effort and higher value-added use of water). • Strong government participation leads to 'crowd-out' private sector participation and local innovation in the water sector. Limited global reach and mostly operating at the low end of the global value chain.

Country	People	Governance	Finance	Information and RDIC	Infrastructure and Technology	Economic Impact
Japan	• Significant investment in next-generation talent for the industry	• Adopts a "**Whole-of-Government**" and "**Whole-of-Society**" approach (EPD, 2007). • Incorporated IWRM and a strong digital governance system (MLIT, n.d.). • Strong internationalisation strategy, dispatching water experts through official development assistance (ODA) (MOFA, 2014) and overseas capacity building (Forbes, 2020). • Government-driven structured multi-stakeholder partnership to encourage MNC leadership in R&D (Government of Japan, n.d.; JST, n.d.; Tomas, 2021).	• **Tiered tariff** system at competitive rates (JICA, 2017). • Balanced mix of GOVERD, BERD and HERD (OECD, 2021), with BERD emphasis on **experimental research**.	• **Smart water management system** enabled by high-speed internet, satellite systems, and 5G deployment (5G Observatory, 2020; Clark, 2012; Galvin, 2017). • Competitive national universities (The Japan Times, 2021). • MNCs in areas of ICT, electronics and energy among others developing water technologies (e.g., NTT, Hitachi, Fujitsu, Sony) (Fujitsu, 2012; Hitachi, 2021; NTT Communications, 2016; Sony, 2020)	• Intelligent water management systems and fully upgraded pipes bring NRW to 10% (Macharia et al., 2021)	Japanese companies' market value of water-related fields (i.e., supply, sewage, desalination) at USD2.6 billion (Matsutani, 2018). The collective market value of drinking water systems, drinking water treatment, and sewage treatment at USD12.9 billion (United Nations, 2016).

Country	People	Governance	Finance	Information and RDIC	Infrastructure and Technology	Economic Impact
South Korea	• Policies encouraging STEAM education (Mani & Trines, 2018). • Dedicated water academy and TVET education developed with industry for local and global training programmes (Mani & Trines, 2018). • World-class tertiary institutions and World Class University Project to increase talent inflow (OECD, 2020b; Woolston, 2020)	• IWRM integrated into existing and future Smart City development (i.e., Smart Water City project). • Publicly-owned water supply operators and largest private sector wastewater providers (I.-C. Choi et al., 2017; Korea Water and Wastewater Association, 2012). • Government-driven private sector development and participation in research, innovation, and commercialisation of water technologies (Ministry of Environment, 2017). • Stakeholder engagement groups and alliances for research and smart city development (Yi et al., 2018). • International collaboration and provide water expertise through ODA to emerging economies (Ministry of Environment, 2017).	• Government-led and funded large scale water management projects. • Significant GERD by percentage GDP, largely contributed by BERD (OECD, 2021) with emphasis on experimental research. • **Block tariff** system with moderate rates and primarily government-funded financing structure. Use of price signals to adjust consumption behaviour (Danilenko & Bahuguna, 2016; OECD, 2018). • Polluter-pays principle.	• Water resource management using **smart water networks** and **digital twin** simulations (K-Water, 2021; Yi et al., 2018). • 5G coverage and **dedicated networks for IoT deployment**. • MNCs are leaders in ICT technologies and innovations (e.g., Samsung, LG, SK Group).	• Major investments upstream and downstream to **modernise water infrastructure** and systems (i.e., smart water meters, pipe upgrades, automating processes) to achieve NRW of 10.6% (Cheol, 2019; Y. J. Choi et al., 2014; K-Water, 2021; Trade, 2019; Yi et al., 2018)	As of 2018, South Korea's water management industry was worth EUR20.75 billion – of the country's EUR79.76 billion environmental market. Doosan Heavy Industries and Construction holds the largest market share in seawater desalination, at 40% in the USD26.81 billion market (EU Gateway, 2020)

Country	People	Governance	Finance	Information and RDIC	Infrastructure and Technology	Economic Impact
Singapore	• People-private-public approach in public education and community relations (IWA, n.d.). • Water education is formalised at all levels of education and online professional skills training platforms. • Policies that emphasise STEM education and continuous investments in research and innovation (Y. P. Ho et al., 2009; Koh, 2006; Quah, 2018)	• Highly coordinated self-regulated proactive public water agency with extensive portfolio allowing it to tackle water security with a '**whole-system**' approach (Jensen & Nair, 2019). • IWRM through holistic cross-sectoral policy framework development and **high-level coordination between agencies** (e.g., land, housing, health) and integration of water security goals in a broader range of policies (Tortajada et al., 2013). • Collaboration with foreign firms and universities to establish research centres and accelerator programmes within Singapore (PUB, 2018a). • Government-driven public-private partnerships.	• **Full-cost recovery block tariff** system (PUB, 2017)with **polluter-pays principle** (PUB, 2018b, 2018c). • Fiscal and non-fiscal incentives and support to drive local and foreign direct investment in research and innovation, as well as support local SMEs' globalisation efforts (PUB, 2018a). • Fiscal and non-fiscal **safety nets** to encourage private participation in water PPPs (S. Ho, 2015; Jensen, 2017)	• Digitalisation of water resources management and strong public investment in emerging digital technologies (PUB, 2020). • Top universities regionally and globally with water expertise (Dhalla, 2017; Times Higher Education, 2021)	• Continuous upstream and downstream improvements to digitalising water management and infrastructure for disaster management and alternative water sources (i.e., **Four National Taps**) (PUB, 2016). • 5G deployment and nationwide access to a high-speed broadband network.	Water industry employs 14,400 and generates SGD2.5 billion in annual value-add (PUB, 2018a). There are over 200 water-related companies and 25 research centres (PUB, 2018a).

Country	People	Governance	Finance	Information and RDIC	Infrastructure and Technology	Economic Impact
Netherlands	• Expansion of water research and capabilities building by renowned universities and leading water education and research institutions (IHE Delft, n.d.; KWR Water Research Institute, 2021; Studyportals Masters, 2021b, 2021a)	• Highly coordinated water governance system with **decentralised water agencies** whose boundaries are determined by catchment and basins (Havekes et al., 2017; Vollebergh & Dijk, 2017). • IWRM through contemporary legislation and proactive governance, enforcement and implementation ensures transparency and overcome corruption (IRC, 2016; Mostert, 2009; Studyportals Masters, 2021a). • **Global water hub** offering international development projects, ODA, and **multidisciplinary water expertise** (i.e., Amsterdam Utility Agreement and Netherlands Water Partnership) (Amsterdam International Water Web, 2021; Kingdom of the Netherlands, 2017; NWP, n.d.).	• **Two-part tariff** system and **user-pays principle** enablers of financially independent water authorities (European Environment Agency, 2013; Havekes et al., 2017; Vollebergh & Dijk, 2017). • Fiscal incentives strong driver of investment into innovative products (Government of the Netherlands, n.d.-a; OECD, 2020a)	• Government push for open data and leader in providing open access geo-data (Hisham, 2015; Overheid.nl, 2021). • Strong indigenous firms in space, geo-data, and environmental technologies (Government of the Netherlands, 2021). • Commercialisation of smart water solutions through collaborations between water authorities, space and geo-data agencies (Kingdom of the Netherlands, 2017)	• Large-scale and long-term investments into comprehensive water infrastructure and digitalisation (e.g., **Delta Works** programme for flood mitigation and land reclamation) helped achieve an **NRW of 5%** (Havekes et al., 2017; Hisham, 2015; Kingdom of the Netherlands, 2017; Macharia et al., 2021). • High-speed internet and 5G deployment (Government of the Netherlands, n.d.-b)	Water tax revenue amounting to EUR2.7 billion (Havekes et al., 2017). Water supply and waste management worth EUR3 billion (18%) value add in the EUR16.7 billion environmental goods and services sector (CBS, 2015).

Country	People	Governance	Finance	Information and RDIC	Infrastructure and Technology	Economic Impact
Australia	• **Citizen science** approach promotes public collaboration and capacity building (ACSA, 2021a, 2021b). • '**Brain gain**' driven by the strong tertiary education sector, tailored visa programmes at education institutions (e.g., TVET, Australian Water School, Water Training Australia) (ARC, 2021; Department of Home Affairs, 2021; Times Higher Education, 2021)	• **"Whole-of-Government"** approach in water reform efforts for IWRM and development of **water markets** (Infrastructure Australia, 2019). • Regulatory instruments ensuring water-efficient products, services, and buildings (e.g., WELS scheme, BASIX). • Government-driven **government-university-industry** partnerships (NWGA, 2020; PMC, 2016; Productivity Commission, 2011)	• **Two-part tariff** system with **user-pays principle**. Urban and irrigation service providers generate sufficient revenue and operate **without government subsidies**. • Service providers regulated by **independent economic regulators** are incentivised to meet key license targets to achieve a cost-reflective pricing structure. • **Co-investment schemes** to encourage state/local government adoption of water solutions and infrastructure.	• Government-led commitment to **data access**. • Strong public research institution investment into **emerging digital and data-driven** water technologies. • High-speed internet and 5G networks (Speedtest, 2021a, 2021b)	• Government-driven investment into water infrastructure (i.e., **National Water Initiative** and **National Water Grid**) and addressing system leaks, achieving NRW of 10% (Harris, 2017)	Water sector employs 27,000 and adds AUD18.9 billion to the Australian economy (Infrastructure Australia, 2019). Trade-in water allocations and entitlements annually range between AUD1-7 billion (Bureau of Meteorology, 2021)

Country	People	Governance	Finance	Information and RDIC	Infrastructure and Technology	Economic Impact
Canada	• **Citizen science** and engaging the public in water monitoring initiatives (Cliche & Freeman, 2016; Sandford et al., 2018). • Talent building through dedicated water research institutes and training centres and world-class universities offering water-related education (Sandford et al., 2018; Times Higher Education, 2021; Walkerton Clean Water Center, n.d.)	• IWRM through "**Whole-of-Society**" water governance. • Government **vertical and lateral coordination** via collaborative institutions (Sandford et al., 2018). • Continuous outcomes monitoring of policies and initiatives (Shrubsole et al., 2016). • Government-driven **government-university-industry** partnerships in data sharing, innovation and research (Alberta Innovates, 2014; Canadian Water Network, 2018; Living Lakes Canada, 2021)	• Fiscal incentives to drive R&D in water technologies (Canadian Water Network, 2018; Natural Sciences and Engineering Research Council of Canada, 2019)	• **IoT and satellite remote sensing** enablers of digital and data-driven water systems (Government of Canada, 2017, 2020; Roper, 2020). • Government-driven commitment to **data access** (Government of Canada, 2021a, 2021b).	• Investment into physical and digital infrastructure (i.e., **Clean Water and Wastewater Fund**) with maintenance and upgrades to pipelines to achieve NRW of 13% (Renzetti & Dupont, 2013; Statistics Canada, 2020)	Water treatment market is worth CAD2.5 billion (Water Canada, 2017).

Based on the above benchmark and policy analyses, the following table highlights the key policies and their respective improvements.

Table 7: Review of Current Policies and Proposed Improvements

No	Gaps Identified	Policies Reviewed	Ministry Involved	Effective Date	Elaboration	Proposed Improvements
1	Lack of specialised skills and career pathway progression for professions within the water sector.	National Water Resources Policy National Policy on Environment Green Technology Master Plan 2017-2030	Ministry of Natural Resources and Environment Ministry of Science, Technology, and the Environment Ministry of Energy, Green Technology and Water	March 2012 October 2002 October 2017	Under the Economic Transformation Programme (ETP), it is projected that Malaysia will require 2.5 times increase in TVET enrolment by 2025. However, the National Education Blueprint 2015 – 2025 highlights an undersupply of TVET workers in 10 of the 12 National Key Economic Area (NKEA) sectors. This is because TVET is perceived as a less attractive pathway than university education, therefore limiting the number of students who enrol in such programmes, especially high performing students. To increase the attractiveness of water and wastewater-related professions, one of the crucial steps is to provide an appealing and defined skill and career pathway progression. The National Water Resource Policy, PTS65 (p. 47) states the importance of formulating education, training, and research programme with local institutions of higher learning, training, and NGOs. However, while the aforementioned strategy emphasises defining skills progression in water-related courses, establishing a clear career pathway will better help define the necessary skills at each career node.	Perform a technology scanning of global water technologies to identify the current and future skills needs of the water sector workforce. Establish clear and attractive skills progression and career pathways for the water sector. These pathways should be deliberated and designed in collaboration between stakeholders (i.e., public, private, industry association, academia, society) to ensure they meet the needs of the industry and are recognised for tertiary education progression.
2	Water education and awareness programmes have been centred on the adult population. There is little emphasis on nurturing sustainability, environmental protection, and water awareness in early education.	Malaysian Education Blueprint 2013 – 2025 National Water Resources Policy	Ministry of Education Ministry of Natural Resources and Environment	2013 March 2012	The Malaysian Education Blueprint 2013-2025 are on the right track in emphasising the importance of strengthening STEM education (Thrust) and imparting important values in the current curriculum. Similarly, the National Water Resources Policy highlights the need to improve understanding and awareness of water security and sustainability. However, upon careful examination of the current curriculum, the values highlighted do not include sustainability, environmental protection, and water awareness. Further, awareness building described in the National Water Resources Policy is focused on the adult population and not on creating a water-sensitive younger generation. Coupling the two strategies while simultaneously including sustainability into formal curricula would greatly improve water awareness and appreciation among the younger generation on the value of water resources in the country.	• Formalising water, sustainability, and environmental protection, as well as the incorporation of the Circular Economy Framework that embeds the **8Rs of water philosophy** (**Respect** water; **Rethink** the value of water; **Reduce** wastage; **Re-Use** used water; **Recharge** groundwater (rain harvesting);

No	Gaps Identified	Policies Reviewed	Ministry Involved	Effective Date	Elaboration	Proposed Improvements
						Recycle wastewater**, Repurpose** water for higher-value use; and **Regenerate** water) at all levels of education (i.e., primary through tertiary). Collaboration with water and wastewater sector players in designing fun and attractive education and "citizen science" programmes to increase the interest among the younger generation in STEM and the water sector.
3	IWRM remains specific to water-related sectors and policies, and not cross-cutting economic sectors that rely on and affect water resources.	National Timber Industry Policy National Biofuel Policy 2006 National Tourism Policy 2020 - 2030 National Agro-Food Policy	Ministry of Plantation Industries and Commodities Ministry of Plantation Industries and Commodities Ministry of Tourism, Arts and Culture Ministry of Agriculture and Food Industries	February 2009 March 2006 December 2020 September 2011	Water's ubiquity in all economic sectors makes it imperative that water resources are not viewed in isolation, but rather in tandem and consideration of both economic growth and environmental protection. Based on this notion, water-related policies, especially the National Integrated Water Resources Management Plan and IWRM Framework should be integrated into policy design across all ministries and portfolios. However, water resources management is rarely discussed or defined in economic sector policies, especially sectors closely intertwined with water, such as the National Timber Industry Policy, National Biofuel Policy 2006, National Tourism Policy 2020 – 2030, and National Argo Food Policy.	Use a Whole-of-Government approach to integrate IWRM and environmental management in policies, state/federal planning, and national plans. This ensures water resource management is a facet of all forms of future development. Specific attention should be given to strengthening the water-energy-food nexus to ensure water and economic security. A stronger nexus will create an economic multiplier effect, thus increasing demand for higher quality water services.

No	Gaps Identified	Policies Reviewed	Ministry Involved	Effective Date	Elaboration	Proposed Improvements
4	There is no formal platform for "collaborative governance" that allows multi-stakeholder participation and consultation on policy design and decision making.	National Water Resources Policy National Policy on Environment	Ministry of Natural Resources and Environment Ministry of Science, Technology, and the Environment	March 2012 October 2002	As mentioned in the National Resources Water Policy, collaborative governance (i.e., stakeholder inclusiveness and collaboration) enables the capitalisation of expertise of different stakeholders. This is especially crucial on a resource as important as water. Even though both policies have highlighted different aspects for the inclusion of multi-stakeholder collaboration and possible channels of communication, it would be beneficial to clearly define the platforms and the rules of engagement and the extent of academia, industry and society's role and level of participation in not just the implementation of policy decisions; but also, the design and decision-making process. Water resources and the environment are nuanced areas that affect different stakeholders differently, hence gathering multi-stakeholder perspectives and input in government decisions will help create both a holistic policy as well as gain the Rakyat's trust, acceptance, and participation.	Establish a formal platform that allows "collaborative governance" between multiple jurisdictions and stakeholders (federal, state, and local government). This "collaborative governance" should also include "citizen participation" - input of all stakeholders to create business and consumer-friendly water and environmental policies, legislation, and regulations (top-down and bottom-up approach).
5	Strategies and implementing bodies are described but there is no designated central entity or agency tasked with monitoring, implementation, and high-level coordination between stakeholders.	National Water Resources Policy National Policy on Climate Change	Ministry of Natural Resources and Environment Ministry of Natural Resources and Environment	March 2012 November 2009	In the National Water Resources Policy (p. 44), strategy 23 elucidated the need to identify stakeholders and clarify roles, as well as respective responsibilities, and PTS51 detailed the importance of identifying and profiling roles for shared responsibilities and collaborations. This strategy provides a good starting point to monitor and coordinate water initiatives between the different stakeholders. Similarly, in the National Policy on Climate change (p. 7), ST8-P4 stated the need to improve collaboration through efficient communication and coordination among all stakeholders for effective implementation of climate change responses, and KA24-ST6 (p. 15) discussed the importance of stocktaking of current measures. Both these policies have discussed the importance of collaboration, shared responsibilities, and coordination. However, these policies do not articulate the effective coordination and implementation of the policies. This leads to overlapping responsibilities, duplication of resources and increase bureaucratic processes. All of which results in the IWRM is not effectively implemented.	Establish the National Water Sector Transformation Task Force, tasked with the monitoring and coordination of agencies and stakeholders in the effective implementation of water resources management strategies.

No	Gaps Identified	Policies Reviewed	Ministry Involved	Effective Date	Elaboration	Proposed Improvements
6	Authority and regulation exist only at the higher level (i.e., federal, state). However, water basins may span across state borders, with overlapping and conflicting resource sharing and regulation.	National Water Resources Policy National Physical Plan	Ministry of Natural Resources and Environment Ministry of Housing and Local Government	March 2012 April 2005	Water resources in the country fall under state jurisdiction. However, river basins often exist across multiple state borders, and oftentimes results in disputes over water resources and regulation (e.g., the ongoing water dispute between Kedah and Penang since 2002). The National Water Resources Policy made important emphasis on the need to promote shared responsibility, to cooperate and resolve conflict (p. 45): PTS55 stated the need to identify processes and procedures that can be integrated to ensure shared governance of water resources, and PTS61 highlighted the need to identify platforms for resolution of conflicts and competing interests. In a similar vein, the National Physical Plan have also stated the importance of addressing anticipated water shortage and uneven water distribution through inter-basin and interstate water transfer. These strategies addressed the need to ensure shared governance of water resources. However, they are, arguably, ineffective in addressing issues or conflicts arising about water resource allocation and governance between states.	Establish river basin organisation and/or independent regulators whose boundaries are tied to key larger water basins and not to state borders or the federal government.
7	Lack of clear accountability and transparency mechanisms for operators and service providers within the water sector related to service quality targets, environmental and sustainability targets, and innovation targets.	National Water Resources Policy National Policy on Environment Green Technology Master Plan 2017 - 2030 National Policy on Climate Change	Ministry of Natural Resources and Environment Ministry of Science, Technology, and the Environment Ministry of Energy, Green Tech and Water Ministry of Natural Resources and Environment	March 2012 October 2002 October 2017 November 2009	There is a lack of discussion on accountable and transparent mechanisms for operators and service providers in water-related policies, such as the National Policy on Environment, the Green Technology Master Plan 2017 - 2030, and the National Policy on Climate Change. This is related to having clear guidelines, standards and targets related to service quality, environmental and sustainability, and innovation. In the National Water Resource Policy (p. 28), strategy 6 outlined the importance of improving and developing measures to determine the threshold and yield of water resources and the integrity of water resource agencies. To do so, specific action plans were created: PTS10 stated the need to profile methods and measures used to determine threshold and yield, and PTS11 stated the need to develop a system to consolidate information to create national standards and parameters for setting threshold and yield levels for different water resource types and waterbodies. Similarly, PTS12 stated the need to review, revise, and reconcile the present standards to determine the integrity and health of water resources. These steps are useful and important as they are the foundational measures towards ensuring accountability (i.e., establishing measuring standards). However, the policy can benefit from more specified procedures or measures to inspect and monitor if the relevant stakeholders adhere to the quality standards and targets sets.	Establish accountability and transparency mechanisms within the water sector, as well as promote the use of smart technologies (greater digital platform adoption with the integration of ledger systems e.g., blockchain) for traceability and monitoring. Water operators make publicly accessible financial reports, annual/5-year business plans, service quality targets, environmental and sustainability targets, and innovation targets. Water operators measured based

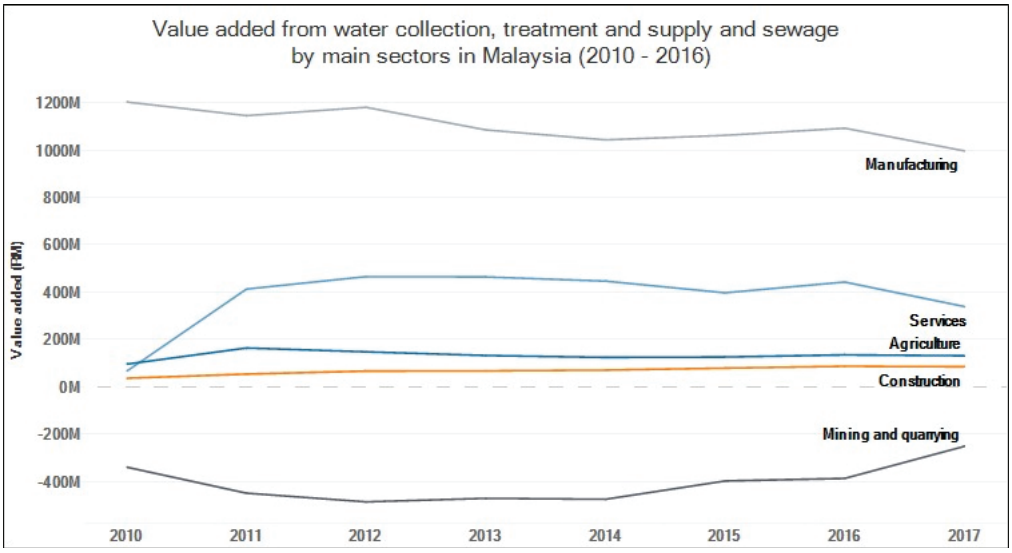
No	Gaps Identified	Policies Reviewed	Ministry Involved	Effective Date	Elaboration	Proposed Improvements
						on service quality, environmental targets, national initiative targets, and should be held accountable when targets aren't met. Accountability mechanisms should be made applicable to all relevant stakeholders (contractors, service providers, material suppliers, etc). This ensures that the entire supply chain is transparent to ensure continuous improvement cycles and efficiency and build trust among the end-users. The latter is critical for ensuring sustainable water demand and willingness to pay a higher premium for quality water services.
8	There is a lack of formal data sharing, e-governance, and open data in national policies to enable data-driven water solutions and transparency.	National Water Resources Policy	Ministry of Natural Resources and Environment	March 2012	E-governance and data sharing are mentioned in the National Water Resources Policy: on page 26, PTS7 which stated the need to develop a profile of stakeholders and existing information database. The PTS8 stated the importance of providing mechanisms for sharing of information and access between stakeholders. While these policies are a step in the right direction, effective implementation of these policies will require formal procedures and implementation strategies to facilitate seamless data sharing among the multiple stakeholders in the water industry.	Reviewing laws/ legislation on data sharing among government agencies (Official Secrets ACT) and designing policies for greater adoption of the use of smart technologies (digital platforms for delivering government services and e-governance); greater coordination between agencies in data collection and sharing; and open-source government data.

No	Gaps Identified	Policies Reviewed	Ministry Involved	Effective Date	Elaboration	Proposed Improvements
9	Tariff review mechanism is not described in the policies that capture the full cost for providing water services (operations, infrastructure, talent building and innovation).	National Water Resource Policy	Ministry of Natural Resources and Environment	March 2012	Revenue from water charges is important not only to cover operation and maintenance costs but also to enable continued investment in advanced water infrastructure to meet the needs of the industry and society. In addition, water pricing is a vital instrument for improving water use efficiency. Hence, it is important to establish a well-planned water tariff system - one that properly and adequately reflects the costs of infrastructure, human capital, innovation etc. The water tariff review mechanism was not described in the National Water Resources Policy to reflect the full cost of water pricing.PTS39 (p. 40) stated the importance of identifying best practices in the valuation of water resources pricing and cost recovery. However, a comprehensive water tariff mechanism is not in place to accurately capture the full cost of water services across all regions in the country. A lack of a comprehensive water tariff has adversely impacted the quantum and quality of water supply across the country.	Incorporating a tariff review mechanism that includes KPIs that are tied to service quality, customer satisfaction, environmental goals, national target alignment, etc. Optimal tariff rates to ensure financial sustainability and KPI targets incentivise water operators to continuously improve services. In addition, the optimal tariff rates also serve as a demand management strategy for more efficient water consumption and conservation practices. Optimal tariff rates are critical to ensure sustainable supply and demand-side management of water resources. Effective management of the supply-side and demand-side of water resources are important drivers for ensuring affordable and competitive water rates, resulting in a profitable water sector.

6.3 Water Sector as a Dynamic New Economic Sector Capable of Driving the Nation's GDP Growth in the Future (Scope 3)

Dynamics in the Malaysian Water Sector Based on the Economic Sectors

Examining Malaysia's water sector in deeper detail in Figure 13 reveals that there are significant differences in the value-added amount between the main sectors of the economy. This value-added component includes water collection, treatment, and supply (which forms the bulk of our water management services) and sewage management services. The manufacturing sector leads the value-added amount to the economy, with almost three times the amount of the next highest, services sector. One of the largest users of water is the agriculture sector, which registers the third-highest value added after the manufacturing and services sector. On the other hand, mining has had a persistent negative value-added since 2010.



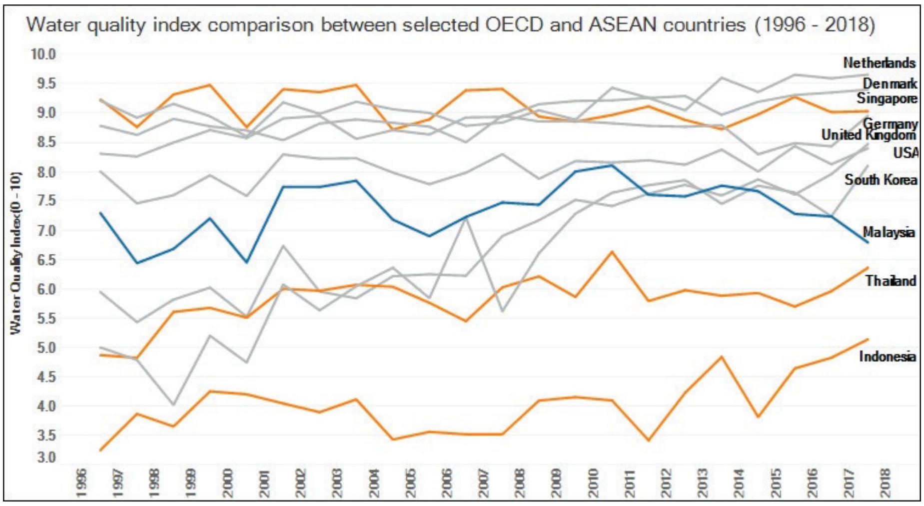
Source: ASEAN Development Bank, Department of Statistics Malaysia

Figure 13: Value-Added Components of Water Based on the Main Malaysian Economic Sectors

International Benchmarking of Quality of Water

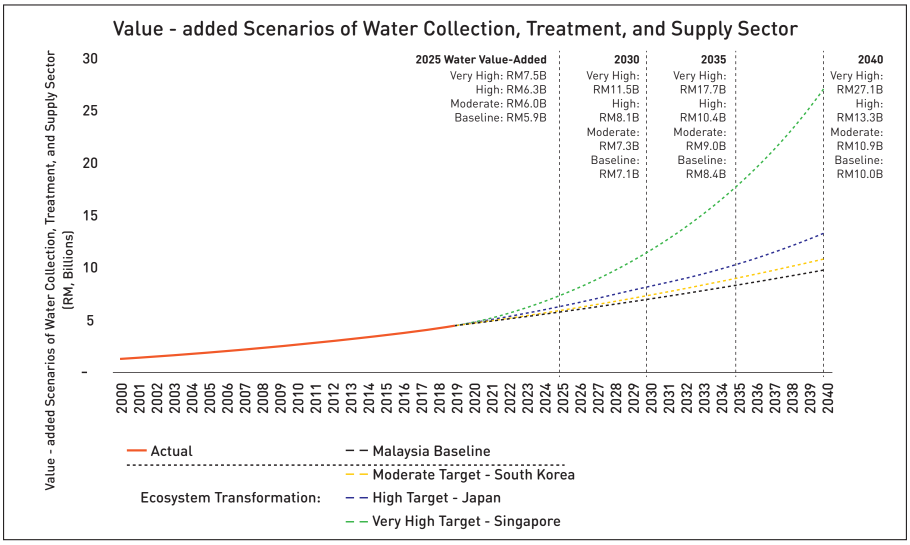
In this section of the report, new data is presented, benchmarking the quality of the Malaysian water industry with that of selected developed OECD and ASEAN countries. Figure 14 shows that the quality of water in Malaysia increased slightly from 1996 to 2010, but experienced a decline from 2011 to 2018. On the other hand, all OECD and selected ASEAN economies (Thailand and Indonesia) have experienced an upward trend in the quality of water from 1996 to 2018. The quality of Malaysia's waterways has steadily declined since 2010 and it can be seen that the regional competitors, such as Thailand and Indonesia catching up to Malaysia's current state.

Next, the value-added per capita of water in Malaysia is compared with that of selected OECD countries. Figure 15 shows that value-added per-capita from the water industry in Malaysia is relatively low compared to many of the other OECD countries. This suggests that the Malaysian water supply is not generating the multiplier effect in other sectors of the economy, as compared to several of the OECD countries Australia, the United Kingdom and Germany. These advanced economies have much stronger water ecosystems that play a key role in ensuring water quality and sustainability, but also are important enablers for raising the productivity and competitiveness of other sectors of the economy.



Source: IMD World Competitiveness Yearbook (1996 – 2018)
Index component: Water transportation – a survey of whether water transportation (harbours, canals, etc.) meets business requirements.

Figure 14: Water Quality between Malaysian and Selected OECD and ASEAN Countries



Source: Department of Statistics, Malaysia and Analytics by Sunway Institute for Global Strategy and Competitiveness.
Note: Economic data for the water collection, treatment, and supply sector was only available for 2010, 2015, 2017, and 2019. Missing data between years were interpolated and backcast.

Figure 15: Value-Added Growth Scenarios of Water Collection, Treatment, and Supply Sub-Sector

A large part of transforming the water sector into a viable economic sector includes moving water-dependent products and services up the global value chain to have a competitive advantage in the future. For this to happen, each pillar of the 8i water ecosystem enablers needs to be strengthened accordingly.

If the enablers of the water ecosystem were strengthened by the implementation of strategic programmes towards positioning the water sector as a new national economic sector, there is much potential in turning the water sector into a dynamic economic sector. In 2019, the water sector had a value-add of RM 4.5B[11]

[11] *Source*: Department of Statistics, Malaysia

which represents a 0.32% contribution to Malaysia's GDP. By accelerating the growth of a skilled labour force, the right investments, and the digital transformation of the water sector, it is possible for the sector to achieve a much higher value-add amount to the economy. If the water sector can achieve a similar growth to Japan's scenario as seen in Figure 15, by implementing the appropriate reforms to the water sector and water ecosystem can lead to a value-add of RM13.3B by 2040, contributing 0.46% to the national GDP. The reforms include transforming the Malaysian water ecosystem to be knowledge-intensive and technology-driven. A developed water ecosystem will ensure a sustainable supply of quantum and quality of water to meet the need of the society and key economic sectors of the economy. A sound water ecosystem will also ensure appropriate strategies are in place that will ensure effective management of the demand for water by the society. Sound supply and demand of water will lead to the strong private sector and foreign direct investment into the water sector spawning local water/aqua tech industries. All of which will nurture a strong local water supply chain with an extensive regional footprint.

Input-Output Analysis[12]

In this section, a deeper investigation is made on how an increase in the final demand[13] of the water sector can impact the overall economy of Malaysia as compared to the main economic sectors. Assuming that the economy is perfectly reactive to changes in the final demand through adjustments to its output level and given the interaction between the various economic sectors, the spillover effects due to increased demand for a particular sector's goods and services are ascertained. Using the Input-Output framework, the economy-wide impact through capturing the interlinkages between the economic sectors were estimated. The multiplier effects of the water sector as compared to other key economic sectors are of particular interest as it indicates the relative potential of the water sector's impact throughout the economy.

Additionally, using the method developed by Boudhar et al. (2017), the study identified which economic sector, directly and indirectly, consume the most quantity of water and the size of economic returns generated from the water consumed. Regional comparison against selected benchmark countries will allow us to gauge Malaysia's standing vis-à-vis other countries on the issue of water efficiencies and use.

Multiplier Analysis

In this study, multiplier measures are calculated in terms of output, income, - gross value-added (GVA) and employment to provide a detailed picture of the economic contribution of the various sectors considered in our analysis (refer to Figure 16, 17, 18 and 19, respectively). Multiplier effects of Malaysia's water sector are consistently ranked the lowest among the eight economic sectors included in this analysis after sewerage across the different measures. Compared to other services[14] , this study shows that water is not an attractive avenue from an investment point of view after accounting for the direct and indirect effects of the additional spending.

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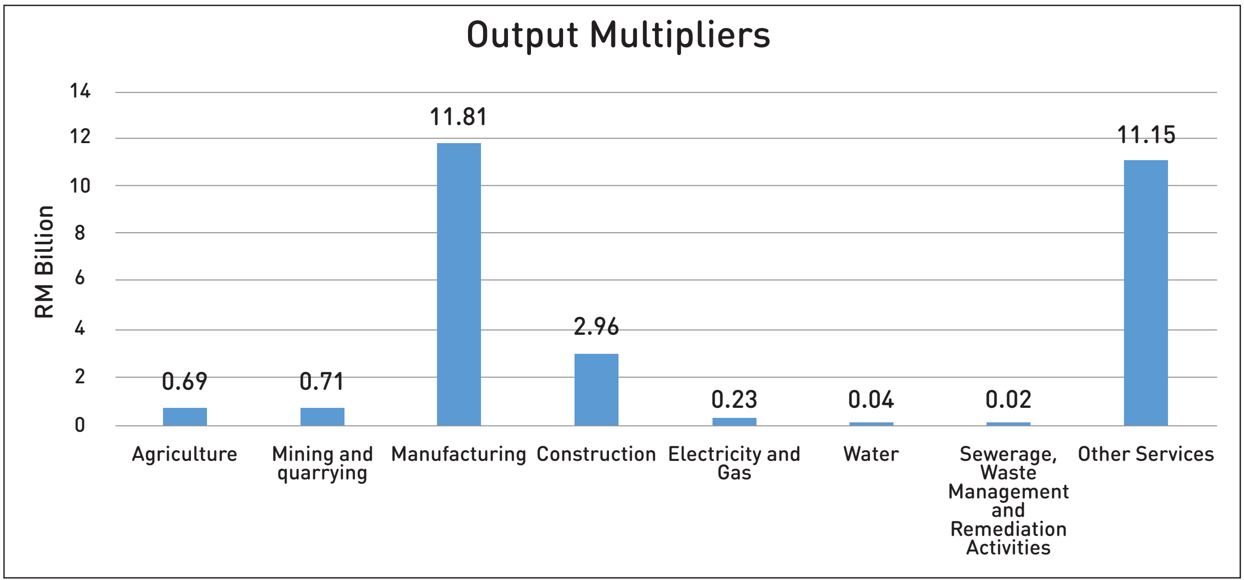
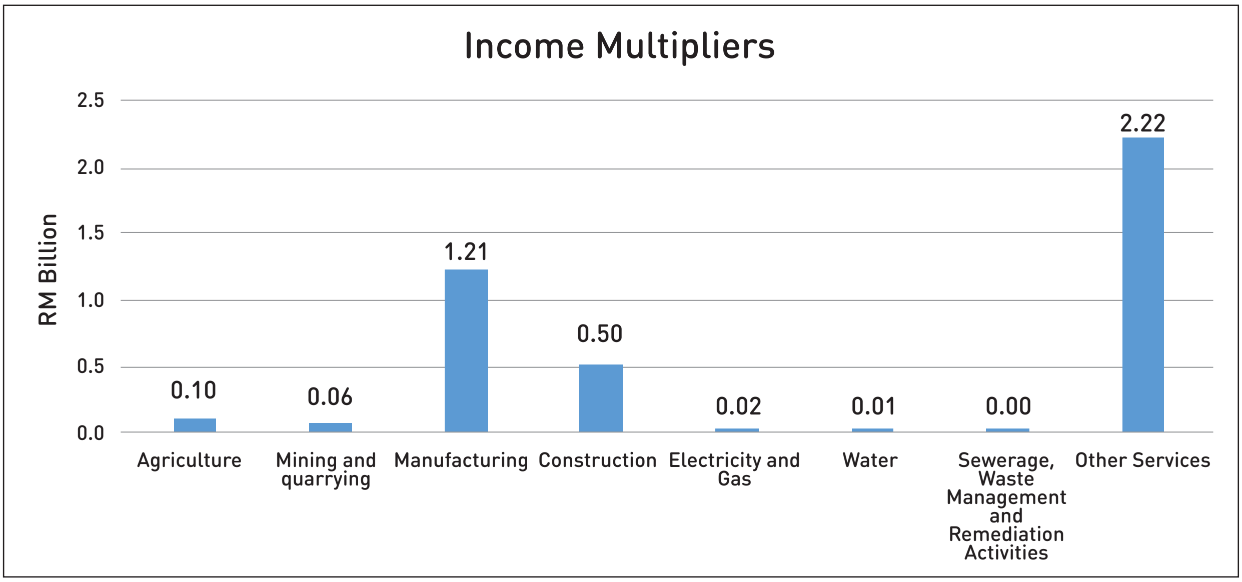
[12] All Input-Output analyses were undertaken using the 2015 Input-Output table published by DOSM. This is the latest data available as these tables are updated every 5 years and 2020's table has not been published yet.
[13] Final demand is the aggregate sum of expenditure on consumption, investment, government spending and net export.
[14] Other Services refers to the services sector excluding Electricity and Gas, Water and Sewerage, Waste Management and Remediation Activities.

For every 1% increase in the Water's final demand spending, it is estimated that only RM 10 million of household income is generated throughout the economy. Compared to other services, the estimated impact is RM 2.2 billion. In terms of the GVA multiplier[15], there is a significant difference between that of water and other services at RM 23 million and RM 5.55 billion respectively. In employment terms, a 1% increase in final demand spending of water only generates 191 new job opportunities. In contrast, a similar increase in other services will lead to 74,694 new employments generated in all economic sectors to meet the higher demand. Therefore, this study concludes that the water sector in its present state is not a strategic sector and has a low potential contribution to the national socio-economic development.



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021) based on Malaysia Input-Output Table 2015 by Department of Statistics Malaysia (DOSM).

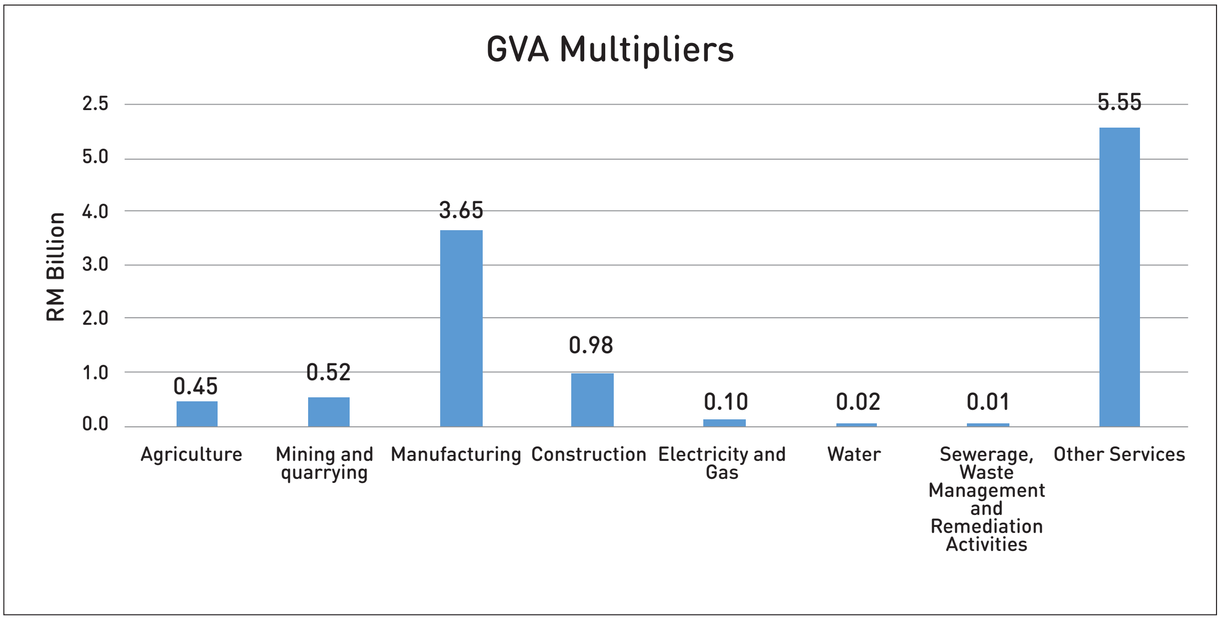
Figure 16: Output Multipliers for Main Economic Sectors of Malaysia



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021) based on Malaysia Input-Output Table 2015 by Department of Statistics Malaysia (DOSM).

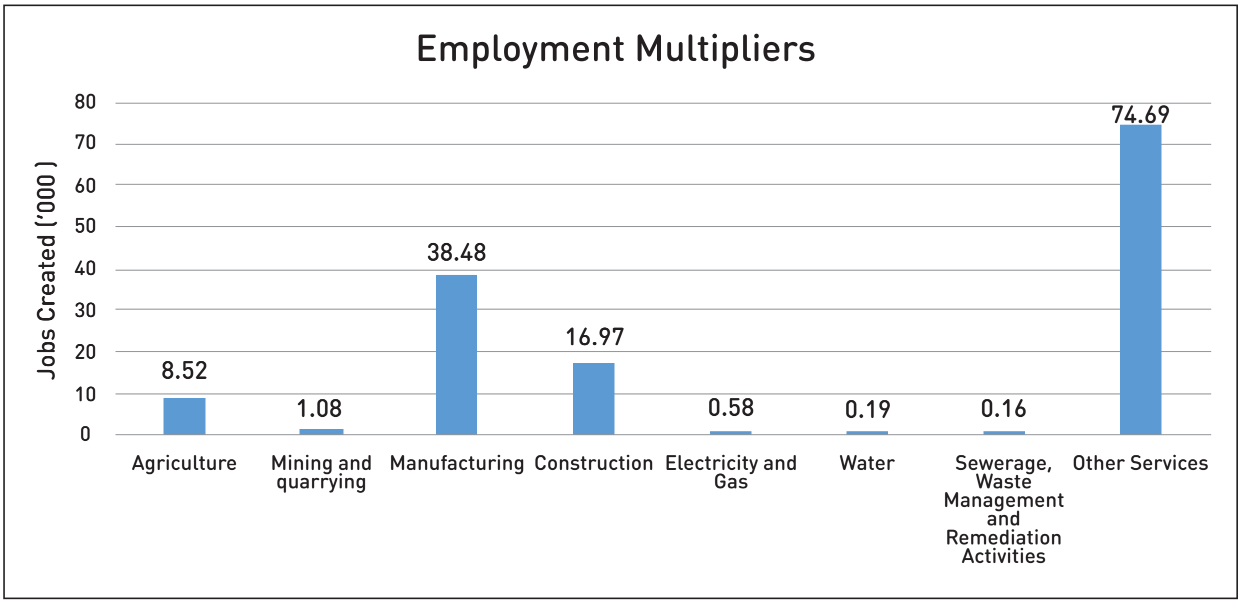
Figure 17: Income Multipliers for Main Economic Sectors of Malaysia

15 An important indicator as GDP is the sum of sectoral GVA plus taxes less subsidies



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021) based on Malaysia Input-Output Table 2015 by Department of Statistics Malaysia (DOSM).

Figure 18: Gross Value-Added Multipliers for Main Economic Sectors of Malaysia



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021) based on Malaysia Input-Output Table 2015 by Department of Statistics Malaysia (DOSM).

Figure 19: Employment Multipliers for Main Economic Sectors of Malaysia

Water Intensity

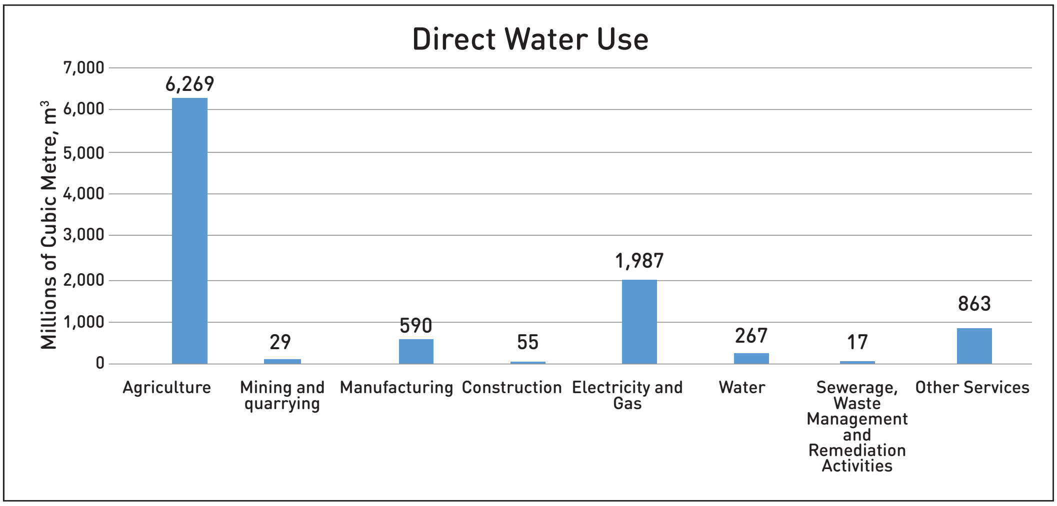
Considering the total water consumed (including distributed water and water abstracted for own use) by the sectors in their production activity, it is noted that the top three sectors with the highest direct water use are agriculture, electricity and gas followed by other services. Figure 20 presents the direct water use of water by all economic sectors of the economy. The agriculture sector recorded a direct water use of 6,269 x 10^6m^3, representing 62% of firms' overall water consumption in 2015. The second-highest direct water consumer is electricity and gas at 1,987 x 10^6m^3 or 20%. On the other hand, direct water consumption of other services is recorded at 863 x 10^6m^3, making up 9% of the overall water use.

Figure 21 presents the water use and water use coefficients for the sectors. Considering the consumption of water by the sectors relative to the value of output produced, the agriculture sector was found to be the least productive sector, where its direct water consumption per currency unit produced is relatively higher than the other sectors. Per one thousand RM of output produced, the direct water consumption required for the agriculture sector is about 53.17m^3. Interestingly, water even though not a major direct water user, exhibits low water productivity, where 45.87 m3 of water is required to produce one thousand RM of output. Coming in third is electricity and gas where 38.84 m^3 of water is used directly in the production of one thousand RM of output. Other sectors have relatively low water intensity of less than 5m^3.

However, looking at the direct water consumption alone might not give the full account of water used by the sector. This is because production inputs of a sector typically use production outputs of another sector. Therefore, the water use of these inputs would not be captured by the direct water consumption of the sector. For example, the manufacturing of canned fruits uses fruits grown by the agriculture sector in the form of virtual water. To account for these indirect water consumptions that occur between and within economic activities, the sectoral total water used coefficient is computed to fully gauge the water intensities of each sector by capturing the virtual water embedded in the intermediate inputs.

After accounting for virtual water, the water efficiency rankings are still consistent with the direct water consumption efficiency rankings, except for sewerage and other services which moved up by one rank while manufacturing dropped by two places. The least water-efficient sectors remain as agriculture, water and electricity and gas across both metrics.

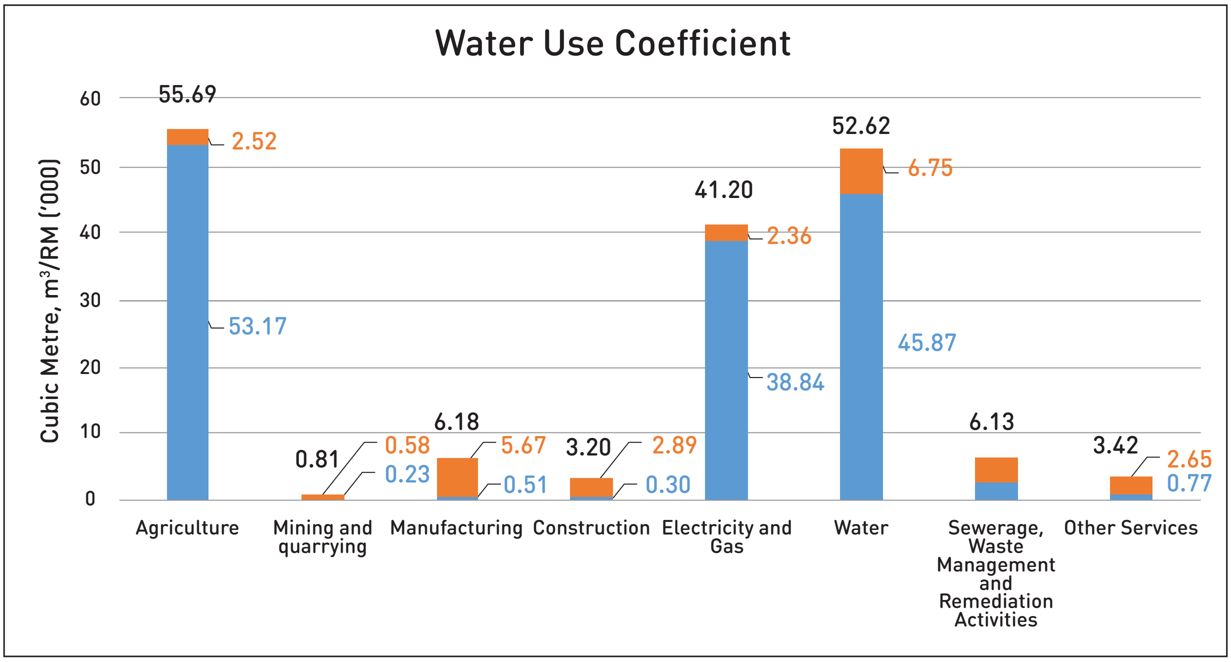
It was also observed that the indirect water use coefficient for the water sector is the highest among the sectors analysed. This highlights the strong linkage between water and the rest of the economy, giving rise to a high level of inter-and intra-industry transactions within the water sector whereby the sector itself purchases its output as an input to production[16]. From these analyses, interventions to improve national water efficiency should be targeted towards agriculture and the utility sectors. Due to the magnitude of water use, these sectors exhibit the largest room for improvement.



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021) based on Malaysia Input-Output Table 2015 and MySEEA PSUT Water 2015 by the Department of Statistics Malaysia (DOSM)

Figure 20: Direct Water Use of Water by all Economic Sectors of the Economy

[16] The water supply sector and sewerage, waste and remediation sector consume high amount of water and are highly interdependent where they are purchasers of the other sector's output.



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021) based on Malaysia Input-Output Table 2015 and MySEEA PSUT Water 2015 by the Department of Statistics Malaysia (DOSM)

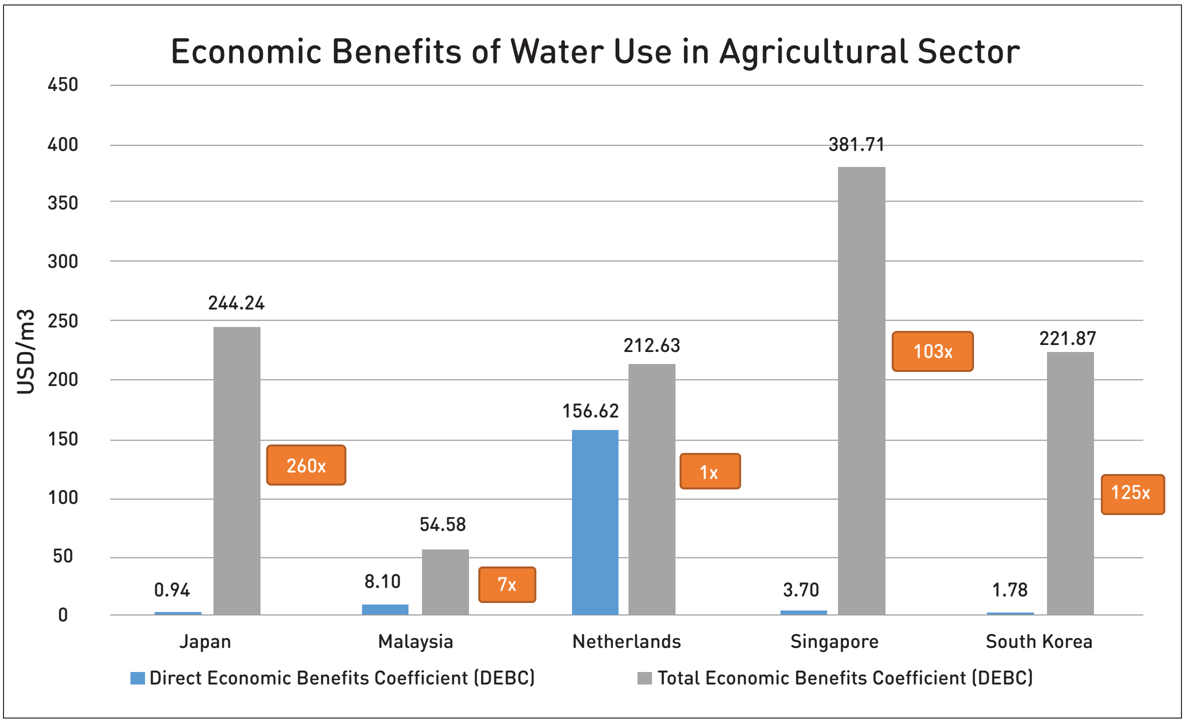
Figure 21: Direct, Indirect and Total Water Use Coefficients for All Sectors of the Economy

Benchmarking Malaysia's Performance against Pace-Setter Countries

In this section, the economic value of water is measured as the return in terms of gross value-added per unit volume of water use and comparisons are made against four benchmark countries: Japan, the Netherlands, Singapore, and South Korea.

From Figure 22 below, the direct economic benefits coefficient (DEBC) of water use for the Malaysian agriculture sector is estimated at $8.10/m^3 [17], second-highest among selected benchmark countries. This shows that Malaysia's agricultural sector's use of water to produce direct consumption products (e.g., raw meat, fruits & vegetables, etc.) is better than most benchmark countries. However, looking at the total economic benefits coefficient (TEBC), Malaysia's ranking dropped to fifth place at $54.58/m^3 with a resulting multiplier effect of 7 times. The Netherlands, first in terms of DEBC, also fell to fourth place when total effects were considered. On the other hand, Japan presented the largest multiplier effect where the TEBC estimated at $244.23/m^3 is 260 times of the DEBC at $0.94/m^3. This highlights that the benchmark countries can leverage on a higher multiplier for economic benefits of water use in agriculture by linking agricultural products to other high value-add sectors such as tourism, hospitality, food & beverage. For example, Singapore might have a low direct economic benefit of water use for their agriculture sector, but they can derive higher economic benefits by linking their agricultural products to their higher value-add sectors. Other potential reasons include the weak supply chain relationship between the agriculture and industrial sectors where the quantity and quality of the agriculture output do not meet the standard required by the industrial production process. Hence, Malaysia's agriculture sector is not able to obtain premium prices at the international level.

[17] This may be skewed by the high value of oil palm which is a high value commodity.



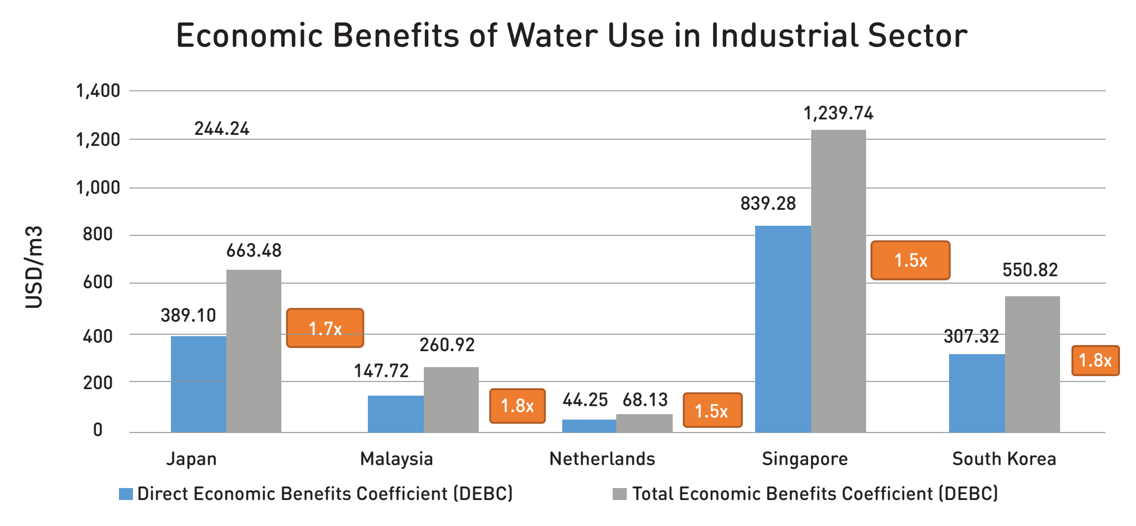
Values were converted from local currency to USD using Oanda exchange rate as of 31 December 2015, https://www1.oanda.com/currency/converter/
Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021) based on Agricultural and Industrial water withdrawal data 2015 by AQUASTAT; Malaysia Input-Output Table 2015 by Department of Statistics Malaysia (DOSM); Japan Input-Output Table 2015 by Ministry of Internal Affairs and Communication, Japan; Netherlands Input-Output Table 2015 by CBS (Statistics Netherlands); Singapore Input-Output Table 2015 by Singapore Department of Statistics (SINGSTAT); South Korea Input-Output Table 2015 by Bank of Korea

Figure 22: Economic Benefits of Water Use in Agricultural Sector

In the case of the industrial sector, as presented in Figure 23, DEBC of Malaysia's industrial sector is the second-lowest among the benchmark countries' industrial sector at $147.72/m^3 after the Netherlands at $44.25/m^3. Although the direct return Malaysian industrial sector is 18 times higher than the agricultural sector, Malaysia's industrial sector's performance is still lagging behind the pacesetter countries. This analysis provides further evidence to the low water efficiency of the Malaysian industrial sector, which is highlighted in Figure 21 where the ranking of Malaysia's agricultural sector fell once sectoral interlinkages are being accounted for. Furthermore, it was also observed that for the industrial sector, the rankings of the countries are consistent across DEBC and TEBC, and the multiplier effect is relatively small (less than 2) compared to the agricultural sector. This can be explained by the relatively smaller size of the agricultural sector compared to the industrial sector. Thus, giving rise to weaker indirect effects for the agriculture sector.

The importance of accounting for intersectoral relationships is also highlighted in this analysis. Looking at the DEBC of Malaysia's agricultural sector alone gives the impression that the Malaysian agricultural sector has high water efficiency. Taking Japan's agricultural sector as an example, despite having the lowest DEBC among the selected countries, their TEBC is the second highest (only behind Singapore) as their agricultural sector is strongly linked to the industrial sector and can generate a high value-added indirectly through the sales of its outputs to the industrial sector for the latter's production process. In contrast, economic returns from water use of Malaysia's agricultural sector are impacted by the low value-adding industrial sector.

Output Multipliers



Values were converted from local currency to USD using Oanda exchange rate as of 31 December 2015, https://www1.oanda.com/currency/converter/
Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021) based on Agricultural and Industrial water withdrawal data 2015 by AQUASTAT; Malaysia Input-Output Table 2015 by Department of Statistics Malaysia (DOSM); Japan Input-Output Table 2015 by Ministry of Internal Affairs and Communication, Japan; Netherlands Input-Output Table 2015 by CBS (Statistics Netherlands); Singapore Input-Output Table 2015 by Singapore Department of Statistics (SINGSTAT); South Korea Input-Output Table 2015 by Bank of Korea

Figure 23: Economic Benefits of Water Use in Industrial Sector

Summary

From the analysis above, a few conclusions can be drawn regarding the present state of the Malaysian water sector as well its impact on other sectors of the economy. Firstly, estimated I-O multipliers of the water sector are relatively lower indicating the lesser potential of the current state of the water sector in having a positive impact on economic growth, household income as well as employment creation. The enablers of the water sector ecosystem need to be strengthened with a systems approach across the 8i framework to transform the water sector into a dynamic economic sector that can drive a positive impact on economic growth, household income, and employment creation.

Secondly, the analysis of direct and indirect water uses at the sectoral level reveals that agriculture exhibits the highest water use at the same time having the lowest efficiency where the amount of water required to produce a currency unit of output is relatively higher than other sectors. However, this does not mean that Malaysia should de-prioritise water for the agriculture sector. As shown by benchmark countries like Japan and Singapore, they can leverage strong supply chains between their agriculture and industrial sectors, where agricultural outputs are converted to higher value-added products via sales to other sectors such as food and beverage and manufacturing as intermediate inputs. Therefore, to enhance the agriculture sector's economic return from water use, the focus should be on strengthening the linkages between the economic sectors to streamline supply chains and efficient matching of inter-sectoral supply and demand of products and services.

Thirdly, policies or strategies to improve water efficiencies should consider both direct and indirect water use in the form of virtual water. An increase in the production activities of sectors with high indirect water use such as the Malaysian manufacturing sector will be reflected as water use in the sector which it depends on for intermediate inputs. A comprehensive understanding of virtual water within a sector's products and services will allow for more precise targeting of incentives and interventions to boost the sector's water efficiency.

Future of Malaysian Water Sector

As a dynamic economic sector, the Malaysian water sector is capable of increasing its output to fulfil additional sales to meet the final demand. Figure 24 below depicts the household income and employment contribution from the water sector as production levels increased to meet the additional final demand. Two different scenarios of final demand are simulated i.e., the baseline scenario and the case of Japan – a country that exhibits high water efficiency as found in the previous analysis. The resulting new household income level and employment generated from matching Japan's water efficiency is then compared with Malaysia's baseline scenario.

Year	Baseline		Japan	
	Income (RM Billion)	Employment ('000)	Income (RM Billion)	Employment ('000)
2025	0.906	32.839	0.965	35.006
2030	1.086	39.367	1.243	45.074
2035	1.291	46.813	1.592	57.737
2040	1.528	55.414	2.033	73.735

Figure 24: Household income and employment contribution from the water sector

Under the baseline scenario, the incremental household income and employment contributed by the water sector in 2040 (after accounting for spillover effects) is estimated to be RM1.5 billion and 55.4 thousand new jobs respectively. In the event the Malaysian water sector can emulate that of Japan, an addition of RM0.5 billion of household income, as well as 18,320 new job opportunities, is expected to be generated throughout the economy.

Multi-Stakeholder Perspective on the Water Ecosystem

Water plays a key role in ensuring the sustainability and competitiveness of local industries and the quality of life of the communities. Hence, it is important to gauge the sentiments of the multi-stakeholders on the state of the water ecosystem in supporting sustainable economic development and ensuring the quality of life of communities. In this section, the state of the water ecosystem from the perspective of the multi-stakeholders is examined.

This study used a mixed-method approach where both the qualitative and quantitative approaches are used to examine the stakeholder's perspective. The qualitative approach where nationwide stakeholder engagement sessions were held involving government agencies, industries, associations, non-governmental organisations, and the communities through in-depth interviews and focus group discussions via an online platform. The stakeholder's views on the water ecosystem enablers and the findings provide robust, insightful, and experiential information. On the other hand, in the quantitative approach, a survey to elicit specifically the sentiments of the public and industry on their willingness to pay for water was undertaken. The following sections will highlight the key findings of the two approaches.

Qualitative Analysis[19]

Focus group discussions (FGDs) and in-depth interviews were conducted via online platforms covering government agencies, industries, associations, and non-governmental organisations. The key objective of the FGDs was to assess if the Malaysian water ecosystem is ready to be a dynamic economic sector. A total of 73 stakeholders were consulted to elicit their perspectives on the state of the Malaysian water ecosystem. Respondents were asked for their views on the sustainability of water as an economic sector, and their organisation's experience in participating within the ecosystem, as a supplier, regulator, industry association or industry. Questions are contextualised by the 8i framework, emphasising the current ecosystem's state of infrastructure, infostructure, institutions, interactions, intellectual capital, incentives, integrity, and internationalisation.

Based on the interviews, the sentiments of these stakeholders on the water ecosystem (enablers) were gauged on two dimensions of interest (i) current emphasis in the water ecosystem and (ii) required intervention to enable the water sector to become globally competitive (represented in Figure 25). Overall, respondents have a negative perception of the current Malaysian water ecosystem. When comparing each of the 8i enablers, the perception of respondents on interaction, infostructure, intellectual capital, and internationalisation was closer to a neutral sentiment. While there is some indication of plans to improve these enablers, they are perceived as less urgent than the intervening measures required for institutions, integrity, incentive, and infrastructure.

Despite individual respondents, lacking a clear view on how changes in the institutions should take place, a composite view of the data has shown strong linkages between institution to interaction and integrity. Among these three enablers, interaction resides in the most advantageous current state, where the respondents observe that beneficial collaborations are more prevalent in the ecosystem. However, these collaborations have been mostly ad-hoc partnerships between supply chains, or within the water supply chain itself. The respondents believe that there are opportunities to scale up these existing networks and leverage such resource channels to collectively revitalise the water sector. These networks can bring together subject-matter experts and best practices from developed countries with a new goal of formulating and revising regulations, policies, property rights (Federal-State jurisdictional issues) and standards to maintain the quality of the water resources, as well as appointing and empowering a singular decision-making entity to bridge the divide between state and federal water governance (institution).

The gaps in integrity appear to be systemic and is not a standalone problem but pervasive in multiple dimensions. The respondents opine that the weak overall performance, accountability, and sustainability

[19] Analytics by Sunway Institute for Global Strategy and Competitiveness (2021)

of the ecosystem can be attributed to the fact that the Malaysian water sector is not structured as a commercially viable operation. Over-reliance on state funding over operational revenue streams results in a commensurate sacrificing of operational viability in favour of capital-saving. Many respondents also conveyed that the current tariff system needs to be reviewed.

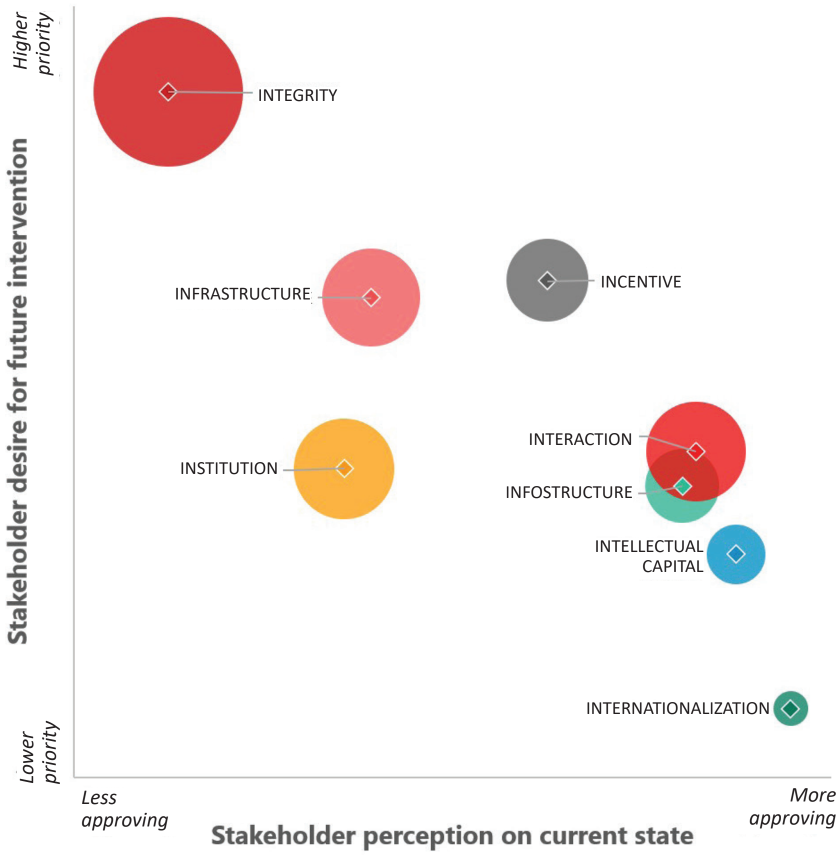
Specifically, higher tariffs can be structured to generate a sustainable revenue stream for water suppliers, and upfront project-based state-federal funding can be curbed. However, it is important to include integrity systems that integrate accountability and transparency mechanisms that relay to both consumers and regulators how operators have utilised their newly acquired funds. Mechanisms that are already adopted by global benchmark countries and even local private enterprises such as annual financial reports, five-year business plans, and sustainability targets are some examples that could be to improve not just operator accountability, but also consumer trust in the system. These easily implementable changes force water suppliers to be more accountable for the continuous service levels upkeep of utility infrastructure and provide high service quality.

Additionally, these mechanisms can be extended to third party contractors and suppliers employed by water suppliers. The inclusion of, for example, product liability, ensures that material vendors supply long-lasting products – imperative in the case of tackling NRW.

Furthermore, tiered rates would also punish waste-prone consumer behaviour. Consideration into what and how these rates should be structured is crucial to avoid straining the B40 communities' access to clean water. Insights must be sourced from a participatory approach, a Whole-of-Society approach to ensure all dimensions and spillover effects are accounted for. Such collaborations between central agencies and the rest of the ecosystem should also be extended to knowledge and IP partnerships, to revitalise the current declining state of the national physical water infrastructure.

Stakeholders view that while few have actively pursued investments into technology and human capital development within the water sector, these efforts have been insignificant in transforming the water sector into a knowledge-driven sector. Notably, the development of national information repositories for real-time telemetry data has provided new avenues for infostructure optimisation across the various economic sectors. However, the extent to which this information is operationalised to yield measurable benefits within the water sector has a lot of room for improvement. As discussed previously, the fundamental commercial structure of the water supply chain disincentivises innovation among water suppliers. For these technologies and expertise to be translated into business value, the right incentive structure must first be in place to create innovation-based competition among water suppliers.

Another prevalent issue that the respondents highlighted is Intellectual Capital, the loss of skilled labour within the water sectors to other sectors and also to other countries. This outflow adversely impacts the dynamic capabilities (absorptive, adaptive, and innovative capabilities) of the industry's workforce, hindering technology and knowledge transfer from other advanced countries. Ultimately this impairs the ability of local supply chains to scale up and integrate into advanced international water supply networks.



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021)
Note: Bubble-size represents the level of awareness/knowledge attributed to the enabler.

Figure 25: Summary of Focus Group Discussions (Qualitative Findings)

In summary, the FGDs show that there are gaps in the Malaysian water ecosystem and has highlighted the areas of improvement to deepen the impact of the water sector on the economy. While its performance in some enablers is better than others, the absolute state of the water ecosystem is lacking.

- The most prevalent systemic issues that the stakeholders perceive can be traced back to weak Integrity (governance systems) – the inability of people and processes to ensure accountability across the ecosystem.

- On closer inspection, even the best-performing dimension, internationalisation, does not provide a substantial driver to anchor the water ecosystem. The level of awareness/knowledge attributed to this dimension (represented by the bubble-size) is by far the lowest of all the 8i metrics, indicating that while stakeholders maintain a positive perception, their views and understanding of international is limited. This could be attributed to the lack of awareness of cross-industry and cross-geographical best practices in internationalisation initiatives for the water sector.

- The above analysis suggests that the water ecosystem is far from being a vibrant and dynamic water sector that can increase its contribution to the national GDP.

In this context, moving forward, the effective intervening measures should include the staged transmission mechanism proposed in the conceptual framework (See Figure 2) to close the gaps in the current state of the water ecosystem.

Quantitative Analysis

Descriptive Analytics

This section provides a brief description of the underlying characteristics of firms to uncover patterns and trends from the data collected from the questionnaire survey. A total of 500 industry and business leaders have participated in a water survey carefully planned and designed by the task force. Similarly, 600 public citizens have been selected at random to participate in the survey. The objective of this survey is to furnish the task force with valuable insights regarding the current needs and perceptions on the water ecosystem, which is an important step in informing and developing effective strategies to develop Malaysia's water sector into a dynamic economic sector. The following section will present the analysis and key findings of the survey, from both viewpoints of businesses and citizens.

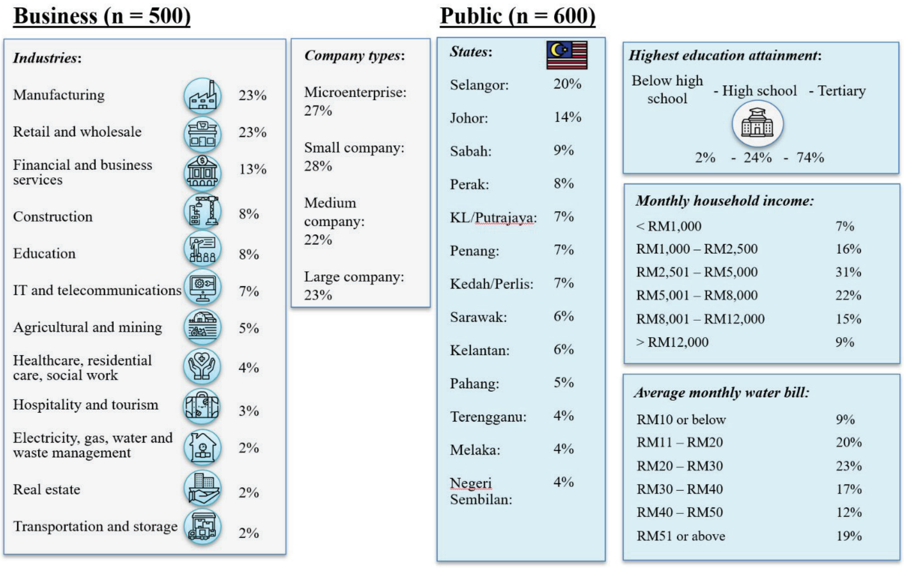


Figure 26: Demographics of survey participants

A. Setting the context: How important is water as a resource?

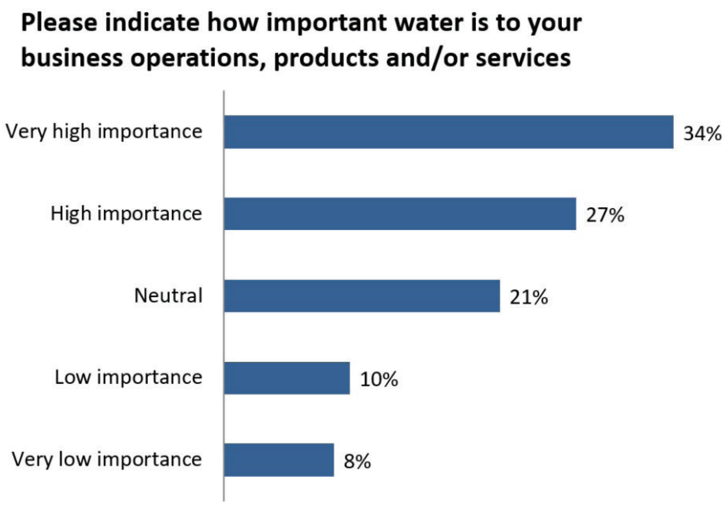


Figure 27: Importance of Water to Businesses

The majority of firms (i.e., 61%) indicated that water is of high importance and very high importance to their business operations. In particular, water is of the highest importance to the hospitality and tourism industry, the electricity, gas and water sector, agriculture and mining, as well as the real estate industry. Looking at all sectors as a whole in Figure 28, most industries have over 50% of respondents who think that water is of high and very high importance, except for the IT and telecommunications industry.

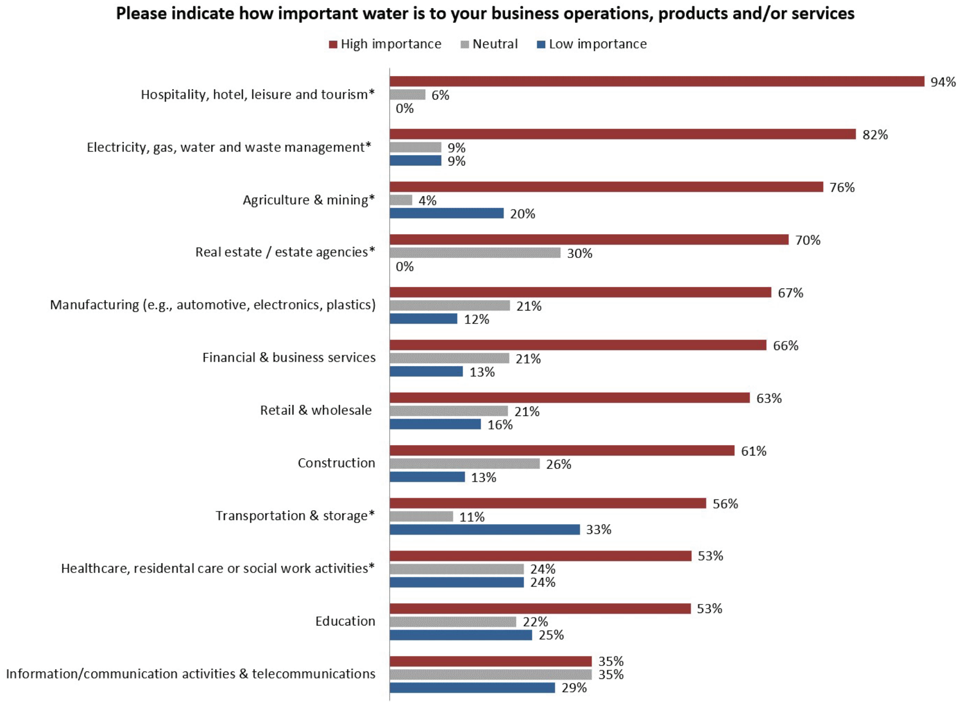


Figure 28: Perception of Water Importance in Different Industries

In the same vein, a dependable water supply of good quality and quantity in the country is of great concern to citizens (i.e., around 75% for both quantity and quality of water). Knowing how important water is to the target population is imperative to inform any consequent strategies, as this is one of the prime factors that determine active and genuine participation in water-related issues.

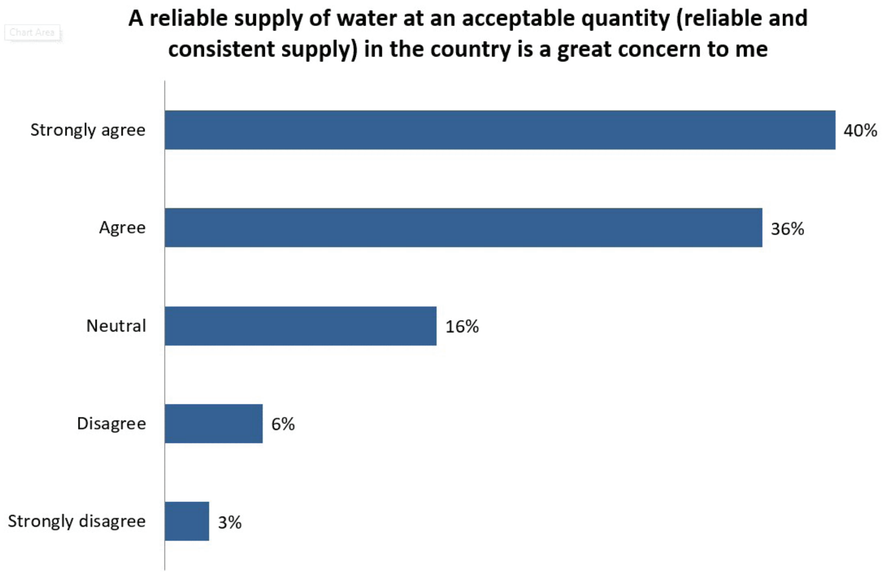


Figure 29: Perception of Water Quantity by the Public

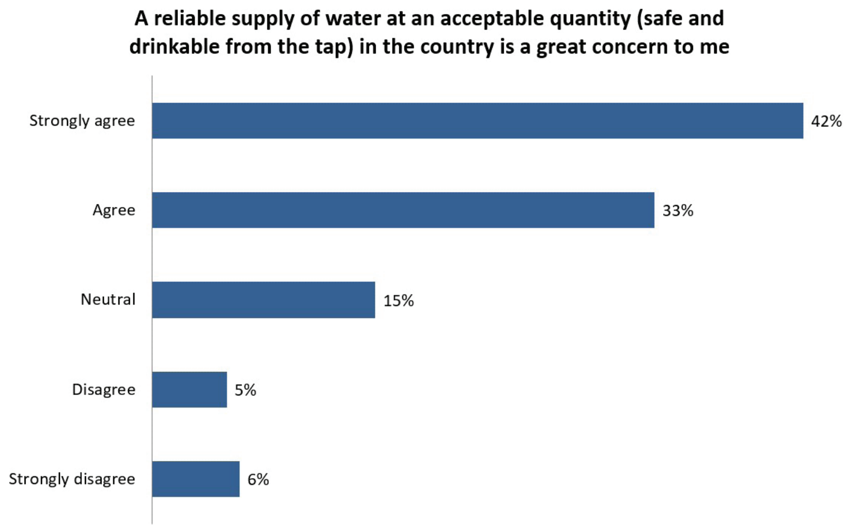


Figure 30: Perception of Water Quality by the Public

B. Impacts of water on businesses

To gauge the current performance of the water industry, businesses are asked about the impacts of the water industry on their businesses from the perspectives of cost, revenue, and efficiencies over the past 3 years. For the categories of efficiencies and revenue, the water did not affect most of the surveyed businesses (i.e., 0% impact for 38% and 36% of respondents for revenue and efficiencies respectively). The next most frequently chosen answer for these two categories is an increase of 1% to 10%, suggesting positive impacts on the water industry. Nonetheless, for the category of cost, the majority of businesses have indicated a negative impact of water on their business over the past 3 years. Specifically, there has been a 1% to 10% increase in operational costs for 37% of surveyed firms over the past 3 years. The next most chosen response is a 0% impact on costs (34%). While the water sector has had some positive impacts on businesses, there still exists a critical need for improvement in the water industry to properly support business operations.

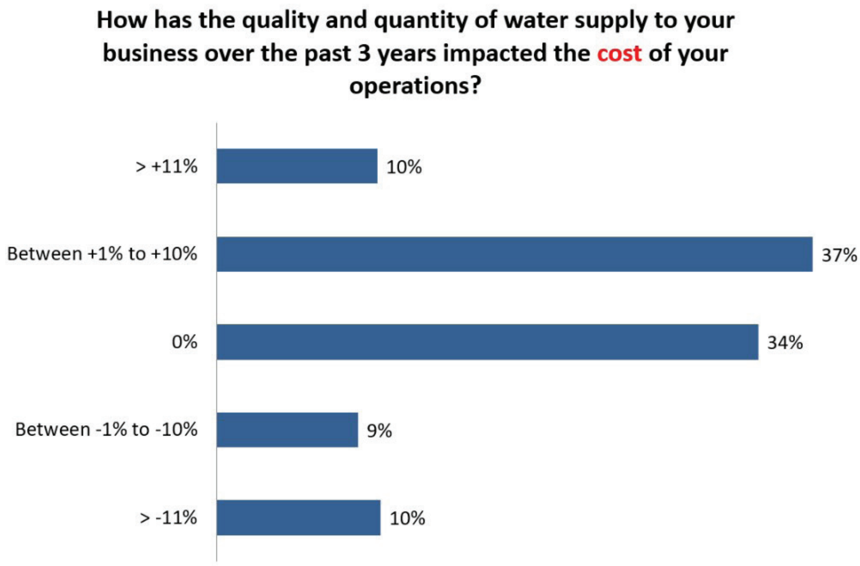


Figure 31: Impact of Water on Business Costs Over the Past 3 Years

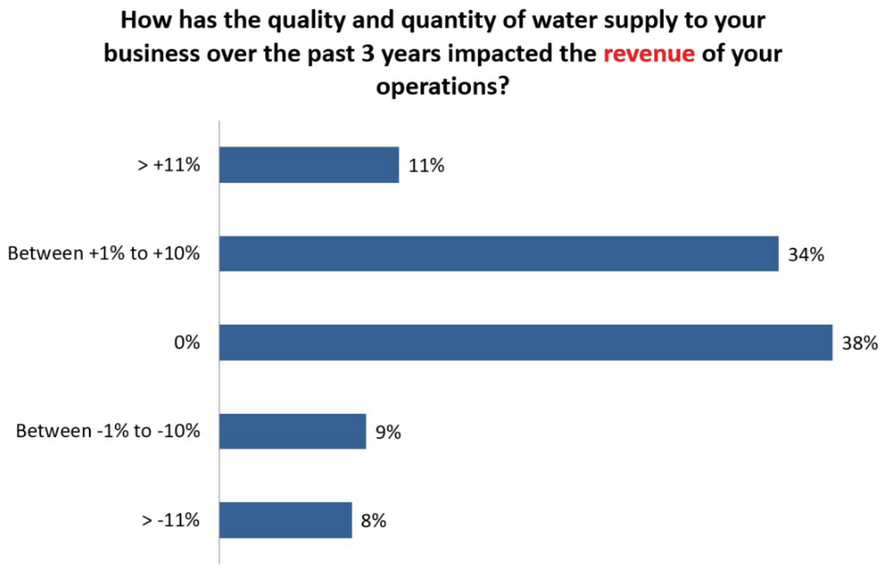


Figure 32: Impact of Water on Business Revenue Over the Past 3 Years

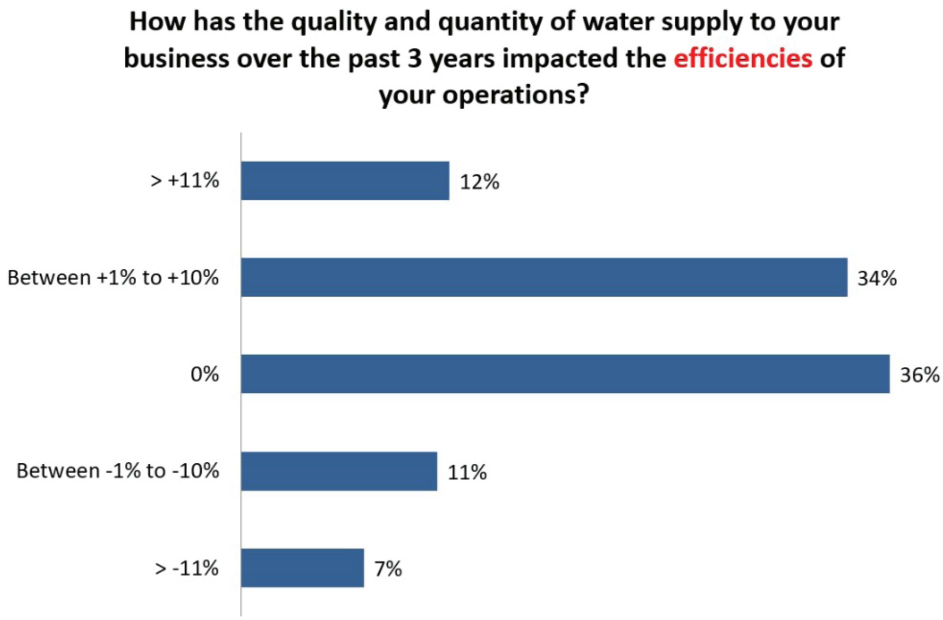


Figure 33: Impact of Water on Business Efficiencies Over the Past 3 Years

C. Consumer satisfaction of the water industry

The next critical finding is customer satisfaction, which can be defined as a state or feeling of fulfilment that consumers possess after using or experiencing an organisation's products or services (Ohwo & Agusomu, 2018). Gaining insights into how happy and content consumers are with the current water provision enables the authorities to carry out proper self-evaluation (e.g., identifying key elements to improve). Categorising the questions using the 8i framework, consumer satisfaction is identified using three drivers[20] – infrastructure, institution (i.e., management) and integrity.

[20] Of the 8 enablers, these were the 3 enablers that were the most relatable and visible to the public consumer. They are able to provide better feedback for these 3 enablers compared to the other enablers.

On average, 60% of the surveyed companies are satisfied and very satisfied with the current water infrastructure provision, management, and integrity of our authorities. On the other hand, about 24% remained neutral, while approximately 15% of respondents indicated low and very low satisfaction. Among the three elements, water infrastructure garnered the highest satisfaction (total of 65% for satisfied and very satisfied) and lowest dissatisfaction rates (total of 13% for dissatisfied and very dissatisfied). This is followed by management of the water industry (total of 59% for satisfied and very satisfied), and lastly integrity of the water industry (total of 56% for satisfied and very satisfied).

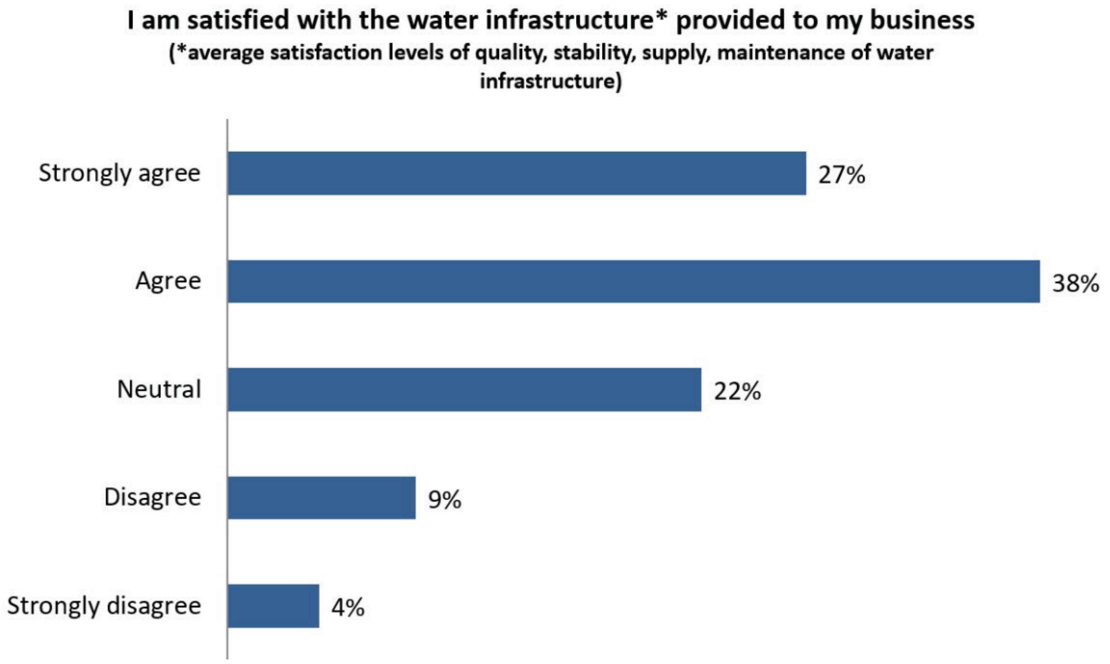


Figure 34: Businesses' Level of Satisfaction on Water Infrastructure

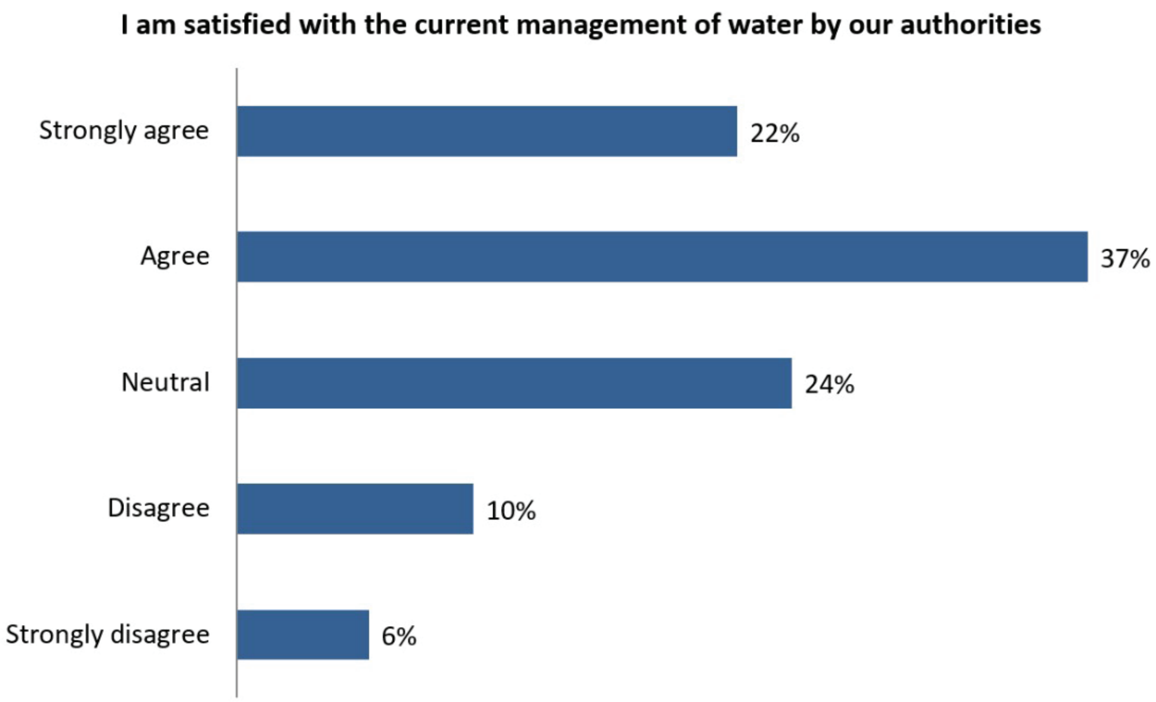


Figure 35: Businesses' Level of Satisfaction on Current Water Management

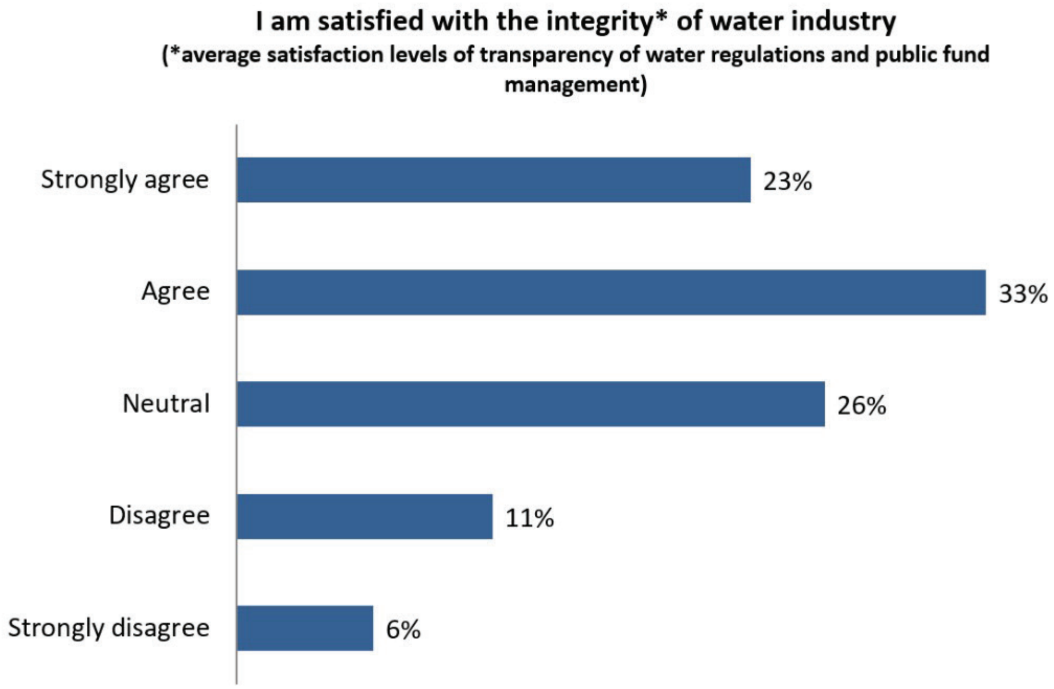


Figure 36: Businesses Level of Satisfaction on Integrity of Water Industry

The findings are similar for public satisfaction: on average, 6 out of 10 citizens are satisfied with the current water infrastructure (total of 70% for satisfied and very satisfied), quality of management (total of 59% for satisfied and very satisfied) and integrity of water industry (total of 53% for satisfied and very satisfied). Notably, the feeling of ambivalence (i.e., indicated by the replacement of agreeing and strongly agree by neutral answers) increases across the different categories, from infrastructure (20%), management (27%), to integrity (32%).

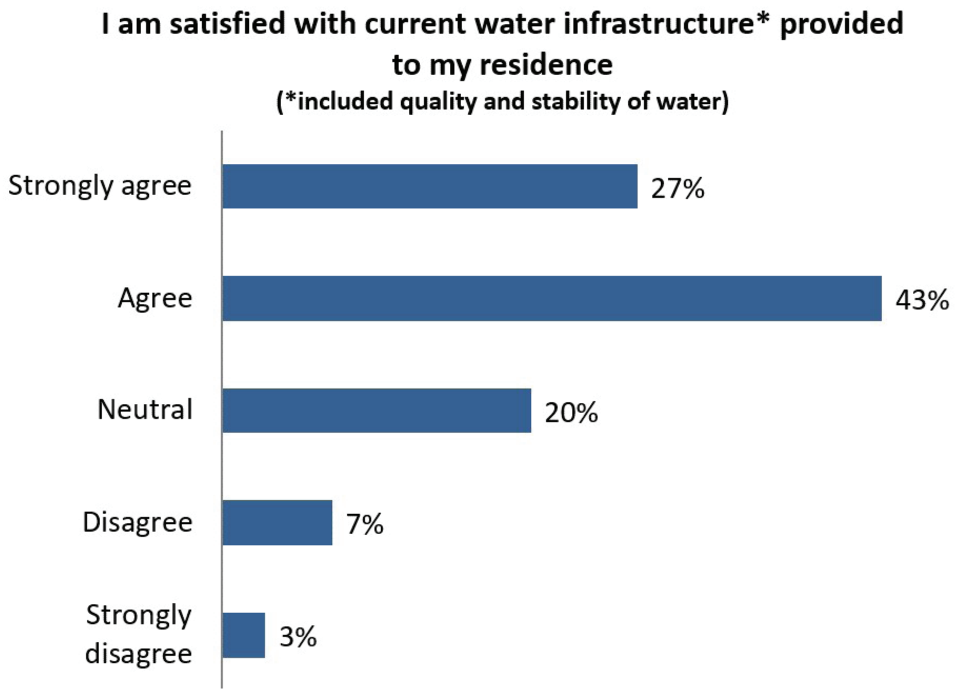


Figure 37: Citizens' Level of Satisfaction on Water Infrastructure

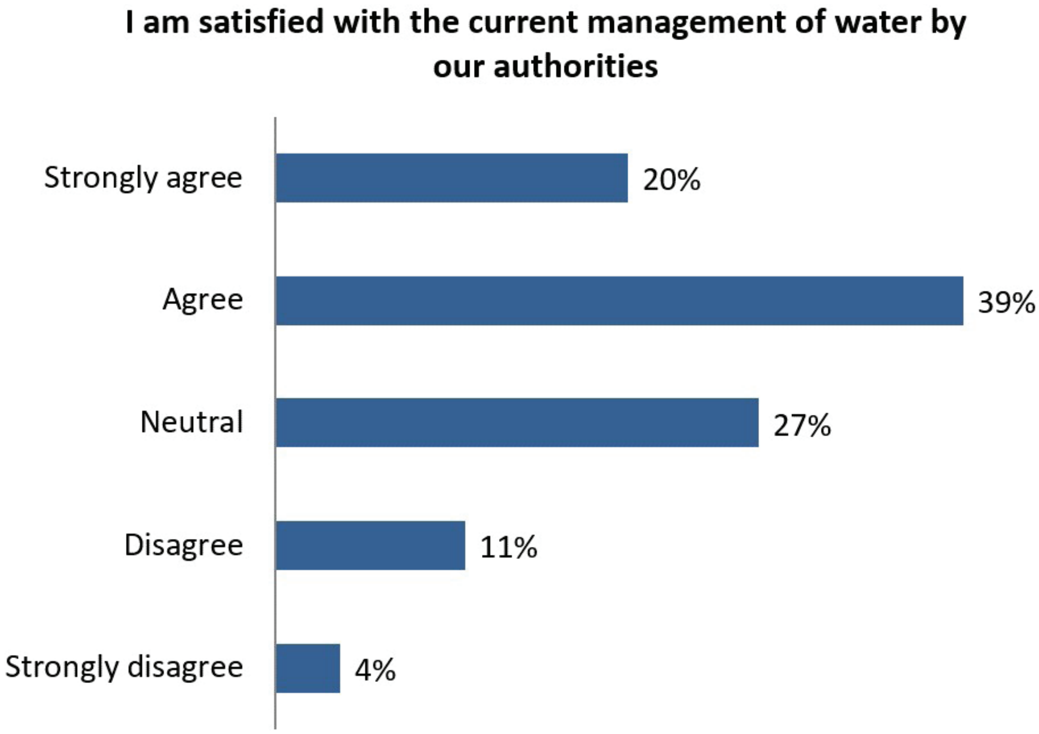


Figure 38: Citizens' Level of Satisfaction on Current Water Management

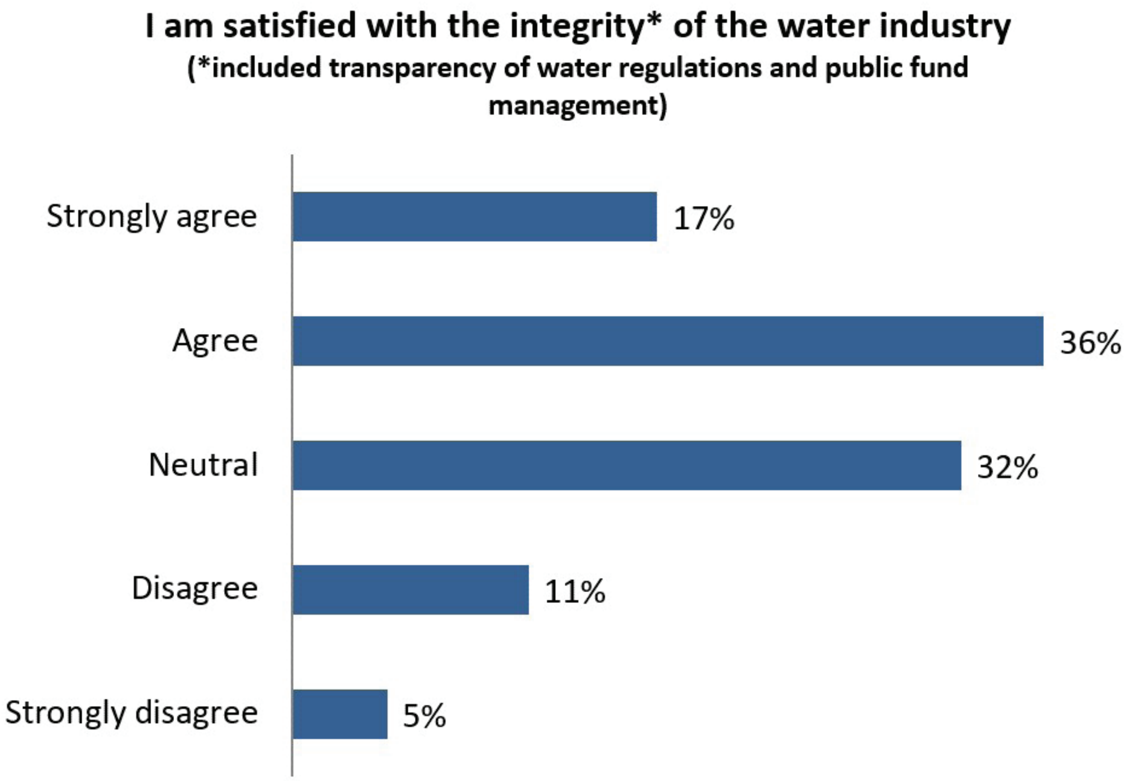


Figure 39: Citizens' Level of Satisfaction on Integrity of Water Industry

To better understand the satisfaction rates, these figures have been benchmarked against the satisfaction rates from other countries. Table 8 demonstrates the water satisfaction rates gathered from different countries.

Table 8: Satisfaction Rates of Water Infrastructure, Institution, and Integrity in Different Countries

Source	Year	City/ Territory/ Country	Satisfaction rates			
			Infrastructure	Institution (management)	Integrity	Average
Timilsena[21]	2020	Lekhnath, Nepal	47%	41%	-	45%
*Kassa. Chernet, Kelemework, Zewde, & Woldemedhin,	2017	Ethiopia	-	-	-	47%
WSAA	2016	Australia	72%	-	56%	54%
WST2040 study[22]	2021	Malaysia	68%	59%	55%	61%
AWWA	2021	U.S.	71%	-	-	71%
ATT, BDEW, DBVW, DVGW, DWA, VKU[23]	2015	Germany	88%	67%	-	78%
Consumer Council for Water	2015	England & Wales	94%	75%	78%	82%
Water Aid Uganda[24]	2018	Uganda	84%	-	-	84%
*Monte Vista Water District & True North Research Inc.	2016	Monte Vista, California, U.S.	-	-	-	89%
OECD	n.d.	Switzerland	95%	-	-	95%
OECD	n.d.	Norway	98%	-	-	98%

*Study with an overall satisfaction rate given / specific elements are indiscernible

Overall, satisfaction rates reported in developed economies are higher than those in Malaysia and other developing countries. As one of the fast-developing countries, as well as the top five economies in Southeast Asia, it is important to ensure each citizen is sufficiently satisfied with the nation's water services, as water is one of the most basic and fundamental needs to ensure the health and wellbeing of people (New Straits Times, 2019). Thus, it is crucial for Malaysia to strive for a higher satisfaction rate – one that is comparable to developed nations.

[21]Infrastructure satisfaction rate calculated by averaging satisfaction rates of quantity, tap pressure, and quality of water; Management satisfaction rate includes satisfaction on responsiveness and communication of water suppliers
[22]Satisfaction rates are derived from average rates of business and citizens' satisfaction rates of the respective categories
[23]Infrastructure satisfaction rate is calculated by averaging customer satisfaction with water quality (pp. 62) and reliability of water supply (pp. 65)
[24]Average infrastructure satisfaction rate calculated using satisfaction in water quality in terms of smell (95%), colour (91%), and reliability (65%)

D. Awareness and perceptions of water industry digitalisation

In this section, the awareness and perception of the Malaysian water industry's digitalisation by the public and industry are examined. Around 70% of the surveyed firms indicated that water industry digitalisation (such as real-time updates on water disruptions and remote bill payment) will be very beneficial to their business operations. Knowing that the majority of firms realise and acknowledge the importance of the water industry digitalisation is a vital step in informing the subsequent strategies to propel the water sector's digital transformation.

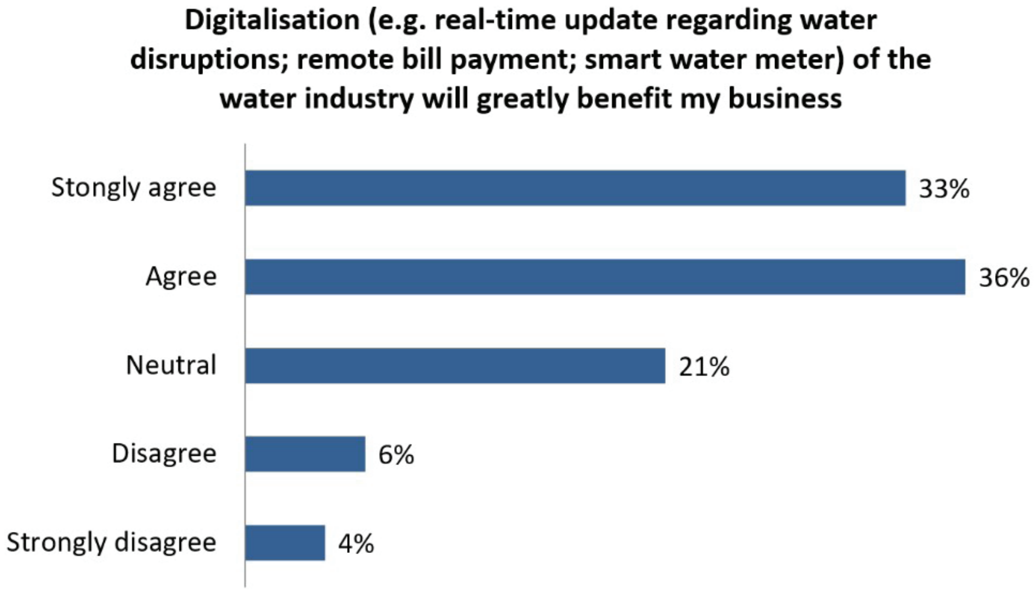


Figure 40: Businesses' Perception on Importance of Water Industry Digitalisation

In the same vein, the level of digital awareness among public citizens is adequate, where 76% of them are aware of the existence of digital water platforms. Among the different functions, the largest percentage of citizens (62%) utilise digital water platforms to execute remote bill payments, while 53% use them to retrieve real-time water-related news.

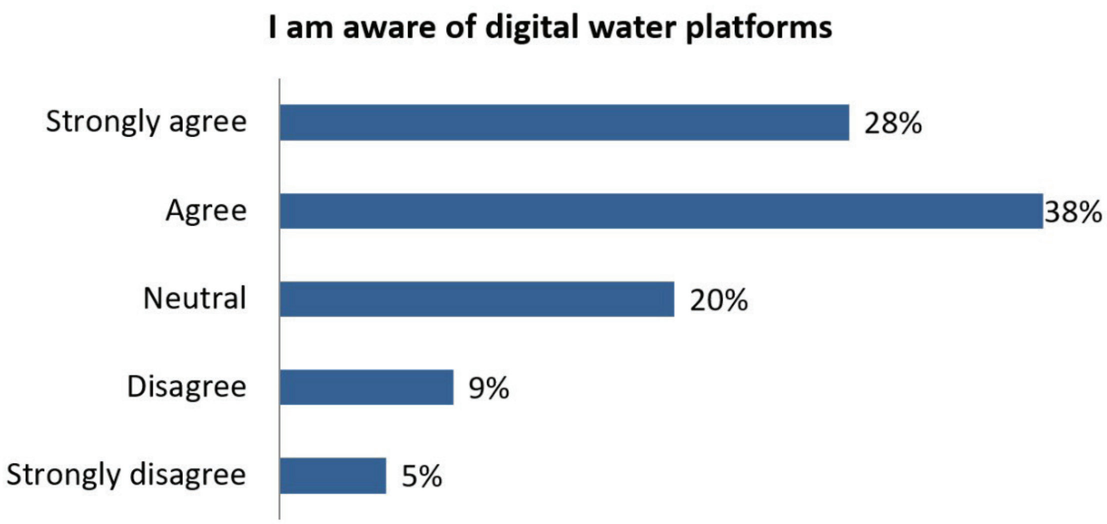


Figure 41: Citizens' Awareness of Digital Water Platforms

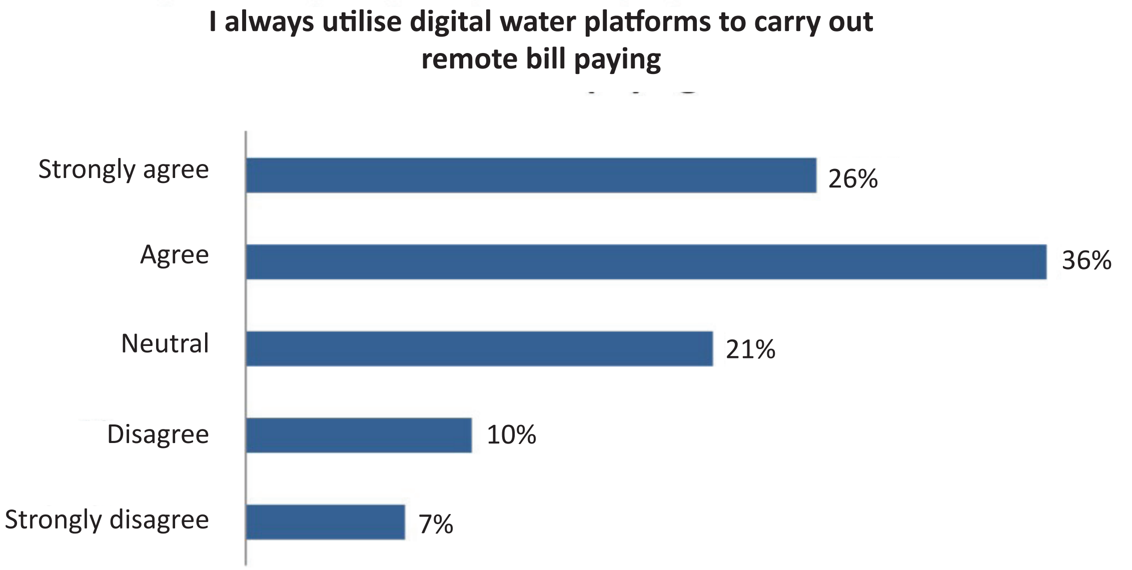


Figure 42: Citizens' Utilisation of Digital Water Platforms to Pay Bills

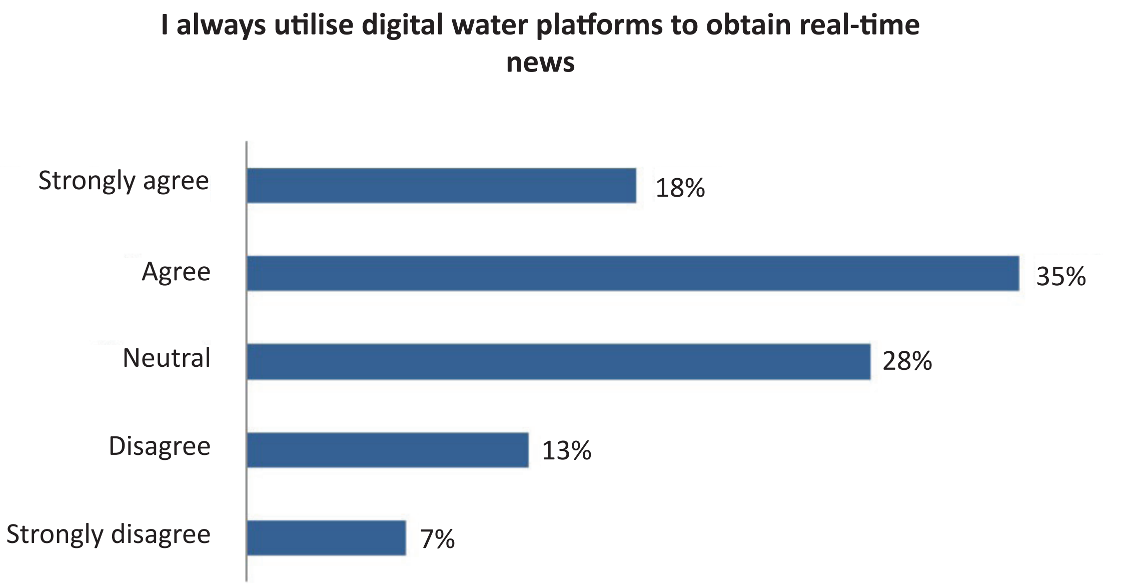


Figure 43: Citizens' Utilisation of Digital Water Platforms to Obtain Real-Time News

E. Organisation attitudes (for business only)

Water scarcity is affecting more than 3 billion people across the globe (Carbon Disclosure Project, 2020). Malaysia is not excluded from this phenomenon – as a country that is endowed with abundant water resources, its water resources are expected to be reduced by 20% to 25% between 2025 and 2030 (Soong, 2020). As businesses and industries account for the lion's share of water usage, this study is interested to examine organisational attitudes regarding environmental awareness and water use. Of the businesses surveyed, 76% agreed that it is their responsibility to use water more sustainably, 18% remained neutral, and 6% disagreed. Slightly lower than the former, 65% indicated that they have started or will embark on environmental protection and sustainability initiatives, 26% remained neutral, and 9% stated that they have not started or will not start.

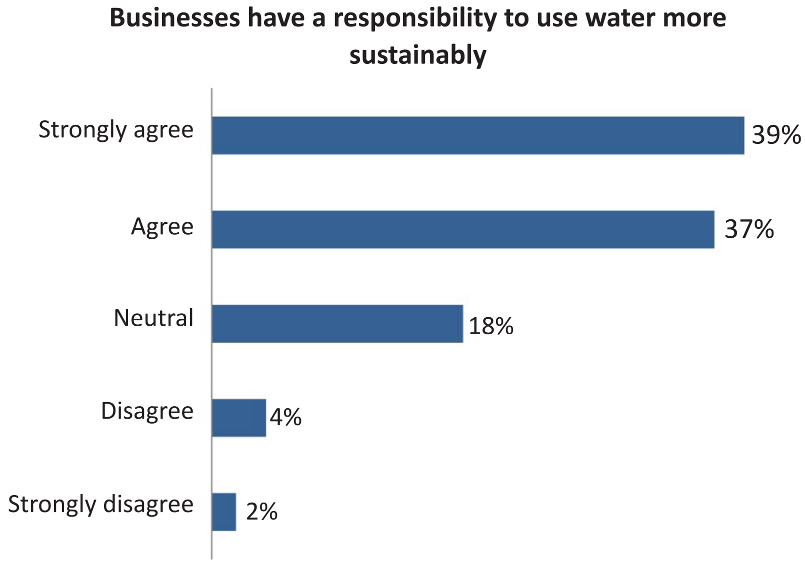


Figure 44: Businesses' Perception on Their Responsibility to Use Water More Sustainably

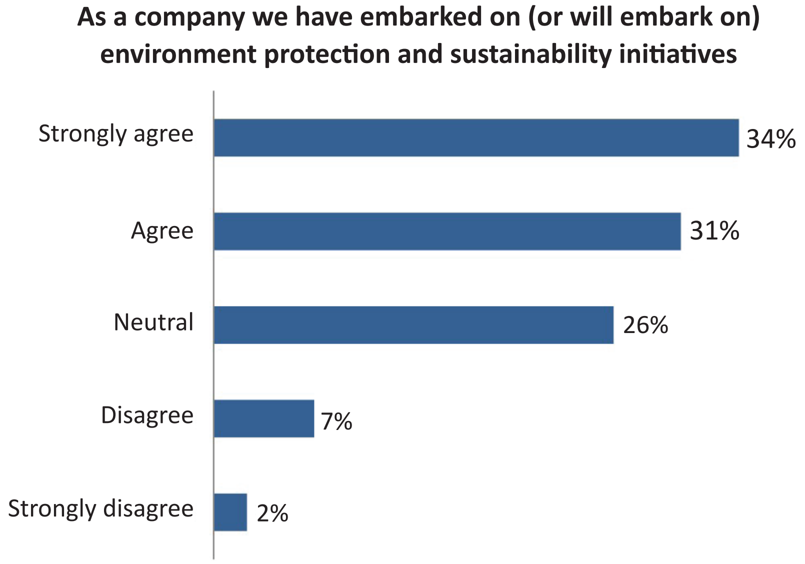


Figure 45: Businesses' Progress on Environmental Protection and Sustainability Initiatives

F. The increase of suppliers' revenue

Understanding customers' preferences are critical to increasing overall customer satisfaction. Customer satisfaction is an important precursor to garner support and encourage participation in any new initiatives. Thus, to better understand consumers' preferred method of increasing water suppliers' revenue, this study included the options of property or land-based tariffs, higher tariffs, and additional taxes for respondents to choose from. The findings indicated that the most preferred way among businesses is property or land-based tariffs (43%), which is followed by higher tariffs (30%). The least preferred medium is additional taxes, which is only chosen by 27% of respondents. On average, businesses are willing to pay around 30% more for their current water usage costs (e.g., If a business is currently paying RM1000 per month for water, they are willing to pay up to RM1300 per month for higher quality and more reliable water supply). This result is not surprising as firms are willing to pay more to avoid the cost of disruptions and poor quality of water (i.e., firms need to buy and install their water filters for their operations). This is also consistent with the focus group studies where firms highlighted that water disruptions are very costly for them and are willing to pay more to address this challenge that is present in the water ecosystem.

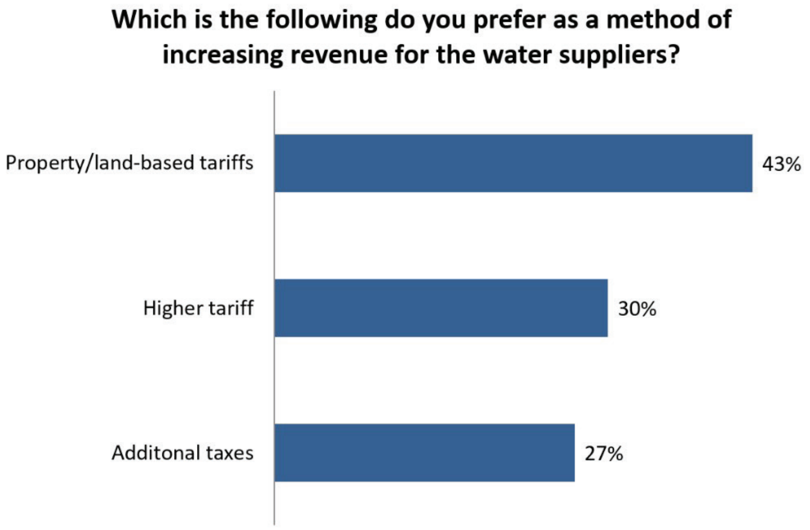


Figure 46: Businesses' Preferred Method of Increasing Water Suppliers' Revenue

The results are similar for the survey done by public citizens: almost half of the respondents prefer property or land-based tariffs (48%), the next most preferred method is higher tariffs (35%). Additional taxes are least favourited by citizens – only 17% has chosen this option. On average, citizens are willing to pay around 23% more for their current water usage costs (e.g., If a household is currently paying RM50 per month for water, they are willing to pay up to RM61.50 per month for higher quality and more reliable water supply). Consumers also opined that the regular water disruptions and poor quality of water have adversely impacted their quality of life and are willing to pay more to address this challenge in the water ecosystem.

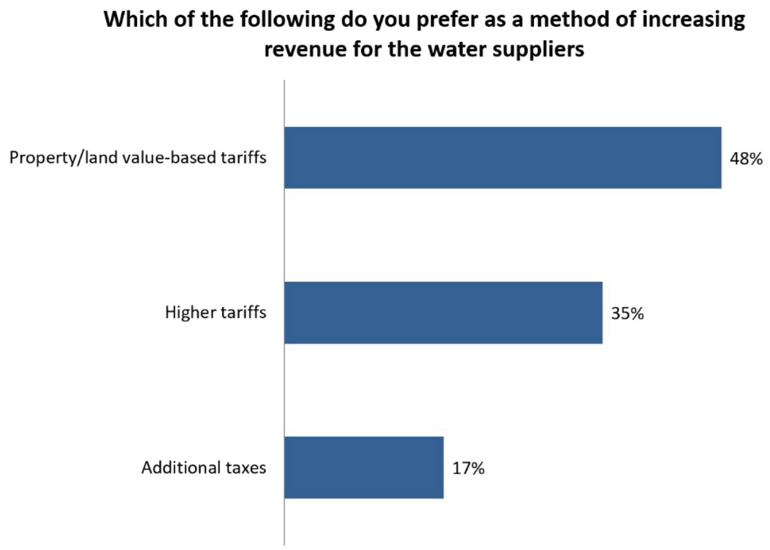


Figure 47: Citizens' Preferred Method of Increasing Water Suppliers' Revenue

Additional analyses were carried out to examine if citizens' willingness to pay more differ across different income groups. To do that, respondents were first categorised into B40, M40, and T20 based on the reported monthly household income, according to the income threshold set by the Department of Statistics Malaysia (2020)[25] .

[25] B40 income threshold in 2019 < RM4,850; M40 income threshold in 2019 < RM10,959; T20 income threshold in 2019 > RM10,959.

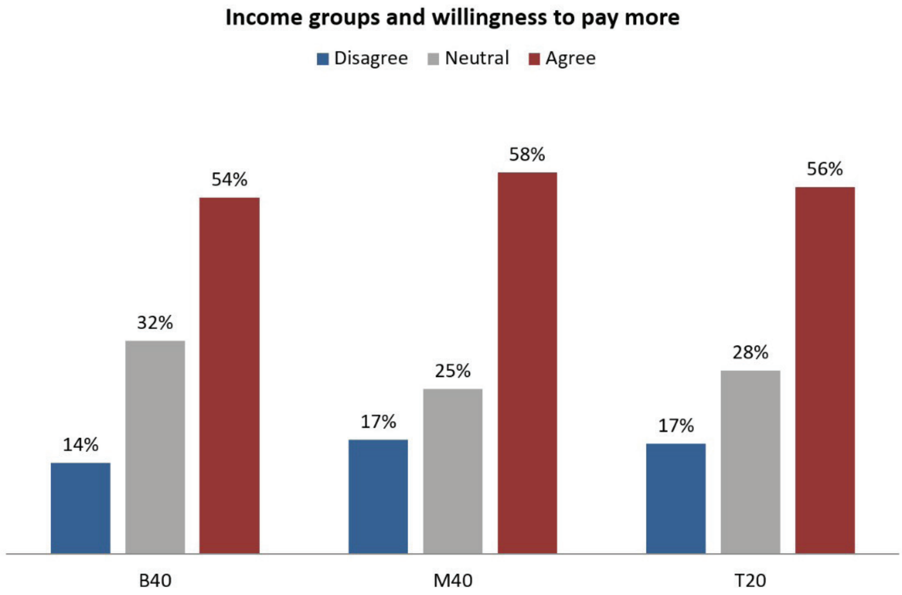


Figure 48: Respondents of Different Income Groups' Willingness to Pay More

The graph indicated that M40 respondents are the most willing to pay more among the three income groups (58%), followed by the T20 (56%) and B40 (54%) groups. However, the differences are only marginal. Thus, there are no significant differences in citizens' willingness to pay across different income groups. This highlights that majority of respondents are willing to pay more for higher quality and reliability of water supply.

Demand-side analysis

Many studies have recognised that water management needs a behavioural shift among the water end-users to encourage sustainable water consumption practices (Koutiva & Makropoulos, 2019; Abu-Bakar, Williams & Hallett, 2021). While consumers of water tend to believe that water is abundant, many others have embarked on water management initiatives, in response to them recognising the need for a sustainable way of doing business. Thus, highlighting the need for a better understanding of the behaviour of end-users of water, be it consumer or industry, should be of interest to guiding practitioners and policymakers to encourage sustainable consumer behaviour. They need to be cognisant of the key drivers that will encourage consumers' willingness to pay for quality and quantity of water.

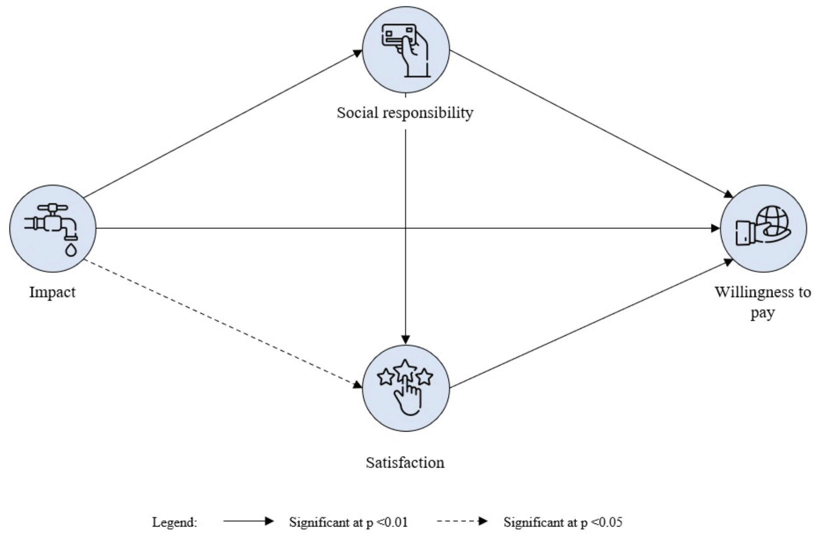
Water demand management policy instruments are categorized into price-related and non-price related strategies (Lavee et al., 2013; Renwick & Archibald, 1998; Reynaud & Romano, 2018). Price-related policies include rates, billing and tariff structures (Kenney et al., 2008) whereas non-price-related policies comprise such instruments as public education and awareness campaigns, technological infrastructure and behavioural measures (Lavee et al., 2013; Inman & Jeffrey, 2006; Reynaud & Romano, 2018). In this context, this section addresses water demand management by examining these two key areas, that is the price and non-price strategies. For price strategies, the question examined if consumers are willing to pay more for better quality and quantity of water and to identify if higher water prices will assist to reduce water demand. Non-price strategies on the other hand examine the awareness of water issues, knowledge and initiatives to conserve water (Russell & Knoeri, 2019) for sustainable water supply. Irrespective of the strategy taken, it is acknowledged that consumers' behaviour is a factor that determines water consumption (Corbella & Pujol, 2009).

Business-level analysis on willingness to pay for premium prices for water

The quantitative methodology is used in this subsection to exhibit the complex relationships between the impact of water on business operations (measured by impact), level of business' social responsibility regarding water utilities (measured by social responsibility), level of satisfaction with water management (measured by satisfaction), and their willingness to pay more for better water management (measured by WTP) (See Appendix Table 1).

The use of behavioural constructs in the survey design is essential to understand the consumer and businesses motives which will offer great insights into policy design (Spash et al., 2009). Subsequently, the proposed model was tested and analysed and the data was collected using structural equation modelling (SEM[26]) on the variables captured. This methodology was chosen mainly because of its ability to estimate the causal relationships between the variables which help to uncover the underlying complex relationship. The SEM methodology has been widely applied in social sciences (for instance Shen, Xiao & Wang, 2016; Ringle, Sarstedt, Mitchell, & Gudergan, 2020). The application of SEM in this study complies with the criteria and guidelines set by Hair, Risher, Sarstedt and Ringle (2019).

The empirical analysis[27] is conducted on the business-level perspective to examine the path relationship between satisfaction level, social responsibility, and impact as predictors of firms' willingness to pay. The model of business-level willingness to pay for better water management is shown in Figure 49 below.



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021)

Figure 49: Results – Business Perspective on Willingness to Pay for Better Water Management

The key findings from the empirical analysis highlight the importance of the impact of water supply on business operations as a factor that drives their behaviours and their willingness to pay more for improved water supply in Malaysia. When the quality and quantity of water supply drives their revenue and efficiencies, businesses are willing to pay more for higher quality and sustainable water (minimal disruptions to water supply). The impact of water supply on business operations also drives businesses' level of social responsibility. The results show that if water is a critical component of the firms' bottom

[26] Details of the SEM is not provided in this report
[27] Using structural equation modelling. Analytics by Sunway Research team

line, firms will be more inclined to adopt the 8R philosophy and devises strategies to utilise water more sustainably. The empirical evidence also shows that the satisfaction of firms to the water management system is dependent on the quality of water and services provided by the suppliers and the ability of the water ecosystem to empower these firms to manage their water management (by adopting the 8R philosophy).

The results also suggest that social responsibility on water issues plays a key role as a mechanism between the impact of water supply and the resulting satisfaction and willingness to pay more for quality and sustainable water supply. This is particularly in the contextual premise specific to firms' discontent on water quality and quantity. Businesses that are aware and take responsibility for their utilisation of water have higher scores in satisfaction towards water resources management in the country. Socially responsible businesses take the matter of sustainable use of water resources into their own hands. The ownership of their environmental footprint from their water utilisation leads to their satisfactory evaluation of the management of water resources. They believe it is their responsibility to minimise environmental damage and therefore do not rely on water authorities for sustainable management. While businesses are taking responsibility, the result also shows that businesses are willing to pay more for upgrades to higher sustainability in water management consistent with past findings (Tanellari et al., 2015). This is particularly true for firms where water is critical for firm performance.

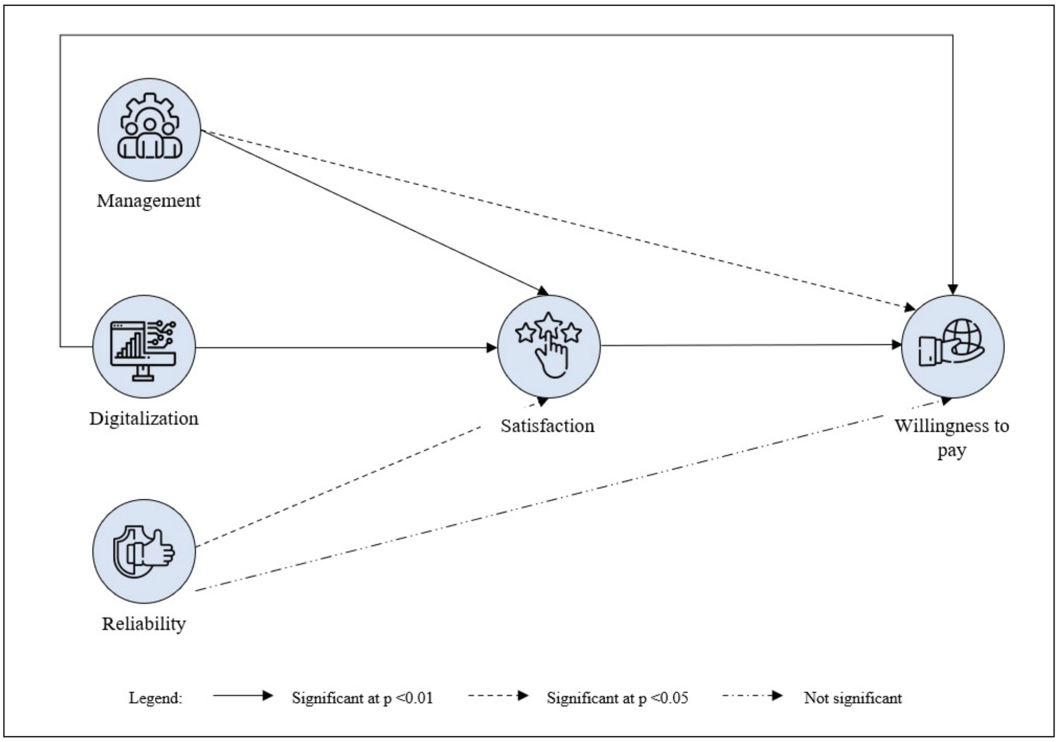
The impact and social responsibility drive willingness to pay more for quality and sustainable water supply. The empirical analysis shows that if businesses are satisfied with the management of water supply, water disruptions and water regulations, then firms will be willing to pay more for water management services. The level of satisfaction of businesses with water management is found to positively influence their willingness to pay for improved water services. This is consistent with existing literature that supports satisfaction with water management on willingness to pay for water resources improvement (Del Saz-salazar et al., 2016). The result also supported that trust in utilities as captured by the satisfaction construct will drive willingness to pay (Acey et al., 2019). Any erosion of trust in the authorities will undermine the institution and deter companies from contributing.

In summary, the willingness to pay for quality and sustainable water supply is dependent on three important factors. First, willingness to pay is dependent on the quality of water services provided to the firms (quality of water and undisrupted water supply) which impact the bottom line of the firms. Second, a water ecosystem that enables firms to take on pro-active solutions to complement and supplement the quality of water supply. This includes retrofitting better technologies by firms to improve the existing water quality. Third, quality service is provided by the water authority using digital technology to provide a seamless flow of information and improve the efficiency and transparency of the water management system. For example, the use of smart meters helps firms understand their water demand and use patterns for strategic decision making. Strategies to increase the water tariff must take into consideration the demand side end-users' perspectives.

Public-level analysis on willingness to pay for premium prices for water

Similar analyses were performed to assess the factors influencing the willingness to pay of the public. A quantitative survey of the public was conducted to determine the key factors that drive the willingness to pay more for better water management. The data were analysed using the SEM approach, similar to the business-level analysis.

Based on the consumer-level path analysis, there are four important antecedents to a willingness to pay for quality and sustainable water supply. These are the importance of good management of water for the environment and quality of life (measured by management), the awareness and utilisation of digital water platforms for water-related activities (measured by digitalisation), the importance of reliable water supply (measured by reliability), and consumer satisfaction with water resources management such as water supply, water disruption and water regulations (measured by satisfaction). The model further highlights the importance of satisfaction as a mechanism to drive willingness to pay more for water resources.



Source: Analytics by Sunway Institute for Global Strategy and Competitiveness (2021)

Figure 50: Public Perspective on Willingness to Pay for Better Water Management

Among the factors, digitalisation shows the most significant positive direct effect on the consumer's willingness to pay more for quality and sustainable water supply, and advance water infrastructure. This result shows that the development of digital water platforms as access to water information, bill payments, feedback and complaints, and account management is an important value-added service that consumers are willing to pay. The willingness to pay more for water services is linked to the continuous improvement undertaken by the water authorities to enhance greater efficiency in the water services and to ensure that consumers have information to make strategic decisions on my water consumption patterns.

From the above analysis, three factors will motivate the public to pay a higher price for water. First, willingness to pay is dependent on the satisfaction that they derive from a water management system that leads to high-quality water and an undisrupted water supply. Second, the consumers are willing to pay more if they are confident that the money is used effectively to continuously improve the water management system and is free from rent-seeking and moral hazard behaviour and poor quality of water sector management. Third, consumers are willing to pay if the authorities are willing to undertake a digital transformation of the water sector to provide a seamless flow of information for consumers to make informed decisions on their consumption patterns. This entails using smart apps and smart meters to continuously monitor real-time usage. Consumers are of the view that digitisation and use of intelligent systems will also improve governance of the water management system, hence reducing wastage and leakages, all of which will lead to lower cost of operations and burden on taxpayers[28].

7.0 Transformation Strategy and Initiative Implementation Framework (Scope 4)

The Roadmap Framework prepared by the Study for the Transformation Strategies and Initiatives has been adopted by the Technical Committee at its meeting on 28th October 2020 and the Steering Committee at its meeting on 19 November 2020.

8.0 Stakeholders and Experts Consultation (Scope 5)

A total of 73 stakeholders were consulted. All stakeholder sessions were conducted via online sessions.

Table 9: List of Stakeholders and Experts Consultation

Ministry/ State Governments / Organisations	Category (Federal Government / State Government / GLC/ University/ Private/ NGOs/ Sabah/	Date Conducted	Participants (Total)
Focus Group Conducted			
Suruhanjaya Perkhidmatan Air Negara (SPAN)	Government (Federal)	28 May, 2021	8
Jabatan Pengairan dan Saliran (JPS)		11 May 2021	1
National Disaster Management Agency (NADMA)		2 June 2021	2
SME Corp		11 June 2021	1
Indah Water Konsortium (IWK)	Government (State)	31 May 2021	8
Lembaga Urus Air Selangor (LUAS)		27 May 2021	1
Ministry of Utilities Sarawak (MOU Sarawak)	Sarawak	8 June, 2021	6
Jabatan Pengairan dan Saliran Sarawak (JPS Sarawak)		6 May 2021	1
Institut Penyelidikan Air Kebangsaan Malaysia (NAHRIM)	Research Institute	10 May, 2021	2
Malaysian Association of Hotels (MAH)	Private Sector	23 June 2021	1
Federation of Malaysian Manufacturers Institute (FMM Institute)		22 July 2021	2
Federation of Malaysian Manufacturers (FMM)		**9 July 2021**	6
ROCKWOOL Malaysia Sdn. Bhd.			1
Top Glove Corporation Berhad			2
Showa Denko Carbon Malaysia Sdn. Bhd.			1
Mega Fortris (M) Sdn. Bhd.			1
FMM Secretariat			1

[28] This view was elicited from the focus group discussions.

Ministry/ State Governments / Organisations	Category (Federal Government / State Government / GLC/ University/ Private/ NGOs/ Sabah/	Date Conducted	Participants (Total)
Federation of Malaysian Manufacturers Malaysian Food Manufacturing Group (FMM MAFMAG)		22 July 2021	3
Etika Holdings			1
Nestle Malaysia			1
FMM Secretariat			1
Malaysia Shopping Mall Association (PPK Malaysia)		5 July 2021	3
See Hoy Chan Holdings Group			1
Hektar Real Estate Investment Trust			1
PPK Malaysia Secretariat			1
Malaysian Plastics Manufacturers Association (MPMA)		2 July 2021	1
Piping Technology Sdn. Bhd.			1
Federation of Malaysian Consumers Associations (FOMCA)	NGO	28 May 2021	1
Extracted from Third Party Discussions [29]			
Pengurusan Aset Air Berhad (PAAB)	Government (Federal)	3 July, 2021	1
Kementerian Alam Sekitar dan Air (KASA)		3 July 2021	1
Ministry of Transport (MOT)		8 June 2021	1
Ministry of Plantation Industries and Commodities (MPIC)		8 June 2021	1
Ministry of Education (MOE)		8 June 2021	1
Jabatan Kimia Malaysia (KIMIA Malaysia)		8 June 2021	1
Air Selangor	Government (State)	8 June 2021	1
PricewaterhouseCoopers (PwC)	Private Sector	28 September 2020	1
Wildlife Conservation Society (WCS)	NGO	8 June 2021	1
Sustainable Development Network Malaysia (SUSDEN)		8 June, 2021	1
Malaysian Water Association (MWA)		8 June, 2021	2
Parti Sosialis Malaysia (PSM)	Other	8 June, 2021	1

[29] Qualitative analysis of external webinars/forum/panel discussions

9.0 Water Sector Transformation 2040 Roadmap (Scope 6)

Figure 51 shows a summary of the strategies and key activities proposed by WES to be implemented across the 4 phases of the water sector transformation. It highlights some of the key milestones that need to be achieved in the 12th MP that will enable the continued transformation of the water sector in the subsequent 13th to 15th MPs. This systemic transformation is crucial in ensuring a holistic approach in setting up institutional frameworks, foundational conditions, and ownerships that will address the current fragmentation of the water sector ecosystem. A complete roadmap for the National Agenda on the Water Sector Transformation 2040 (Figures 52a to 52d) has been prepared.

An example for the Supply Side Water Management strategy, KA1.1 (Key Activity 1.1): Establishing a National Water Sector Transformation Task Force is a key first step in the transformation process. This advisory body will guide and coordinate the water sector transformation that cuts across the other focus areas:

- Combining KA1.1 *Establishing a National Water Sector Transformation Task* Force and KA5.1 *Review Existing Water-Related R&D and Education* will then provide the foundational conditions needed to successfully implement KA5.2 *Establish a National Water Centre of Excellence* (COE);
- KA5.2 coupled with KA1.1 will lead into KA6.1 CoE *to Lead and Foster Strong Collaborative Partnerships in the Water Sector* and KA6.2 *Establish a Neutral Agency to Build Trust and Knowledge Sharing Culture in the Water Sector*;
- The continued review process of KA6.1 and 6.2 will then be informed by KA1.4 *STIE Foresighting and Scenario Planning to Future-Proof Water Sector Water-Related Industries*.

For the Governance focus area, another key pathway is as follows:

- Setting up KA1.1;
- From KA1.1, lead into KA1.2 *Establish River Basin Organisations*;
- KA1.2 coupled with KA1.1 will then flow into KA1.3 *Harmonise Regulation and Legislation between Federal and State*.

This process sets up the necessary institutional bodies to bridge the gap between the objectives of the Federal and State governments.

For the Demand Side Water Management strategy, a key pathway is as follows:

- Start with KA3.1 Embed 8R Water Philosophy at all Levels of Education and Practice;
- Once this philosophy has been embraced, KA3.2 Review Existing End-User Policies & Incentives to Ensure Consistency with 8R Water Philosophy & ESG Standards can then begin;
- The review will then facilitate the implementation of KA4.1 End-User Friendly Policies go Encourage Greater Private Sector Participation and KA4.3 Increase R&D Grants, Investments, and Incentives for Water Sector Solutions Aligned to 8R Water Philosophy & Adherence to ESG Standards.

The above are just some examples of the pathways within the roadmap. Similar pathways for the WES roadmap to transform the water sector into a dynamic economic sector are mapped out in Figure 51. Without the series of progressions and inter-related outcomes from previous strategies and key activities, implementation efforts will be hindered by a piecemeal approach.

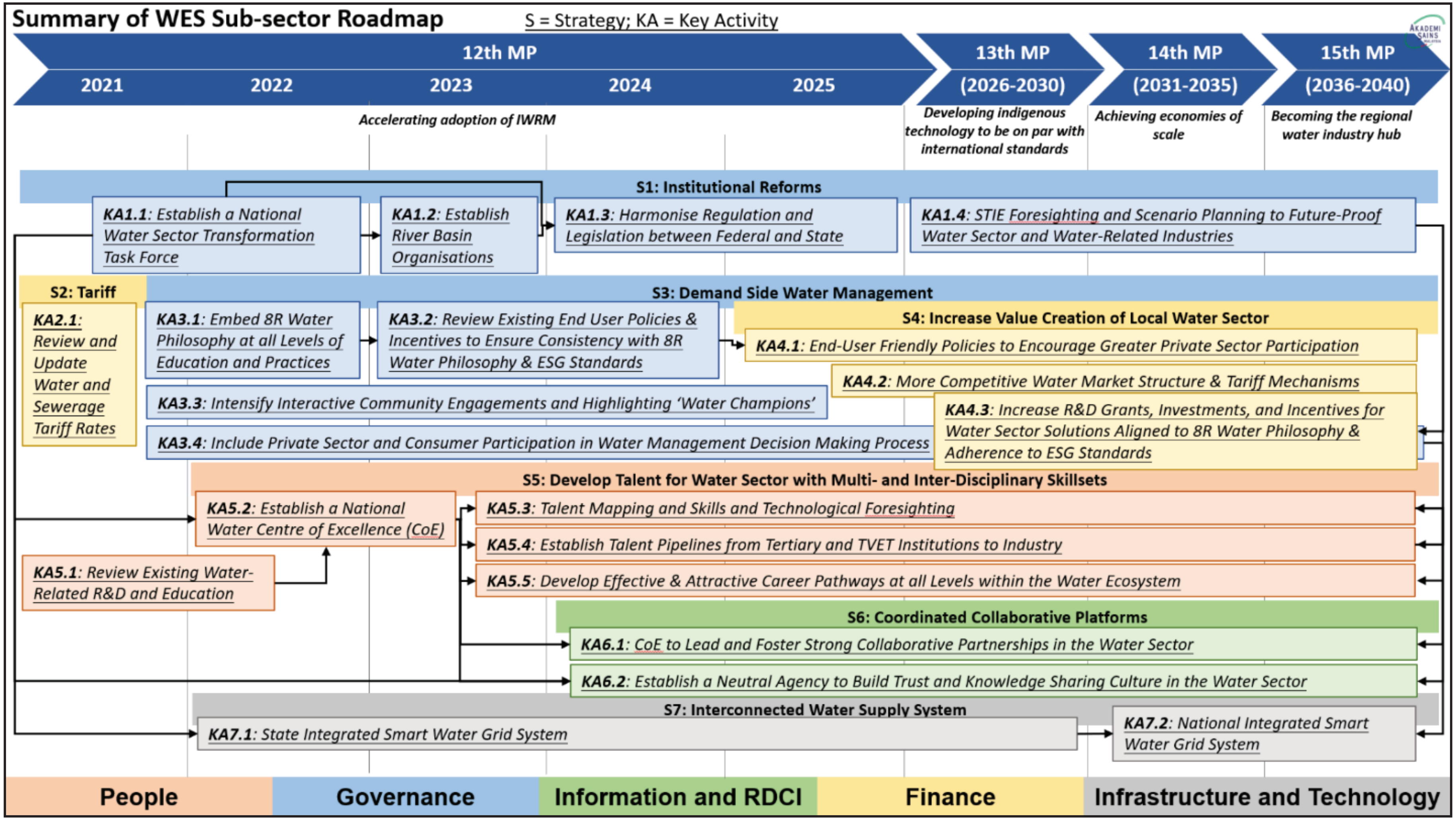


Figure 51: Summary of WES Sub-sector Roadmap

	Draft WST2040 Strategy Plan and Implementation Road Map									
		NIWRMP Strategies		11MP Strategies			WST2040 Strategies			
		Water as a Resource/Water Security and Sustainability								
		11MP/12MP/13MP/14MP/15MP								
Focus Area	Strategy	Initiatives	Programmes/ Activities	Hierarchical Level	Lead Authority/ Collaborating Partners	Implementing Authority	Current Status	Target Completion	Remarks	Focus Area
People	Develop talent for water sector with multi/inter-disciplinary skillsets	Upgrade existing talent with key competencies across all key activity areas	Review existing water-related research and development, research-inspired educational programs, training, and micro credentials in all educational institutions	National	KASA	MOHR, MOHE Ministry of Entrepreneurship Development and Cooperatives, KASA, SMECorp, MAGIC, MDEC.	On-going	2022	Annual review of talent mapping, curriculum development, and career pathways should be undertaken to ensure the water sector is able to attract the best talent to enhance the sustainability and competitiveness of the sector.	People
People	Develop talent for water sector with multi/inter-disciplinary skillsets	Upgrade existing talent with key competencies across all key activity areas	Establish a National Water Centre of Excellence (CoE) that will futureproof water-related research and development, research-inspired educational programs, training, and micro credentials that meets the need of the water sector.	National	KASA	MOHR, MOHE Ministry of Entrepreneurship Development and Cooperatives, KASA, SMECorp, MAGIC, MDEC.	On-going	2023	Annual review of talent mapping, curriculum development, and career pathways should be undertaken to ensure the water sector is able to attract the best talent to enhance the sustainability and competitiveness of the sector.	People

Figure 52a: Water as Resources

Draft WST2040 Strategy Plan and Implementation Road Map

Focus Area	NIWRMP Strategies		11MP Strategies					WST2040 Strategies		Focus Area
		Water as a Resource/Water Security and Sustainability 11MP/12MP/13MP/14MP/15MP								
	Strategy	Initiatives	Programmes/ Activities	Hierarchical Level	Lead Authority/ Collaborating Partners	Implementing Authority	Current Status	Target Completion	Remarks	
People	Develop talent for water sector with multi/inter-disciplinary skillsets	Upgrade existing talent with key competencies across all key activity areas	Establish talent pipelines from tertiary and TVET institutions that work together with industry to meet needs of the water sector	National	MOHE/ MOHR	MOHR, MOHE Ministry of Entrepreneurship Development and Cooperatives, KASA, SMECorp, MAGIC, MDEC.	On-going	Continuous	Annual review of talent mapping, curriculum development, and career pathways should be undertaken to ensure the water sector is able to attract the best talent to enhance the sustainability and competitiveness of the sector.	People
People	Develop talent for water sector with multi/inter-disciplinary skillsets	Upgrade existing talent with key competencies across all key activity areas	Incorporate continuous review and accreditation cycle of the current supply and demand talent requirements.	National	MOHE/ MOHR	MOHR, MOHE Ministry of Entrepreneurship Development and Cooperatives, KASA, SMECorp, MAGIC, MDEC.	On-going	Continuous	Annual review of talent mapping, curriculum development, and career pathways should be undertaken to ensure the water sector is able to attract the best talent to enhance the sustainability and competitiveness of the sector.	People
Governance	Demand Side Water Management	Adopt the 4Es (Enable, Encourage, Engage, Exemplify) of demand side (public & industry) behavior management Ensuring appropriate education, incentives, and policies are in place to encourage stronger water conservation practices	Enable: Embedding water education that incorporates the 8Rs of water philosophy in school curriculums, general public, and industrial practices.	National	KASA	MOE/MOHE, Ministry of Entrepreneurship Development and Cooperatives	On-going	2022	CEPA will be a key enabler for the demand side water management	People

Figure 52a: Water as Resources

Draft WST2040 Strategy Plan and Implementation Road Map

Focus Area	NIWRMP Strategies			11MP Strategies			WST2040 Strategies			Focus Area
		Water as a Resource/Water Security and Sustainability								
		11MP/12MP/13MP/14MP/15MP								
	Strategy	Initiatives	Programmes/ Activities	Hierarchical Level	Lead Authority/ Collaborating Partners	Implementing Authority	Current Status	Target Completion	Remarks	
Governance	Demand Side Water Management	Adopt the 4Es (Enable, Encourage, Engage, Exemplify) of demand side (public & industry) behavior management Ensuring appropriate education, incentives, and policies are in place to encourage stronger water conservation practices	Encourage: Review existing business/consumer-friendly policies/practices to ensure that they are consistent and aligned with 8Rs of water philosophy.	National	Ministry of Entrepreneurship Development and Cooperative	Ministry of Entrepreneurship Development and Cooperative, FOMCA	On-going	2024	From the Focus Group discussion analysis, there are contradicting policies/practices that disincentivises businesses from adopting sustainable practices. One of reasons cited is the lack of guidelines from local council on establishing water storage systems. Businesses that have developed their own water storage systems were penalized for erecting their own storage systems in their premises. While industry and consumers are already embarking on recycling initiatives, there is a lack of guidelines and fiscal incentives for them to pursue these practices.	Governance
Governance	Demand Side Water Management	Adopt the 4Es (Enable, Encourage, Engage, Exemplify) of demand side (public & industry) behavior management Ensuring appropriate education, incentives, and policies are in place to encourage stronger water conservation practices	Encourage: Review current tax incentives, subsidies and grants for local technology development aligned to 10-10 MySTIE to encourage more affordable technologies that will increase efficient use of water. This includes strengthening incubator and accelerator programs to nurture next generation local technologies and enterprises.	National	Ministry of Science, Technology, and Innovation	Ministry of Finance	New	2023		Finance

Figure 52a: Water as Resources

Draft WST2040 Strategy Plan and Implementation Road Map

Focus Area	NIWRMP Strategies			11MP Strategies			WST2040 Strategies			Focus Area
		Water as a Resource/Water Security and Sustainability 11MP/12MP/13MP/14MP/15MP								
	Strategy	Initiatives	Programmes/ Activities	Hierarchical Level	Lead Authority/ Collaborating Partners	Implementing Authority	Current Status	Target Completion	Remarks	
Governance	Demand Side Water Management	Adopt the 4Es (Enable, Encourage, Engage, Exemplify) of demand side (public & industry) behavior management Ensuring appropriate education, incentives, and policies are in place to encourage stronger water conservation practices	Engage: Include private sector and consumer participation in the water management decision making process.	National	KASA, Sabah/Sarawak	FOMCA, Ministry of Entrepreneurship Development and Cooperatives, other Industry Associations (e.g. FMM)	New	Continuous	Private sector feels many of the initiatives are top-down without consideration of industry needs	People
Governance	Demand Side Water Management	Adopt the 4Es (Enable, Encourage, Engage, Exemplify) of demand side (public & industry) behavior management Ensuring appropriate education, incentives, and policies are in place to encourage stronger water conservation practices	Engage: Intensify interactive community engagements (i.e. River of Life project in Klang/Gombak river)	National	KASA	State Gov., DID	On-going	2022	Embark on more flagship projects to increase engagement and appreciation of water-related activities	People

Figure 52a: Water as Resources

Draft WST2040 Strategy Plan and Implementation Road Map

Focus Area	NIWRMP Strategies			11MP Strategies			WST2040 Strategies			Focus Area
		Water as a Resource/Water Security and Sustainability 11MP/12MP/13MP/14MP/15MP								
	Strategy	Initiatives	Programmes/ Activities	Hierarchical Level	Lead Authority/ Collaborating Partners	Implementing Authority	Current Status	Target Completion	Remarks	
Governance	Demand Side Water Management	Adopt the 4Es (Enable, Encourage, Engage, Exemplify) of demand side (public & industry) behavior management Ensuring appropriate education, incentives, and policies are in place to encourage stronger water conservation practices	Exemplify: Identifying industry and community water champions/role-models/influencers/ambassadors that showcase best practices for a circular economy	National	KASA	Malaysia Water Association, NGOs (e.g. WWF), Ministry of Primary Industries, Ministry of Rural Development, Ministry of Agriculture, Industry Associations, Chambers of Commerce.	New	2025		People
Governance	Institutional Reforms	National Water Sector Transformation Task Force	Establish river basin organisations	National	KASA	KASA and State Governments	New	2023		Governance
Governance	Institutional Reforms	National Water Sector Transformation Task Force	Establish the National Water Sector Transformation Task Force (strengthen Federal-State cooperation and collaboration)	National	KASA	KASA, State water authorities and government, river basin organisations, industry associations, community organisations	New	2022	Implement whole-of-government, whole-of-society approach	Governance
Governance	Institutional Reforms	National Water Sector Transformation Task Force	Undertake STIE foresighting and scenario planning to future-proof water sector and water-related industries	National	KASA	MIGHT, state water authorities and government, river basin organisations, industry associations, community organisations	New	Continuous	Align water STIE plan with 10-10 MySTIE framework and continuously update the STIE trends to future-proof the water sector	Governance

Figure 52a: Water as Resources

Draft WST2040 Strategy Plan and Implementation Road Map

Focus Area		NIWRMP Strategies		11MP Strategies			WST2040 Strategies			Focus Area
		Water as a Resource/Water Security and Sustainability								
		11MP/12MP/13MP/14MP/15MP								
	Strategy	Initiatives	Programmes/ Activities	Hierarchical Level	Lead Authority/ Collaborating Partners	Implementing Authority	Current Status	Target Completion	Remarks	
Governance	Institutional Reforms	Harmonising and strengthening the water legislative framework and Environmental, Sustainability, Governance (ESG) standards related to water	Strengthen economic regulatory legislation (e.g. pricing policies, tax incentives, tariffs setting, FDI rules, and business-friendly policies) that encourage private sector participation and foreign investments into the water sector.	National	MOF	MOF, MITI	On-going	2023		Governance
Governance	Institutional Reforms	Harmonising and strengthening the water legislative framework and Environmental, Sustainability, Governance (ESG) standards related to water	Harmonize regulation and legislation between federal and state governments.	National	KASA, Sabah/Sarawak	KASA	On-going	2025		Governance
Governance	Institutional Reforms	Harmonising and strengthening the water legislative framework and Environmental, Sustainability, Governance (ESG) standards related to water	Incorporate ESG standards related to water sector management in green rating of buildings and halal certification.	National	KASA, Sabah/Sarawak	KASA	On-going	2023		Governance
Governance	Institutional Reforms	Harmonising and strengthening the water legislative framework and Environmental, Sustainability, Governance (ESG) standards related to water	Review and strengthening of laws and enforcement capacity on pollution control from non-point sources	National	KASA	KASA	On-going	Continuous		Governance

Figure 52a: Water as Resources

Draft WST2040 Strategy Plan and Implementation Road Map

Focus Area		NIWRMP Strategies			11MP Strategies		WST2040 Strategies			Focus Area
		Water as a Resource/Water Security and Sustainability								
		11MP/12MP/13MP/14MP/15MP								
	Strategy	Initiatives	Programmes/ Activities	Hierarchical Level	Lead Authority/ Collaborating Partners	Implementing Authority	Current Status	Target Completion	Remarks	
Governance	Institutional Reforms	Harmonising and strengthening the water legislative framework and Environmental, Sustainability, Governance (ESG) standards related to water	Review laws on data/information sharing among government agencies and the public (e.g. Official Secrets Act)	National	Ministry of Home Affairs	Ministry of Law, JPA, Department of Statistics	On-going	2023		Governance
Governance	Institutional Reforms	Increasing transparency and accountabiltiy	Operators within the water-value chain need to provide 5-year business plans with annual audited reporting against established targets	National & State	KASA	State authorities, river basin organisations	New	2022	Standardised templates for tracking and reporting of targets and milestones across national, states, and river basins	Governance
Governance	Institutional Reforms	Increasing transparency and accountabiltiy	Greater adoption of digital platforms aligned with 10-10 MySTIE for ensuring better management, transparency, and accountability (e.g. adoption of blockchain technology for tracking compliance)	National & State	KASA	State authorities, river basin organisations	New	2025		Governance

Figure 52a: Water as Resources

Draft WST2040 Strategy Plan and Implementation Road Map										
		NIWRMP Strategies		11MP Strategies			WST2040 Strategies			
		Water as a Resource/Water Security and Sustainability								
		11MP/12MP/13MP/14MP/15MP								
Focus Area	Strategy	Initiatives	Programmes/ Activities	Hierarchical Level	Lead Authority/ Collaborating Partners	Implementing Authority	Current Status	Target Completion	Remarks	Focus Area
Infrastructure & Technology	Interconnected water supply system across the country to improve water supply, and quality of water, and water security	Develop a comprehensive national smart water grid system	Put in place a staged state-wide water grid system that has future capabilities to develop into an integrated national grid system. The grid system should be a public-private partnership initiative to reduce the burden of cost on the government. The smart water grid system should integrate water from all sources and for all uses.	National & State	KASA	National & State water authorities, private sector	New	State grid: 2030 National grid: 2040	A smart water grid system is critical in ensuring the quality of treated water and efficient distribution of water across the country. Refer to IR4.0 sub-sector for detailed activities.	Infrastructure & Technology
Infrastructure & Technology	Interconnected national water supply systems across the SEA region	Extend the reach of national water grid to regional water hubs	Establish collaboration with regional partners to strengthen their national water grid system	Regional & National	MITI	MITI, KASA	New	2040	Strong regional water grid system will lead to a sound management of the quality and supply of water. This will be an important resource to attract high quality FDIs that are water-dependent to Malaysia and the region.	Infrastructure & Technology
Information & RDIC	Strong national and regional water resource planning and water market intelligence	National and regional data sharing	One-stop national and regional data centre	Regional, National & State	KASA	Regional, National & State water authorities, private sector	New	National Centre: 2025 Regional Centre: 2040		Information & RDIC

Figure 52a: Water as Resources

Draft WST2040 Buget Requirements

Focus Area	NIWRMP Strategies			11MP Strategies						WST2040 Strategies						Focus Area
	Water as a Resource/Water Security and Sustainability															
					Budget (RM '000,000)											
	Strategy	Initiatives	Programmes/ Activities	Lead Ministry/ Organisation	2021	2022	2023	2024	2025	Total 12MP	13MP	14MP	15MP	Target Completion	Remarks	
People	Develop talent for water sector with multi/inter-disciplinary skillsets	Upgrade existing talent with key competencies across all key activity areas	All education and talent related activities	KASA	150	150	150	150	150	750	700	600	500	Continuous	WES propose that the education investment must be proportionate to the expected water contribution to GDP. Education development applies for water-related industries as well. Invesment in water-related education is 0.3% of national education budget for 2021 - 2025, 0.2% for 2026 - 2030, 0.15% for 2031 - 2035, 0.1% for 2036 - 2040. Estimated 1/3 goes to CAPEX and OPEX, 1/3 goes to curriculum design and development, 1/3 goes to institution reforms. The 12MP requires a major investment to initiate structural change towards a more knowledge-intensive water sector. The subsequent investments will be a more steady state where public spending will slow down and private sector will complement the education investments.	People
Information & RDIC	Increase water-related STIE investements (public and private) for the water sector.	Development of indigenous innovations and technologies	All STIE investments related activities	KASA						2% of GERD	2% of GERD	2% of GERD	2% of GERD	Continuous	WES propose that 2% of GERD should be spent on water-related STIE investments for the water sector. 1% from public sector, 1% from private sector. Quantum of R&D investments will increase as the GDP increases over the years. Includes all science, technology, and innovation related to water sector and it's contribution to the other sectors.	Information & RDIC

Figure 52b: Water as Resources – Proposed Budget

Focus Area	NIWRMP Strategies			11MP Strategies				WST2040 Strategies			Focus Area
	Water for Livelihood/Water as an Economic Opportunity										
	11MP/12MP/13MP/14MP/15MP										
	Strategy	Water User Category	Initiatives	Programmes/ Activities	Hierarchical Level	Lead Authority/ Collaborating Partner	Implementing Authority	Current Status	Target Completion	Remarks	
People	Develop talent for water sector with multi/inter-disciplinary and entrepreneurial skillsets	Community, Researchers, Entrepreneurs	Upgrade existing talent with key competencies across all key economic areas	Nurture next generation STI-preneurs within the water sector to lead local water technology and enterprise development that are able to create new sources of growth and markets for water resources.	National	MOE/MOHE	Ministry of Human Resources & KASA	On-going	Continuous	Annual review of talent mapping, curriculum development, and career pathways should be undertaken to ensure the water sector is able to attract the best talent to enhance the sustainability and competitiveness of the sector.	People
People	Develop talent for water sector with multi/inter-disciplinary and entrepreneurial skillsets	Community, Researchers, Entrepreneurs	Upgrade existing talent with key competencies across all key economic areas	Local institutions of learning and training should be linked to global knowledge networks, centres of excellence, and supply chains to foster two-way technology and knowledge transfer.						Optimal talent mapping will lead to high income and sustainable employment opportunities in the water sector. It will also lead to the sector being less reliant on cheap foreign labor.	Information & RDIC
Finance	Increase value creation of the local water sector to nurture and sustain a circular economy	Water operators, households, and industry	Attract high quality local private sector and foreign direct investments into the water sector	Ensure business-friendly policies to encourage greater private sector participations into the water sector	National	MIDA	MIDA	On-going	2022		Finance

Figure 52c: Water for Livelihood

Draft WST2040 Strategy Plan and Implementation Road Map

Focus Area	NIWRMP Strategies			11MP Strategies				WST2040 Strategies			Focus Area
	Water for Livelihood/Water as an Economic Opportunity										
	11MP/12MP/13MP/14MP/15MP										
	Strategy	Water User Category	Initiatives	Programmes/ Activities	Hierarchical Level	Lead Authority/ Collaborating Partner	Implementing Authority	Current Status	Target Completion	Remarks	
Finance	Increase value creation of the local water sector to nurture and sustain a circular economy	Water operators, households, and industry	Attract high quality local private sector and foreign direct investments into the water sector	Instill a more competitive market structure for the water suppliers from the private sectors	National	KASA, Sabah & Sarawak State Governments	SPAN, Sabah & Sarawak State Departments	On-going	2025	Needs to be done in tandem with competitive tariff rates	Finance
Finance	Increase value creation of the local water sector to nurture and sustain a circular economy	Water operators, households, and industry	Attract high quality local private sector and foreign direct investments into the water sector	Adopt competitive tariff rate mechanisms to ensure business sustainability	National	Ministry of Economic Affairs	Ministry of Economic Affairs	New	2022		Finance
Finance	Increase value creation of the local water sector to nurture and sustain a circular economy	Water operators, households, and industry	Attract high quality local private sector and foreign direct investments into the water sector	Long-term transition into property/land-value based water tariff rate mechanism	National	Ministry of Economic Affairs	Ministry of Economic Affairs	New	2025		Finance
Finance	Increase value creation of the local water sector to nurture and sustain a circular economy	Water operators, households, and industry	Attract high quality local private sector and foreign direct investments into the water sector	Attractive incentives (e.g. grants, subsidies, tax) for STI within the water sector to encourage local technology and business development in the water sector	National	MOSTI	MOSTI, MOF	On-going	Continuous		Finance
Finance	Increase value creation of the local water sector to nurture and sustain a circular economy	Water operators, households, and industry	Attract high quality local private sector and foreign direct investments into the water sector	Attractive incentives (e.g. grants, subsidies, tax) for adherence to ESG standards within the water sector.	National	MOSTI	MOSTI, MOF	On-going	Continuous		Finance

Figure 52c: Water for Livelihood

Focus Area	NIWRMP Strategies			11MP Strategies				WST2040 Strategies			Focus Area
	Water for Livelihood/Water as an Economic Opportunity										
	11MP/12MP/13MP/14MP/15MP										
	Strategy	Water User Category	Initiatives	Programmes/ Activities	Hierarchical Level	Lead Authority/ Collaborating Partner	Implementing Authority	Current Status	Target Completion	Remarks	
Finance	Increase value creation of the local water sector to nurture and sustain a circular economy	Water operators, households, and industry	Attract high quality local private sector and foreign direct investments into the water sector	Increasing quantum of research grants and other support systems to foster collaboration between research institutions, universities, and industry to develop the local supply chain	National	MOSTI	MOSTI	On-going	2023		Finance
Finance	Increase value creation of the local water sector to nurture and sustain a circular economy	Water operators, households, and industry	Attract high quality local private sector and foreign direct investments into the water sector	Review the current tax, grants, and incentive systems to encourage GLCs to lead the development of local technologies in the water sector	National	MOSTI	MOSTI, MOF	On-going	2023		Finance
Finance	Increase value creation of the local water sector to nurture and sustain a circular economy	Water operators, households, and industry	Attract high quality local private sector and foreign direct investments into the water sector	Preferential investments are given for foreign companies that fill the gaps of the local water supply chain and undertake technology and knowledge transfer to local companies	National	MITI	MITI, MOF	On-going	2023		Finance
Finance	Increase value creation of the local water sector to nurture and sustain a circular economy	Water operators, households, and industry	Establish collaborative platforms among multiple stakeholders to foster a strong spill over and multiplier effect to the water sector and from the water sector to the other sectors of the economy	National water centre of excellence to work closely with NTIS and i-Connect to foster strong collaborative partnerships in the water sector.	National	KASA	KASA, NTIS, i-Connect	On-going	2024		Finance
Finance	Increase value creation of the local water sector to nurture and sustain a circular economy	Water operators, households, and industry	Establish collaborative platforms among multiple stakeholders to foster a strong spill over and multiplier effect to the water sector and from the water sector to the other sectors of the economy	Establish a neutral agency for the water sector to build trust and nurture knowledge sharing culture in the water sector.	National	KASA	KASA	On-going	2024		Finance

Figure 52c: Water for Livelihood

Draft WST2040 Budget Requirements

Focus Area	NIWRMP Strategies			11MP Strategies						WST2040 Strategies						Focus Area
	Water as a Resource/Water Security and Sustainability															
	Strategy	Initiatives	Programmes/ Activities	Lead Ministry/ Organisation	Budget (RM '000,000) 2021	2022	2023	2024	2025	Total 12MP	13MP	14MP	15MP	Target Completion	Remarks	
People	Develop talent for water sector with multi/inter-disciplinary skillsets	Upgrade existing talent with key competencies across all key activity areas	All education and talent related activities	KASA	150	150	150	150	150	750	700	600	500	Continuous	WES propose that the education investment must be proportionate to the expected water contribution to GDP. Education development applies for water-related industries as well. Invesment in water-related education is 0.3% of national education budget for 2021 - 2025, 0.2% for 2026 - 2030, 0.15% for 2031 - 2035, 0.1% for 2036 - 2040. Estimated 1/3 goes to CAPEX and OPEX, 1/3 goes to curriculum design and development, 1/3 goes to institution reforms. The 12MP requires a major investment to initiate strucutural change towards a more knowledge-intensive water sector. The subsequent investments will be a more steady state where public spending will slow down and private sector will complement the education investments.	People
Information & RDIC	Increase water-related STIE investements (public and private) for the water sector.	Development of indigenous innovations and technologies	All STIE investments related activities	KASA						2% of GERD	2% of GERD	2% of GERD	2% of GERD	Continuous	WES propose that 2% of GERD should be spent on water-related STIE investments for the water sector. 1% from public sector, 1% from private sector. Quantum of R&D investments will increase as the GDP increases over the years. Includes all science, technology, and innovation related to water sector and it's contribution to the other sectors.	Information & RDIC

Figure 52d: Water for Livelihood – Proposed Budget Shared with Water as Resources

10.0 Way Forward – 8i Ecosystem Approach

To strengthen all 8 enablers of the water ecosystem into a dynamic one, that is capable of being a vibrant economic sector, it is important to first understand the current challenges of the water ecosystem. The following is an overview of the gaps and potential solutions for each of the 8 enablers raised by the sub-sectors that need to be addressed before the water ecosystem can be transformed into a viable and competitive economic sector.

Infrastructure

Current State of Play:

Many natural water ecosystems in the country do not use advanced technology to manage and monitor the quality of water supply. As such, many of them are poorly managed and this impacts the quality of water supply and the down-stream industries that are dependent on the water supply. Lack of sophistication in the water infrastructure and fragmentation of the national water grid system also has several negative externalities impact and they include lack of flexibility in meeting water shortage in many parts of the country; managing natural disasters; and mitigating risks associated with water contamination and pollution.

In rural areas and island communities, there is a lack of access to quality water services due to poor infrastructure. There are frequent disruptions of service due to limited water treatment plants. With the prevalence of flooding in Malaysia, drainage from sewage leads to bacterial contamination in wells, emphasising the importance of catchment management to ensure the protection of current and alternative water supplies. In terms of water usage, there is low water use efficiency in irrigation which is important in ensuring food security while reducing greenhouse gas emissions. Poor application of recycling and reuse technology in industries is also a major challenge where many are unwilling to invest in water-efficient technology due to low water tariffs and the high cost of adopting these technologies.

Way Forward:

The water infrastructure needs major upgrading and expanding new sources of water supply to meet the basic needs of the people and industry. This will require many of the water basins to adopt advanced technology and knowledge management systems to derive a better return on value (ROV) and return on investment (ROI). In this context, IWSDC will establish linkages to integrate data from various providers, set data quality standards and produce systems efficiency reports as well as incorporate Space technology (with MySA) and data analytics technology to assist in decision making.

Environmental policies also need to consider climate variability and the long-term impacts of climate change including infrastructures such as dam construction and design. Initiatives that can be taken in academia include establishing websites related to water resources management, showcasing project-based learning (PBL) activities. Higher education institutions (HEIs) and research institutions can develop interactive tools that encourage communication between sectors. These institutions can work with the relevant government agencies and business entities to provide One-stop Training Centres at the national and state levels.

Priority should also be given to developing the service sector for groundwater including the mineral water industry. It is important to utilise groundwater as a supplement for surface water to prevent disruption of services. Technologies for groundwater mapping and assessment, metering and licensing, monitoring of groundwater extraction and recharge, hard-rock aquifer delineation needs to be deployed to support Integrated Aquifer System Management. Furthermore, measures to improve safe drinking water supply include upgrading water treatment plants and improving water quality parameters monitoring instruments. Alternative water sources should be improved via developing tube wells in all states and rainwater harvesting. Storm-water reuse could lead to a significant reduction in consumption. Groundwater utilisation for agriculture use and emergency use should also be developed. To make this a reality, detailed groundwater assessment studies should be conducted to allow groundwater use in emergencies with priority given to major urban areas in relatively dry regions. Approaches such as innovation of planting techniques that use less water and adopting more water-efficient technology, especially in industry, agriculture and mining sector are important. There should be greater investments in smart farms and intelligent farming methods to ensure consistent quality of crops planted, requiring less water usage. Lastly, attractive schemes to upgrade technology and the review of water tariffs by state governments should be conducted to encourage the usage of technology in enhancing careful water utilisation. A competitive water tariff will also increase greater private investments in the sector, particularly, jointly developing the water-smart grid infrastructure with the government.

Infostructure

Current State of Play:

Digital architecture is becoming increasingly important for ensuring greater efficiency and enhancing greater network externalities in the water sector. The digital ecosystem in the water sector is still in its infant stage, hence will require major investments to raise the quality of service and economic outcomes. The water infostructure is still not integrated and not designed to produce a seamless flow of information for strategic decision-making and effective management of the water ecosystem. Data are scarce and scattered, lack of coordinating mechanism (no data repository) and accessibility. This impacts the quality of the data, and decision-making process. . Hence, there is an urgent need for a review of the digital ecosystem in the water sector. This includes ensuring a systematic and integrated development of the water infostructure across all the water basins. The lack of an integrated digital plan for the water ecosystem has rendered managing natural disasters such as floods, landslides, including man-made disasters such as pollution a challenge. These challenges in developing a comprehensive digital ecosystem for the water sector can be traced back to the absence of partnership between government agencies, the private sector, community organisations, institutions of learning and local communities that reside near the water basins of the country. A weak digital ecosystem has resulted in poor surveillance systems and early warning systems and a lack of preparedness in facing flood and climate-related events, especially in the least developed states.

Way Forward:

IWSDC aims to establish linkages between the databases developed by different departments to integrate data and produce strategic reports to fill the gaps in the water management spectrum. IWRM approach entails the creation of a comprehensive data-sharing framework to ease decision-making processes. Other potential initiatives towards infostructure enhancement include the development of a common platform for government officials and relevant stakeholders' engagement. Furthermore, continuous RDIC (Research, Development, Commercialization, and Innovation) for National Integrated Data Bank will be the key driver to accelerate the implementation of IWRM and effectively facilitate decision making.

Data sharing with built-in security will be useful for complex analysis and relationships between multiple stakeholders to mitigate risks that impact water supply systems. There is a strong need to develop a national groundwater database with a good distribution map, from regulator, state, federal and government agencies. Although groundwater is an alternative water source, it is susceptible to deterioration/pollution during flood events, thus similar studies are needed for other parts of Malaysia, especially those that are flood-prone to substantiate vulnerability assessment. A dedicated Groundwater Research Centre to study the impact of climate change on aquifer depletion, saltwater intrusion, and aquifer recharge, should be established to collect data, study on aquifer recharge, develop groundwater innovation and industry clusters as well as develop centres of groundwater excellence in local academia. The groundwater quality monitoring network should also be capable to detect saltwater intrusion in the coastal aquifers and act as mitigation and rehabilitation for impacted aquifers.

In addition, Environmental Health indicators should be developed to identify pollutants and measure water quality during water crises and disasters with real-time monitoring and the introduction of a surveillance system to detect environmental burden. Initiatives that can be taken include establishing a real-time flood forecast hazard map, introducing impact base forecast as a new tool for early warning for the public and frequent updates of land use and the state of rivers and other water resources in the country. Emerging risks from pollutant mobilisation in flood-susceptible areas can be overcome by identifying catchment areas that are susceptible to legacy pollutants and inclusive adaptation measures through potential risk assessment. It is essential to analyse climatic data to determine the potential impact of floods, dry spells, or sea-level rise so adaptation measures can be developed. To curb water issues during dry spells for irrigation, a guideline and early warning system should be developed for the reservoir operation for water demand management. Overall, the digital ecosystem is critical to ensure seamless flow of information to all stakeholders in the water ecosystem for strategic decision to ensure the water resources of the country is managed effectively, translating to a better return on value (ROV) for society and industry.

Intellectual Capital

Current State of Play:

Access to information and knowledge are important drivers for the sustainable development of communities and industries. While Malaysia has embraced a knowledge-intensive society, the water sector has remained a low user of knowledge. There is a lack of understanding of the value of water among all segments of the population. As such, water resources in the country have been taken for granted and has been prone to wastage and the water basins have been a source of contamination and pollution. In many instances, the water resources have been treated as garbage dumping grounds by people and industry. Lack of civic consciousness on the value of these water basins has resulted in many of the rivers and other water resources being contaminated and a source of constant water disruptions. The state of the current water sector is attributed to low investments in education and training to nurture the next-generation leaders who will harness, manage, and derive a better return on value from the water resources of the country. In the nation's endeavour to transform the Malaysian water sector into a viable economic sector, "knowledge" which includes civic consciousness on the value of water, innovative ideas, information, and best practices related to water must be capitalised. However, Malaysia is currently facing a talent shortage in the water sector, characterised by a lack of a high-skilled labour force in key focus areas that are essential to transform the water sector into a knowledge-driven sector.

A knowledge-intensive water sector will require talent with a sound understanding of the value of water to society aligned to the 8R water philosophy; the types of technologies required to improve efficiency in the management and delivery of water supply to all stakeholders; undertake a risk assessment to address climate change, natural and man-made disasters to the water supply; and, develop innovative regulations, standards, incentive systems, financial and business models to derive a better return on value and investment (ROV and ROIs) from the water resources in the country. Due to the lack of investment in the above skill set, there has been a mismatch in the supply and demand of talent in the water sector. As such, the water sector has remained at the lower end of the innovation and economic value chain. This mismatch can also be attributed to the lack of specialised training that has increasingly required multidisciplinary skills, encompassing expertise in engineering, information technology, bioscience, business management and entrepreneurship.

One of the major challenges that the public sector faces in retaining institutional memory and building deep and strong knowledge capabilities in the water sector is the regular movement of expertise across government ministries and agencies. Furthermore, the problem is exacerbated by the inability of the sector to attract some of the best talent and potential for brain-drain to other sectors in the economy or more attractive overseas employment opportunities.

Way Forward:
To promote intellectual capital development, training programmes should be kept current and tailored based on the role of the individual staff. The different taskforces in this study have put forward training programmes that aim to address the issue of talent deficit in the water sector. Given the close linkage between the water, food, and agriculture sectors in terms of security and sustainability, WFE Nexus has called for education on the nexus approach to be provided to all stakeholders. AACB has proposed programmes such as IWRM training and disaster risk reduction which are mainly targeted at civil servants. Besides, AACB also stressed the importance of capacity building and continuous improvement in areas such as communication skills, river care knowledge, environmental subjects such as ecology, general organisation and management skills and others in related fields. IWSDC aims to develop dedicated personnel in the data technology and water sector while CCIA envisions skill and knowledge sharing between different government agencies, academicians, groundwater users and international experts. Lastly, water footprint also needs to be promoted as a priority research area by showcasing its potential socioeconomic benefits. Educators should also include the importance of rivers, inculcate local values in promoting sustainable water resources management in their teachings aligned to the 8R water philosophy.

Integrity
Current State of Play:
In Malaysia, fragmented and siloed water resources management, and lack of digitalisation of water resources management systems led to low transparency and accountability in the water industry. This data conundrum can be attributed to the absence of a 'Rights to Information Policy and Law' in Malaysia. Besides data availability, the lack of quantifiable water governance tools such as water accounting also poses significant challenges towards ensuring the integrity of water activities.

Way Forward:
The current AACB training module aims to enhance the leadership roles of civil servants to facilitate enforcement of policies and laws for better water governance to digitalise its training modules moving forward. Some strategies that can be taken in academia to aid in closing the gaps include the development of a guidebook on water sustainability, compiling local and international case studies on the best practices of river/water management and success stories related to water resources management in HEIs (public and private). In the future, key legislations and regulations related to IWRM/IRBM should be improvised

and publicised. There should be an Interim Data Sharing Agreement between IWSDC and data providers while proposing water data to be included in Amendment of Statistics Act 1965. It is also essential to implement rights to information policy and produce Annual Water Security Report and Annual Water Accounting Report.

The lack of a specific policy that supports Water Footprint (WF) in Malaysia where WF is not perceived as a priority issue among industries is a reflection that many basic water issues have remained unresolved. These can be overcome by conducting the review on WF studies and global policy and initiatives, the inclusion of WF components in Dasar Air Negara, formulating appropriate policies, incentives, and penalties. There also exists a different school of thought in conducting WF research which leads to counterproductive culture and a lack of interest among industries to implement WF labelling scheme. A water manager certification programme and initiatives to accommodate different schools of thought in WF by adopting hybrid methods alongside awareness enhancement programmes are steps that can be taken.

Although the National Water Resources Policy (2012) has incorporated actions to protect surface and groundwater connectivity, these are insufficient. Thus, appropriate plans drawing on a comprehensive inventory are required for the protection of the groundwater resources and recharge areas. Groundwater Policy needs to be developed and adopted nationwide. Moreover, there is a lack of standards and guidelines to refer to, making it important to develop a standard on groundwater quality. With priorities shifting towards maintaining the environment, environmental considerations need to be integrated into policies, programmes, plans and project formulation as well as implementation. This can be done via conducting a comprehensive assessment process, considering social, ecological and health effects. Other water sources such as coastal ecosystems are vulnerable to climate change as the rise in sea level will lead to damage of infrastructure, degradations of agricultural areas, contamination of surface and groundwater and loss of biodiversity; thus, it is essential for continuous enhancement of existing policies and guidelines with latest findings from scientific studies.

The lack of integration of climate change adaptation and disaster risk management in national and sector policies & development plans, limited capacity for climate change adaptation and disaster risk management integration, limited capacity and appropriate technology for climate change adaptation and disaster risk management amongst practitioners are also major hurdles. A national policy on Disaster Risk Management (DRM) will strengthen disaster risk management, making it essential to incorporate DRM into development planning, evaluation, and implementation. Lastly, the establishment of a national crisis and disaster management centre can improve disaster detection and risk mitigation in the water sector.

Incentives

Current State of Play:

Incentives or the lack thereof determines the commitment level of the players in the water sectors particularly the water operators and industry players involved in the development and management of water resources. The two main disincentives facing the players in the Malaysian water sector are the suboptimal water tariff rates and the lack of funding for water-related R&D. Tariff is an important economic tool in regulating the behaviour of producers and consumers. Consumers are not motivated to use water efficiently given the low cost of water. On the supply side, due to the suboptimal water tariff rates, most of the water service providers in Malaysia are having difficulties even with recovering their cost of operation. Infrastructure investments in water and wastewater projects are known to be highly capital intensive.

Due to the low water tariff rates which in turn leads to a low rate of return of investment, investors do not find the water sector to be an attractive investment avenue. As a result, capital spending to upgrade or maintain water and wastewater treatment infrastructure in the country is inadequate.

On the issue of lack of R&D funding, there is no research grant dedicated to water research despite the high socio-economic benefits that can be gained from contemporary research in water such as water footprint and WFE nexus. Funding from government and private sectors for water projects are either fragmented or event-based. These have resulted in a lack of long-term research strategy and investment to nurture local scientific and technological developments in the water sector. Moreover, there is also a lack of reward and recognition programmes for sustainable practices such as the implementation of water recycling and reuse technology and the use of water-efficient products. These could potentially enhance water consumption behavior and enable the water resources to create greater return on value (ROV).

Way Forward:
Despite the inertia to raise tariffs, water tariffs must be adjusted to cover both operating and capital expenditures to ensure the sustainable operation of water service providers and quality water service. The government must implement the *Tariff Setting* Mechanism (*TSM*)[30] that leads to tariff rates increase and give an immediate boost to the water operator's revenue. It also sends a positive signal to the market that the water sector is on the path to full-cost recovery, and investment opportunities are emerging in the industry. Besides setting the optimal water tariff rate, other instruments such as payment for ecosystem services (PES), application of the "polluter pays" principle, the uniform pricing model for water resources and pollution taxes could incentivise consumers to be more cautious of the environmental impact of their consumption behaviours. More should be also done to identify financial resources and investment needs and to provide incentives, especially to the private sectors to encourage investment in the water sector. Examples of measures that can be taken include an extension of the license period of the public water supply system from three years to ten years or more. Performance-Based Contract (PBC) is also an effective tool to incentivise the private sector to fund water projects, especially pipe replacement for reducing non-revenue water. The PBC model involves private investment to reduce NRW, and the recovered income from the reduced water loss pays back the project cost. The main feature of this model is that it is tied with the performance level promised by the private company.

As most water projects still depend on government funding through grants, a continuous stream of funding particularly from the Federal government is crucial to ensure the successful project completion and the adoption of green economic approaches and nature-based solutions according to IWRM. A *Water Industry Fund* can be enacted to fund critical projects such as rehabilitation and restoration of river basin management, water resources assessment, groundwater development and management as well as training water experts to advocate IWRM and training of future water leaders that embrace the 8R water philosophy. In addition, incentives including lower interest rates, tax deductions of green certification should be awarded to organisations for the purchase and implementation of green technology and other environmental initiatives such as green water restoration. The adoption of sustainable use of water in green building and halal certifications will go a long way to modify corporate and consumer behaviour towards more responsible use of the nation's water resources.

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[30] Refer to Demand Side Analysis section for analysis on end users' willingness to pay for higher tariffs for higher quality and reliability of water supply.

Institutions

Current State of Play:

There have been numerous institutional initiatives across academia, communities, public and private sectors to increase awareness on the importance of water management from the individual to the national level. However, understanding of the importance of water management remains low. Additionally, the existing fragmentation in institutional water governance has also weakened institutional authority, resulting in states being sceptical towards federal policies. The disconnect between state and federal government creates inconsistent regulations and enforcements which in turn discourages industry participation. Moreover, many state governments do not have a dedicated water regulatory body to handle matters related to water resource governance in the state and are not empowered with enforcement capability. On the issue of climate change, there is a lack of urgency and commitment from related agencies and ministries.

Way Forward:

Institutions such as local governments need to be strengthened with appropriate tools to monitor water quality and quantity aligned to the IWRM. This creates a strong on-the-ground presence that can track compliance, enforce rules and regulations, and disseminate important water management information to stakeholders at the respective localities. This bottom-up approach needs to be accompanied by a clear and consistent top-down IWRM strategy that is communicated across all water-related agencies and ministries.

If every state has a State Water Authority (along the lines of LUAS and other similar bodies in the country), this can be an effective way to integrate all the available resources from different agencies to deal with localised challenges faced by the state's river basins. Greater cooperation between Federal and State government agencies at the river basin level could also build trust and officers' capacity to handle natural and financial resources.

The establishment of a water bank was also proposed due to the sheer size of funding requirements in the industry, which PAAB does not currently cover. This includes projects for water resources, flood mitigation, coastal erosion, sewerage, climate mitigation, water reclamation, among others. It has also been proposed that all existing water companies are to be consolidated under one operation for cost reduction and achieving economies of scale.

Having an integrated IWSDC serve as a one-stop centre to consolidate and understand water and water-related data from all localities is also key to bridging the gaps in water management. These can be under the purview of a National Technical Water Committee that ties all water-related government agencies together and facilitate collaborations with the private sector and community organisations. Based on the discussions above, a virtual water & water footprint (VW&WF) centre that coordinates with the Department of Standards and KASA for competency programmes are needed to get stronger buy-in from state agencies to foster better VW&WF awareness and knowledge.

Furthermore, water needs to be prioritised as a national agenda with water-related diseases and disasters being included in discussions of health and security of the nation. The government has taken an important first step to place water resources under the National Security Policy. The next crucial step is that the measures accorded under the National Security Policy must be incorporated into the management, regulation, and legislation of all water resources in the country. This includes empowering water and environment-related agencies to take punitive actions against water polluters that endanger the public water supply. This will safeguard our national water resources, ensuring safe drinking water is always available by developing and updating clear SOPs to address emergencies such as breakdown of water supplies, pollutions, floods, droughts, and waterborne diseases. The coordinating and managing agencies for water need to also focus on future risks while responding to the current ones. There needs to be mechanisms in place to assess future risks and opportunities such as infrastructure wear and tear, more efficient water usage, water conservation and reuse, and easy access to alternative water sources such as rainwater. This will help future-ready and increase the resilience of the water supply sector.

Interactions

Current State of Play:

At present, the level and quality of cooperation, collaboration and knowledge sharing between stakeholders are patchy and fragmented with overlapping roles and unclear rules of engagement. The existing interaction between industries and government in Malaysia is based on the individual initiatives as partnership have not been established due to a lack of coordination among state governments and there is no dedicated platform for collaboration among stakeholders. Fragmented interactions are also evident between stakeholders within the water sector (inter-sector, inter-jurisdictions) and ad-hoc interactions between RDIC stakeholders. Without strong inter-sectoral linkages, nexus approach which requires interaction of the water, food, and energy sectors for instance, might not be possible.

There is also a lack of awareness among the local community on water resource protection especially on the importance of groundwater as a water resource where misconceptions about groundwater extractions are common. This problem is further exacerbated by the lack of participation of multilevel stakeholders for the governance of groundwater. There is an urgent need to foster awareness-raising activities and empowerment training in communities to inform the general public outside the water community about water-related challenges and its implications. However, educators themselves are also found to have low understanding on the issues of climate change and public health.

Way Forward:

Poor communication and linkages can be strengthened among stakeholders via an effective national platform. An integrated platform will facilitate partnerships between agencies and promote joint programmes between government sectors. These engagements will build cross-inter- and intra-organisational linkages, enhancing knowledge transfer and fostering connectivity which in turn accelerate the implementation of IWRM.

There is a need for public and private sectors, civil society organisations and scientific research institutions to work closely to create opportunities for collaboration, and for businesses to integrate these values into their management practices. Governments should also intervene by forming a strategic partnership with businesses, and industry and establishing resource person directory within their regional network to enhance communication.

The successful transformation of the water sector cannot be achieved by any single party but instead requires the cooperation and collaboration of multiple stakeholders. For example, participation from government agencies is required to incorporate Water Footprint (WF) agenda in-laws and regulations, stronger interaction between government and WF professionals in establishing WF definition in-laws and regulations, better coordination between federal and state government through IRBM's initiative and a national task force on WF research and implementation. To enable this, IWSDC has proposed an integrated formal stakeholder platform involving policymakers, government institutions and the public, providing commonly accepted data as a basis for negotiations and proposing linkages with all RDIC stakeholders.

A key solution to groundwater emerging issues is transitioning groundwater management to groundwater governance, which stresses the participation of multilevel stakeholders, involving scientists, policymakers, and end-users by considering each of their concerns on the freshwater supply with supervision from local governments. This reduces the burden of governments while ensuring sustainable groundwater resources management.

Internationalisation

Current State of Play:

The water sector has the potential of becoming an international revenue earner for the country. This would require a mindset change in ensuring the water sector meet its international obligation on climate change and other international best practices and standards. A sound internationalisation strategy contributes to the sustainable development of the water sector through the adoption of global best practices by local players as well as supporting inward investment into the sector. Overall awareness and adherence to global best practices are low among key agencies, industry players and community organisations in the water sector. At the organisational level, there is also a call for more international cooperation and capacity-building, as well as training and collaboration with the involvement of international experts. The lack of a global presence of Malaysia's water sector is also evident where participation in global platforms such as the Water-Food-Energy Network and Water Footprint is limited due to financial constraints.

Besides, the local regulatory environment also present barriers towards the internationalisation of the water sector. Due to the absence of supportive regulations on open data legislation such as rights to information policy and law, the adoption of open data initiatives according to international standards remains a challenge. The difficulty in establishing a common data repository or knowledge database causes data collection and storage to be fragmented and confined by organisational structure. Local data on environmental health metrics including water and climate change is also lacking causing Malaysia's records to be missing in many international databases. As the environmental and disaster risk profile is unique to a particular country, the lack of information and scenarios of the individual country in the public system further hinders regional cooperation and collaboration including efforts and research to prevent climate change and disaster risks management. These challenges hinder the sector from moving up the global innovation and economic value chain.

Way Forward:

The need for strong leadership to drive the internationalisation of Malaysia's water sector is required given a large number of players in the sector. Strong leadership would provide clear direction in the implementation of standards, guidelines and incentive structures that align the country with global best practices adopted in other countries such as the IWRM. Government officials and researchers involved in IWRM should actively participate in international networking and collaboration efforts to promote knowledge sharing and cross-country comparisons in the adoption and implementation of IWRM. To this end, the National Research and Capacity Building institutes' endeavour to enter strategic alliances with renowned regional and international water research and training centres will bring mutual benefit to the involved countries. Government should also provide sufficient resources and funding to encourage

Malaysian participation in reputed water-related international water fora to establish Malaysia's water agenda at the international level and at the same time increase the country's global presence.

On the policy front, the establishment of Rights to Information Policy and Law is required and the adoption of the Open Science concept should be promoted. National policies, the legal and institutional environment should also be conducive to foreign investment with various financing instruments and mechanisms made available to foreign investors to invest in Malaysia's water sector. Other ways internationalisation can also be intensified include: (i) international cooperation in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling, and reuse technologies and (ii) Skill and knowledge sharing between different government agencies and academician with international experts. A strong commitment to meet international standards and best practices will have significant positive spill-over on the water sector in terms of intensifying multi-lateral knowledge and technology transfer, raising the quality of service and increasing opportunities for foreign investment and trade in international markets.

11.0 Conclusions and Recommendations

The key focus of the WES sub-sector is to transform the water sector into a strong economic sector. To ensure the water is a strong economic sector, both the supply side and the demand side of the water sector should be strengthened. A strong water ecosystem will impact the supply side in the following ways: increase the quality of water; raise the reliability of the supply of water; and improve the cost-efficiency and productivity in the water sector. On the demand side, a strong water ecosystem that produces high-quality water will lead to the following: increase new markets, including virtual water markets, where economic agents are willing to pay a higher price for quality water. Further, the use of technology in the water sector will enable firms to enhance their market intelligence and market reach. This also increases the demand for locally developed water technology, education, and training programmes. Both sound supply and demand conditions can transform the water sector into an affordable and profitable sector, generating higher economic revenue and jobs for the Malaysian economy. WES sub-sector has consolidated the findings and mapped the 8i water ecosystem enablers onto the 5 focus areas[31] as outlined by the terms of reference of the study as presented below:

1. **People**
   Current State of Play:
   Supply Side
   There is a lack of people with specialised knowledge, technical, entrepreneurial and leadership skills in the sector to future-proof the sector with the rapid technological changes and increasing demand for high-quality water. There is a serious shortage of graduates that have the necessary skills and many of them are not interested to work in the water sector. Many of the best talents are poached by other industries, far less, getting them to manage water basins in the rural area. As such the sector remains labour intensive and operates at the lower end of the value chain.

[31] Refer to Figure 10: How the IWRM Focus Areas Map onto the 8i Framework

Demand Side

There is also a lack of awareness and civic consciousness among the general public on the importance of water resources in the country as a source of socio-economic development: *"Tak tahu, maka tak cinta"* – there is a tendency for them to take the water resources for granted. There is also a lack of training centres in many of the rural and remote areas which are located near the water basins. This poses problems in terms of training the local people concerning best practices of water basin management.

Way forward:

Supply Side

Establish strong water research and training institutes to nurture the next-generation talent for the water industry. These include intensification of talent development in the STI areas that can transform the sector into a knowledge- and technology-intensive competitive economic sector. Adequate support should be given to colleges, polytechnics, technical colleges, and universities to nurture talent with specialized and multidisciplinary skills; including research capabilities and entrepreneurial acumen to transform the sector into a knowledge-driven and competitive sector. These training institutes must inculcate the 8R water philosophy, which includes:

- **Respect** water;
- **Rethink** the value of water;
- **Reduce** wastage of water;
- **Re-Use** water;
- **Recharge** Ground Water;
- **Recycle** waste-water;
- **Repurpose** water for higher-value use; and
- **Regeneration** of water.

To overcome the shortage of training centres across the country to support the industry, there is a need to continuously review the curriculum of the courses and training programmes. This is to ensure that the value of water (8R Philosophy) is acculturated in the graduate attributes where the talent competency of the next generation leaders who will develop this sector to knowledge-intensive and high-valued economic sector. Transform the water training institutes in Malaysia to emulate that of Japan, Korea, and Singapore[32] to nurture the next-generation talent and technology for the water industry in Malaysia and other developing countries in the region.

Demand Side

The 8R water philosophy needs to be embedded at all levels of water education, from school curriculums to public awareness and education campaigns, and industrial practices. This acculturation process is the foundation for building a more civic conscious mindset to effectively manage end users. Instilling good civic consciousness (in all water resources and related water activities) and nature-centric values and principles will nurture a culture of cleanliness and respect for our water sources among end-users - e.g., the Shinto culture from Japan on avoidance of *Kegare* (impurity or dirt)[33] . This will ensure the next generation of responsible and ethical consumers.

2. **Governance**

Current State of Play:

Supply Side

Quality of institutions of governance (federal, state, and local council), including regulatory framework and standards bodies (that ensures transparency and accountability), and industry associations, community organisations, institutions of learning and research institutes vary significantly. Some are more advanced in using advanced technologies and digital governance systems, while others lag. The understanding of the value of water varies across the different institutions. These differences lead to fragmentation in policy planning and implementation.

While there are many players in the water sector, there is a lack of a "**Champion with Clout.**" Without an effective "Conductor", the water sector has been plagued by a lack of coordination and harmony in policy direction, planning and execution. For the water sector to be a vibrant and competitive economic sector, it will require a non-partisan and inclusive approach to managing the water resources of the country.

Moreover, due to the different stages of development of the institutions (federal, state, local council, industry, and community organisations), the level and quality of cooperation, collaboration and knowledge sharing among the stakeholders are **patchy and fragmented**. In some instances, there exist overlapping roles among institutions; and rules of engagement are often not clearly articulated. As such water policy environment is rather complex and institutions tend to take a functional and silo approach, rather than a strategic and inclusive approach in managing the water resources. In some cases, turf wars among key stakeholders are prevalent.

The low use of digital technologies in managing complex relationships and facilitating the seamless integration of information hinders effective governance across multiple agencies, jurisdictions, and the public. Without sound governance systems underpinned by digital mechanisms, managing the complex relationships between the multiple stakeholders remains a challenge. Lack of proper regulation and planning of data collection and dissemination results in low levels of information sharing among institutions in the water sector. This further impedes policy planning, implementation, and review cycles. The fragmentation in the governance system has resulted in the water sector's inability to create strong economic spill over impacts to another sector of the economy which are dependent on water for production processes. These gaps in the water governance system also led to challenges in managing and monitoring water basins, especially enforcement of pollution control of the water sources of the country. The constant water disruptions pose a major cost for firms and adversely impacts the quality of life of the people.

Weak governance systems also hinder the adherence to global best practices. This results in the water sector operating at the lower end of the global innovation and supply chain. The weak governance also adversely impacts the depth and breadth of international linkages with global centres of excellence and players from the global water markets. As such, the level of knowledge and technology transfers between local and foreign players are low. This negatively impacts the level of FDIs in the water sector. This also limits the potential for a strong export market for high value-added water-dependent

[32] Refer to Table 6: Targeting the Five Focus Areas of the Water Ecosystem – Policy Strategies Comparison between Malaysia and Benchmark Countries

[33] The Shinto concept of *Kegare* is from Powell, S.J and Cabello, A.M. (2019), What Japan can teach us about cleanliness, BBC Travel, https://www.bbc.com/travel/article/20191006-what-japan-can-teach-us-about-cleanliness

products and services. Low external market innovation and market footprint have relegated the water sector to be a primarily domestic-focused industry. As a result, the water sector has not been a major export earner for the country.

Demand Side

Several policies and strategies to fully transform the sector into a dynamic and competitive economic sector are not in place (e.g., competitive tariff/pricing policies, water trading rules, water footprint and virtual water, and other competitive market mechanisms) to attract private or foreign investments into the water sector. Due to the fragmented governance system in the water supply chain, the full potential of water as a vibrant economic sector has not been realised.

Way forward:

Supply Side

Establish an integrated water management institutional framework that will foster strong collaboration between government agencies (at the federal, state, and municipal levels), industry, and community organisations to work in partnership to better manage and harness the economic value of the national water resources. Fostering a "**Whole-of-Government & Whole-of- Society**" approach and establishing a lead agency to champion water as a dynamic economic sector. The government has also taken an important first step to place water resources under the National Security Policy. The next crucial step is that the measures accorded under the National Security Policy must be incorporated into the management, regulation, legislation, and implementation of strategies for all water resources in the country.

Put in place an institutional architecture for a River Basin Organisation to manage the water ecosystem. Since some of the River Basin Organisation will overlap multiple states and jurisdictions, the complex relationships must be managed using incentive-driven arrangements for federal, states, local council and industry to invest jointly in the development of river basins and obtain appropriate returns-on-investment. This "**Win-Win-Win-Win**" incentive for the federal, state, local council and industry will encourage all parties to work together to ensure more effective management of the river basin. All of which will benefit the rakyat and ensure the competitiveness and sustainability of the economic sectors that are dependent on water.

To ensure the complex relationships between all stakeholders are managed effectively across multiple jurisdictions, there is a need to intensify the governance systems using the best technology identified under the 10-10 MySTIE framework to capture multiple spills across the different economic sectors. These include taking a more holistic and integrated approach in setting the direction for the water ecosystem concerning policy formulation and implementation to develop the enablers of the ecosystem (8i-enablers or the 5 focus areas).

Demand Side

The 'Synergistic Governance Model' should put in place strategies and policies to foster strong collaboration and partnership between government, research institutions, industry, and community organisations to create the multiplier effects in the water industry. These include ensuring the policies are business-friendly and conducive to attracting foreign investment into the water sector. The governance system should also enable sharing of data and best practices by all stakeholders to effectively manage the water demand. Other initiatives include fostering cooperation among key players to strengthen water-food-energy nexuses and the multiple players in other sectors of the economy to develop the virtual water markets. These include establishing a common platform (one-stop platform such as the Open Science platform) for enhancing engagement, sharing of information and best practices among all players in the water sector.

Establish 'Community Champions' in the various localities, who play catalytic roles to foster strong cooperation with key agencies and authorities to ensure effective management of the upstream and downstream water ecosystem of the country.

3. **Finance**

Current State of Play:

Supply Side

Fiscal and non-fiscal incentives are not competitive to foster R&D in the water sector. This has resulted in the low levels of development and adoption of new technology, innovation, and systems to enhance the competitiveness and sustainability of water resources. There is a strong reliance on foreign technology by the local industry. The adoption of new technology, innovation, and systems are low and many of the firms in the industry are labour intensive. As such, this impedes the competitiveness and sustainability of water resources.

Demand Side

Additionally, the water tariff system is also not competitive enough to attract the private sector or foreign investments into the water industry. Low water tariff rates also lead to sub-optimal use of water by consumers and some economic sectors (e.g., agriculture and utilities). Firms and consumers are also reluctant to adopt innovative water-saving technologies due to the low profitability and high costs of these technologies. The water resources of the country are not used optimally and the demand for quality water and willingness-to-pay a higher premium for water remains low for the current state of the water sector. Hence, the water sector is unable to derive higher value-added returns from the existing water resources in the country.

Way forward:

Supply Side

Increase the quantum of R&D funding for water-related research aligned to the 10-10 MySTIE framework. Priority investment should be given to the development of frontier technologies, experimental R&D, research personnel and the development of collaborative platforms for research centres, industry, and community to foster strong translational STI spill over for the water industry. This will go a long way to move the industry up the global innovation value chain. The incentives should also be provided to industries to adopt locally developed non-polluting water technology and products. Further, the government should be a key user of the locally developed water innovations and technologies.

Demand Side

Developing a multi-tiered pricing/water tariff model will also be critical for the sustainability of the water sector. A competitive water tariff system will encourage private sector participation and foreign investment into the sector, which can reduce public expenditure on water infrastructure and other related expenditures for the sector.

Other incentives include the introduction of the "polluter pays" principle and pollution taxes to incentivize firms and consumers to be more cautious on the environmental impact due to their actions. Incentives in the form of tax deductions and subsidies should be given to firms and consumers who use environmentally friendly technology or products that reduce water pollution. Such financial support should be extended to economic agents who adopt the 8R Water Philosophy.

4. **Information and RDIC**

Current State of Play:

Supply Side

The use of ICT and Industry 4.0 technologies in the water sector is relatively low. The speed of internet connectivity in many parts of the country are slow; thus, it is not adequate to support Industry 4.0 capabilities and advanced ICT infrastructure. Obtaining real-time data is a challenge, which impedes knowledge sharing and obtaining market intelligence for strategic decision-making. Low levels of knowledge sharing using the digital platform hinders the sector from monitoring the quality of water, pollution and other negative externalities that impact the water basins in the country.

Demand Side

One of the major challenges faced by the local industry is access to R&D funding to undertake research in the water industry. There is also a lack of support for the commercialisation of local water technology. The problem is further exacerbated by siloed research in the water industry due to weak 'quadruple-helix" (cooperation and collaboration among government agencies, industry, universities/research institutes and community organisations). Due to this, there is low participation from industry in the uptake of research, development, and commercialisation of indigenous technologies.

Way forward:

Supply Side

Intensification in the use of digital technology in all segments of the water ecosystem value chain – the primary, secondary, and service sectors in the water industry is required. These include the use of 5G/6G, advanced intelligence systems, cyber-security & encryption technology, and augmented analytics & data discovery to ensure that the sector has the enabling technologies to monitor, manage and obtain valuable market intelligence to create economic value for the sector. Further, the use of advanced technologies to manage the water grid and reticulation systems is required to enhance the quality and sustainability of the water delivery systems.

Demand Side

Greater alignment of R&D work undertaken in institutions of higher learning/research institutes and the water industry will go a long way to help bridge the chasm between academic research and translational outcomes that benefit the water sector. The Grand challenges funding by MOSTI is a great step in the right direction to address this gap, and institutions of higher learning should be encouraged to work with industry players to develop local technologies that meet the needs of the industry. These include technologies that are used to monitor water quality, water supply and potential risks of climate change and other natural disasters to the water basins. These initiatives have the potential to develop a strong local water-tech/aqua-tech industry. All these initiatives will have a direct impact on enhancing the demand for water services and indigenous water technologies.

The national water centre of excellence can also play a key role as a one-stop, end-to-end centre. The centre works in partnership with the National Technology and Innovation Sandbox (NTIS) and i-Connect initiatives to leverage different stakeholder expertise and specialisations within the water sector that can enable stronger synergistic innovations.

Having a neutral water sector equivalent agency such as The Collaborative Research in Engineering, Science and Technology Centre (CREST) for the electronic & electrical sector, can further build trust and enhance knowledge sharing among industry players, research institutions, and institutions of learning. The innovation-driven network externalities from these initiatives will lead to a stronger water-food-energy nexus and the virtual water sector. All of which will contribute to an increased demand for quality water resources and increase the economic value of water.

5. **Infrastructure & Technology**

Current State of Play:

Supply Side

The quality of the natural infrastructure (water basins - rivers, oceans, lakes, and other groundwater sources) and physical infrastructure (dams, logistic supply chains and transportation systems) vary across the country. Many of these infrastructures are not STI-driven. The use of advanced technologies such as sensor technology, big data, data analytics systems, artificial intelligence and other technologies is low. Low use of advanced technologies among the water basins impedes firms from improving productivity, efficiency, transparency, accountability, and accessing valuable market intelligence for strategic decision-making. The water grid system is also fragmented and is unable to transport water from water-rich states to states with low reserve margins. Weak infrastructure contributes to high non-revenue water (36.4%) and low reserve margins in some states in Malaysia (below 10%).

Demand Side

In many areas in the country, the infrastructures are old and fragmented. This limits the capability of the infrastructure to capture, treat and recycle rainwater. There is also a low use of technology to gather market intelligence on end-users. This results in a high opportunity cost of not capturing key market data that are valuable in creating new market demand and opportunities for the water sector.

Way forward:

Supply Side

There is a need for a staged plan for the water basins in the country to adopt advanced STI (the application of 10-10 MySTIE Framework) to raise the quality and sustainability of the water supply. These include replacing old and broken pipes with more durable and smarter infrastructure that enable water suppliers to continuously monitor and effectively manage the water supply. This includes continuously improving the quality of service and reducing NRW to below 10% by 2040.

The new infrastructure should also enable the expansion of alternative water supply, which include claimed water from sewage, rain-harvesting, groundwater, recycling industrial effluent water, and more efficient water audit. All of this will increase the overall supply of water and potential revenue for the water sector.

A plan should also be in place for a more integrated national water grid system, consolidating the water supply system. These will enable more effective management of the national water supply, allowing the transfer of water from water-rich states to states that experience water shortages.

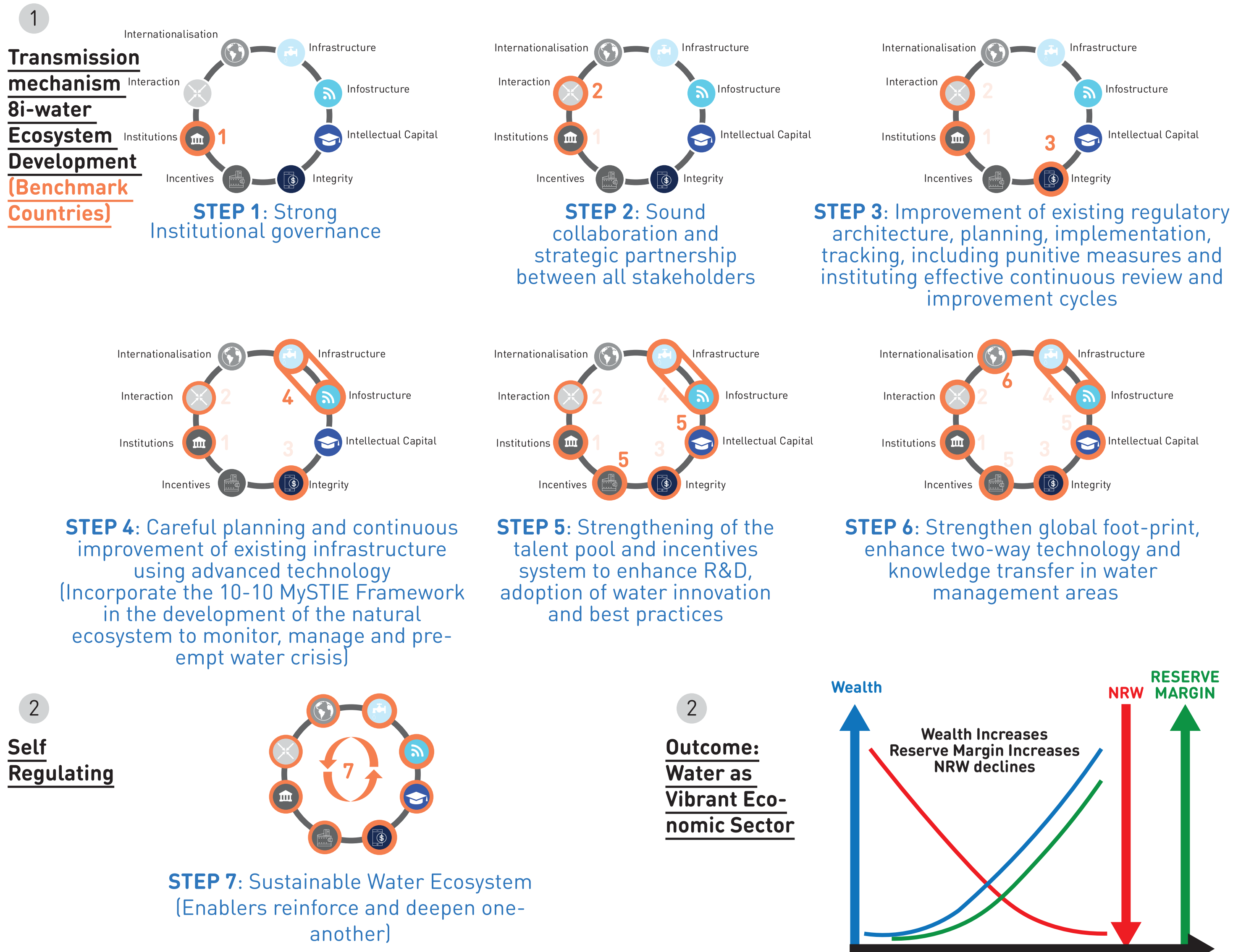
Demand Side

The downstream water system should incorporate intelligent water management systems, which enable traceability (ability to trace the source of water and contaminants), harmony (balanced use among householders, industry, and the environment), sustainability (safe and reliable water services) and self-reliance (energy-efficient systems). Intelligent water apps and smart water meters are also needed to monitor real-time water usage by consumers. These technologies can help end-users monitor their usage patterns and adjust their water consumption behaviours that will lead to more optimal use of water resources in the country. Effective management of the demand side of the water is critical to reducing the nation's water consumption per capita from 245 litres per capita per day (LCD) in 2020 to 160 LCD by 2040.

The extension of the smart grid system to the region will open up new market opportunities for the Malaysian water sector concerning creating a vibrant regional virtual water market by 2040. This will play a key role in transforming the water sector into a dynamic regional water hub contributing significantly to the Malaysian economy.

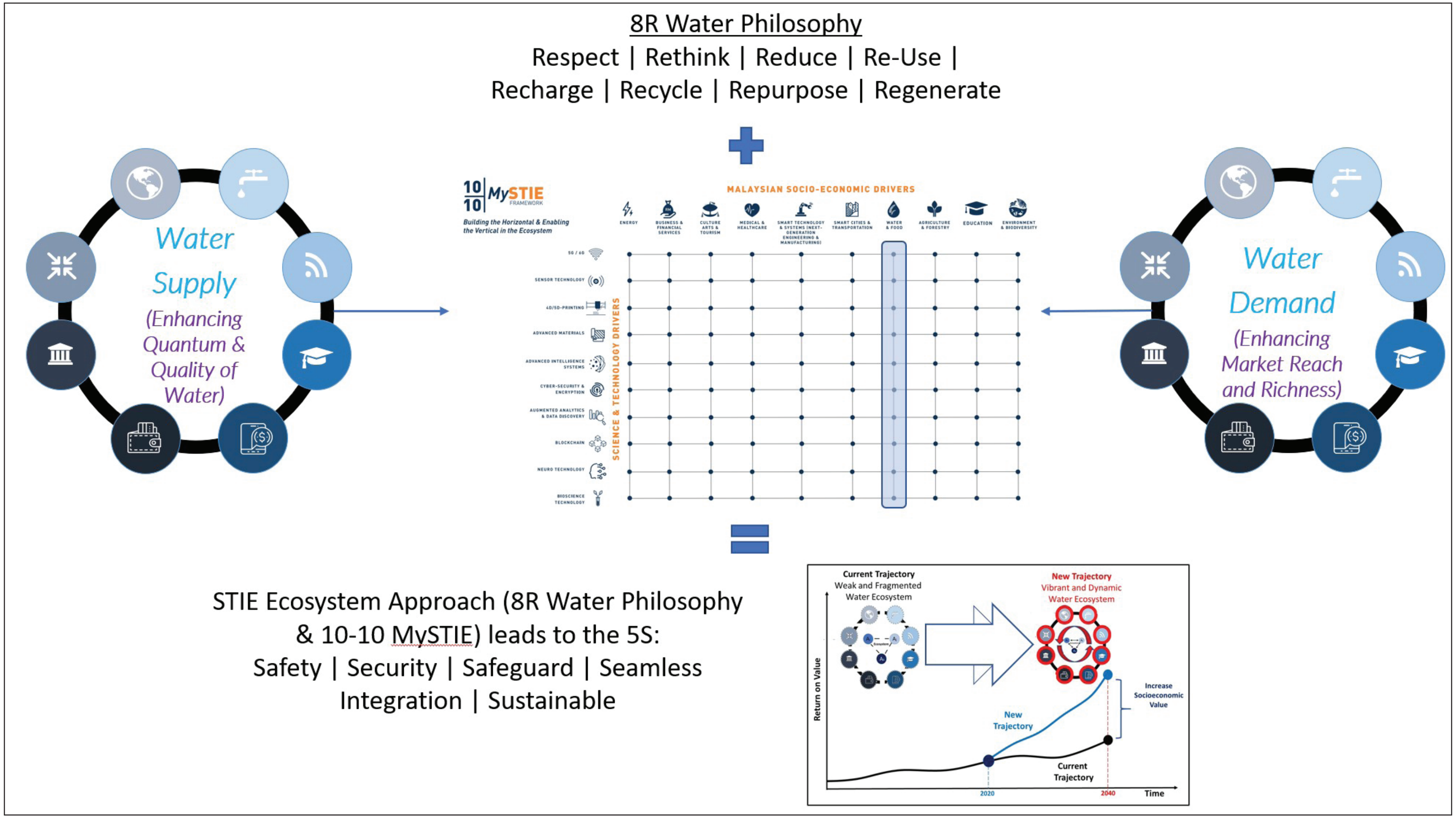
Summary

The above 8i-ecosystem analysis shows 7-step systems approach in transforming the Malaysian water sector into a vibrant economic sector that will reduce NRW, increase reserve margin, create high-income job opportunities, and enhance economic wealth. This systemic sustainable water ecosystem transformation is summarized in Figure 53. Applying this transformation in an integrated ecosystem approach for both the supply and demand sides together with the 8R Water Philosophy, 5S, and 10-10 MySTIE as shown in Figure 54, the water sector could be a major contributor to the Malaysian economy, directly as an economic sector, and indirectly raising the return-on-value (ROV) of other economic sectors.



Source: Framework by Sunway Institute for Global Strategy and Competitiveness (2021)

Figure 53: Systemic Sustainable Water Ecosystem Transformation



Source: Framework by Sunway Institute for Global Strategy and Competitiveness (2021)

Figure 54: Integrated Ecosystem Approach to Nurture a Vibrant and Dynamic Water Economic Sector

12.0 Proposed Immediately Implementable Projects for 12th MP

Table 10: Proposed Immediately Implementable Projects for 12th MP

Projects	Lead Authority	Implementing Authority	Remarks
Review current curriculum for water sector training and embedding water education that incorporates the 8Rs of water philosophy in school curriculums, the general public, and industrial practices.	MOE/MOHE	MOE/MOHE, Ministry of Entrepreneurship Development and Cooperatives	Consolidate existing water education and awareness materials and supplement them with the 8Rs.
Review existing business/consumer-friendly policies/ practices to ensure that they are consistent and aligned with 8Rs of water philosophy and ESG standards.	Ministry of Entrepreneurship Development and Cooperative	Ministry of Entrepreneurship Development and Cooperative, FOMCA	From the Focus Group discussion analysis, there are contradicting policies/practices that disincentivises businesses from adopting sustainable practices. One of the reasons cited is the lack of guidelines from the local council on establishing water storage systems. Businesses that have developed their water storage systems were penalised for erecting their storage systems in their premises. While industry and consumers are already embarking on recycling initiatives, there is a lack of guidelines and fiscal incentives for them to pursue these practices.
Intensify interactive community engagements (i.e., River of Life project in Klang/Gombak River).	KASA	State Governments; Department of Irrigation and Drainage	Embark on more flagship projects to increase engagement and appreciation of water-related activities.
Adopt periodic review cycle for competitive water and sewerage tariff rate mechanisms to ensure business sustainability	KASA	KASA	Low tariff rates in the water sector are one of the key factors that hinder the sustainability of water suppliers and disincentives private sector investments into the water sector.
Identifying industry and community water champions/ role-models/influencers/ambassadors that showcase best practices for a circular economy.	KASA	Malaysia Water Association, NGOs (e.g., WWF), Ministry of Primary Industries, Ministry of Rural Development, Ministry of Agriculture, Industry Associations, Chambers of Commerce.	Engage existing leading water influencers and champions of circular economy to build the culture of water sustainability and transform the water into a dynamic economic sector.

Projects	Lead Authority	Implementing Authority	Remarks
Include private sector and consumer participation in the water management decision-making process.	KASA, Sabah/Sarawak	FOMCA, Ministry of Entrepreneurship Development and Cooperatives, other Industry Associations (e.g., FMM)	Many stakeholders are already eager to participate in the decision-making process. The water transformation process needs to start from a Whole-of-Government and Whole-of-Society approach. Strong stakeholder participation will encourage private sector investment into the water sector.
Undertake STIE fore sighting and scenario planning to the future-proof water sector and water-related industries.	KASA	MIGHT, state water authorities and government, river basin organisations, industry associations, community organisations	Align the water STIE plan with the 10-10 MySTIE framework and continuously update the STIE trends to future-proof the water sector.
National Water Sector Transformation Task Force (strengthen Federal-State cooperation and collaboration)	KASA	KASA, State water authorities and government, river basin organisations, industry associations, community organisations	Implement Whole-of-Government, Whole-of-Society approach.
Operators within the water-value chain need to provide 5-year business plans with annual audited reporting against established targets	KASA	State authorities, river basin organisations	Standardised templates for tracking and reporting of targets and milestones across national, state, and river basins.

13.0 Proposed WES Mission Critical Projects for WST2040

Table 11: WES Mission Critical Projects for WST2040

Focus Area	Projects	Lead Authority	Implementing Authority	Remarks
People	Establish a National Water Centre of Excellence that will futureproof water-related research and development, research-inspired educational programmes, training, and micro-credentials that meets the need of the water sector.	KASA	MOHR, MOHE Ministry of Entrepreneurship Development and Cooperatives, KASA, SMECorp, MAGIC, MDEC.	Annual review of talent mapping, curriculum development, career pathways, and industry R&D needs should be undertaken to ensure the water sector is able to attract the best talent to enhance the sustainability and competitiveness of the sector.
People	Embedding water education that incorporates the 8Rs of water philosophy in school curriculums, the general public, and industrial practices.	MOE/MOHE	MOE/MOHE, Ministry of Entrepreneurship Development and Cooperatives	Instilling good civic consciousness (in all water resources and related water activities) and nature-centric values and principles to nurture a culture of cleanliness among end-users - e.g., the Shinto culture from Japan on avoidance of *kegare* (impurity or dirt)[34] - Responsible and Ethical consumers.
Governance	Establish the National Water Sector Transformation Task Force (strengthen Federal-State cooperation and collaboration)	KASA	KASA, State water authorities and government, river basin organisations, industry associations, community organisations.	Implement Whole-of-Government, Whole-of-Society approach.
Infrastructure & Technology	Put in place a staged state-wide smart water grid system that has future capabilities to develop into an integrated national smart grid system. The grid system should be a public-private partnership initiative to reduce the burden of cost on the government. The national smart water grid system should integrate water from all sources and for all uses.	KASA	National & State water authorities, private sector.	A national smart water grid system is critical in ensuring the quality of treated water and efficient distribution of water across the country.
Finance	Adopt competitive tariff rate mechanisms to ensure business sustainability.	KASA	KASA	Tariff rates are one of the top bottlenecks to the water sector's sustainability and performance.
Information & RDIC	National water centre of excellence to work closely with NTIS and i-Connect to foster strong collaborative partnerships in the water sector.	KASA	KASA, NTIS, i-Connect	A common collaborative platform for RDIC is a key factor that is currently missing in the water sector. Having a clear RDIC leader that fosters these partnerships will better enable the development of local water knowledge and technologies that can achieve economies of scale and scope quicker.

[34] The Shinto concept of *Kegare* is from Powell, S.J and Cabello, A.M. (2019), What Japan can teach us about cleanliness, BBC Travel, https://www.bbc.com/travel/article/20191006-what-japan-can-teach-us-about-cleanliness

14.0 Strategies and Proposed Targets for 12th to 15th MP

Table 12: Summary of Key Strategies and Proposed Targets for 12th to 15th MP

FOCUS AREA	TRANSFORMATION ITEM	MEASUREMENT	TARGET	BASELINE	12MP	13MP	14MP	15MP
People	Upgrade existing talent with key competencies across all key activity areas	Skilled : Unskilled labour ratio	1: 2	1: 4.3	1: 4	1: 3.5	1: 3	1: 2
Governance	Demand side water management: 8Rs of water philosophy	Water consumption per capita (treated water supply)	155L /Day	245L /Day	180L /Day	160L /Day	158L /Day	155L /Day
	National Water Sector Transformation Task Force	Number of Task Force	Strengthen Task Force for an expanded role of NMC	Nil	1	Strengthen Task Force for an expanded role of NMC	Strengthen Task Force for an expanded role of NMC	Strengthen Task Force for an expanded role of NMC
	National Management Committee (NMC)	Institutional Reforms	1 (Regional Leadership)	Nil (Fragmented)	1 (Whole-of-Government)	1 (Whole-of-Government & Whole-of-Society)	1 (Regional Outreach)	1 (Regional Leadership)
	Harmonising and strengthening the water legislative framework and Environmental, Sustainability, Governance (ESG) standards related to water	State of ESG regulatory architecture & incentives	Promote water as a strong regional economic sector & security (↑private sector participation & FDIs), contributing to the economic wealth of the country	Under-developed	Strengthening 154 local authorities and ensuring strong stakeholder participation to generate better ROV and economic multiplier effect from water resources	Harmonise water sector and water-related sectors regulation between federal and states to ensure efficiency and productivity of water as an economic sector	Aligning policies and legislations with global best practices to ensure regional and global economic competitiveness of the water sector and its impact on other economic sectors	Promote water as a strong regional economic sector & security (↑ private sector participation & FDIs), contributing to the economic wealth of the country
Infrastructure & Technology		4IR adoption (cumulative)	85%[2]	5%[1]	20%	40%	60%	85%

FOCUS AREA	TRANSFORMATION ITEM	MEASUREMENT	TARGET	BASELINE	12MP	13MP	14MP	15MP
	Develop a comprehensive national smart water grid system	Non-revenue water reduction	10.0%	36.4%	25.0%	20.0%	15.0%	10.0%
		Water reserve margins (national average)	20%	Assess baseline	15%	20%	20%	20%
Information & RDIC	Attractive incentives for STI within the water sector to encourage local technology and business development	Nurturing local firms (including start-ups)	↑ 20%	Assess baseline	↑ 5%	↑ 5%	↑ 5%	↑ 5%
	National and regional data sharing	Reach and richness of national data centres	Regional water resource planning and market intelligence	Fragmented	One-stop national data centre	Strong market intelligence for all stakeholders domestically	Regional data warehouse	Regional water resource planning and market intelligence
Finance	Increase quantum of funding for water-related RDIC aligned to MySTIE 10x10 plan	Amount of funding	↑ 20%	Assess baseline	↑ 5%	↑5%	↑ 5%	↑ 5%
	Adopt competitive tariff rate mechanisms to ensure business sustainability	Sustainable and competitive tariff model	Full adoption of updated tariffs for OPEX and CAPEX recovery	Tariff rates have not been updated and are not sustainable	Full adoption of updated tariffs for OPEX and CAPEX recovery	Refine tariff model[3]	Refine tariff model	Refine tariff model
	GDP Contribution of Water Sector for High Target Trajectory (Water Collection, Treatment and Supply)	Value-added amount (total amount for each MP)	RM 172.7 billion	RM 4.5 billion	RM 28.4 billion	RM 36.8 billion	RM 47.2 billion	RM 60.3 billion

[1] Estimates from stakeholder engagements.
[2] Estimates from global benchmarking of South Korea and Singapore.
[3] Refinements to ensure that the water tariff is sustainable and competitive and transforms the sector into a major economic contributor.

Table 13: Number of Targets and Key Performance Indicators for 12th to 15th MP

FOCUS AREAS	12MP		13MP		14MP		15MP	
	Targets	KPIs	Targets	KPIs	Targets	KPIs	Targets	KPIs
People	2	2	2	2	2	2	2	2
Governance	3	3	3	3	3	3	3	3
Infrastructure & Technology	3	3	3	3	3	3	3	3
Information & RDIC	2	2	2	2	2	2	2	2
Finance	3	3	3	3	3	3	3	3
Total	13	13	13	13	13	13	13	13

Table 14: Strategies and Proposed Targets for 12th MP

STRATEGIES	INITIATIVES	PROPOSED TARGETS
Develop talent for the water sector with multi/inter-disciplinary skillsets	Review existing water-related research and development, research-inspired educational programmes, training, and micro-credentials in all educational institutions.	Establish a National Water Centre of Excellence (CoE) that will futureproof water-related research and development, research-inspired educational programmes, training, and micro-credentials that meets the need of the water sector.
	Upgrade existing talent with key competencies across all key activity areas	• Skilled: Unskilled labour ratio – 1:4 • Number of employed persons growth of 5% per year
Demand Side Water Management	Ensuring appropriate education, incentives, and policies are in place to encourage stronger water conservation practices	Water consumption per capita: 180L/Day
Institutional Reforms	National Water Sector Transformation Task Force	Achieved Whole-of-Government approach
	Harmonising and strengthening the water legislative framework and Environmental, Sustainability, Governance (ESG) standards related to water	• Harmonize regulation and legislation between federal and state governments. • Incorporate ESG standards related to water sector management in the green rating of buildings and halal certification.
	Increasing transparency and accountability	Water operators publish 5-year plans and annual audited reports against established targets.
Interconnected water supply system across the country to improve water supply, quality of water, and water security	Develop a comprehensive national smart water grid system	• 50% of each state is covered by an integrated state water grid. • 20% of water grid and operators are digitalised and using best-practice technologies.
	Non-revenue water reduction	25%
	Water reserve margins	15% national average minimum / 5% state minimum
	National and regional water-related data sharing	A centralised database to integrate water-related data and information on research, development, commercialisation, and innovation (RDIC).

STRATEGIES	INITIATIVES	PROPOSED TARGETS
Increase value creation of the local water sector to nurture and sustain a circular economy	Attract high quality local private sector and foreign direct investments into the water sector	Water-related local firms (including start-ups) growth of 5% per year.
	Increase quantum of funding for water-related RDIC aligned to 10-10 MySTIE framework to strengthen local technology companies in the water/aqua sector and strengthen the local water supply chain.	Funding growth of 5% per year.
	Competitive water and sewerage tariff rates	Full adoption of updated tariffs for OPEX and CAPEX recovery for water operators.
	Establish collaborative platforms among multiple stakeholders to foster a strong spill over and multiplier effect to the water sector and from the water sector to the other sectors of the economy	National water centre of excellence to work closely with NTIS and i-Connect to foster strong collaborative partnerships in the water sector. Establish a neutral agency for the water sector to build trust and nurture knowledge sharing culture in the water sector.

Table 15: Strategies and Targets for 13th MP

STRATEGIES	INITIATIVES	PROPOSED TARGETS
Develop talent for the water sector with multi/inter-disciplinary skillsets	National Water CoE puts in place a talent review cycle based on technology trends and demand conditions	The CoE undertakes continuous review and refinement of the talent needs of the water sector to ensure the supply of talent meets the demand of the industry.
	Continuing to upgrade existing talent with key competencies across all key activity areas based on technology trends and demand conditions	• Skilled: Unskilled labour ratio – 1:3.5 • Number of employed persons growth of 5% per year
Demand Side Water Management	Ensuring refinements in educational capability and training programmes, incentives, and policies are in place to encourage stronger water conservation practices	Water consumption per capita: 160L/Day
Institutional Reforms	Reviewing and refining the terms of reference of the National Water Sector Transformation Task Force according to the changing landscape of the water sector and the Malaysian economy	Achieved Whole-of-Government & Whole-of-Society approach.
	Continuing to harmonise and strengthen the water legislative framework to meet global best practices.	Aligning legislation with global best practices, including adherence to global ESG best practices and standards.
	Increasing transparency and accountability aligned to global best practices (e.g., ESG standards)	Water operators publish 5-year plans and annual audited reports against established targets including adherence to ESG standards.
Interconnected water supply system across the country to improve water supply, quality of water, and water security	Continuing the development of the national smart water grid system to ensure wider coverage across the country	• 75% of each state is covered by an integrated state water grid. • 40% of water grid and operators are digitalised and using best-practice technologies.
	Non-revenue water reduction	20%
	Water reserve margins	20% national average minimum / 7.5% state minimum

STRATEGIES	INITIATIVES	PROPOSED TARGETS
	National and regional water-related data sharing	Strong market intelligence for all domestic stakeholders.
Increase value creation of the local water sector to nurture and sustain a circular economy	Continuing to attract high quality local private sector and foreign direct investments into the water sector to modernize the water sector and move up the innovation value chain.	Water-related local firms (including start-ups) growth of 5% per year
	Increasing quantum of funding for water-related RDIC aligned to 10-10 MySTIE framework based on more recent technology fore-sighting exercise to transition the local water industry up the innovation value chain	Funding growth of 5% per year.
	Review and revise the water and sewerage tariff rates according to market conditions and costs structures	Continuous review of tariff model for OPEX and CAPEX recovery and expansion.
	Strengthen collaborative platforms among multiple stakeholders to foster a strong spill over and multiplier effect to the water sector and from the water sector to the other sectors of the economy	National water centre of excellence to work closely with NTIS and i-Connect to explore new frontier technologies and business models to enhance the competitiveness of the water sector. The new neutral agency for the water sector continues to foster strong collaboration among the key players in the water sector and water-related industries.

Table 16: Strategies and Targets for 14^{th} MP

STRATEGIES	INITIATIVES	PROPOSED TARGETS
Develop talent for the water sector with multi/inter-disciplinary skillsets	National Water CoE puts in place a talent review cycle based on technology trends and demand conditions	The CoE undertakes continuous review and refinement of the talent needs of the water sector to ensure the supply of talent meets the demand of the water sector and other water-related industries (including a talent for the virtual water sector, water footprint, and water-food-energy nexus).
	Continuing to upgrade existing talent with key competencies across all key activity areas based on technology trends and demand conditions	• Skilled: Unskilled labour ratio – 1:3 • Number of employed persons growth of 5% per year
Demand Side Water Management	Ensuring refinements in educational capability and training programmes, incentives, and policies are in place to encourage greater adoption of more sophisticated technology to ensure a higher return on the value on the water to society and the Malaysian economy	Water consumption per capita: 158L/Day
	Reviewing and refining the terms of reference of the National Water Sector Transformation Task Force according to the changing landscape of the water sector and its deepening role in the Malaysian and regional economies	Regional outreach of taskforce based on the past decade of achievements.
Institutional Reforms	Continuing to harmonise and strengthen the water legislative framework to meet global best practices.	Aligning legislation with global best practices.
	Reviewing and refining policies and strategies related to ensuring greater transparency and accountability aligned to global best practices (e.g., ESG standards)	Water operators publish 5-year plans; annual audited reports and other key performance indicators against established targets annually, including ESG standards.

STRATEGIES	INITIATIVES	PROPOSED TARGETS
Interconnected water supply system across the country to improve water supply, quality of water, and water security	Continuing the development of the national smart water grid system to ensure wider coverage across the country	• 100% of each state is covered by an integrated state water grid. • 60% of water grids and operators are digitalised and using best-practice technologies.
	Non-revenue water reduction	15%
	Water reserve margins	20% national average minimum / 10% state minimum
Increase value creation of the local water sector to nurture and sustain a circular economy	National and regional water-related data sharing	Regional data centre and sharing.
	Continuing to attract high quality local private sector and foreign direct investments into the water sector to modernize the water sector and move up the innovation value chain.	Water-related local firms (including start-ups) growth of 5% per year.
	Increasing quantum of funding for water-related RDIC aligned to 10-10 MySTIE framework based on more recent technology fore-sighting exercise to transition the local water industry up the innovation value chain	Funding growth of 5% per year.
	Review and revise the water and sewerage tariff rates according to market conditions and costs structures	Continuous review of tariff model for OPEX and CAPEX recovery and expansion.
	Strengthen collaborative platforms among multiple stakeholders to foster a strong spill over and multiplier effect to the water sector and from the water sector to the other sectors of the economy	National water centre of excellence to work closely with NTIS and i-Connect to explore new frontier technologies and business models to create wider spill over and multiplier effects across the different sectors of the economy. The neutral agency for the water sector to continue to foster strong collaboration among the key players in the water sector and water-related industries with a clear focus on leading global multi-national entities in the water sector.

Table 17: Strategies and Targets for 15^{th} MP

STRATEGIES	INITIATIVES	PROPOSED TARGETS
Develop talent for the water sector with multi/inter-disciplinary skillsets	National Water CoE in place a talent review cycle based on technology trends and demand conditions	• The CoE to play a leadership role in the talent development for the water sector in the region. • The CoE and key institutions become an important training centre for nurturing next-generation talent for the water sector in the region and other developing countries.
	Continuing to upgrade existing talent with key competencies across all key activity areas based on technology trends and demand conditions	• Skilled: Unskilled labour ratio – 1:2 • Number of employed persons growth of 5% per year
Demand Side Water Management	Ensuring refinements in educational capability and training programmes, incentives, and policies are in place to encourage greater adoption of more sophisticated technology to ensure a higher return on the value on the water to society and the Malaysian economy	Water consumption per capita: 155L/Day
Institutional Reforms	Reviewing and refining the terms of reference of the National Water Sector Transformation Task Force according to the changing global landscape of the water sector and providing leadership at the regional level.	Regional leadership for the water sector.
	Continuing to strengthen the national water legislative framework to meet global best practices and to contribute to the development of a regional water framework that harmonises the legislative and regulatory architecture in the region to foster the establishment of the regional water grid system and strengthen the virtual water sectors.	Promote water as a regionally strong economic sector, including the establishment of a vibrant regional virtual water sector (increase private sector participation & FDIs in the water sector and the virtual water sector).

STRATEGIES	INITIATIVES	PROPOSED TARGETS
	Reviewing and refining policies and strategies related to ensuring greater transparency and accountability aligned to global best practices (e.g., ESG standards)	Water operators publish 5-year plans; annual audited reports and other key performance indicators against established targets annually, including ESG standards.
Interconnected water supply system across the country and the region to improve water supply, quality of water, and water security	Continuing the development of the national smart water grid system to ensure a wider coverage across the country and extend the reach to the other neighbouring countries in the region.	• Connect the state integrated smart water grid system into a national grid. • Extend the national integrated smart water grid system to the regional water grid system. • 85% of water grids and operators are digitalised and using best-practice technologies.
	Non-revenue water reduction	10%
	Water reserve margins	20% national average minimum / 15% state minimum
	National and regional water-related data sharing	Regional water resource planning and market intelligence.
Increase value creation of the local water sector to nurture and sustain a circular economy	Continuing to attract high quality local private sector and foreign direct investments into the water sector to modernize the water sector and move up the regional value chain.	Water-related local firms (including start-ups) growth by 5% per year and extend their reach (and export their technology and know-how) to countries in the region.
	Increasing quantum of funding (from domestic and foreign investors) for water-related RDIC aligned to 10-10 MySTIE framework based on more recent technology fore-sighting exercise to transition the local water industry up the innovation value chain and extend its reach to other regional countries	Funding growth of 5% per year.
	Review and revise the water and sewerage tariff rates according to market conditions and costs structures	Continuous review of tariff model for OPEX and CAPEX recovery and expansion.
	Strengthen collaborative platforms among multiple stakeholders to foster a strong spill over and multiplier effect across the region.	National water centre of excellence to work closely with NTIS, i-Connect and other leading institutions in the region to explore new frontier technologies and business models that meet the needs of the regional water sector. The neutral agency for the water sector to continue to foster strong collaboration among the key players in the regional water sector and water-related industries.

15.0 Appendix

The COVID-19 Pandemic has certainly impacted the processes involved in the study. Most of the physical engagements and activities envision in the initial processes of the sub sectoral study were important methodology, that was adjusted to adapt to the frequent changes in the travel restrictions. The key challenges faced throughout this study would be provided in this section.

The availability and quality of Malaysian water sector data pose a major challenge to the sub-sector after an extensive search. While we know that the relevant agencies are custodians of the data, there have been delays in obtaining some of the requested data at the initial stage of the study. The lack of a coordinated public repository of reports or database has also derailed some of the progress of the secondary data analysis for the local water sector impacting the progress of the primary data analysis.

The primary data analysis of the study involved a planned nationwide survey among industries and the general population. The initiatives towards the preparation and implementation of the nationwide survey were delayed significantly due to the restrictions posed by the pandemic. The development of the survey instruments was also affected by the inability to validate the survey instrument using pilot focus group sessions. However, the final survey instruments were strategically designed, taking into consideration the lack of valuable secondary data and nationwide stakeholder engagements that are implemented before the survey implementation instead of after as initially planned.

The nationwide stakeholder engagement sessions involving government agencies, industries, associations, non-governmental organisations and the communities at each state, region and river basin localities were impacted by the movement control order as the engagement sessions were conducted via online platforms. The qualitative findings from the stakeholder engagements would have been more robust, insightful, and experiential if the sessions were conducted via the initial planned physical engagements.

Despite the challenges faced, the sub-sectoral study was able to progress and provide valuable insights into the state of play in the water industry as an economic sector.

Table 1: Definitions of the Construct Used in Water Model

No	Construct	Definition
	Public	
1	Management	The importance of good management of water for the environment and quality of life.
2	Digitalisation	The awareness and utilisation of digital water platforms for water-related activities.
3	Satisfaction	The satisfaction with the management of water supply, water disruptions, and water regulations.
4	Willingness to pay	The willingness to pay more for quality and sustainable water supply, and advanced water infrastructure.
5	Reliability	The concern is for reliable water supply at an acceptable quantity and quality.
	Business	
1	Impact	The impact of water supply on business operations.
2	Social Responsibility	The awareness for water issues and initiatives for sustainable water supply.
3	Satisfaction	The satisfaction with the management of water supply, water regulations, and digital integration of water industry.
4	Willingness to pay	The willingness to pay more for quality and sustainable water supply, and advanced water infrastructure.

Table 2: Measurement Items for Water Business-Level Impact Study

No	Construct	Indicators
1	Impact	How has the quality of the water supply to your business over the last 3 years impacted the cost of your operations?
		How has the quality of the water supply to your business over the last 3 years impacted the revenue of your operations?
		How has the quality of the water supply to your business over the last 3 years impacted the efficiencies of your operations?
		How has the quantity of the water supply to your business over the last 3 years impacted the cost of your operations?
		How has the quantity of the water supply to your business over the last 3 years impacted the revenue of your operations?
		How has the quantity of the water supply to your business over the last 3 years impacted the efficiencies of your operations?
2	Social responsibility	Water issues are an important consideration in my business strategy and operations.
		Businesses have a responsibility to use water more sustainably
		My company has (or already has plans) to have processes that save water (either through reduce, reuse, or recycling).
		My company has (or already has plans) a plan to have processes that prevent water contamination from our premises.
		As a company, we have embarked on (or will plan to embark on) environment protection and sustainability initiatives(s).
3	Satisfaction	I am satisfied with the stability of the water supply provided to my business.
		I am satisfied with the supply of basic water infrastructure needed for my business operations.
		I am satisfied with the current management of water by our authorities.
		I am satisfied with the transparency of how water regulations are made in our country.
		I have trust in our authorities to properly manage public funding.
		Digitalisation (e.g., a real-time update regarding water disruptions; remote bill payment; smart water meter) of the water industry will greatly benefit my business.
		I am satisfied with the current digital integration in the water industry.
4	Willingness to pay	My company is willing to incur higher costs to ensure our water usage is sustainable.
		I am willing to pay more if the water supply companies can provide higher quality water (including higher reliability of water supply) to my business.
		I am willing to pay more for the water suppliers' continued ability to invest in advanced water infrastructure.
		I am willing to pay more for a sustainable way of supplying water.

Table 3: Measurement Items for Water Public-Level Impact Study

No	Construct	Indicators
1	Management	Good water management is important in ensuring a good environment for the country
		Good water management is important for my quality of life
2	Digitalisation	I am aware of digital water platforms (e.g., Mobile apps by Air Selangor or Indah Water)
		I have easy access to digital water platforms
		I always utilise digital water platforms to obtain real-time news
		I always utilise digital water platforms to carry out remote bill paying
		I always utilise digital water platforms to carry out other water-related activities
3	Satisfaction	I am satisfied with the current quality of water supplied to my residence (e.g., free from bad smell and taste; drinkability)
		I am satisfied with the stability of the water supply provided to my residence
		I am satisfied with the current management of water by our authorities
		I am satisfied with the transparency of how water regulations are made in our country
		I have trust in our authorities to properly manage public funding
		Our water suppliers are doing their best to prevent water disruptions
		Our water suppliers are quick to respond to water disruptions
4	Willingness to pay	I am willing to pay more if the water supply companies are able to provide higher quality water (including higher reliability of water supply)
		I am willing to pay more for the water suppliers' continued ability to invest in advanced water infrastructure
		I am willing to pay more for a sustainable way of supplying water
5	Reliability	A reliable supply of water at an acceptable quantity (reliable and consistent supply) in the country is a great concern to me
		A reliable supply of water at an acceptable quality (safe and drinkable from the tap) in the country is a great concern to me

Background on Input-Output Analysis

Input-output (I-O) tables provide a detailed snapshot of a given economy, describing the flow of products and resources between the different agents in the economy in a given year. Figure 1 shows a simplified structure of an I-O table,

		Intermediate Uses				Final Demand					Gross Output
		Industry 1	Industry 2	...	Industry n	Households	Government	GFCF	CIIs	Exports	
Domestic	1	Z_{11}	Z_{12}	...	Z_{1n}	f_{11}	f_{12}	f_{13}	f_{14}	e_1	x_1
	2	Z_{21}	Z_{22}	...	Z_{2n}	f_{21}	f_{22}	f_{23}	f_{24}	e_2	x_2
	...	...	...	...	...	...	...	...	...	...	...
	n	Z_{n1}	Z_{n2}	...	Z_{nn}	f_{n1}	f_{n2}	f_{n3}	f_{n4}	e_n	x_n
Imports		Zm_1	Zm_2	...	Zm_n	fm_1	fm_2	fm_3	fm_4		
Gross Value Added		v_1	v_2	...	v_n						
Total Inputs		x_1	x_2	...	x_n						

CII = changes in inventories, GFCF = gross fixed capital formation

Source: Adapted from Miller and Blair (2009)

Figure 1: Example of an Input-Output Table

At the heart of I-O analysis is the Leontief Inverse, also known as the total requirements matrix, which is derived from the classical I-O identities:

$$x = (I - A)^{-1} f = Lf \qquad (1)$$

Where,

$$(I - A)^{-1} f = (l_{ij}) \qquad (2)$$

$A = a_{ij}$ is the matrix of technical coefficients or also known as the direct input matrix and is computed as $A = Z\hat{x}^{-1}$ or $A_{ij}\ Z_{ij} / X_j$.

Multiplier Analysis

Common I-O analysis includes the estimation of industry-specific economic multipliers. These multipliers form the basis of economic impact analysis where they provide estimates of incremental effects in terms of income, new job creation or GVA as a response to exogenous changes that affect the sectors' final demand (Miller & Blair, 2009). These measures convert the total value of new final demand expenditure into additional output produced, new income earned by households, value-added generated and new employment created throughout the economy. The size-adjusted version of the multipliers was used in our study where the impact is calculated based on a 1% increase in the final demand expenditure of each sector.

Multiplier	Identity
Output	$m(o)_j = \sum_{i=1}^{n} l_{ij}/0.01f_j$
Household Income	$m(h)_j = \sum_{i=1}^{n} a_{h,i}l_{ij}/0.01f_j$
GVA	$m(va)_j = \sum_{i=1}^{n} a_{va,i}l_{ij}/0.01f_j$
Employment	$m(e)_j = \sum_{i=1}^{n} a_{e,i}l_{ij}/0.01f_j$

$a_{h,j} = Z_{h,j} / X_j$ where $Z_{h,j}$ which represents sector *j's* payments to households. To compute the GVA and Employment multiplier, $Z_{h,j}$ is replaced by $Z_{va,j}$ and $Z_{e,j}$ which represents sector *j's* employment measured in physical units and sector *j's* value-added payments respectively to obtain $a_{va,j}$ and $a_{va,j}$. For further details of the analysis please contact the Academy of Sciences Malaysia.

Data Sources

Table 4 shows the data sources and indicators used for the Input-Output analysis.

Table 4: Data Sources for I-O Analysis

Indicators	Data Used	Source(s)
Output, Income and GVA multipliers	• Malaysia Input-Output Table 2015	Department of Statistics Malaysia
Employment multiplier	• Malaysia Input-Output Table 2015 • Employed persons by Industry, Malaysia, 2015	Department of Statistics Malaysia
Sectoral water uses and water use coefficients	• Malaysia Input-Output Table 2015 • System Of Environmental-Economic Accounting Physical Supply and Use Table: Water Account (MySEEA PSUT Water)	Department of Statistics Malaysia
Regional economic benefits of water use	• Japan Input-Output Table 2015 • Malaysia Input-Output Table 2015 • Netherlands Input-Output Table 2015 • Singapore Input-Output Table 2015 • South Korea Input-Output Table 2015 • Agricultural and Industrial water withdrawal data for 2015	• Ministry of Internal Affairs and Communication, Japan • Department of Statistics Malaysia • CBS (Statistics Netherlands) • Singapore Department of Statistics • Bank of Korea • AQUASTAT – Food and Agriculture Organisation of the United Nations

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