Zero Waste Masterplan

SINGAPORE

Ministry of the Environment and Water Resources
SINGAPORE

Zero Waste Masterplan Singapore

Published by:
Ministry of the Environment and Water Resources
National Environment Agency

www.towardszerowaste.sg

With thanks to all agencies, companies, organisations and individuals who contributed their feedback and suggestions and gave their support for the Zero Waste Masterplan Singapore.

Copyright © Ministry of the Environment and Water Resources

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording or otherwise, without the prior permission of the copyright owners.

ISBN: 978-981-14-2915-6

FSC
www.fsc.org
MIX
Paper from responsible sources
FSC™ C001507

Printed on FSC-certified paper

Produced by: The Nutgraf LLP
Design by: Garçon Design

CONTENTS

Foreword
2

CHAPTER 1
Towards A Zero Waste Nation
5

CHAPTER 2
Keeping Our Resources Within A Closed Loop
17

CHAPTER 3
A Circular Economy Approach To Closing Three Resource Loops
35

CHAPTER 4
Optimising Infrastructure For Maximum Waste Recovery
49

CHAPTER 5
Transforming The Environmental Services Industry
57

CHAPTER 6
Shaping A Greener Future With Science And Technology
70

CHAPTER 7
Towards A Zero Waste Nation, Together
80

FOREWORD

MR MASAGOS ZULKIFLI

MINISTER FOR THE ENVIRONMENT
AND WATER RESOURCES

DR AMY KHOR

SENIOR MINISTER OF STATE FOR
THE ENVIRONMENT AND WATER RESOURCES

Singapore's inaugural Zero Waste Masterplan is an important step towards our vision of a Zero Waste Nation. It encapsulates the aspirations of Singaporeans and embodies the spirit of Singapore moving forward as one – individuals, businesses, civil society and the Government. It demonstrates our belief that the Government must work with Singaporeans and for Singaporeans, to build a sustainable Singapore.

Singapore has shown how economic growth, environmental protection and social inclusion can go hand in hand. But we face new challenges. As a low-lying island-state, climate change threatens our way of life and existence. Addressing how we manage waste together with Singaporeans also goes a long way to tackle climate change. That is because our planet's limited resources are increasingly strained by rising consumption from global population growth and rapid urbanisation, which contributes to more waste. Indeed, our only landfill, Semakau Landfill, will run out of space by 2035 at current waste disposal rates.

To overcome these challenges, and seize the opportunities in them, we must collectively build three new resiliences. **Climate resilience** to address the existential threats of climate change, especially rising sea levels. **Resource resilience** to ensure a safe and secure supply of critical resources. **Economic resilience** to ensure the future Singapore economy remains competitive by overcoming carbon and resource constraints.

The Masterplan will lay out Singapore's strategies to build these resiliences. Our economy is currently based on the linear "take-make-dispose" model. We want to move away from this, towards a circular one that reuses resources endlessly. To do this, we have set ourselves an ambitious target – **we will reduce the amount of waste (per capita) that we send to landfill by 30% by 2030**. This is on top of our existing target to achieve a 70% overall recycling rate by 2030. We can achieve these targets through sustainable production and consumption, and transforming trash into treasure.

Sustainable production involves changing the way we do business. Climate change, resource constraints and growing consumer demands for sustainability mean companies will need new capabilities to produce more with less. Products have to be designed more efficiently and processes re-engineered. We will also need to push the boundaries of applied science and develop new circular economy solutions. The Government will support

this through research and development, in close partnership with industry and academia. In short, the problems that come with climate change are also opportunities for companies to position their businesses for.

Sustainable consumption, on the other hand, starts with us – a change in our mindsets and behaviours. We designated 2019 as the Year Towards Zero Waste to build a national consciousness to care for the environment. Public participation has been very encouraging. More than 6,000 stakeholders participated actively in online consultations, surveys and focus group discussions to refine the Zero Waste Masterplan with us. Our industry has also provided extensive feedback, with more than 250 companies consulted. We will continue to work with you to inspire changes through co-creation. A Citizens' Workgroup to improve household recycling in Singapore will start work in the coming months. Our quest towards "Zero Waste" will be a long journey but we are heartened by the strong start.

The Government has taken the lead to catalyse the transition to a circular economy. We have introduced the landmark Resource Sustainability Act to impose regulatory measures upstream. This addresses our priority waste streams – Extended Producer Responsibility for e-waste, a mandatory reporting framework for packaging, and mandatory segregation and treatment regulations for food waste. Extended Producer Responsibility will also cover packaging waste no later than 2025.

Even as we transform our trash into treasure, the global demand for waste management and recycling solutions is projected to grow. McKinsey has highlighted the potential for a fourfold increase in plastics reuse and recycling by 2030. This would generate US$60 billion in profit-pool growth for the global petrochemicals and plastics sector. Such trends will drive the demand for workers with skills in science, engineering, automation and related capabilities. The Government will support industry transformation and the upskilling of our workforce to create new economic opportunities for local companies, and good jobs for Singaporeans.

This is our commitment. But the Masterplan cannot be effected by the Government's efforts alone. There is a role for everyone to play and we must work as one. Only by doing so can we realise the full potential of the Masterplan and ensure that future generations will continue to enjoy the green and liveable island we call home.

TOWARDS
ZERO WASTE
Sustainable
Singapore

Chapter 1

Towards A Zero Waste Nation

Singapore has an efficient waste collection and disposal system. But if we wish to meet the new environmental challenges we face and continue to grow sustainably, we would need to change the way we view waste management and encourage everyone to consume less and conserve more.

The case for "Zero Waste"

At the heart of Singapore's rapid development lies an inconvenient question: Is it sustainable? Resources around the world are being used up far faster than they are replenished, and the burning of fossil fuels has caused the build-up of greenhouse gases and rising global temperatures.

As the global community shifts towards low-carbon economies to ensure a sustainable future, Singapore plays our part by following three key principles:

- First, economic development, environmental protection and social inclusion are equally important
- Second, everyone must work together to achieve the best outcome
- Third, plans and policies should be focused on the long term and cater to the local context, with an integrated approach to achieve better synergies and resource efficiencies

These principles have guided our policies on waste management, and will continue to do so as we confront environmental challenges such as climate change and a growing worldwide waste problem.

CLIMATE CHANGE – AN EXISTENTIAL THREAT

Climate change has altered weather patterns, affected food and water supplies and caused rising sea levels. As a low-lying island city-state, it is an existential threat for Singapore.

Climate change has made our tropical country even warmer, and brought about longer dry spells. And when there is respite from the scorching heat, the rainfall is more frequent and intense.

Such erratic weather patterns will only worsen resource constraints and supply shocks worldwide, in turn giving rise to crises like food shortages – a serious concern for Singapore where 90% of food products are imported.

Rising temperatures and more erratic weather patterns from climate change will worsen resource constraints and supply shocks. Coupled with a throwaway culture that increases waste generation, there is a need to move towards a more sustainable future economy.

OUR THROWAWAY CULTURE

Leaving behind a half-eaten plate of rice, discarding a shirt worn only once or throwing away a plastic bottle or two everyday – these seemingly harmless and even common actions are creating a mounting waste problem across the globe.

The world's population continues to swell, projected to hit almost 10 billion by 2050. This, along with economic growth, increasing urbanisation and rising affluence, has placed pressure on all forms of resources. The "take, make and dispose" way of consumption – also known as the linear economy model – is no longer sustainable.

The global recycling landscape is also facing challenges. Some countries are introducing stricter requirements on the import of scrap materials for recycling. This has left other countries unprepared to treat their own recyclables.

At home, Singapore has a waste collection and disposal system that is efficient at clearing our waste through incineration. However, at current waste disposal rates, we would need to build a new incineration plant every seven to 10 years. By 2035, the ash generated from incineration may have nowhere to go as Singapore's only landfill, Semakau Landfill, is projected to run out of space by then. This compels us to drastically cut the amount of waste we throw away to conserve it for as long as possible.

SEIZING OPPORTUNITIES IN SUSTAINABILITY

Even though climate change and growing resource constraints are key challenges for Singapore, we can turn these challenges into opportunities.

Technological advances have allowed us to explore solutions to problems that were previously thought impossible to overcome. Through chemical recycling, some plastics can now be upcycled back to their original building blocks, allowing them to re-enter the production cycle as if they were virgin plastic. The treatment of incineration bottom ash has also opened doors to using it as an alternative material in construction, potentially replacing the need for sand.

ECONOMIC OPPORTUNITIES FOR A CIRCULAR ECONOMY IN EUROPE

According to a study conducted by the Ellen MacArthur Foundation and McKinsey in 2015, adopting a circular economy approach could boost the continent's resource productivity by 3% by 2030, generate cost savings of €600 billion a year and bring €1.2 trillion in other non-resource and externality benefits. The key areas of benefit are mobility, food and buildings.

Another 2015 study by the United Kingdom's Waste and Resources Action Programme found that a circular economy has the potential to create 1.2 to 3 million jobs in Europe by 2030.

At the same time, businesses and citizens are developing a growing awareness of the need to do their part for the environment. More citizens are channelling their energies towards driving change from the ground up, while businesses are incorporating sustainability into their business models, in ways that benefit both the environment and the economy. These new business models will create new, good economic opportunities and jobs for the future economy. One such area is in e-waste recycling, where valuable precious metals are recovered from waste, turning trash into treasure.

There has been a shift towards sustainable growth on the global stage as well, with world leaders recognising the need to act. In 2015, world leaders adopted the 2030 Agenda for Sustainable Development (2030 Agenda) and its 17 Sustainable Development Goals (SDGs). The 2030 Agenda provides a shared blueprint and acts as an urgent call to action for sustainable development for all countries.

The adoption of the Paris Agreement in 2015 also demonstrates the commitment by the international community to address climate change. It is another call to action for every country to take ambitious actions and work together to limit global temperature rise this century to well below 2°C above pre-industrial levels, and strive to limit temperature increase to 1.5°C.

CHARTING THE NEXT STEPS FOR SINGAPORE

We need to act now to ensure that Singapore is prepared to seize these opportunities and overcome our challenges.

To prepare Singapore for the future, we must build 3 "Resiliences":

- **Climate resilience – Do our part to mitigate climate change and protect Singapore from its effects**
- **Resource resilience – Secure our critical resources, such as food, water and materials, through optimisation and recovery of treasure from trash**
- **Economic resilience – Ensure our companies can thrive in the future economy in the face of climate change and growing resource constraints**

To do so, Singapore will play our part in the global effort to protect our planet.

We have put forward an ambitious climate pledge under the Paris Agreement to reduce our emissions intensity by 36% below 2005 levels by 2030 and stabilise our emissions with the aim of peaking around 2030.

We are also committed to implementing the 17 SDGs under the Government's long-term agenda, with the aim of uplifting our people's lives while protecting the environment and ensuring social inclusion.

Our efforts in this Zero Waste Masterplan will particularly support:

- SDG 12: Responsible Consumption and Production
- SDG 13: Climate Action
- SDG 14: Life Below Water

In a resource- and carbon-constrained world, we need to adopt a circular economy approach, where scarce resources are valued and kept in use for as long as possible.

By conserving resources, we can also reduce greenhouse gas emissions from production and the incineration of waste. These will help mitigate climate change.

A circular economy approach will also provide new economic opportunities by creating synergies across the water, energy, food and waste sectors to enhance resource efficiency.

By investing in innovation, Singapore can become a leader in urban solutions for sustainable cities, similar to how the nation paved the way for water treatment technologies. These solutions can subsequently be exported to Asia and beyond.

Climate change is a clear and present danger and time is ticking away at our only landfill. There is a growing affirmation that sustainability is an issue that requires everyone to work together to ensure survival and success. The circular economy approach is the best, if not the only, way forward against these challenges. As we do this, Singapore will move closer towards our vision of a "Zero Waste Nation".

Minister for the Environment and Water Resources, Mr Masagos Zulkifli, presented Singapore's first Voluntary National Review of the SDGs at the 2018 United Nations High-Level Political Forum on Sustainable Development

Overcoming the environmental challenges of our past

Singapore in the 1960s and 1970s was marked by night soil buckets, water rationing and unhygienic street hawkers.

Workers shovelled refuse from open roadside bin points onto pushcarts, and discarded them at open dumping grounds across the island.

This form of waste collection was irregular and inefficient. In 1964, only around 60% of each day's refuse was cleared. Refuse often piled up along roads, in back alleys and other common areas. This left streets reeking of decomposing refuse and caused pest problems, both made worse by the hot and humid weather.

Inspection on garbage collection
Photo: Ministry of Information and the Arts Collection, courtesy of National Archives of Singapore

(Top) View of hawker stalls along Singapore River
Photo: A J Hawker Collection, courtesy of National Archives of Singapore

(Above) Night soil carrier
Photo: Courtesy of National Archives of Singapore

The solid waste journey

Our waste management needs started changing from the 1970s. Singaporeans were moving from kampongs to high-rise apartments, and competition for land became more intense as the country developed.

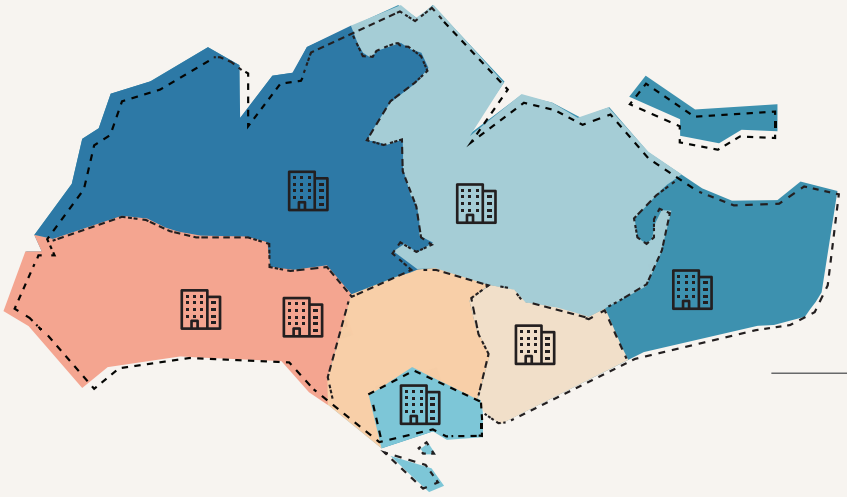
CLEANING UP OUR STREETS THROUGH WASTE COLLECTION

To safeguard public health and avoid disease outbreaks, we had to devise an organised waste collection system.

This prompted the formation of the Ministry of Environment (ENV) in 1972, now called the Ministry of the Environment and Water Resources (MEWR).

Environmental Health Districts

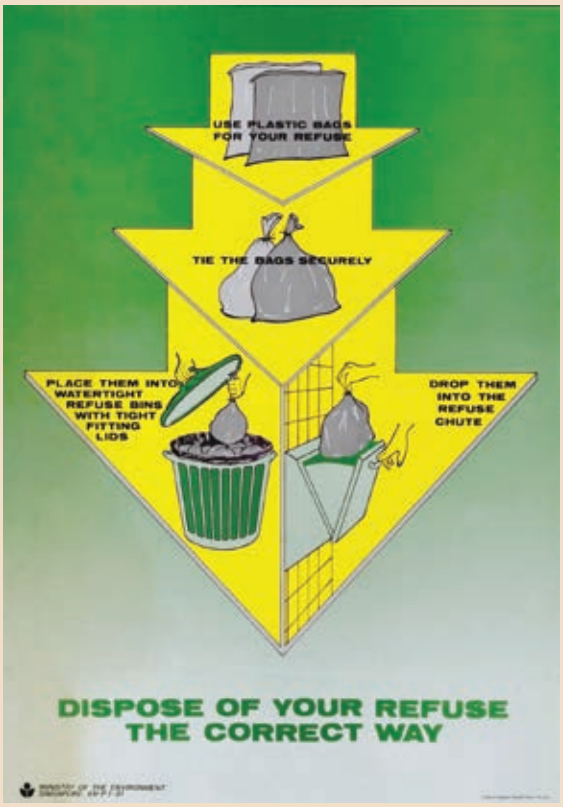
- Western Urban
- Central Urban
- Eastern Urban
- Katong
- Serangoon
- Bukit Panjang
- Jurong
- District Office



Map of seven district offices

A refuse collection vehicle in the 1970s

A district-based solid refuse collection system was set up. Daily refuse collection services for domestic and trade premises started operating from seven district offices, and refuse collection fees were paid through household utility bills. Waste collection vehicles also replaced pushcarts, making collection faster and less strenuous for workers.



Posters from the educational programme run by the Ministry of Environment to encourage residents to bag their waste

DOWN THE CHUTE TO CLEANLINESS – TEACHING SINGAPORE TO "BAG IT"

As Singaporeans moved from kampongs to high-rise apartments, vertical refuse chutes were introduced as a quick and convenient way to collect refuse from multiple flats.

Public housing flats built up to 1988 each came with a refuse hopper in the kitchen. Waste thrown into the chute fell into a bin at the bottom that was emptied daily by refuse collection workers.

But this collection system was unproductive and took up too much space. Hence, in 1989, the improved Central Refuse Chute (CRC) system was launched, where flats had a common chute at the lift landing of each floor. This allowed for more efficient refuse collection.

In preparation for the shift to the CRC system, ENV launched an educational programme in 1986 to encourage residents to bag their refuse before throwing it down the chute. Educational posters showing the steps for bagging waste were produced and distributed across the island. It took many years for Singaporeans to get it right, but it is a practice that continues till today.

PIONEERS IN TURNING WASTE TO ENERGY

Ulu Pandan Refuse Incineration Plant

Reducing waste to just one-tenth of its volume while generating electricity sounds like a great way to make the most of our waste.

But this was unimaginable in the 1970s in Singapore.

It was only done in some parts of Europe and Japan, which adopted waste-to-energy (WTE) incineration, where electricity was generated from waste incineration. These WTE plants were also expensive.

But faced with a shortage of land for landfilling, Singapore took a bold step in 1973 to build the first WTE plant in Asia outside of Japan. In 1979, Singapore's first WTE plant, located at Ulu Pandan, was completed at a cost of $130 million, a hefty investment at the time.

Singapore took a $25 million loan from the World Bank to fund the project, which marked the first time the international financial institution supported the construction of a WTE plant.

Since then, four other WTE plants have been commissioned – Tuas Incineration Plant (1986), Senoko WTE Plant (1992), Tuas South Incineration Plant (2000) and Keppel Seghers Tuas WTE Plant (2009). Together, they incinerate about 7,600 tonnes of waste a day.

By reducing the volume of waste by up to 90%, while generating electricity that is sold to the grid, incineration has been an effective method of waste disposal for Singapore.

While Singapore has achieved our aim of developing a waste management system that has safeguarded public health, we can do more. We can recover valuable materials from waste. This involves a paradigm shift to manage our waste in new, more sustainable ways to deal with our growing resource constraints.

SEMAKAU LANDFILL

AN ENGINEERING MARVEL AND HAVEN FOR BIODIVERSITY

Endangered birds such as the great-billed heron and Malaysian plover call Pulau Semakau's mudflats home, wading through the water in search of their next catch.

When the tides recede, you may encounter the giant carpet anemone, sea urchins, sickle seagrass, nudibranchs and the impressive knobbly sea star. Pulau Semakau's waters are also home to a fish farm.

Looking at the landscape, it may be hard to believe that this is a landfill. Some have even called it the "Garbage of Eden". The 350 ha landfill is able to contain 28 million m^3 of waste. Semakau Landfill was the brainchild of engineers at then-ENV, who proposed turning the sea space between Pulau Sakeng and Pulau Semakau into a landfill.

It was an ideal solution, as space was running out at the last inland dumping ground at Lorong Halus in the 1990s. Competition for land was also getting increasingly intense with rapid urbanisation.

Japan's near-shore landfills were studied, along with the United States' barging systems for offshore facilities.

In 1994, Parliament gave its stamp of approval and construction began in 1995.

It was constructed in two phases, costing $610 million for phase 1 and $36 million for phase 2.

Various measures were taken to minimise the impact on the environment due to construction. This included planting 400,000 mangrove saplings to replace those affected by construction works and the installation of fine mesh silt screens near work areas to reduce the impact of sediment on the corals.

Today, Pulau Semakau is open to the public for intertidal walks to allow everyone to enjoy the island's biodiversity.

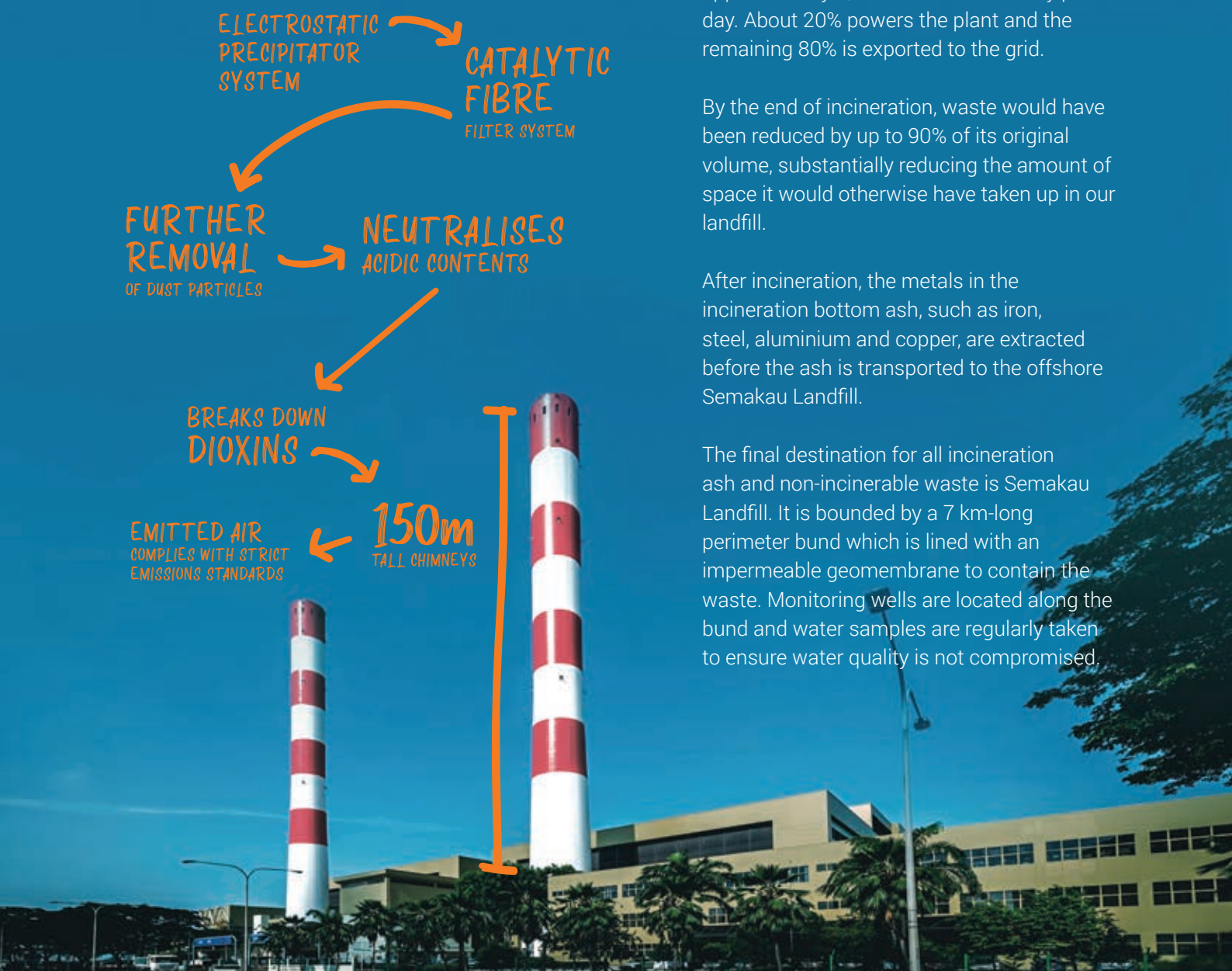
THE SCIENCE BEHIND INCINERATION

Each day, about 600 refuse trucks roll into Tuas South Incineration Plant (TSIP), Singapore's fourth and largest WTE plant.

Before tipping their waste load into a bunker, the vehicles are weighed at the weighbridge.

Air pressure in the bunker is kept below atmospheric pressure to contain the stench, while crane operators mix the waste to ensure the composition is homogenous before feeding it into six incinerators.

After the waste is unloaded, the vehicles are weighed again to determine the amount of waste disposed of.



The $890 million TSIP, commissioned in 2000 on a 10.5 ha plot of reclaimed land, uses an advanced combustion control system to control the combustion process so that the waste is completely burnt.

To ensure that harmful gases are not emitted, the flue gas produced from the combustion process passes through an electrostatic precipitator and catalytic fabric filter system. This removes the dust particles, neutralises the acidic contents and breaks down dioxins into harmless gases before it is emitted through two 150 m-tall chimneys.

The heat produced from the incineration process is harnessed to produce approximately 1,600 MWh of electricity per day. About 20% powers the plant and the remaining 80% is exported to the grid.

By the end of incineration, waste would have been reduced by up to 90% of its original volume, substantially reducing the amount of space it would otherwise have taken up in our landfill.

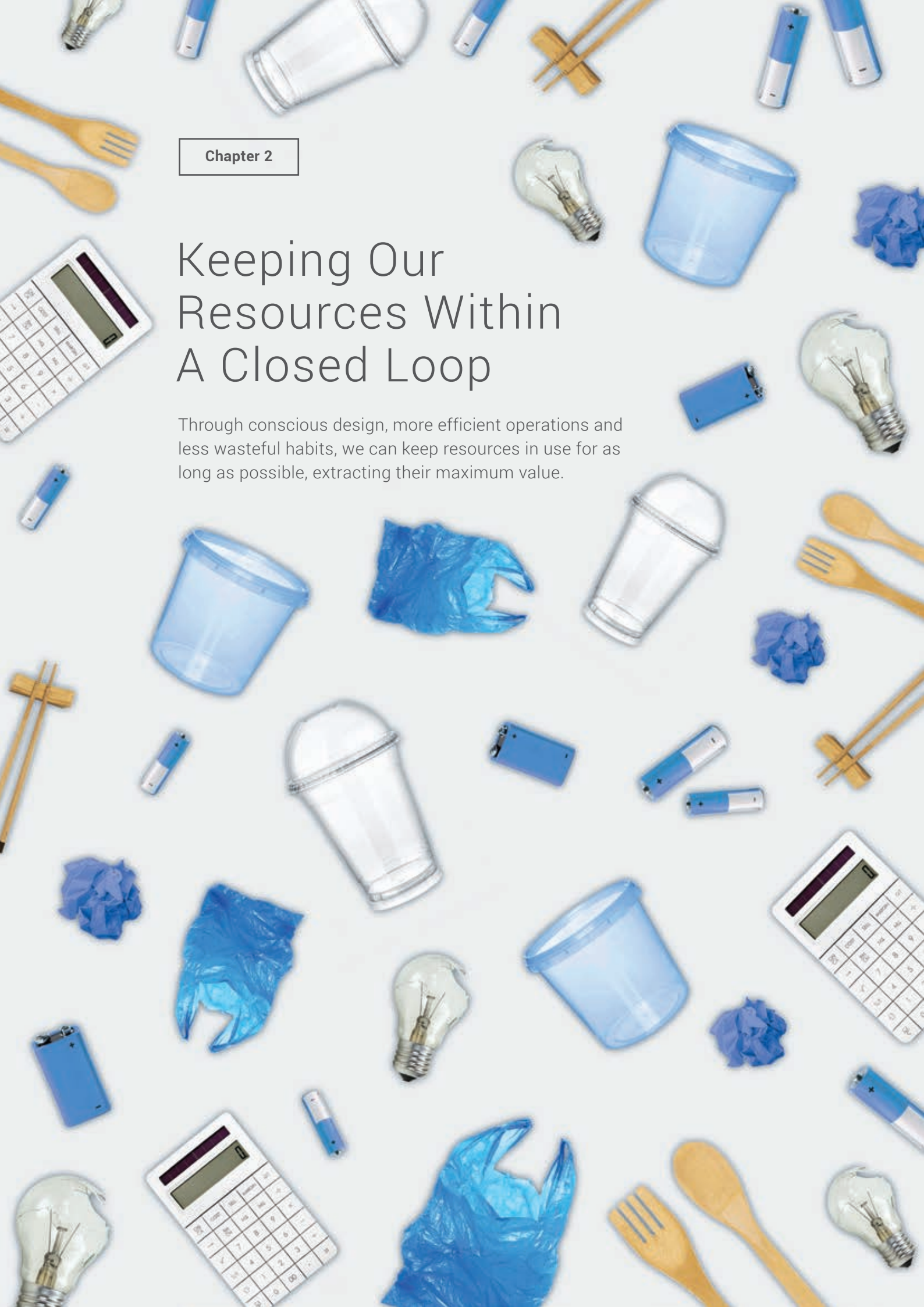
After incineration, the metals in the incineration bottom ash, such as iron, steel, aluminium and copper, are extracted before the ash is transported to the offshore Semakau Landfill.

The final destination for all incineration ash and non-incinerable waste is Semakau Landfill. It is bounded by a 7 km-long perimeter bund which is lined with an impermeable geomembrane to contain the waste. Monitoring wells are located along the bund and water samples are regularly taken to ensure water quality is not compromised.

Chapter 2

Keeping Our Resources Within A Closed Loop

Through conscious design, more efficient operations and less wasteful habits, we can keep resources in use for as long as possible, extracting their maximum value.



For decades, businesses and people around the world believed that the earth's resources would not run out. Many live by the linear economy model whereby materials are harvested, used to manufacture products and eventually discarded.

However, the global population continues to grow and experts have sounded warnings of resource constraints with consequences for generations to come.

We need to change the way we view waste. Rather than just something useless to be buried or burnt, waste should be seen as a valuable material that can be reintroduced into the production cycle.

In other words, we want to adopt a circular economy approach by keeping our resources in use in an endless loop.

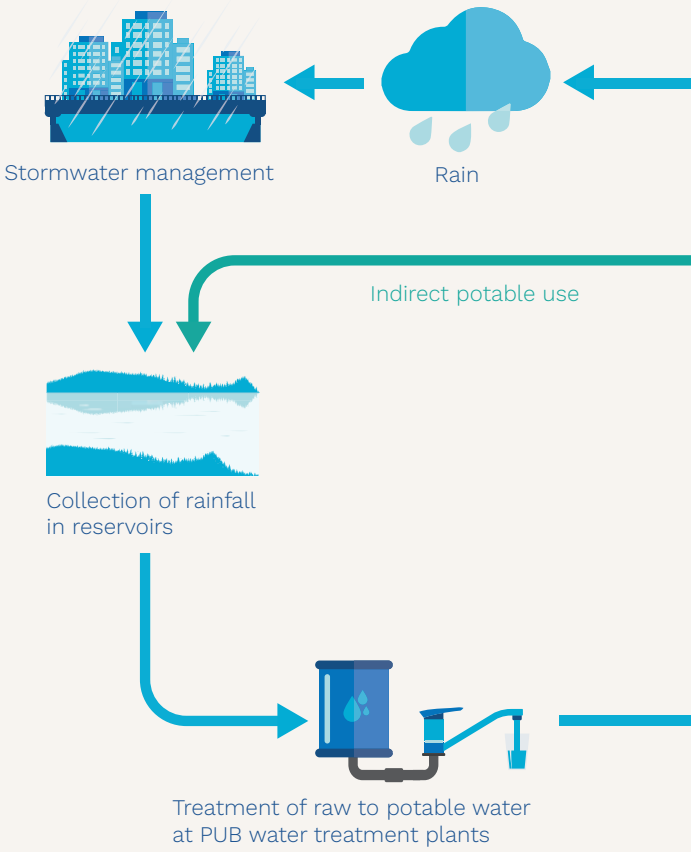
What is a circular economy?

Unlike the linear economy, the circular economy focuses on designing waste out of the resource ecosystem and maximising the value of resources by keeping them in use for as long as possible.

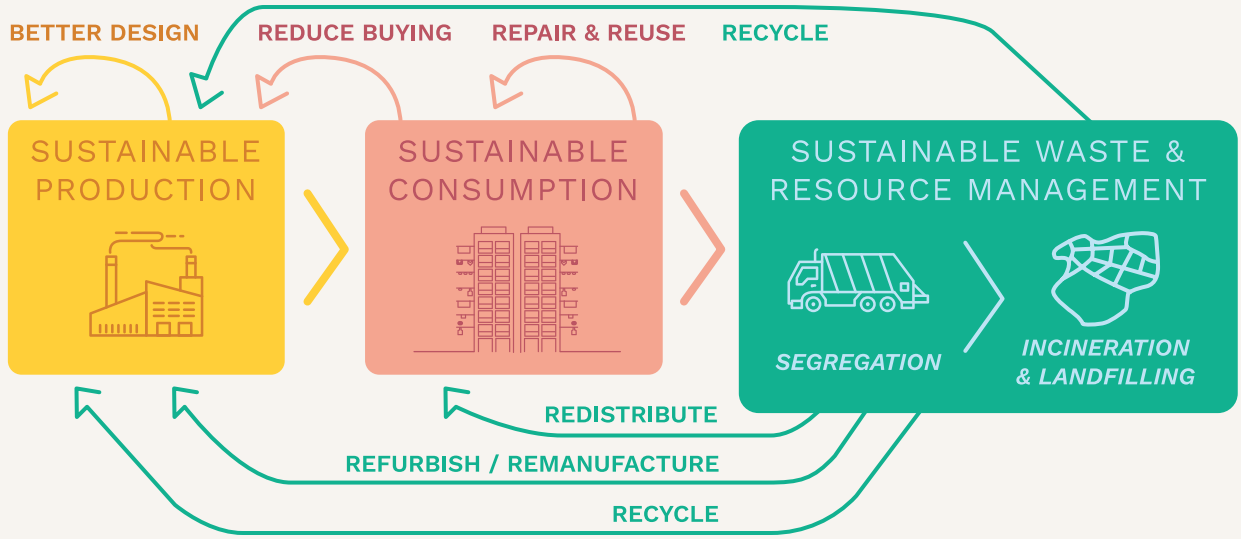
Many countries, such as the Netherlands, Finland, China and Japan, already adopt this approach in their national agenda, driven by resource scarcity, volatile resource prices and the environmental impact from extraction and excessive use of resources.

Even as we learn from other countries, we need to examine Singapore's context and pinpoint how a circular economy is relevant to us. Adopting a circular economy approach can help to contribute to building up three "Resiliences" to sustain Singapore's future.

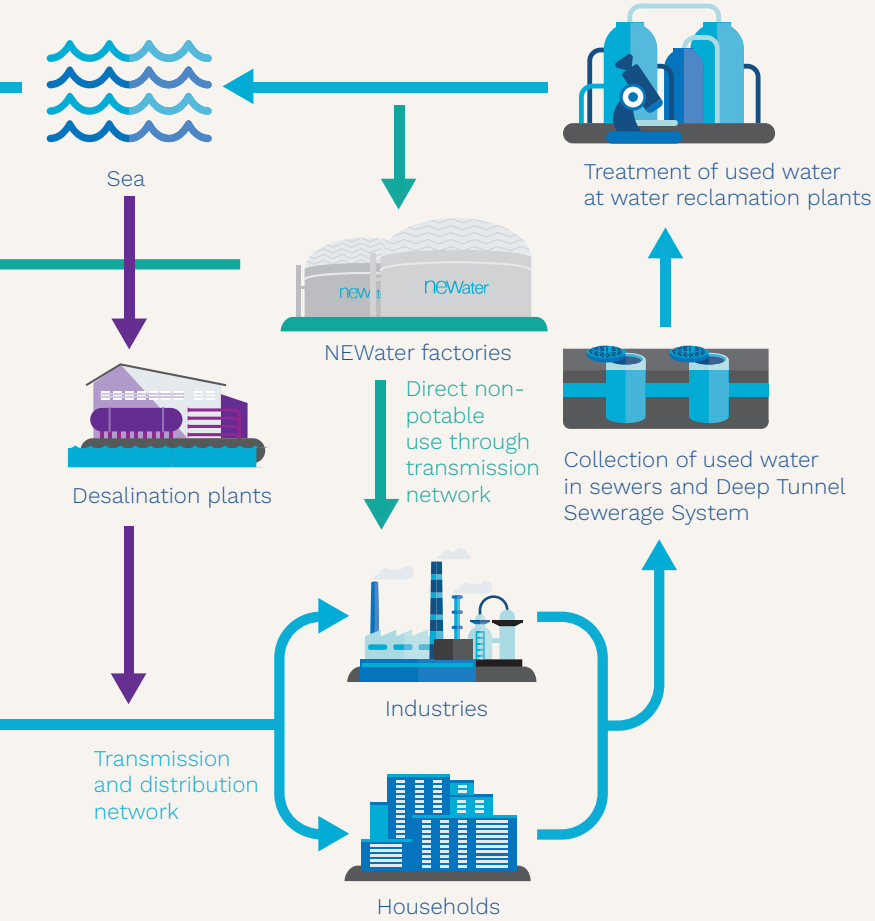
The adoption of the circular economy approach will require measures to be taken across the entire value chain, from production and consumption to waste and



Closing the water loop in Singapore
Credit: PUB



A circular economy approach will require measures to be taken across the entire value chain



resource management. Measures include better product design that reduces the amount of resources used at production, change in consumer habits where products are repaired instead of replaced with new ones and the recycling of waste and their reintroduction into the value chain.

We have already embraced the circular economy approach in several areas through our successes in closing a number of resource loops. Almost all construction waste and metals are recycled.

We have also closed the water loop. By combining water and sanitation, Singapore is able to endlessly recycle water, reusing it again and again. Every drop of used water is collected and treated, turning much of it into drinking water again. This has allowed Singapore to reintroduce up to almost 800,000 m^3 of ultra-pure recycled water into our system each day.

SETTING NEW TARGETS TOWARDS ZERO WASTE

Under the Sustainable Singapore Blueprint 2015, we set the 2030 target of increasing our national recycling rate to 70%, domestic recycling rate to 30% and non-domestic recycling rate to 81%.

Through the adoption of the circular economy approach and the efforts outlined in this Masterplan, we want to go beyond these targets.

IN ORDER TO EXTEND

SEMAKAU LANDFILL'S LIFESPAN BEYOND

2035

WE WANT TO

REDUCE THE AMOUNT OF WASTE

SENT TO SEMAKAU EACH DAY FROM

0.36 KG/CAPITA IN 2018 **TO** 0.25 KG/CAPITA BY 2030

THIS IS A

30% REDUCTION

IN INCINERATION ASH AND NON-INCINERABLE WASTE

BEING SENT THERE TODAY!

Achieving this target will require the successful implementation of the various measures outlined in this Masterplan, including those to better manage our priority waste streams of food waste, e-waste and packaging waste, including plastics.

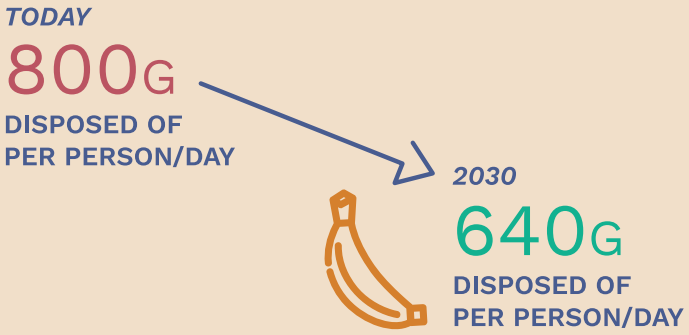
Support from all segments of society will also be needed to take closing our waste loop to the next level. Individuals should play their part by recycling right and not contaminating our blue recycling bins. Businesses that produce the most electrical and electronic equipment or packaging will be required to take a life-cycle approach to products. Large food waste generators must also ensure that food waste is properly segregated and treated.

Lastly, the research and development community will be crucial in developing solutions and technologies that enable us to turn our waste into resources, such as through the use of incineration bottom ash by turning it into NEWSand. (See Chapters 4 and 6 for more information on NEWSand.)

WHAT DOES THE WASTE-TO-LANDFILL REDUCTION TARGET MEAN FOR EACH PERSON?

Today, each person disposes of 800 g of waste per day.

To achieve our waste-to-landfill reduction target of 30%, each person needs to reduce the total amount of waste they dispose of per day to 640 g by 2030. This adds up to a reduction of about 30 bananas or 15 glass bottles per month. It's that simple!



Sustainable production

When companies better manage their resources and reduce the amount of waste generated from conducting their business, both the environment and their bottom line stand to benefit.

How can they produce sustainably? Some ways include sustainable design, improving resource efficiency and adopting industrial symbiosis where companies use the waste of others as raw materials for its own operations.

SUSTAINABLE DESIGN

Designing products to be more durable and repairable lengthens their lifespan, delaying their entry into the waste stream. Creating them with materials and components that could be taken apart easily also makes them easier to recycle.

The National Environment Agency (NEA) has been encouraging companies to reduce packaging waste through the Singapore Packaging Agreement, a voluntary agreement formed in 2007 among the Government, companies, industry associations and non-governmental organisations.

Now we are stepping up this effort. The NEA will introduce mandatory packaging reporting in 2020 for producers of packaged products and supermarkets and target to implement an Extended Producer Responsibility (EPR) framework for managing packaging waste including plastics no later than 2025. (See Chapter 3 for more information.)

Companies are also coming together to take action through better product design and processes. For example, as of June 2019, 15 food and beverage (F&B), retail and hospitality companies, including Hilton Singapore, Kraftwich and SaladStop!, have committed to reducing their plastics production and usage by 2030 through the World Wide Fund for Nature's (WWF) voluntary agreement – Plastic Action (PACT). As part of PACT, over 270 F&B outlets in Singapore have also phased out plastic straws (as of 1 July 2019).

PROMOTING RESOURCE EFFICIENCY

As the world population grows, competition for resources will increase. According to a 2017 report by the International Resource Panel, global material resource use is expected to double between 2015 and 2050 based on current trends.

The report highlighted the need to adopt resource efficiency policies and initiatives, which could save $2.9 to $3.7 trillion a year by 2030. This will also cut resource use by 26% and reduce greenhouse gas emissions by around 20% by 2050.

This global shift towards greater resource efficiency presents opportunities for Singapore companies and industries to be leaders in this area and reap economic benefits.

We are already making headway in improving energy efficiency. For instance, the Energy Conservation Act (ECA) requires large energy users to adopt good energy management practices. This includes conducting regular energy audits, setting up an energy management system and submitting energy efficiency improvement plans.

Companies also track their materials efficiency through sustainability reports such as those required by the Singapore Exchange of Singapore-listed companies. The reports cover five primary components: (a) material Environmental Social Governance (ESG) factors; (b) policy, practices and performance; (c) targets; (d) sustainability reporting framework and (e) Board statement.

However, the commercial and industrial sector still contributes around half of total waste disposed of. Material and waste audits can thus allow companies to identify opportunities for reduction through a systematic evaluation of material flows and costs, and develop concrete plans to improve material efficiency. We will be exploring means to support more companies to do this.

At the same time, the Sustainable Manufacturing Centre (SMC) of the Agency for Science, Technology and Research (A*STAR) aims to promote sustainability in the manufacturing industry by bringing industry associations and the research community together to work with Government agencies to develop and implement sustainable manufacturing technologies.

TWEAKS IN PACKAGING SAVES COMPANY MATERIALS AND MONEY

OLD

PP MOULDED CASE
packaging for the Field Replacement Unit (FRU)

NEW

Lighter packaging for the FRU
PAPER CARTON BOX
with polyethylene foam

Photos: Greenpac (S) Pte Ltd

By making a crucial material swap, a packaging company helped its client save money.

Instead of packing its client's product – a Field Replacement Unit (FRU) – in a polypropylene moulded case, Greenpac (S) Pte Ltd designed a paper carton box with polyethylene foam which did the job just as well.

This reduced the overall weight of packaging from 5 kg to 1.5 kg, saving 53,000 kg of packaging material and $6,000 in material costs per year.

This, and several other initiatives, won Greenpac an Excellence Award (SMEs) at the Singapore Packaging Agreement Awards in 2017.

Photo: A*STAR

BRINGING TRANSFORMATIVE TECHNOLOGIES TO THE INDUSTRY

The Model Factory @ Advanced Remanufacturing and Technology Centre of A*STAR offers capabilities and expertise in three areas underpinning smart manufacturing. It provides companies with a platform to learn how technologies are implemented in manufacturing use-cases or test process improvements without disrupting their own operations.

Secure connectivity and intelligent system
Real-time analytics allows for decentralised decision-making, while condition monitoring provides data for predictive model and optimisation. Together, they make factories more intelligent and, in turn, more agile and efficient.

Virtual manufacturing
With a full digital footprint of a factory, every machine and process will generate real-time information that will provide the data required for optimisation, decision-making, planning and learning. Meanwhile, virtual design will shorten the product design life cycle and the need for physical prototypes. The use of augmented reality will help in training operators and machine maintenance.

End-to-end solutions
The end-to-end digital thread, from customer-specific orders, product design and manufacturing to after-sales service, provides seamless data exchange and new business opportunities. These digital threads also enable better supply chain management and management of distributed manufacturing assets globally.

PROMOTING INDUSTRIAL SYMBIOSIS

Industrial symbiosis refers to mutually beneficial collaborations, where what is deemed as waste by one company could be raw material for the operations of another. This leads to more sustainable industrial processes and cost savings.

To optimise such alliances, both entities are typically sited within close proximity to reduce transportation costs, and their infrastructures are carefully designed.

Industrial symbiosis can also be applied to brownfield sites, where waste-resource flows are matched by an independent organisation. The Finland Industrial Symbiosis System (FISS) is one example. To date, there are around 600 companies and 4,700 resources involved in the FISS.

In Singapore, industrial symbiosis is illustrated through the design of the Tuas Nexus, where the NEA's Integrated Waste Management Facility will be integrated with PUB's Tuas Water Reclamation Plant. Output from one facility will be used as feedstock to another, while keeping the land use footprint and environmental impact to a minimum. (See Chapter 4 for more details on Tuas Nexus.)

Similarly, at upcoming districts such as Jurong Lake District and Punggol Digital District, Government agencies across various domains are working together to optimise resource flows and minimise transport within the district. For example, we are exploring closing waste loops at the district level, such as by converting food waste into useful products like compost, which can be used for landscaping.

STUDYING THE CIRCULAR ECONOMY ON JURONG ISLAND

Aerial view of Jurong Island
Photo: JTC

Singapore is home to Jurong Island – one of the top 10 chemical parks in the world and a key anchor for Singapore's energy and chemicals industry. It is an example of industrial symbiosis, facilitated by shared infrastructure and an inter-connected industrial cluster. To remain competitive, Jurong Island companies have been seeking to optimise resources, such as water and energy, and also to minimise waste in their own plants.

The close proximity of related industries on Jurong Island provides an ecosystem where one company's product can become the feedstock of another. For example, waste from some companies is burnt to generate steam for industrial use. Similarly, wastewater is recovered and recycled for industrial use.

However, there are limitations to the efforts by individual companies. Increasingly, companies are recognising the importance of collaboration so as to jointly discover opportunities for further resource optimisation at the systems level.

To deepen this industrial symbiosis, companies on Jurong Island have come together to support a study commissioned by JTC Corporation (JTC) – the Jurong Island Circular Economy Study. The study seeks to bring about environmental and economic gains for companies by mapping out the current water, energy, and waste flows on Jurong Island, and to identify further synergies and reduce resource use at the systems level.

It is the next step towards positioning Jurong Island as an economically and environmentally sustainable chemicals park. The study is ongoing, with recommendations targeted to be ready in 2020.

Sustainable consumption

Rising disposable income levels have led to more comfortable lives for current generations. But as our affluence grows, so does our consumption of goods and services. This in turn generates waste, with the amount of waste disposed of in Singapore increasing by over seven times over the last 40 years.

How we consume is influenced by social norms, such as pressure to over-order food at meals, keep up with fashion trends or get the latest mobile phone model.

To promote more sustainable consumption, we need to do more and better with less. This can be achieved by having a reduce and reuse mindset, and by shifting towards the use of green products.

REDUCE

To reduce waste, we need to be conscious consumers, mindful of the materials and energy poured into every product or meal.

The ongoing fight to curb food waste

The battle to cut food waste is intensifying, with more organisations joining hands to spread the message of sustainable consumption.

The NEA launched a food waste reduction publicity and outreach programme in November 2015 to raise awareness of Singapore's food waste situation and encourage consumers to adopt smart food purchase, storage and preparation habits to help them minimise food wastage.

Informational advertisements and educational videos on practical ways to reduce food waste were featured on various mass media platforms to reach the public. A comprehensive handy guide was also developed and made available online and distributed at community events. It provided tips on reducing food waste in different scenarios, such as when cooking at home, eating out or organising events.

The NEA has been ramping up engagement efforts, such as talks, food waste reduction demonstrations and other activities with support from the Food Waste Reduction Ambassadors (FWRAs) programme. To date, more than 400 ambassadors have been trained to help spread the word on food waste reduction to their communities, families and friends.

The NEA's food waste reduction publicity and outreach programme was launched in November 2015. In 2019, the key message was to encourage everyone to "Buy, Order or Cook Just Enough".

Four years on, as part of the 2019 Year Towards Zero Waste, the NEA partnered 25 hawker centres and organisations such as Dairy Farm Singapore, NTUC FairPrice, Prime Supermarket and Sheng Siong Supermarket, as well as schools and Institutes of Higher Learning, to engage consumers at points-of-consumption.

Together, they promote three key actions that consumers can adopt to reduce food waste – order only what you can finish, ask for less rice or noodles if you cannot finish them and to say "no" to side dishes you will not eat.

Among the campaign's features were visual reminders, such as wobblers, table-top stickers, wallscapes and pillar wraps, and an edutainment web series that inspires viewers to incorporate food waste reduction practices into their day-to-day lives.

Launch of Say YES To Waste Less campaign at IKEA Tampines on 8 June 2019. The event was launched by Senior Minister of State for the Environment and Water Resources, Dr Amy Khor.

Scan this QR code for more information on the Say YES to Waste Less campaign and initiatives by partners:

Tackling single-use disposables

Just as important is the need to address the problem of disposables that are often used for only a short period before being thrown away.

The Say YES to Waste Less campaign was launched on 8 June 2019 to build public awareness on excessive consumption, the impact on Singapore's environment and future generations and the need for reduction.

With the campaign message, "Make the Right Choice. Choose Reusables", consumers were encouraged to take simple, actionable steps to reduce their impact on the environment. They could start simply by using a reusable bottle, bag or food container instead of disposables.

Opened in 2018 by Ms Florence Tay and Mr Jeff Lam, the aim of social enterprise UnPackt is to encourage consumption consciousness so that customers only buy what they need. This also provides fresher food items while generating less packaging and food waste. Another core objective of UnPackt is to educate the public about zero waste through workshops, community outreach with schools and corporations, and collaborations with like-minded social enterprises.
Photo: UnPackt Pte Ltd

At its launch, the campaign brought together 59 partners, with support from over 1,600 outlets and premises from across the F&B, retail, commercial and community sectors. These partners helped to nudge consumers to make the right choice at points of consumption using a wide range of initiatives. These included visual reminders at cashier points, training of cashiers and providing incentives for using reusables.

The campaign also included district events and 100 roadshows in collaboration with the community to build awareness and encourage action.

To further reduce the use of disposables, the NEA disallowed their use for dine-in at new hawker centres such as at Our Tampines Hub, Pasir Ris Central and Yishun Park. The NEA has also extended this requirement to new stallholders operating in existing hawker centres.

There has also been increasing support from the private sector to tackle the excessive use of disposables. Several F&B retail outlets such as KFC Singapore, Burger King Singapore and Resorts World Sentosa no longer provide plastic straws at their outlets. Yakult Singapore also started selling its probiotic cultured milk drink without straws.

Packaging-free grocery stores have also emerged, where packaging is eliminated. They encourage customers to bring their own containers, and allow them to buy what they need instead of a pre-packaged amount. These stores also offer more competitive prices as going without packaging reduces the cost of its products by an estimated 10%, allowing customers to save both the environment and money.

REUSE AND DONATE

How often have you thrown away a pair of jeans still in mint condition because it no longer fits, or a rice cooker that broke down after just a couple of months?

Often, these items can be repaired, donated or sold second-hand. We want to establish a habit of reuse in the community, such that we will not easily discard unwanted or faulty products.

To promote the repair trade, the NEA has allocated space in some hawker centres for businesses which repair small household appliances or clothing, and will continue to explore new ways to make it more convenient for people to repair their goods. This includes compiling a list of repair options in Singapore.

Another avenue is to equip Singaporeans with basic repair skills and empower more individuals to enter the repair trade. Therefore, we are supporting non-governmental organisations (NGOs) and corporates, such as Repair Kopitiam, to promote repair workshops and courses in the community.

We can also tap on existing platforms to share or buy second-hand items, such as mobile applications or physical stores. To facilitate the sharing of less frequently used items in the neighbourhood, such as ladders and trolleys, the People's Association (PA) launched Resource Centre @ Residents' Committee (RC) in 2016.

However, many Singaporeans are still unfamiliar with what they can do with their used clothing, shoes, bags and other reusables. Instead of donating these items, they often discard them in the blue recycling bins. Therefore, the NEA will be studying how to make donating more convenient, going beyond the list of second-hand shops and donation points currently found on its website. This could include making donation stations accessible to more Singaporeans.

Residents from every corner of Singapore have been turning up at a void deck in Jurong West and in Tampines to seek the help of repair gurus at Repair Kopitiam sessions every last Sunday of the month. Repair coaches teach people how to fix their spoilt items. Organised by social enterprise Sustainable Living Lab, Repair Kopitiam aims to tackle the throwaway culture. It has also organised courses to impart repair skills and support active ageing in the community.
Photo: Repair Kopitiam

Where to donate:

As for the donation of excess food, the NEA and Singapore Food Agency (SFA) have produced a set of guidelines to promote food safety, which includes how to manage pre-packed or perishable food, and transport donated food to recipients.

To further nudge people to donate extra food, the NEA will be working with SFA, National Volunteer & Philanthropy Centre (NVPC) and other stakeholders on new initiatives. One such possibility is a Good Samaritan Law, which has been implemented overseas to provide legal protection to food donors.

PROMOTE GREEN-LABELLED PRODUCTS

Spending your money on environmentally-friendly products is a powerful way of endorsing a greener planet. The Singapore Green Label Scheme (SGLS), the NEA's Mandatory Energy Labelling Scheme (MELS) for household appliances, and Logo for Products with Reduced Packaging support such decisions as they identify products with minimum environmental impact or are made with recycled, recyclable or less materials.

Not only do we want more companies to design their products with environmental considerations or import more green-labelled products, but we also want them to adopt a green procurement policy.

REDUCED PACKAGING
An initiative of the SPA
www.nea.gov.sg/SPA

Logo for Products with Reduced Packaging

Need a chiller box for a house party or a trolley to move some furniture? These items can be borrowed from your nearby RC or Residents' Network (RN) Resource Centre. PA launched the Resource Centre @ RC in 2016 across 460 RCs in Singapore.
Photo: PA

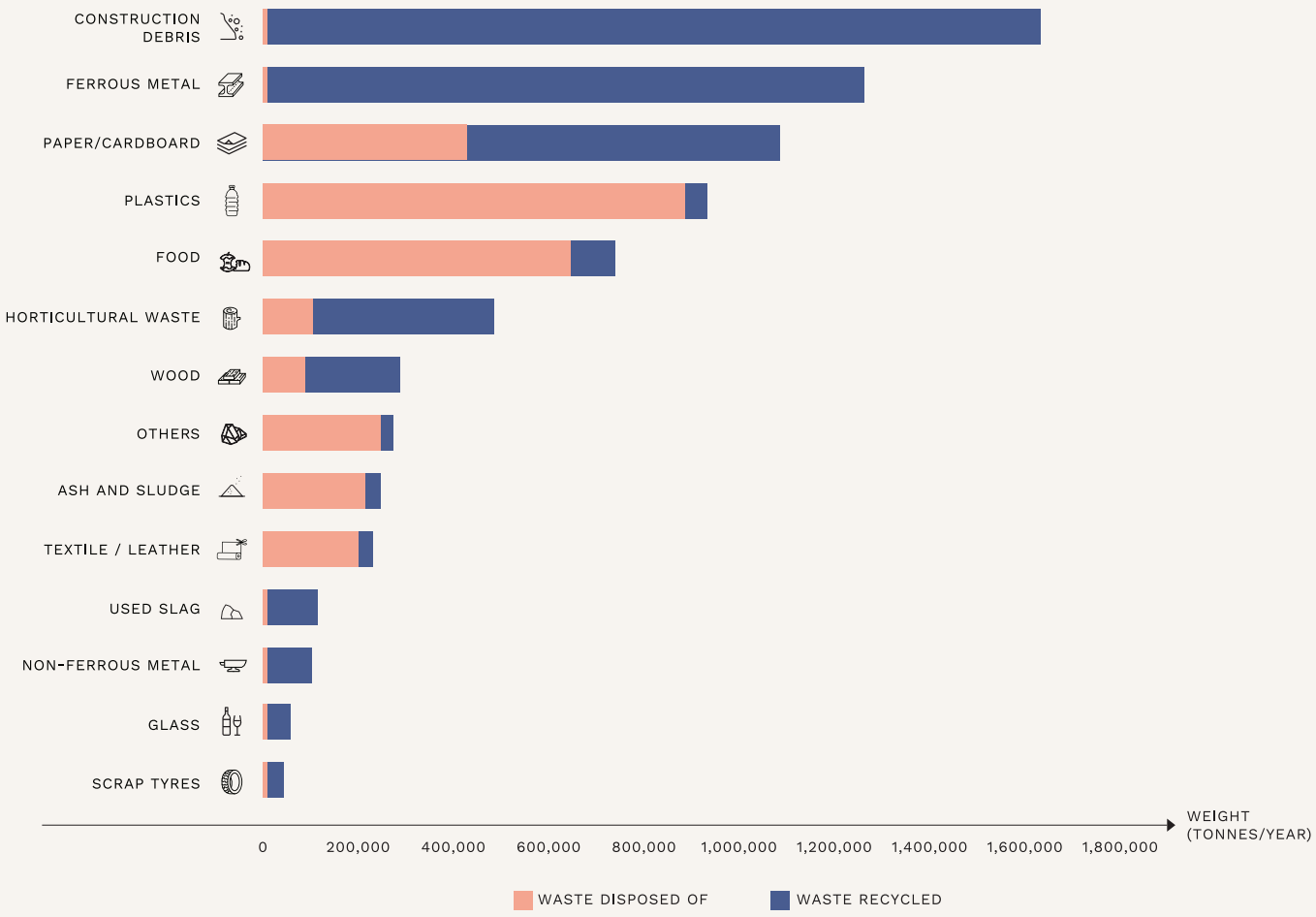
The Government has adopted a green public procurement policy under the Public Sector Taking the Lead in Environmental Sustainability (PSTLES) initiative. For example, all Government agencies are required to purchase energy-efficient appliances with minimum MELS ticks, and white printing paper certified by SGLS.

How do we manage waste sustainably?

Living more sustainable lifestyles means reducing how much we consume and reusing our items where possible. When these are not feasible, recycling comes in, helping us to turn waste into resources.

Singapore has had some success, recycling 60% of its waste since 2012 by focusing on individual waste streams. This has led to a nearly 100% recycling rate for Construction and Demolition (C&D) waste, ferrous and non-ferrous metals.

WASTE STATISTICS 2018



Singapore's waste statistics by waste stream (2018)

PUTTING C&D WASTE BACK INTO BUILDINGS

C&D waste is generated during the construction, demolition and renovation of structures.

To help demolition contractors plan their demolition procedures to maximise C&D waste recycling, the Demolition Protocol was implemented by the Building and Construction Authority (BCA).

Under the Demolition Protocol, reusable and non-reusable parts of a building have to be identified, then separately dismantled and removed. Reusable parts include piping and wiring, which are placed in separate bins and sent to a recycling facility. Non-reusable parts that contaminate the concrete debris, such as ceiling boards and tiles, are discarded. Only when the building has been stripped to its bare frame can demolition start.

This protocol has led to the development of several new materials, like recycled concrete aggregate (RCA), which is made up of more than 70% demolition waste, reclaimed from waste concrete made with natural aggregates.

RCA PROCESS

1 C&D WASTE

2 PRELIMINARY CRUSHING AND REMOVAL OF FERROUS METALS

3 REMOVAL OF FOREIGN MATERIALS SUCH AS BRICKS, PLASTICS AND ASPHALT

4 FURTHER CRUSHING AND SCREENING OF RCA INTO VARIOUS SIZES

5 STOCKPILE OF RCA FOR USAGE

6 VARIOUS APPLICATIONS OF RCA

The Eco-Green Building was constructed using concrete with up to 100% recycled construction aggregates.

Photo: Samwoh Corporation Pte Ltd

Incineration bottom ash (IBA) is processed at the REMEX metal recovery facility to recover ferrous and non-ferrous metals
Photo: REMEX

CLOSING THE METAL RESOURCE LOOP

Recycling 99% of ferrous and non-ferrous metals in Singapore is no mean feat, made possible only with novel processes that can detect even a speck of material.

At a metal recovery facility located at Tuas Marine Transfer Station, 90% of the ferrous metals and more than three-quarters of the non-ferrous metals are recovered from incineration bottom ash (IBA) using special magnets, micro-grain eddy current separators and multi-stage sieving techniques.

The facility, built on a 1.4 ha plot, is capable of processing up to 1,800 tonnes of IBA a day. It has been in operation since July 2015 by REMEX Minerals Singapore Pte Ltd (REMEX).

ENCOURAGING HOUSEHOLDS TO RECYCLE RIGHT

But we can do more in the area of household recycling. In 2018, only 22% of Singapore's domestic waste was recycled, much lower than the 74% recycling rate for non-domestic waste.

The infrastructure is already in place. The National Recycling Programme (NRP) was

introduced under the Public Waste Collection (PWC) scheme in 2001, originally providing fortnightly door-to-door collection of recyclables in recycling bags.

However, this form of collection posed several issues – households did not like keeping their recyclables for two weeks, new recycling bags left outside the doors of flats during delivery were stolen and recyclables were pilfered from the bags. In addition, collection was labour-intensive.

This led to the enhancement of the NRP with the provision of recycling bins in housing estates. The recycling bins overcame the earlier issues, giving residents the convenience of depositing their recyclables at any time. The number of recycling bins gradually grew from one for every five Housing & Development Board (HDB) blocks to one per block, and the frequency of collection increased to at least three times a week. Landed households were each provided with a recycling bin, emptied once a week along with weekly garden waste collection for recycling.

This enhanced NRP also complemented other modes of recycling such as the sale of recyclables to the *karang guni* for a small price, cash-for-trash collection stations and recyclables collection at community events.

While the recyclables collected under the NRP has increased between 2013 and 2018 (77,000 kg/day to 119,000 kg/day), approximately 40% of what is thrown into the blue recycling bins are contaminants. This refers to items that cannot be recycled (e.g. toys, clothes and shoes) or contaminated recyclables (e.g. by remnants of food or liquid).

To tackle this high contamination rate, the next phase for household recycling will focus on improving Singaporeans' knowledge about our commingled recycling system and reducing contamination.

MEWR and the NEA embarked on a #RecycleRight campaign in 2019, as part of the Year Towards Zero Waste.

The key messages of the #RecycleRight campaign are:

- Only place the right recyclables into the blue bins, not general waste – follow the labels on the blue bins on what can be put inside
- Make sure recyclables are free from food and liquids
- No need to sort recyclables to be deposited into the blue bins – they will be sorted centrally before being recycled
- Clothes, shoes and stuffed toys are not recyclable. Donate them if they are in good condition

To support this messaging, the NEA has redesigned the labels on the blue recycling bins to make information clearer on what can and cannot be deposited in the bins. The replacement of the labels is expected to be completed by mid-2020.

New blue recycling bin label helps residents #RecycleRight

We also recognise that it is important to make recycling convenient and to make it a habit in order to boost household recycling. Surveys conducted by MEWR and the NEA in 2018 found that 60% of households recycle regularly at home. Finding recycling convenient and developing a habit of recycling were factors that encouraged them to recycle.

Therefore, since August 2019, the NEA has been in partnership with IKEA Singapore to provide residents of Build-to-Order flats in new HDB precincts with a free household recycling bin. This bin, redeemable via a voucher at IKEA Singapore stores, will make it easier for residents to recycle in their own home.

As we move beyond household recycling to encourage further conversion of waste into resources, we will be turning to legislative or economic measures. As recycling grows, we will need the recycling industry to grow in tandem. Hence, we are supporting the development of the industry through the Environmental Services Industry Transformation Map. All these efforts will be supported by research and development and our crucial 3P partners.

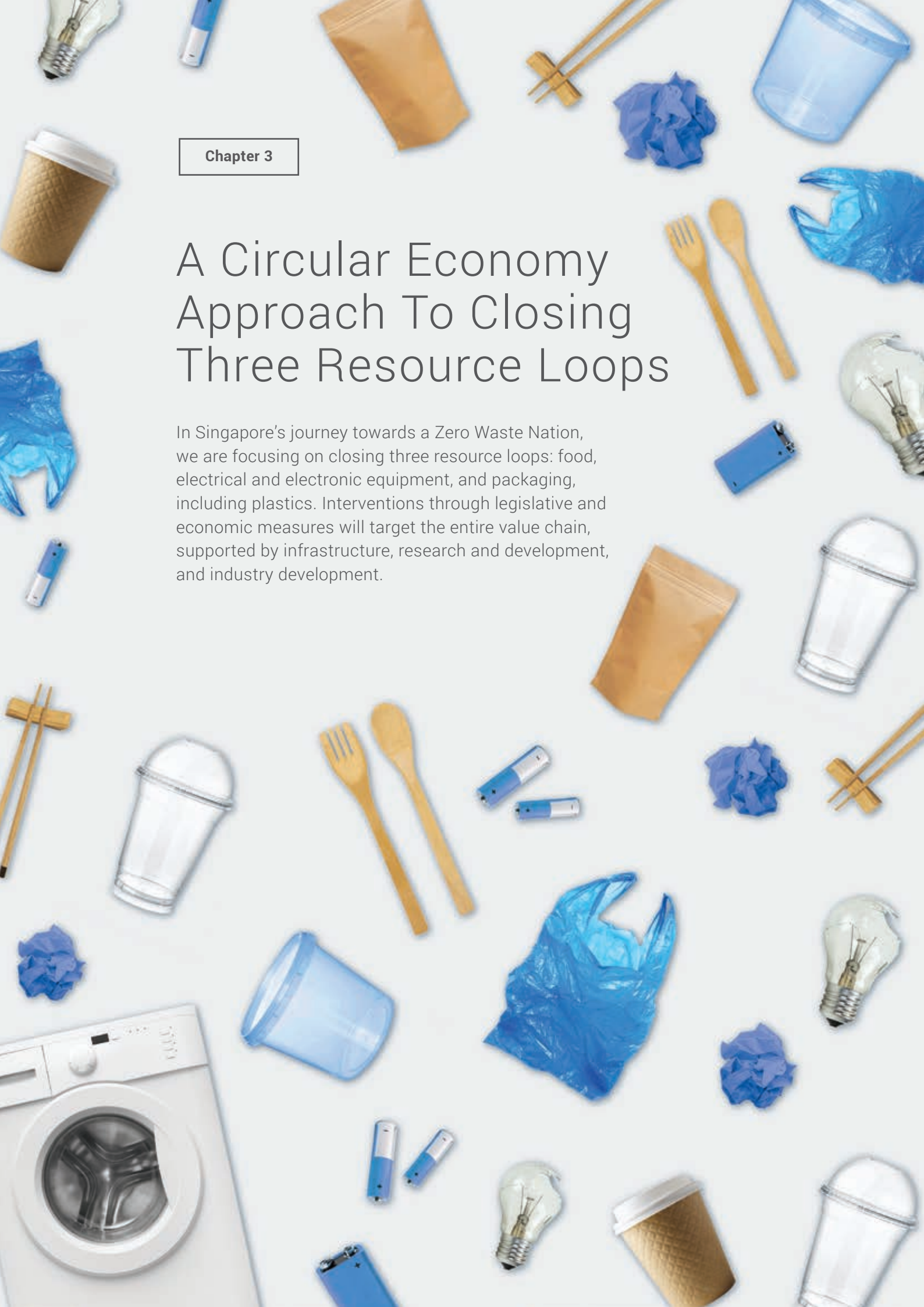
Together, these will help close the loop on more waste streams as we adopt a circular economy approach.

Recycling receptacle for new HDB homeowners

Chapter 3

A Circular Economy Approach To Closing Three Resource Loops

In Singapore's journey towards a Zero Waste Nation, we are focusing on closing three resource loops: food, electrical and electronic equipment, and packaging, including plastics. Interventions through legislative and economic measures will target the entire value chain, supported by infrastructure, research and development, and industry development.



Three priority waste streams

As Singapore prepares for an increasingly carbon- and resource-constrained future, with limited space for waste disposal, MEWR and the NEA are pushing towards a wider adoption of circular economy approaches, where resources are used over and over again, and waste is designed out of the system. We have had some successes, like the near 100% recycling rate for construction and demolition waste and metals. However, some types of waste are generated in large quantities, but have a low recycling rate, such as food and packaging. Though electrical and electronic waste (e-waste) makes up less than 1% of total waste generated in Singapore, it could have a detrimental effect on the environment if not properly managed.

This is why we have made food, e-waste and packaging, including plastics, our three priority waste streams for closing the resource loop and working towards our vision of a Zero Waste Nation. The Government will support the proper management of these three priority waste streams through a regulatory framework to promote resource sustainability. The Resource Sustainability Act is a landmark legislation introduced in 2019 to give effect to the regulatory framework. Through legislation, the Government will mandate the segregation and treatment of food waste by large food waste generators and impose the Extended Producer Responsibility framework on producers and retailers of electrical and electronic equipment (EEE). The Government will also mandate the reporting of packaging data and submission of plans to reduce, reuse or recycle packaging by producers of packaged products and supermarkets.

These regulatory measures are expected to drive demand and create a viable industry for resource recovery in Singapore. They have the potential to create net economic benefit for Singapore and provide an early-mover advantage in the global push towards a circular economy. We hope to promote innovative circular business models and position our companies to seize opportunities in the region for specialised waste treatment, recycling or remanufacturing.

Regulatory measures are complemented by outreach and engagement efforts to businesses and consumers, to develop sustainable production, consumption and waste and resource management habits across the entire value chain.

More on these measures and efforts will be shared in this chapter.

Food

Despite Singaporeans' love for food, households are one of the largest generators of food waste, contributing around half of the food waste generated in Singapore.

According to an NEA study in 2016-2017, each household disposed of 2.5 kg of avoidable food waste each week. Rice, noodles and bread were among the most commonly wasted food items.

The amount of food waste generated has grown by almost 30% over the past 10 years and is expected to rise further with a growing population. In 2018, food waste made up one-fifth of the total amount of waste disposed of in Singapore, but only 17% of food waste was recycled.

There is hope for improvement. The study also found that more than half of the food waste could have been prevented if people were more mindful of how much food they bought, ordered or cooked.

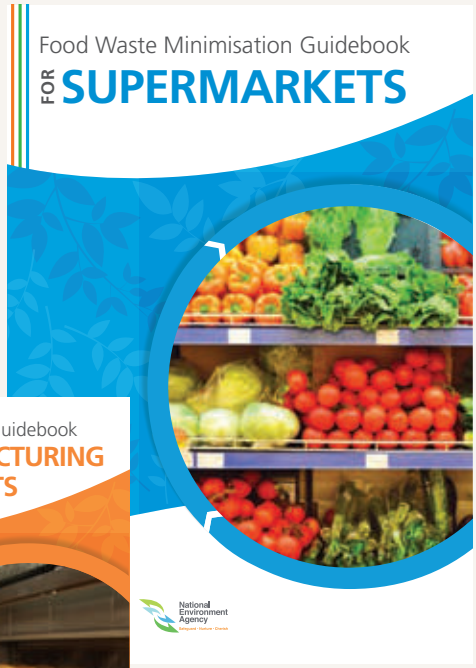
WHY WE SHOULD NOT WASTE FOOD

Food is an essential and precious resource. Singapore is exposed to the volatilities of the global food market as we import over 90% of our food supply. As we work on strengthening our food security, everyone also needs to play a part by reducing food wastage.

Food waste also contributes to odour nuisance in our general waste and attracts pests, requiring more frequent waste collection and increased truck traffic on our roads.

By reducing food waste, we can also reduce the contamination of recyclables, giving recycling a boost.

Find the food waste reduction guides here:



Food waste minimisation guidebooks developed by the NEA to help establishments reduce food waste across the supply chain

CONSUMING FOOD SUSTAINABLY

The best way to manage food waste is to avoid generating it from the outset.

The NEA has developed various resources to encourage sustainable consumption of food. This includes a food waste reduction guide for consumers, as well as food waste minimisation guidebooks for food manufacturing establishments, food retail establishments and supermarkets. The guidebooks aim to help such establishments reduce food waste across the supply chain.

The NEA has also collaborated with different organisations, including private organisations and schools, to raise awareness of food waste reduction through educational materials.

Where there is unsold or excess food that is still suitable for consumption, consumers and food establishments can donate them to food distribution organisations such as The Food Bank Singapore, Food from the Heart, Willing Hearts and Fei Yue Community Services.

But what about unavoidable food waste that needs to be thrown away? With today's technology, we can adopt a circular economy approach by viewing food waste as a valuable resource. Food waste can be converted into products like non-potable water, liquid nutrient, compost and biogas for energy generation.

ON-SITE: TREATING FOOD WASTE

On-site food waste treatment systems convert food waste into non-potable water, liquid nutrient or compost.

To kickstart the roll-out of such systems, the NEA conducted a pilot project at a hawker centre at Block 628 Ang Mo Kio Ave 4 Market in 2016. It was found that active participation and support of stallholders and cleaning staff were crucial to the success of the project.

Similar systems have since been implemented at several other hawker centres, such as the hawker centre at Our Tampines Hub (OTH), Kampung Admiralty Hawker Centre and Yishun Park Hawker Centre.

Read more on OTH's on-site food waste treatment efforts here:

Read more on the NEA's 3R Fund here:

Apart from harnessing useful by-products from food waste, recycling food waste can save money too. At OTH, food waste is converted into organic fertiliser, which is used at its rooftop Eco-Community Garden and distributed to members of the community at the end of each month. This has contributed to annual savings of about $40,000 from the reduction in daily waste disposal charges as food waste is no longer disposed of as general waste.

Companies looking to put in place food waste minimisation projects, including the implementation of on-site food waste treatment systems, can tap on the NEA's 3R Fund.

OFF-SITE: TURNING FOOD WASTE INTO ENERGY

In 2016, the NEA and PUB conducted a pilot at Ulu Pandan Water Reclamation Plant where food waste – segregated at source from general waste and deposited in dedicated food waste bins – was collected from 23 locations and mixed with used water sludge. The combined food waste and used water sludge undergoes a process called anaerobic digestion, where biogas is formed through microbial activity in the absence of oxygen.

The pilot found that co-digesting food waste and used water sludge can triple the biogas yield as compared to digesting used water sludge alone, thereby enhancing energy generation. The NEA and PUB will be working together to implement the co-digestion process at the upcoming Tuas Nexus, where the NEA's Integrated Waste Management Facility is co-located with PUB's Tuas Water Reclamation Plant.

BRINGING FOOD WASTE SEGREGATION TO HOMES

A resident disposes of food waste into a food waste recycling bin

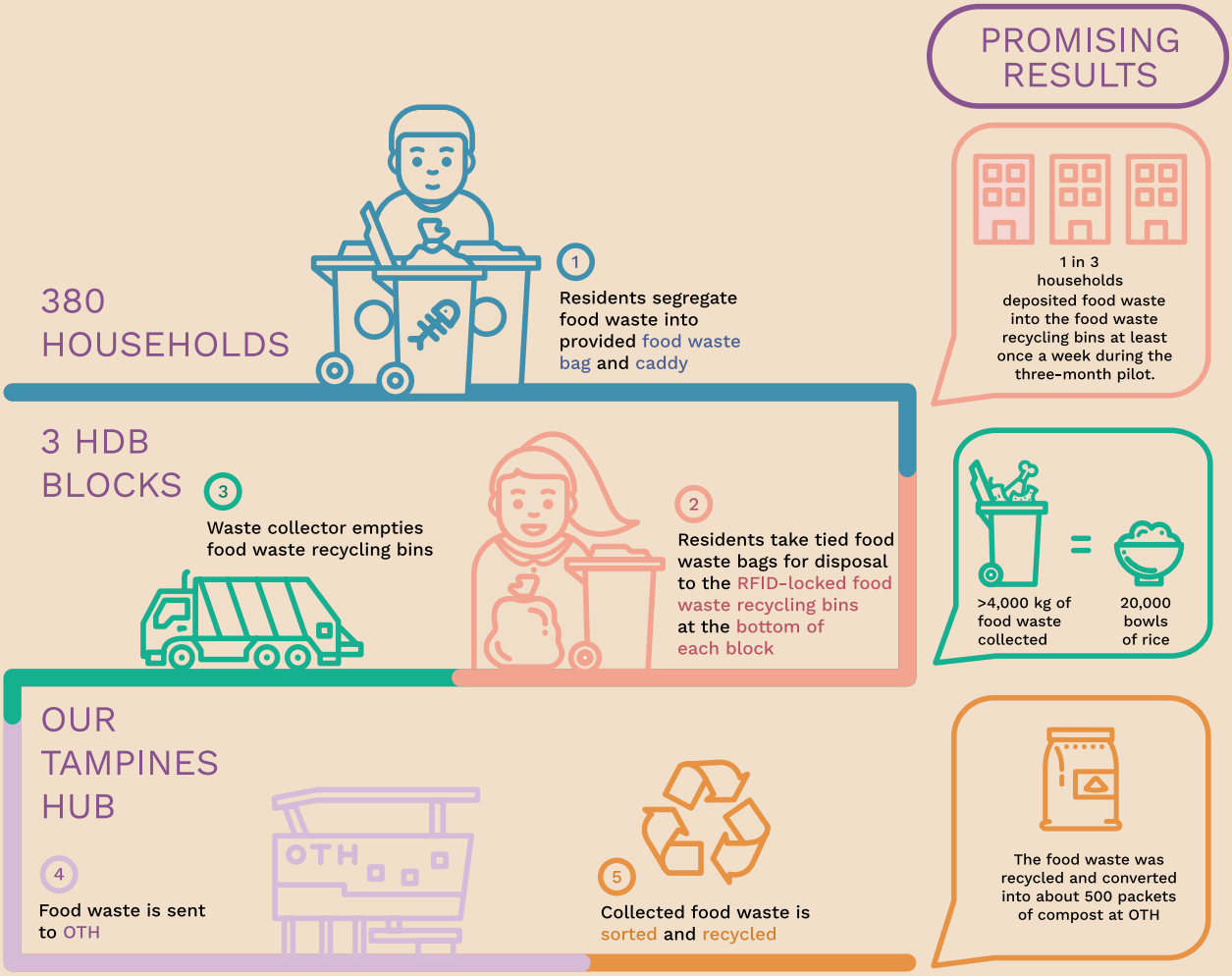
To gather insights on household routines to encourage households to segregate food waste for treatment, the "Food Waste? Don't Waste!" household food waste segregation and recycling pilot was conducted by MEWR and the NEA, in collaboration with OTH, the People's Association (PA) and the Tampines Town Council.

Since 1 August 2018, households in the Tampines GreenLace HDB estate were provided with information on how to separate food waste, as well as food waste caddies and bags to collect their food waste.

Residents were asked to bag their food waste and deposit them into food waste recycling bins located at the foot of their block. The food waste collected was then sent to OTH for treatment.

The pilot has yielded valuable insights on food waste generation and disposal behaviours and it has helped increase awareness of food waste recycling amongst the residents of GreenLace by more than 23 percentage points to 82% after three months.

To build upon this awareness following the pilot, we have partnered Zero Waste SG to engage the residents and explore ways of making their journey towards zero waste even more meaningful. Some possibilities include fully closing the food waste loop within GreenLace via composting in a community garden. We will continue to work with the community for more opportunities to reduce food waste.



THE FOOD WASTE SEGREGATION ROADMAP

Discarded food is not simply waste to be incinerated. Instead, as shown in the examples above, there is potential to turn them into useful products.

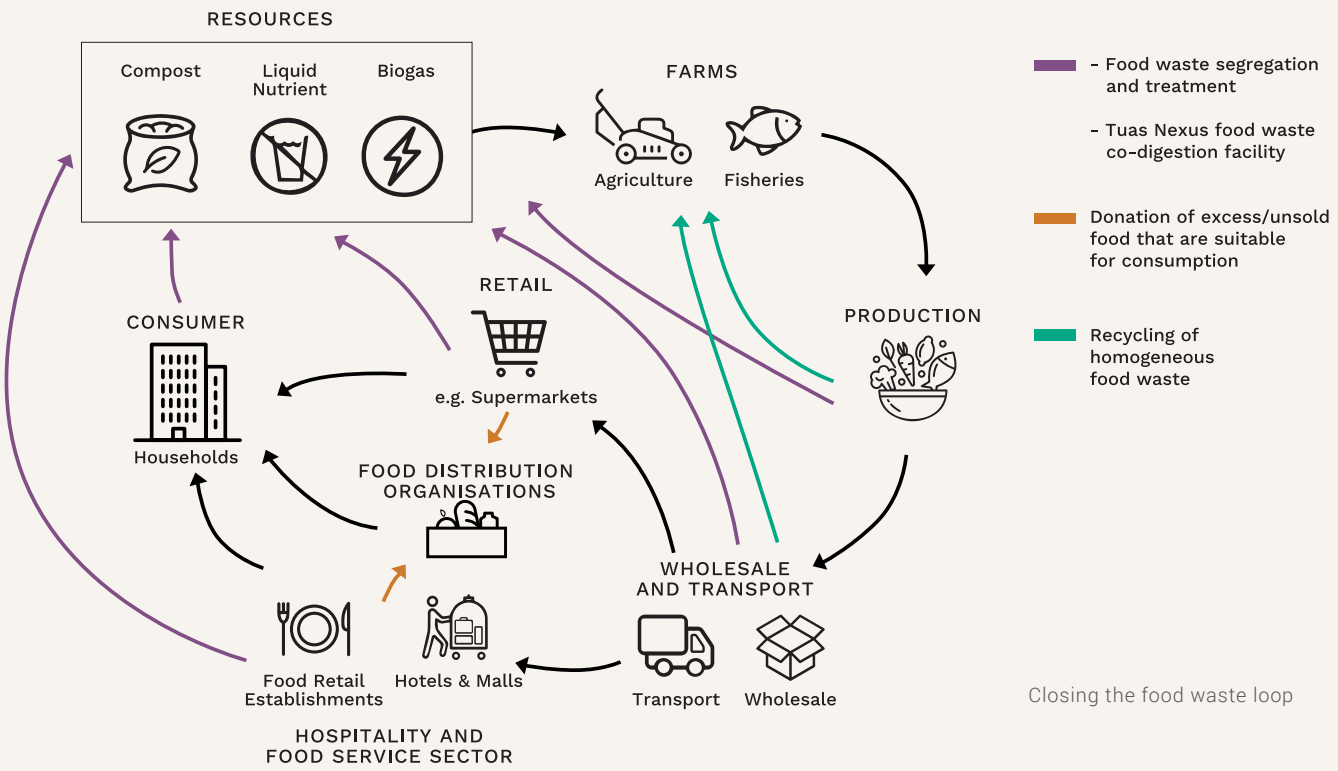
Therefore, under the Resource Sustainability Act, we will be making it compulsory to segregate food waste for treatment.

FROM 2021

- We will work with owners of large public sector buildings with food and beverage outlets to segregate their food waste for treatment. This could be done under the Public Sector Taking the Lead in Environmental Sustainability (PSTLES) initiative.
- It will be mandatory for developers of new commercial and industrial premises, where large amounts of food waste are expected to be generated, to allocate and set aside space for on-site food waste treatment systems in their design plans.

FROM 2024

- Large commercial and industrial food waste generators will have to segregate their food waste, but they will get to choose the food waste treatment method that suits their operations best. For instance, they can recycle homogenous food waste into animal feed, install on-site food waste treatment systems or send their food waste to an off-site treatment facility.
- Developers of new developments who were required to set aside space for on-site food waste treatment systems in their design plans from 2021 will be required to implement the on-site treatment of food waste.



Closing the food waste loop

Electrical and electronic equipment

As a country, we discard an estimated 60,000 tonnes of e-waste annually. This is equivalent to each person throwing away 11kg of e-waste, or the weight of 73 mobile phones. With new mobile phone and laptop models launched every few months, and smart televisions and other tech gadgets becoming more common, the amount of e-waste generated will only increase.

E-waste is EEE that has been thrown away. EEE refers to anything powered by an electrical source, including laptops, mobile phones, televisions, refrigerators, as well as batteries and electric mobility devices. It makes up less than 1% of total waste generated in Singapore, but contains small amounts of hazardous substances such as mercury and cadmium and may be potentially harmful to human health and the environment if improperly disposed of.

However, e-waste also offers great potential for the circular economy approach. EEE contains valuable resources such as precious metals and working components. If we are able to extract these resources or reuse them, we can reduce the need to mine virgin raw materials.

RESTRICTIONS ON HAZARDOUS SUBSTANCES IN EEE

Since June 2017, Singapore has restricted six hazardous substances found in common types of EEE to reduce the chances of these substances entering our environment due to improper disposal methods.

Singapore also ratified the Minamata Convention on Mercury. Since 31 March 2018, Singapore has phased out all batteries (including button cell batteries) containing more than 5 ppm by weight of mercury. The manufacture, import and export of certain mercury-added products such as fluorescent lamps (exceeding specified mercury limits) and non-electronic measuring devices will be phased out by 1 January 2020.

But many more forms of EEE still enter our shores. To promote proper recycling and treatment of discarded EEE, the NEA formed a national voluntary partnership for e-waste recycling in 2015. Members work together to spearhead recycling programmes for such wastes.

6 Restricted Hazardous Substances	**HEXAVALENT CHROMIUM** (Cr VI) **POLYBROMINATED BIPHENYLS** (PBBs) **POLYBROMINATED DIPHENYL ETHERS** (PBDEs)	**LEAD** (Pb) **MERCURY** (Hg)	**CADMIUM** (Cd)
Allowable concentration limits	**MAXIMUM 1,000 PPM** (0.1% by weight)		**MAXIMUM 100 PPM** (0.01% by weight)
Controlled EEE	Mobile phones Air conditioners	Portable computers Panel televisions	Refrigerators Washing machines

RECYCLING NATION'S ELECTRONIC WASTE (RENEW) PROGRAMME

RENEW e-waste collection bins

The RENEW programme was launched in 2012 to encourage the public to dispose of their electrical and electronic devices in a responsible manner. The programme, a collaboration between StarHub, DHL, and TES, and supported by the NEA, aims to make e-waste recycling more convenient and accessible by placing collection bins all around the island.

Since its launch, more than 450 RENEW bins have been placed at over 400 locations (as of March 2019), including Government buildings, community clubs, schools, condominiums, shopping malls and major electronics retail stores.

They each come with a deposit slot, which is large enough to fit items such as cables, mobile phones, tablets, laptops, DVD players, car stereos, telephones and answering machines.

The programme has collected more than 320 tonnes of e-waste since 2012, with the e-waste collection rate growing exponentially over the years – over 126 tonnes was collected in 2018, up from 2 tonnes in 2012.

THE E-WASTE MANAGEMENT ROADMAP

To ensure the proper treatment of EEE at their end-of-life and prevent the valuable resources they contain from going to waste, Singapore is implementing the Extended Producer Responsibility (EPR) approach to manage e-waste. The legislative framework will be provided under the Resource Sustainability Act. EPR is an environmental policy tool that has been used effectively to promote e-waste recycling in other countries, including South Korea and Sweden. While producers are conventionally only responsible for the manufacture and sales of their products, EPR extends their responsibility to the proper end-of-life management of their products.

Come 2021, producers of EEE – including manufacturers and importers – will be physically and/or financially responsible for the end-of-life treatment of their products. This means they will need to collect and ensure that the products are recycled by licensed companies.

Producers of covered consumer EEE, which are products that are commonly used by the general public such as laptops, mobile phones and household appliances, are required to join a Producer Responsibility Scheme (PRS).

The operator of the PRS will be appointed by the NEA, and take on the producers' responsibilities to develop and implement a collection and recycling system specifically for consumer EEE. This will include scheduling collection drives, providing e-waste bins, transporting the e-waste to licensed recyclers and reporting the tonnage of e-waste collected and recycled to the NEA.

The PRS will also need to conduct public education programmes to encourage e-waste recycling and meet e-waste collection targets.

As important touchpoints for consumers, retailers will be required to provide free one-for-one take-back services upon the delivery of new products.

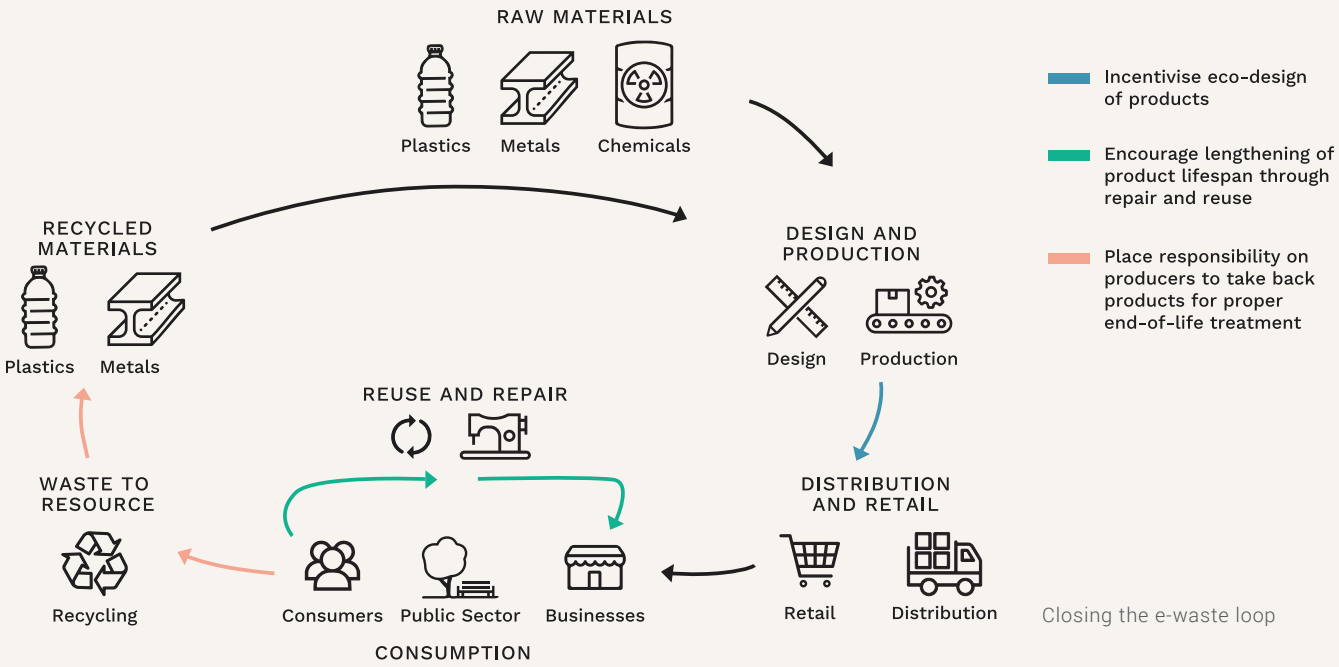
For large EEE retailers with a floor area above 300 m^2, provision of in-store e-waste collection points for Information and Communication Technology (ICT) equipment, lamps and/or batteries will be made mandatory.

As for non-consumer EEE, which includes solar photovoltaic (PV) panels and servers, their producers will be required to provide free take-back services for all of their end-of-life equipment from their clients upon request.

COVERED EEE AND PRS COLLECTION TARGETS

PRODUCT CATEGORY	PRODUCT TYPE	COLLECTION TARGET
ICT EQUIPMENT	Printers / Personal computers / Laptops / Mobile phones / Tablets / Routers / Modems / Set-top boxes / Servers	20% of put-to-market (PTM) by weight
LARGE APPLIANCES	Refrigerators / Air-conditioners / Washing machines / Dryers / Televisions / Electric mobility devices, including Personal mobility devices, Power assisted bicycles and Electric mobility scooters	60% of PTM by weight
BATTERIES	Portable batteries	20% of PTM by weight
	Industrial batteries	NA
	Hybrid / electric vehicle batteries	NA
LAMPS	Bulbs and tubes	20% of PTM by weight
SOLAR PV PANELS	All types	NA

Having an e-waste management system will reduce the risk of improper handling of e-waste, and through it, support a circular economy approach by harvesting the precious metals in e-waste, turning trash into treasure.



Closing the e-waste loop

Packaging, including plastics

Packaging can be made from any material and is used to contain, protect, handle, deliver or present goods. A large proportion of our domestic waste is packaging waste. In 2018, about one-third of domestic waste disposed of consisted of packaging waste. Approximately 55% of the packaging waste was plastic packaging, whilst 25% was paper packaging. The remaining 20% was made up of other types of packaging materials, such as metal and glass.

As packaging is so common yet hardly reused, we need to find ways to reduce and consume them more sustainably.

TYPES OF PACKAGING

GLASS

Examples:
Beverage bottles
Oil bottles
Sauce containers

METAL

Examples:
Aluminium drink cans
Food tin cans
Aerosol cans
Paint tin cans
Milk tins
Biscuit tins

PAPER

Examples:
Paper bags
Disposable cups
Food containers and wrappers

PLASTIC

Examples:
Carrier bags
Beverage bottles
Takeaway cups and containers
Bubble wraps
Foam protective packaging
Plastic shrink wrap

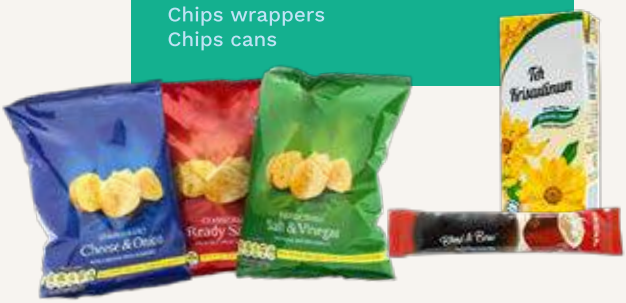
WOOD

Examples:
Boxes
Crates
Pallets

COMPOSITE

(packaging made up of more than one type of material that are not separable physically)

Examples:
Beverage cartons
Sachets
Chips wrappers
Chips cans



ENCOURAGING SUSTAINABLE CONSUMPTION OF PACKAGING

The Singapore Packaging Agreement

The Singapore Packaging Agreement (SPA) is a joint initiative started in 2007 by the Government, industry and non-governmental organisations (NGOs) to reduce packaging waste. Since its inception, more than 200 organisations in Singapore have worked together to cut down on packaging waste. As of 2019, they have cumulatively reduced about 54,000 tonnes of packaging waste, resulting in estimated packaging material cost savings of $130 million for locally consumed products.

The NEA will continue to work with the industry to develop its capabilities in adopting the circular economy approach through sustainable production and design, and establishing best practices in the 3Rs (reduce, reuse and recycle).

Supporting ground-up movements

We are supporting ground-up initiatives through funding support.

One such initiative was Zero Waste SG's Bring Your Own (BYO) campaign, supported by the Call for Ideas Fund, aimed at encouraging consumers to use reusable bags and containers when they buy takeaway food, beverages and groceries. Since 2017, more than 400 retail outlets have joined the campaign, providing incentives to customers who bring their own reusables. This has saved approximately two million pieces of plastic disposables and packaging. Leveraging the success of BYO, the NEA supported Zero Waste SG with the Partnership Fund to further develop the campaign in 2019 into Bring Your Own Bag (BYOB) to focus on reducing disposable plastic bag usage.

THE PACKAGING WASTE MANAGEMENT ROADMAP

Packaging is not all bad. It extends the shelf life of food and protects new products from damage during transportation. However, the problem is excessive packaging. That is why we are introducing measures to encourage companies to adopt sustainable production by reducing packaging upstream.

Mandatory reporting of packaging data and 3R plans for packaging will be introduced in 2020 and legislated under the Resource Sustainability Act. This builds on an existing mandatory waste reporting framework for large malls and hotels, which will also be expanded to all large industrial and commercial premises, including large convention and exhibition centres, in 2020. For the mandatory packaging reporting framework, for a start, producers of packaged products and supermarkets with an annual turnover of more than $10 million will be required to report data on packaging that they put on the market and their 3R plans for packaging.

The mandatory packaging reporting framework will also lay the foundation for an EPR framework for managing packaging waste, including plastics. This ensures producers are responsible for the collection and recycling of the materials they use to package their products. We are currently studying the approach, and will hold consultations with the industry. The aim is to have the EPR system for packaging waste management in place no later than 2025.

EPR MECHANISMS USED IN OTHER COUNTRIES FOR PACKAGING WASTE MANAGEMENT

TAKE-BACK WITH RECYCLING RATE TARGETS

Government mandates that producers take back products to achieve specific recycling or diversion-from-landfill targets

DEPOSIT REFUND SYSTEM

Surcharge on a product when purchased, and rebate when returned

PERFORMANCE STANDARDS / RESTRICTIONS

Standards required for particular parameters (e.g minimum recycled content in products, volume space ratio for specific products)

ECOLOGICAL MATERIAL TAXES

A policy that taxes packaging material while weighing the ecological footprint (e.g virgin natural resources, tax based on lifecycle assessment of climate impact)

PURE FINANCING MECHANISMS SUCH AS ADVANCE DISPOSAL / RECYCLING FEES (ADF / ARF) AND TRADEABLE CREDITS

An ADF / ARF is a tax assessed based on product sales and often used to cover the cost of disposal or recycling

Tradeable credits include Packaging Waste Recovery Notes (PRNs) that producers purchase to provide financial incentives for the recycling industry to collect / reprocess packaging waste

CLOSING THE PLASTICS LOOP

The use of plastics is prevalent in our daily lives – many of our beverage bottles, takeaway food containers and grocery bags are made of plastics. While plastics can be useful, they are often used in excess and discarded in large amounts.

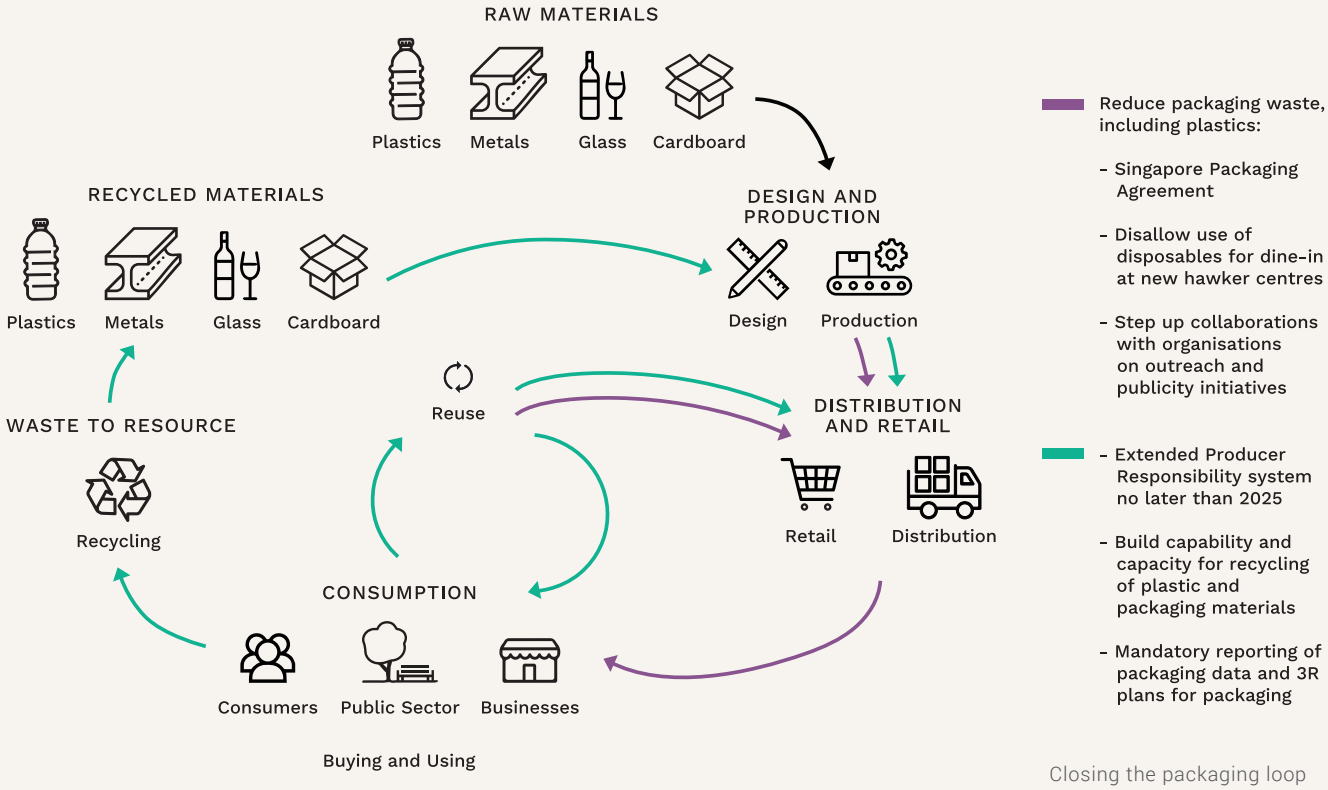
Plastic has become an issue of significant concern globally as countries re-examine how to sustainably manage their plastic waste. In Singapore, we incinerate all our general waste, minimising the amount of plastic that ends up as litter both on land and in the oceans. At the same time, with the drive towards circular economy to replace the "take-make-dispose" linear economy, and the push to reduce industrial carbon emissions, we have observed an increasing interest among the industry to explore more advanced technology to close the plastics loop.

Take for example the adoption of chemical recycling to turn plastic into feedstock or fuel. Apart from the current prevalent technology of using mechanical recycling to recycle plastics[1], chemical recycling technology involves converting separated or mixed plastics back into pyrolysis oil, naphtha, methanol and syngas. These products can either be converted back into building blocks which can be used to make new plastic products, or converted into fuel to replace fossil fuel sources. In particular, there are opportunities for mixed or dirty plastics, which cannot be recycled currently through mechanical means, to be recycled. As a petrochemical hub, Singapore is well-placed to harness this new growth area to close the plastics loop.

The Government will work with stakeholders from various industry sectors to explore how these technologies can be applied to Singapore such that it is both environmentally and economically sustainable. We will also continue to engage stakeholders to holistically assess the benefits of other measures to manage plastic waste better. For instance, imposing a charge for single-use plastic bags may divert demand to paper or bio-degradable bags, which may not be more resource-efficient from a lifecycle perspective. This is because the production and disposal of all materials have some degree of environmental impact. Therefore, we will work on managing excessive consumption of all types of packaging and disposables.

[1]Mechanical recycling involves recycling high-value plastics into recycled resins. These resins can then be used to create new plastic products.

Reverse vending machines, or RVMs, take in PET bottles and aluminium cans, and offer a small incentive in return, such as discount or redemption coupons. Singapore will be rolling out a series of RVMs in selected malls and in the community progressively from end 2019.
Photo credit: F&N Singapore



Closing the packaging loop

Through the adoption of a circular economy approach to close the resource loops of food waste, e-waste and packaging waste, including plastics, we can move closer towards our Zero Waste future, where both households and the industry consume less, waste less and recycle more.

Chapter 4

Optimising Infrastructure For Maximum Resource Recovery

Even as new policies are implemented and infrastructure developed to achieve our vision as a Zero Waste Nation, we will need to continually improve existing waste management technologies to enhance our treatment of waste and recovery of resources.

For decades, Singapore has invested in infrastructure to collect, recycle and turn our waste to energy. Our waste collection infrastructure, such as refuse chutes, bin centres and waste collection vehicles have served us well in maintaining high environmental public health standards by ensuring that waste is properly collected and sent for disposal. Our Waste-to-Energy (WTE) plants, which reduce waste to ash, enable extensive space savings at Singapore's only landfill while recovering energy from waste.

However, we want to go beyond converting waste into energy, to produce greener forms of energy such as syngas and recover other valuable resources from waste, such as turning waste into feedstock for the chemical industry. At the same time, we want to reduce the landfilling requirements from any residue of the waste treatment process. This will reduce our carbon footprint from incineration and further extend the lifespan of Semakau Landfill.

The Government has set our sights on closing the waste loop by encouraging Singaporeans to waste less and recycle more, developing new policies, and investing in research and development to find new ways to convert waste into usable, and even marketable products. This includes upgrading our waste management infrastructure, from collection to waste treatment and post-treatment options. We want to make waste collection more manpower-efficient, improve the energy efficiency of our WTE plants, and create new material out of incineration bottom ash (IBA).

Here is how we plan to do it.

PNEUMATIC WASTE CONVEYANCE SYSTEM

Waste collection today is often associated with unpleasant odours and pests. Within many developments, it is also manpower-intensive for waste to be transported from refuse chutes to the bin centre.

The Pneumatic Waste Conveyance System (PWCS) provides a solution to these problems. It is an automated waste collection system which conveys waste by air suction from individual buildings through a network of pipes to a central location for collection. This removes the need for manual collection of waste from individual refuse chutes. As an enclosed system, waste is not exposed throughout the transfer process, reducing odour and pest problems. Waste collection can become more manpower-efficient. PWCS will offer a cleaner and more liveable environment.

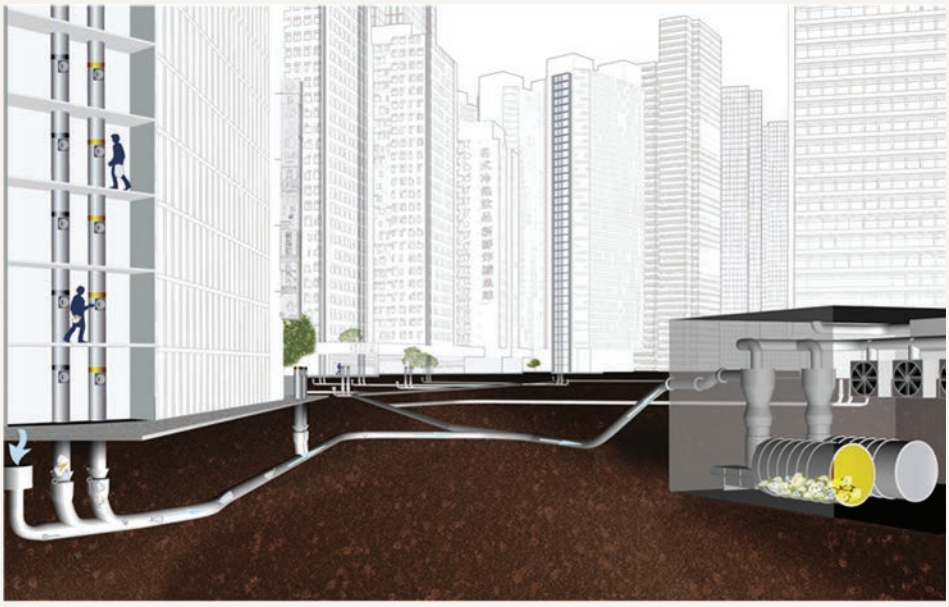


Illustration of a Pneumatic Waste Conveyance System
Photo: Envac

To increase the adoption of PWCS, since 1 April 2018, new development applications for non-landed private residential developments with 500 Dwelling Units (DUs) or more have been required to implement the system. This adds to over 140 existing private residential and commercial developments with PWCS.

Further economies of scale can be reaped by implementing district-level PWCS (DPWCS). Instead of bin centres for each development, the district can share a central bin centre, which can be located away from residents' homes. This will also reduce refuse truck traffic within the district, as refuse will only be collected from one bin centre. HDB has already introduced DPWCS in new HDB estates such as Tampines North, Punggol North and Bidadari and will also be introducing it in the latest new town, Tengah.

The first DPWCS to serve multiple private developments is being planned for the Kampong Bugis precinct. It is expected to serve commercial developments and approximately 4,000 private residential DUs.

Through these efforts, the Government aims to mitigate future challenges that the waste collection industry will face due to increasing manpower shortages and an ageing workforce.

PILOT MECHANICAL BIOLOGICAL TREATMENT FACILITY

Designed to recover materials from refuse, a pilot Mechanical and Biological Treatment (MBT) facility offers an alternative way to treat Domestic and Trade Waste (DTW).

It will have a mechanical process to recover recyclables like plastics, ferrous and non-ferrous metals, and an aerobic biological treatment process to convert the waste into Solid Recovered Fuel (SRF). Only a small amount of residue will be left for disposal.

Artist's impression of TuasOne Waste-to-Energy plant

The pilot facility will be able to treat 500 tonnes of DTW daily. The mechanical process will be able to recover up to 15% of recyclables, or over 500,000 tonnes of recyclables over 20 years. With this, we are able to extract valuable recyclables from waste that would otherwise be incinerated, allowing the materials to re-enter the value chain. Whatever is not recovered will undergo a biological process which produces SRF as an end product.

The NEA will monitor the operation of the pilot facility and assess its viability for wider adoption.

TUASONE WASTE-TO -ENERGY PLANT

The TuasOne WTE plant – Singapore's 6th WTE plant – illustrates the circular economy principle of resource efficiency. With a treatment capacity of 750 tonnes of waste per day per ha (t/d/ha), it will be the most compact plant in the world. It will also be the most energy-efficient among Singapore's existing WTE plants.

Built to meet part of our waste incineration needs for the next 25 years, the plant – developed on 4.8 ha of land – will have the capacity to incinerate 3,600 tonnes of waste per day.

DID YOU KNOW THAT

2%

OF SINGAPORE'S ELECTRICITY SUPPLY

IS GENERATED FROM WASTE?

TUAS NEXUS: INTEGRATED WASTE MANAGEMENT FACILITY

By co-locating and integrating the treatment of solid waste and used water, Tuas Nexus will be able to recover resources from waste more efficiently and with less space.

Tuas Nexus will comprise the NEA's Integrated Waste Management Facility (IWMF) and PUB's Tuas Water Reclamation Plant (TWRP).

The IWMF will use advanced technologies to handle multiple waste streams and construction will be completed over two phases. The first phase of IWMF will be completed by 2024 while the second phase is estimated to be completed by 2027.

TREATMENT FACILITIES WITHIN IWMF

WTE FACILITY

INCINERABLE WASTE

5,800
tonnes/day

MATERIALS RECOVERY FACILITY

HOUSEHOLD RECYCLABLES

250
tonnes/day

FOOD WASTE TREATMENT FACILITY

SOURCE SEGREGATED FOOD WASTE

400
tonnes/day

SLUDGE INCINERATION FACILITY

DEWATERED SLUDGE FROM TWRP

800
tonnes/day

What makes the IWMF novel?

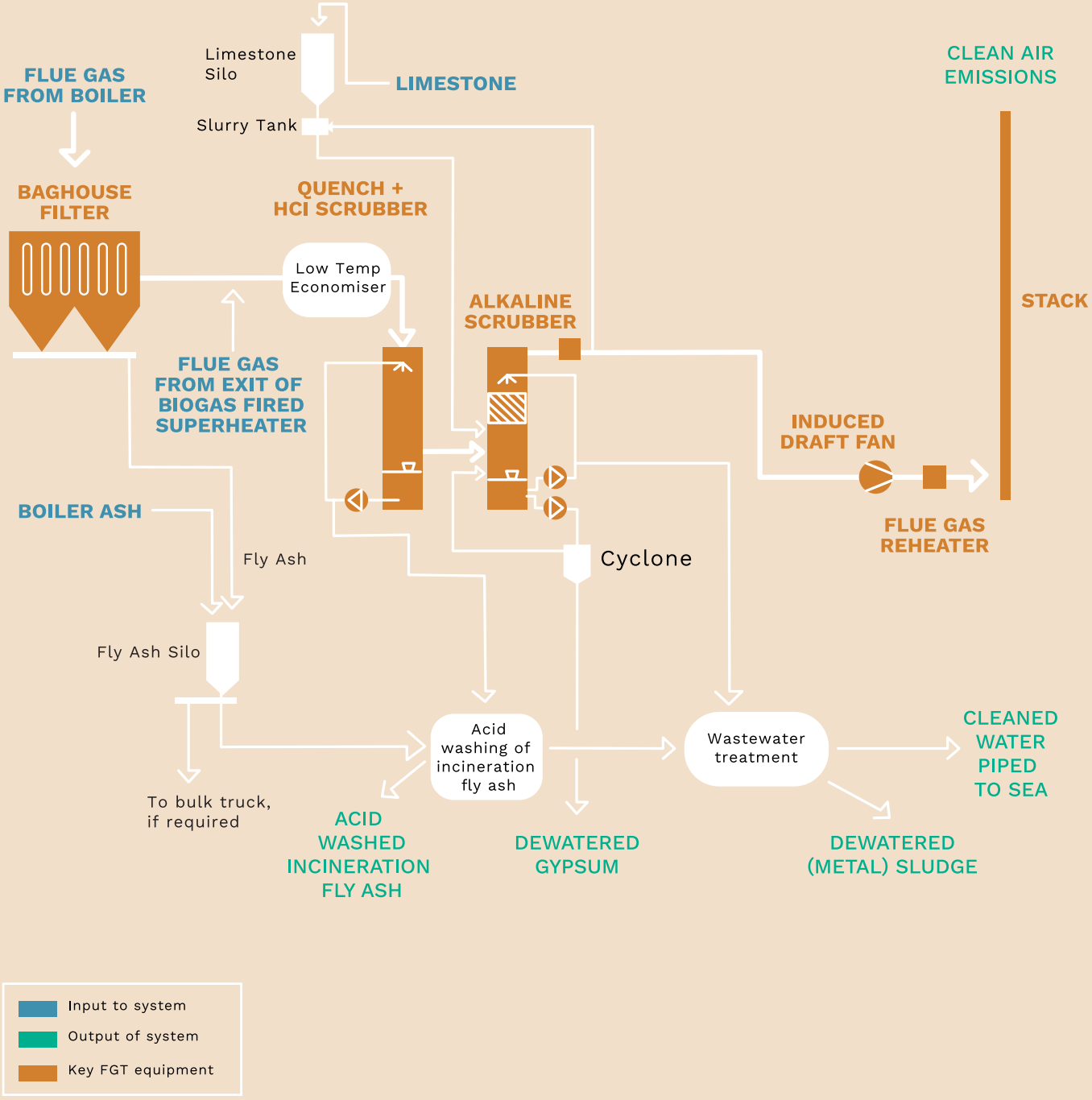
Expected to produce enough electricity to power about 300,000 four-room apartments a year, the IWMF comes with a slew of advanced technologies.

Its combustion processes and boiler designs will operate at high steam parameters of about 440°C/55 bar as compared to 365°C/33 bar at our existing WTE plant.

The use of external biogas super heaters will further boost the steam parameters at IWMF from 440°C/55 bar to 480°C/55 bar to achieve high overall plant energy conversion efficiency of about 28% and maximise electricity production.

PROCESSES WITHIN A

WET FLUE GAS TREATMENT SYSTEM



Artist's impressions of Tuas Nexus

To keep its environmental impact to the minimum, the IWMF will adopt a Wet Flue Gas Treatment (FGT) system that produces the cleanest possible air emissions and fulfils Singapore's air emission requirements. The Wet FGT system will also minimise the amount of solid residue for disposal as less fly ash is generated compared to conventional dry FGT systems.

The IWMF will be designed as an iconic, green development to showcase the NEA's vision as a leader in environmental stewardship to achieve zero waste and a circular economy. The Tuas Nexus will integrate processes and systems to optimise resources and achieve long-term environmental sustainability.

SYNERGIES WITHIN TUAS NEXUS

USED WATER AND WASTE SYNERGIES

SOURCE-SEGREGATED FOOD WASTE will be processed at IWMF into food waste slurry for co-digestion with used water sludge at TWRP. This can triple biogas yield, compared to the treatment of used water sludge alone.

DEWATERED SLUDGE will be sent to the IWMF for incineration and subsequent heat recovery. This eliminates the need for dewatered sludge to be trucked out to another location for disposal and reduces carbon footprint.

ENERGY SYNERGIES

ELECTRICITY from IWMF will power both TWRP and IWMF. Excess electricity will be exported to the grid.

STEAM from IWMF will be supplied to TWRP for its Thermal Hydrolysis Process to pre-treat used water sludge and greasy waste.

BIOGAS from TWRP will be burnt in IWMF's external biogas super heaters to increase its steam temperature from 440°C/55 bar to 480°C/55 bar to enhance overall plant thermal efficiency and maximise electricity production.

WATER SYNERGIES

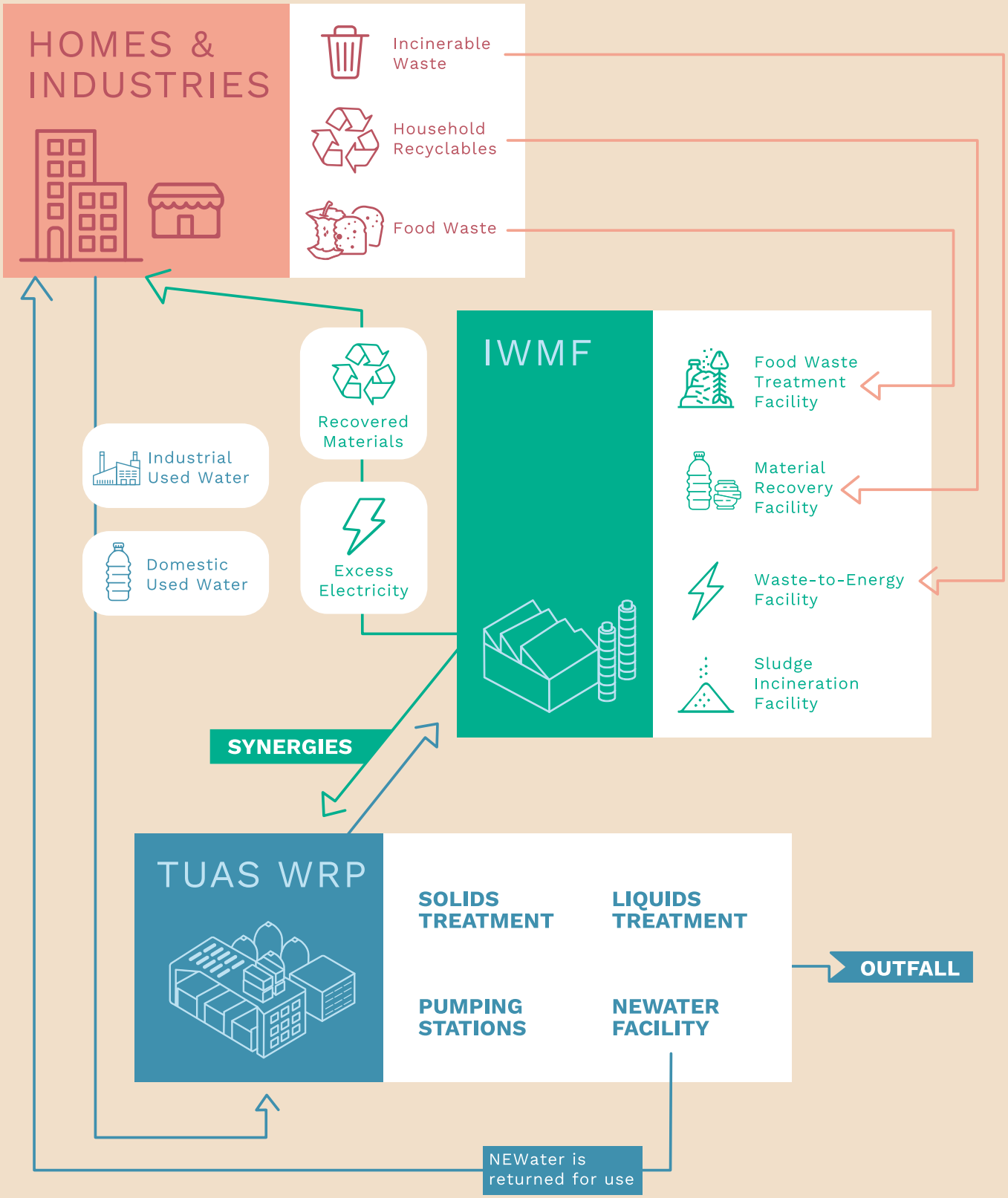
TREATED EFFLUENT WATER from TWRP will be supplied to IWMF for process use.

SLUDGE DRYER CONDENSATE from IWMF will be piped to TWRP for treatment.

COMMON ADMINISTRATION BUILDING

Both IWMF and TWRP will share a common administration building to optimise land use and resource sharing.

TUAS NEXUS


HOMES & INDUSTRIES
Incinerable Waste
Household Recyclables
Food Waste
Recovered Materials
Industrial Used Water
Domestic Used Water
Excess Electricity
IWMF
Food Waste Treatment Facility
Material Recovery Facility
Waste-to-Energy Facility
Sludge Incineration Facility
SYNERGIES
TUAS WRP
SOLIDS TREATMENT
LIQUIDS TREATMENT
PUMPING STATIONS
NEWATER FACILITY
OUTFALL
NEWater is returned for use

HARVESTING INCINERATION BOTTOM ASH FOR CONSTRUCTION

While we reduce our waste to just a fraction of its original volume on a daily basis, the resulting ash still takes up space on our offshore Semakau Landfill.

Each year, about 500,000 tonnes of IBA and 200,000 tonnes of non-incinerable waste are disposed of at the landfill. At this rate, Semakau Landfill will be full by 2035.

To divert IBA from our landfill, we are developing ways to use it in non-structural construction such as road base/sub-base materials or aggregates in non-structural concrete as "NEWSand". This is a key strategy to maximise resource recovery and the lifespan of current and future landfills.

The NEA is developing environmental standards and guidelines to regulate the use of NEWSand, and ensure that the environment and public health are not compromised.

A tender for the demonstration of IBA treatment methods was awarded in 2018 to identify and validate treatment methods that would render it suitable and environmentally safe for use. Field trials will be conducted after the demonstration. More details can be found in Chapter 6.

If successful, the use of IBA in non-structural applications, together with new waste treatment facilities that maximise waste recovery such as the MBT facility, TuasOne WTE Plant and Tuas Nexus, will help us to treat the waste disposed of more efficiently, maximise resource recovery and reduce waste residues sent to Semakau Landfill.

IBA pit at Tuas South Incineration Plant. NEA is studying the use of IBA for non-structural construction purposes.

Chapter 5

Transforming The Environmental Services Industry

From the adoption of technology to making cleaning and waste management jobs smarter, safer and easier, to helping local companies go global – the environmental services industry is getting a facelift to sparkle with higher productivity and capabilities.

They keep roads, housing estates, schools and offices clean. But the labour-intensive Environmental Services (ES) industry suffers from an image problem. The industry, comprising 1,280 licensed cleaning firms, 450 waste management companies and over 300 pest management companies, is often viewed as low-skilled and low-tech, and overlooked by young job seekers due to the lack of career prospects.

But that will soon change. With the adoption of a circular economy approach in waste and resource management, we will require the support of relevant enterprises and a skilled workforce. This will require the ES industry to become sleeker and more sophisticated with a makeover.

This is the aim of the Environmental Services Industry Transformation Map (ES ITM), which focuses on four main areas: technology and innovation, jobs and skills, productivity and standards, and internationalisation. These areas will be supported by enablers.

By 2025, we expect about 30,000 people from the industry to benefit from higher-value jobs through skills upgrading and technology adoption.

ITM FOCUS 1

Technology and innovation

By ramping up the use of technology, the industry will find innovative ways to get the job done with less sweat – raising the productivity of all employees. This will also create new and more highly-skilled jobs that will attract younger Singaporeans to join the industry. Ultimately, we hope to export these technologies overseas.

NO LONGER A MAD RUSH FROM BIN TO BIN

There is no longer a need for a two-men collection crew, running from one recycling bin to the next, and having to push the recycling bins to the truck to be emptied. Now, a truck driver can complete the whole operation from the comfort of his truck cabin, thanks to a side loader.

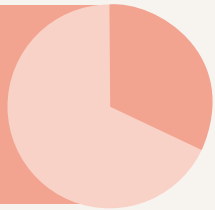
The side loader has a robotic lifting arm attached to the side of the truck. With simple button clicks and the use of a joystick, the driver can lift and empty the recycling bins into the truck.

Supported by the Singapore Economic Development Board (EDB), this has helped waste management firms like 800Super become more manpower-lean, while improving the working conditions of its staff.

For more information on EDG:

EDG ENTERPRISE DEVELOPMENT GRANT

BY ENTERPRISE SINGAPORE



Funds up to

70%

of the cost of projects that help a company upgrade its business, innovate or venture overseas

For more information on RISC:

RISC

RESEARCH INCENTIVE SCHEME FOR COMPANIES

BY EDB

Encourages the development of

R&D Capabilities & Technologies

by supporting projects in science and technology fields

For more information on CTWL:

CTWL

CLOSING THE WASTE LOOP R&D INITIATIVE

BY THE NEA

$45 ***million***

funding programme to support R&D activities that look at extracting value and resources from key waste streams, including plastics, food, e-waste and incineration ash

Here are two strategies to achieve this target:

STRATEGY 1

SPUR INNOVATION

There are four approaches to drive the development of new technologies and solutions:

- Develop new ways to perform cleaning and waste management tasks that can be scalable and replicated overseas
- Help companies expand their capabilities and grow by providing opportunities to expand their businesses in global markets
- Promote research and development (R&D) within companies
- Position Singapore as the technology centre of excellence by showcasing locally developed cleaning and waste management solutions, and nurturing companies which innovate

Instead of relying heavily on manual labour, Singapore aims to automate waste management processes, including waste collection and the sorting of recyclables. Doing so will make the industry less labour-intensive, enable workers to take on more complex tasks and improve overall efficiency.

To encourage Singapore companies to develop novel ES solutions that can cut our manpower needs, bring about cost savings and improve the quality of operations, the NEA and Enterprise Singapore launched the Gov-PACT innovation calls. The opportunity to supply such solutions to the Government will help our local enterprises build innovation capabilities and track records when scaling up locally or exporting overseas.

Companies can tap on several funds to reduce the cost of venturing into R&D or automating their processes.

In order to boost the productivity of Jewel Changi Airport, robots developed by Lionsbot International will be deployed to help with cleaning and waste collection. The robot Leopull helps cleaners by transporting waste carts around Jewel Changi Airport, freeing cleaners up to complete other tasks.

Photo: Lionsbot International Pte Ltd

STRATEGY 2

DRIVE WIDESPREAD ADOPTION OF TECHNOLOGY

To encourage the adoption of technology, we focus on three areas:

- Identify technologies to be used on a wider scale
- Establish partnerships for technology exchanges
- Leverage platforms such as the Whole-of-Government Business Grants Portal to provide a technology repository for ease of technology adoption, and Technology Connect Sessions to link the technology providers to service buyers

If we want to create a leaner, more elderly-friendly and productive industry, we need to change the way we currently clean spaces and manage waste.

Job redesign is the way forward. The ES Job Redesign Initiative was a joint collaboration between the NEA and Workforce Singapore (WSG), supported by the Environmental Management Association of Singapore (EMAS) and Waste Management and Recycling Association of Singapore (WMRAS). It provided a list of solutions that companies were able to adopt easily, as well as a grant that they could tap on.

The NEA also launched a $30 million Productivity Solutions Grant (PSG) that funds the adoption of commercially available and proven ES technologies, including equipment and digital solutions that raise productivity. It is open to both small and medium-sized enterprises (SMEs) and multinational corporations.

For more information on PSG:

ITM FOCUS 2

Jobs and skills

While technology makes jobs easier, it is also crucial to improve the skills of workers to take on higher-value jobs within the industry. The overall goal is to do more with less – reducing manpower needs through better infrastructure and building design, as well as promoting a "self-serve" mindset where people clean up after themselves.

There are three strategies to achieve these goals:

STRATEGY 1

MODERATE MANPOWER DEMAND

Everyone plays an important part in minimising the need for cleaning and waste management services. This can be done through simple acts of clearing trays after meals at hawker centres and food courts, or reducing the waste we throw away.

The load of ES workers can be lightened through the following measures:

- Design buildings that enable cleaning and waste collection to be done faster, easier and with fewer workers
- Encourage Singaporeans to keep their surroundings clean through ongoing programmes such as the Keep Singapore Clean Movement, Tray Return initiative and the Daily Cleaning at Ministry of Education (MOE) schools
- Promote the habit of reducing, reusing and recycling

STRATEGY 2

SUSTAINABLE MANPOWER SUPPLY

As we aim to reduce manpower in the industry, there is still a need to ensure a steady stream of workers for the future.

Senior Minister of State for the Environment and Water Resources, Dr Amy Khor, with recipients of the Certificate of Excellence at the ES Workforce Day in November 2018

We look to improve on six areas:

- Redesign jobs and adopt automation and assistive technology to reduce the physical demands of the job. This will make the work less strenuous for older employees and reduce the total number of workers needed
- Focus on attracting mid-career switches, senior workers, women returning to the workforce and fresh school leavers
- Improve the industry's image
- Strengthen human resource policies and practices
- Facilitate internship opportunities
- Tap on National Jobs Bank to connect employers with suitable candidates

The NEA is working with WSG, the industry and solution providers to encourage companies on these fronts. For instance, they have organised appreciation events for ES professionals to recognise their commitment and excellence in their work. They also collaborated with Institutes of Higher Learning (IHLs) to attract the younger generation to the industry, such as by increasing internship opportunities.

For more information on the Skills Framework for ES:

STRATEGY 3

SKILLED AND RESILIENT WORKFORCE

Every worker should be given the opportunity to learn new skills and grow in their jobs. Four possible ways to do so are:

- Create a Skills Framework for ES together with SkillsFuture Singapore (SSG), WSG and industry stakeholders
- Develop apprenticeship and scholarship programmes to attract and retain talent, especially at Associate Professionals and Technicians (APT) and Professionals, Managers and Executives (PME) levels
- Facilitate Pre-Employment Training (PET) and Continuing Education and Training (CET) Programmes together with IHLs, and the expansion of PET and CET offerings
- Review the Singapore Workforce Skills Qualifications (WSQ) modules to ensure that they are still relevant to the industry, particularly for rank and file workers

In 2018, Republic Polytechnic launched a new Part-Time Diploma in Applied Science (ES and Management), which is a Work-Study Programme. This diploma course provides opportunities for participants to deepen their skills and knowledge needed for a career in the ES industry, especially in operational roles from Operations Executives to Hazardous Waste Specialists.

More PET and CET programmes will be gradually put in place to address the skills and training needs of the industry.

Mr Koh Kheng Huat enrolled in the SkillsFuture Work-Study Programme leading to a Part-Time Diploma in Applied Science (ES and Management) by Republic Polytechnic in 2019. The course will prepare him for his job at PV Vacuum Engineering Pte Ltd, a company providing pneumatic waste conveyance system services, by teaching him project management skills and imparting knowledge on environmental operations and environmental sustainability.
Photo: PV Vacuum Engineering Pte Ltd

NOT JUST A LOW-SKILLED INDUSTRY

At local SME Biomax Green Pte Ltd, a dedicated team of professionals leverage advanced biotechnology to develop innovative solutions that improve and diversify the company's services and offerings. The company specialises in solutions that convert organic waste into high-grade organic fertiliser through the use of digesters and enzymes, which were developed by biotechnology research specialists. The company also employs a qualified team of sales and operations managers to engage local and international clients, and manage projects from around the world.

Biomax laboratory
Photo: Biomax Green Pte Ltd

Ms Jade Loh, Operations Manager at Plaspulp Union, explores recycling solutions for waste materials
Photo: SSG

As the environmental impact of plastic waste takes the spotlight, Plaspulp Union offers an efficient plastic treatment solution. Ms Jade Loh (pictured), works at Plaspulp Union as an Operations Manager, where she and her team explore recycling solutions for complicated waste materials. Using advanced technology and automation, plastic waste is segregated and processed faster, ensuring a better quality output.

SembWaste Pte Ltd, one of Singapore's Public Waste Collectors, has adopted a Smart Waste Collection System (SWCS). This system leverages sensor technology to detect the capacity of waste in compactor bins and uses this information to plan vehicle routing and scheduling to optimise resources. This improves productivity, while the use of technology provides higher-skilled jobs in waste collection.

SembWaste waste collection crew uses a smart device to receive waste collection jobs from SembWaste's Command Centre, where waste capacity levels in compactor bin centres are remotely monitored

ITM FOCUS 3

Productivity

To transform the industry, service buyers have to get involved. By relooking their procurement practices, they can facilitate innovation, productivity and technology adoption.

One way is to shift towards performance- or outcome-based contracts, which specify the service outcomes or performance standards required. This is unlike the traditional headcount-based approach to procurement, which states the number of workers required. Another way is to have a longer contract period that allows companies to make returns on their investments in technology.

We are also looking at ways to better optimise land use and create additional spaces to raise land productivity. These include housing various recycling activities under one roof, in the form of a multi-storied development, and reusing our closed landfills.

SINGAPORE'S FIRST MULTI-STOREY RECYCLING FACILITY

Slated to be launched in 2021, the Multi-Storey Recycling Facility (MSRF) will create space to house recyclers handling different forms of waste streams like metals, e-waste, paper and plastics under one roof. The co-location of these recyclers will support the circular economy approach by promoting synergies amongst them.

Developed by JTC, and designed in consultation with the NEA and the industry, the facility will offer industrialists heavy production floor loading, high ceiling and wide column span, replicating a land-based operating environment in a high-rise setting. In addition, shared green spaces and facilities will be provided for greater community interaction.

The MSRF will be located next to JTC's TimMac @ Kranji. The MSRF will facilitate the re-use of wastes and by-products from the metals, machinery and timber industries that will be housed within TimMac @ Kranji.

Artist's impression of the multi-storey recycling facility.
Photo: JTC

SARIMBUN RECYCLING PARK

Tucked away in the north-western corner of Singapore that was once the Lim Chu Kang Dumping Ground is Sarimbun Recycling Park (SRP).

Set up in 1995 to give recycling a boost, it is home to over 10 recycling plants that handle a quarter of the country's recycling.

There, construction waste is turned into recycled material for roads and buildings, horticultural waste into compost and charcoal, and scrap plastic into plastic pellets that can then be reused to manufacture new products.

The NEA is now looking at using SRP once more to push the recycling sector forward.

In 2017, it launched a study into the strength and stability of the ground, soil and ground water conditions at SRP. The NEA is currently working with other Government agencies to explore redeveloping and intensifying the land use at SRP so that it can continue to support the circular economy approach of closing our waste loops through recycling in Singapore.

ITM FOCUS 4

Internationalisation

Limited by Singapore's small market size, companies can only grow by venturing overseas. Expanding across borders gives companies the impetus and opportunity to gain new capabilities and expertise that will help them to be globally competitive.

There are three strategies to achieve this.

STRATEGY 1

ENHANCE MARKET ACCESS

Breaking into a new market is difficult, especially when in a foreign land and up against household names. To get the word out about what we have to offer, the NEA will be collaborating with its overseas counterparts, as well as participating in international projects.

We will also continue to widen the horizons of our ES companies and trade associations, by supporting their learning trips overseas where they can be exposed to the world's most innovative technologies.

Through international platforms and events that the NEA regularly organises, such as the CleanEnviro Summit Singapore, we also help them link up with the international audience. The key objective of this event is to serve as a platform for local companies to showcase their products, solutions and services to international buyers, distributors and collaborators. It also offers in-depth discussions, roundtables and sharing of best practices. The fourth edition in 2018, held in conjunction with the World Cities Summit and the Singapore International Water Week, attracted over 24,000 visitors from more than 120 countries and regions, with over 1,100 participating companies.

STRATEGY 2

GROW CAPABILITIES TO CAPTURE OVERSEAS MARKETS

Innovation and internationalisation go hand in hand. To be globally competitive, companies cannot survive with "me-too" products that do not top their competitors' offerings.

We support companies that venture overseas by developing their capabilities in identified growth areas with high market potential. Solutions developed can also be adopted by other countries with the same aspirations for a clean and liveable environment as us.

STRATEGY 3

SCALE UP AND OFFER INTEGRATED SOLUTIONS

To be a world leader in providing solutions to environmental challenges, we need the whole industry to work together to put ideas into action. By working with other industry sectors in the Built Environment Cluster, the NEA aims to develop integrated solutions, tapping on the unique capabilities of each sector, for city planning and development projects overseas.

Enablers

Strengthening trade associations to support transformation

We look to our trade associations such as WMRAS and EMAS to spearhead industry-wide collaboration, and support them through various initiatives.

For instance, Enterprise Singapore's Local Enterprise and Association Development (LEAD) programme supports WMRAS and EMAS in initiatives that build up their core capabilities to better support industry transformation in their subsectors. They include internships for students, which create a pipeline of talent for the industry, and overseas mission trips to help enterprises hunt for opportunities abroad and source for new technologies.

Artist's impression of Hong Kong's first Integrated Waste Management Facility (IWMF). Singapore company Keppel Infrastructure Holdings Pte Ltd, and China Harbour Engineering Company Limited, through their respective wholly owned subsidiaries, Keppel Seghers Hong Kong Limited and Zhen Hua Engineering Co. Ltd., clinched the S$5.3 billion project to design, build and operate Hong Kong's first IWMF for municipal solid waste. The IWMF will include a 3,000 tonnes/day Waste-To-Energy (WTE) plant that is capable of generating approximately 480 million kWh of net electricity/year, as well as a 200 tonnes/day mechanical treatment plant for sorting and recycling glass, plastics and metals.

Photo: Keppel Infrastructure

LOCAL R&D FINDS OPPORTUNITIES OVERSEAS

A Westcom Solutions researcher conducting research to develop microbes to break down food waste at a low operating temperature
Photo: Westcom Solutions Pte Ltd

A microbial treatment developed to break down food waste at low operating temperature has produced odourless fertiliser.

Westcom Solutions collaborated with researchers from the A*STAR Institute of Chemical and Engineering Sciences to develop the treatment. Test-bedded in JTC's Pandan Loop Industrial Estate, it works under a lower temperature than current food waste conversion processes.

The company has exported the solution overseas, and 70% of its revenue is now generated from overseas sales.

Other channels to help companies capture opportunities overseas include the Environmental & Water Technology Centre of Innovation (EWTCOI), which is supported by Enterprise Singapore. It aids companies in developing and commercialising technology to meet market demand.

For instance, EWTCOI helped company Regentech bring the technology to convert unwanted coconut husks into biochar to Singapore. This solution was subsequently exported to Thailand.

Using regulations and standards to transform the industry

As with any new disruptive technology, regulation can sometimes hold back new ideas from taking flight. Hence the NEA launched a Regulatory Sandbox for ES in July 2018. This allows companies to trial innovative ES-related technologies and solutions without compromising the environment, public health and safety.

Regulations that previously prohibited the trial of a solution can be relaxed for a fixed duration and within certain parameters. This helps companies develop innovations that have the potential to become industry game-changers. Examples of technology on trial in the Regulatory Sandbox include a waste management solution that demonstrates circularity within premises.

Improving safety, quality and productivity of the ES industry is a critical concern. The Singapore Standardisation Programme, administered by Enterprise Singapore, addresses the issue by setting standards for adoption by companies. For example, the new pneumatic waste conveyance system standard reduces manpower requirements and enhances the hygiene and safety of waste collection.

Moving forward, Singapore will continue to participate in the International Organisation for Standardisation (ISO) Technical Committees. New areas where Singapore will be involved in are waste collection and transportation management, as well as solid recovered fuels and circular economy. By setting and meeting international standards, we will help smoothen the path for local companies looking to export their products and services overseas.

MAKING GOOD USE OF RESOURCE

SP Group's gasification pilot converts waste collected from Gardens by the Bay into heat and a solid by-product containing carbon. This technology is being tested under the NEA's Regulatory Sandbox initiative.

GASIFICATION PROCESS

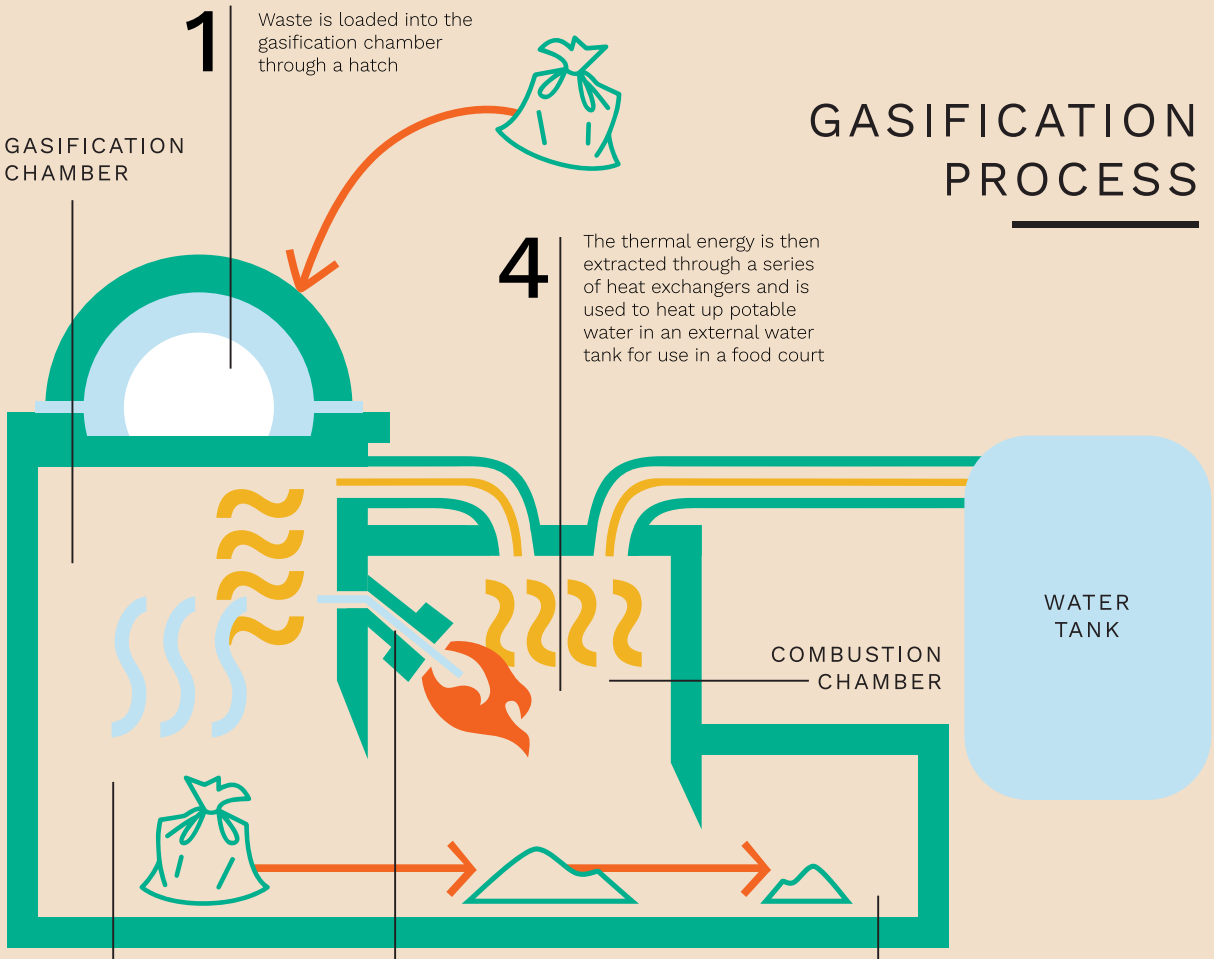


Photo: SP Group

Establishment of demonstration sites

The **IN**novating **CU**rating **B**etter **A**utomation and **T**echnologies for **E**nvironmental Services (INCUBATE) partnership was set up to bring the public and private sectors together to prototype, pilot and profile solutions. We currently have 18 partners.

Our partners are working with the NEA to explore the adoption of innovative solutions such as smart compactors, and the use of in-sink grinders with on-site food waste treatment systems to increase operational efficiency.

RECYCLE FOOD WASTE, AND SAVE MONEY

Several food waste recycling machines have been tested through the INCUBATE programme and helped to close the food waste loop, diverted waste away from our only landfill and resulted in cost savings.

Nanyang Polytechnic and Republic Polytechnic have used food waste digesters at their school food court while Changi Airport Group has deployed food waste digesters at all its terminals for tenants to use.

Meanwhile, City Developments Limited launched a pilot project at the Le Grove Serviced Residences where food waste is ground through an in-sink grinder. It is then conveyed automatically to a food waste treatment system, where it is converted into compost.

DESIRED OUTCOMES

BY 2025

1 Best in class & productive enterprises

2 High degree of automation & innovation

3 A professional, skilled and manpower-lean workforce

4 Environmental services companies with global footprint

With the wheels of transformation in motion, our goal is to have a competitive and attractive environment services industry by 2025. By harnessing the power of technology and automation, we will create better jobs that are less laborious and more highly skilled. Through these, we will move closer to our vision of an ES industry that is vibrant, sustainable and professional.

Chapter 6

Shaping A Greener Future With Science And Technology

As Singapore grapples with climate change and mounting waste, we are investing in research and development (R&D) and collaborating with industry experts to develop new, more efficient and eco-friendly ways to support the circular economy approach by recovering resources from waste.

Be it using microbes to convert food waste into compost, or turning incineration ash into construction materials – these are just two of the many possible ways to close our waste and resource loops through recycling or reuse.

These innovations came about because we have been experimenting with cutting-edge science and technology for more sustainable solutions.

For instance, R&D enabled the creation of Semakau Landfill, the first offshore landfill of its kind in the world, and Tuas Nexus – the first Waste-to-Energy incineration plant co-located with a water treatment facility to reap synergies.

As we face increasingly pressing and complex environmental issues, it is not enough to rely solely on our current expertise and infrastructure, or shape greener behaviour with policies and regulations alone.

We will continue focusing on R&D to create and refine new technologies, products or systems that we can use and eventually share with others. In the coming years, we hope to pioneer transformative ways to enable Singapore to maximise our resource use.

Overcoming challenges and creating opportunities, together

Developing cutting-edge technologies requires collective effort, bringing together the expertise and resources of academia, enterprise and Government. Each has an important role to play.

- **Academia from Institutes of Higher Learning (IHLs), Research Institutes (RIs) and polytechnics** contribute deep scientific knowledge, scholarship and know-how to turn theoretical concepts into potential solutions

- **Enterprises** provide market experience and ideas, and in some instances, financial resources or manpower. They are crucial partners for test-bedding R&D outcomes, scaling up solutions and translating them into commercially viable applications

- **The Government** helps nurture and grow a thriving ecosystem, catalysing R&D by providing infrastructure, funding support, policy guidance, platforms for collaboration and test-bedding opportunities

Having a cohesive R&D ecosystem helps turn ideas into commercially viable solutions. This goes from envisioning and theorising the best scientific approach to a given problem, testing it in a laboratory, to piloting it under real-life conditions. Eventually, we will have a market-ready solution.

This approach benefits all parties. Academics can see their ideas translated into real-life applications, while enterprises gain new business opportunities. All these boost economic growth and create highly-skilled jobs.

Our solutions could help other cities and regions too, and position Singapore as a global leader and centre of excellence in waste management and circular economy solutions.

CROSS-BORDER PARTNERSHIPS YIELD GREENER E-WASTE RECYCLING METHODS

From extracting gold, silver and other precious or strategic metals from printed circuit boards without using harmful pollutants, to creating greener chemical processes to recover materials from laptop batteries – these are just two tracks of R&D that the Nanyang Technological University (NTU) Singapore-CEA Alliance for Research in Circular Economy (SCARCE) will focus on to develop less energy-intensive and more eco-friendly methods to treat and recycle e-waste.

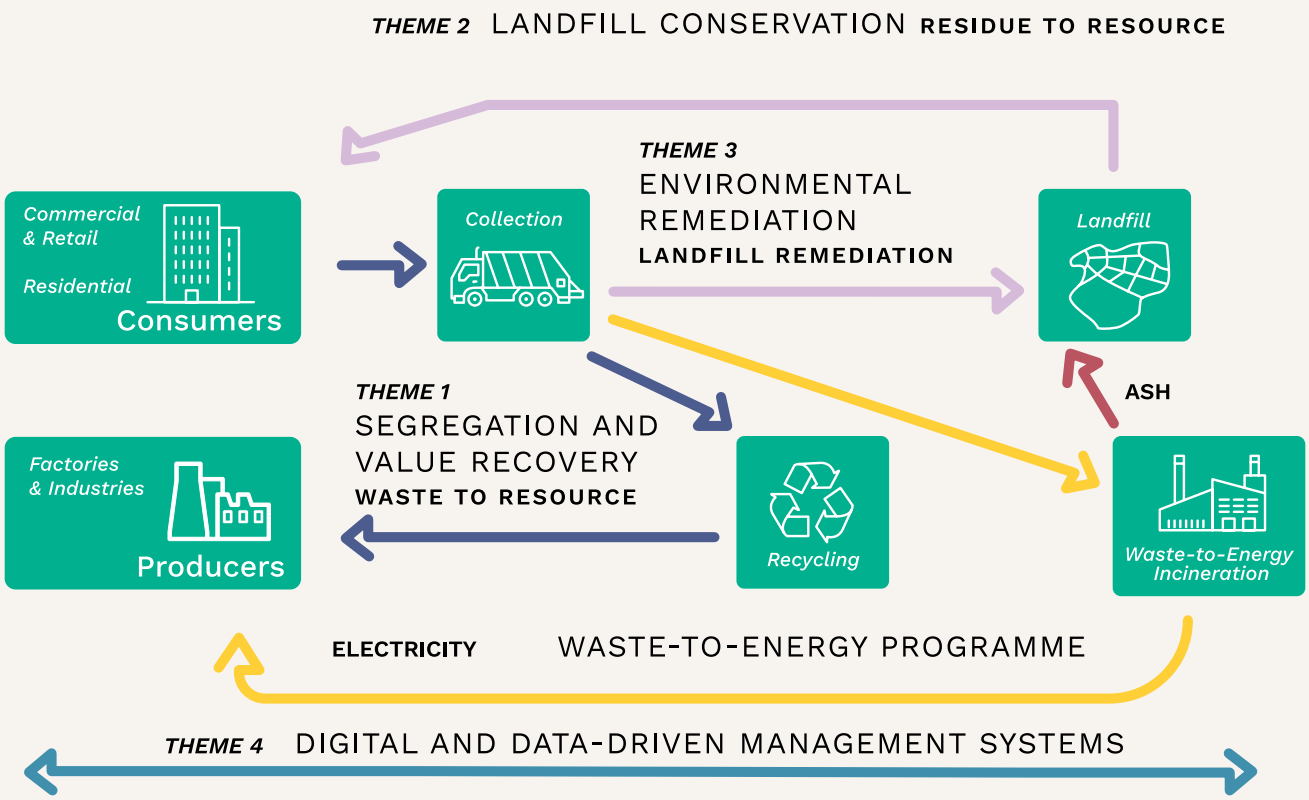
SCARCE is a research centre that the French Alternative Energies and Atomic Energy Commission (CEA), a renowned multidisciplinary research centre in Europe, has set up together with NTU, and is CEA's first joint laboratory outside France. It is also the first and largest single recipient of funding under the NEA's Closing the Waste Loop R&D Initiative, with the NEA committing $12.5 million towards this $20 million centre.

One of its research projects is to develop eco-friendly methods of recycling lithium ion batteries commonly used in laptops, mobile phones and tablets. The goal is to extract up to 75% of the useful metals by weight, like cobalt, nickel and lithium, from used batteries. These can then be reused to produce new batteries.

Another project will look at extracting valuable metals from printed circuit boards, which are thin copper-plated or etched circuitry boards that mount integrated chips and electronic components in electronic equipment and appliances. The target is to develop novel methods to separate and recover metals, organics and ceramics from these discarded boards.

Local companies like Virogreen (Singapore) Pte Ltd have plans to collaborate with SCARCE, while TES-AMM (Singapore) Pte Ltd has expressed interest in industrial-scale pilot testing, to take the developed technology from the lab to the industry.

Professor Madhavi Srinivasan, co-director of SCARCE, explains how a battery shredder is used for shredding used lithium ion batteries (LIBs) as an initial step to extract the electrode materials, which can then be reused to produce new LIBs



Closing the Waste Loop R&D Initiative and Waste-to-Energy Programme, overlaid across the entire waste management value chain

Our R&D investments to achieve zero waste

To improve technologies and solutions for recovering resources from waste and come up with new ways to do the job, the NEA has established two key R&D programmes.

CLOSING THE WASTE LOOP

Launched in December 2017, the Closing the Waste Loop (CTWL) R&D Initiative is a $45 million programme that has funded eight projects worth almost $20 million as of 2019. The programme has three objectives:

- **Resource efficiency** – Develop ways to utilise resources efficiently and for as long as feasible. This includes better waste segregation, both at source and after disposal, which will maximise material and value recovery from waste. This ensures waste management processes are manpower-, energy- and water-efficient.
- **Landfill avoidance** – Convert residues and waste (i.e. incineration bottom ash, incineration fly ash and non-incinerable waste) currently discarded at Semakau Landfill into useful resources, to extend the landfill's lifespan beyond 2035.
- **Maintaining high standards of public health** – Besides protecting the environment, waste management (i.e. collection, recycling, disposal and treatment of waste) should be carried out in a safe and hygienic manner to maintain high public health standards.

The CTWL initiative was developed with collaboration in mind, to encourage partnerships between IHLs, RIs and private sector enterprises. These stakeholders were consulted to develop the four themes under the CTWL initiative, which goes hand in hand with the Waste-to-Energy Programme, to maximise the use of resources at every opportunity.

EIGHT PROJECTS

worth almost $20 million have been awarded under the CTWL initiative so far, and we will call for more projects in the near future.

We will work with industry and research stakeholders to identify new focus areas of research.

THEME 1

Segregation and value recovery

Large amounts of leftover food, packaging waste and discarded electrical and electronic devices still end up at incineration plants today. We want to increase the recovery rate of valuable, usable materials from these key waste streams, and lower the economic cost and environmental impact of current recycling processes.

A NEW LEASE OF LIFE FOR PACKAGING WASTE

Potato chip packaging made of multilayer films

With no commercially viable way of recovering plastic layers found in most of the food, beverage and pharmaceutical packaging today, these materials are currently just incinerated.

But scientists are now trying to break the code to recycle these plastic-embedded multilayer films (MLFs).

A team from A*STAR's Institute of Chemical and Engineering Sciences is developing a chemical recycling method that can separate and individually recycle the different polymer layers from MLFs.

This makes it possible to extract valuable, pure components that can then be reused multiple times.

If successful, this chemical process could also remove additives like colour pigments and soluble polymers commonly found in plastic goods.

THEME 2

Landfill conservation

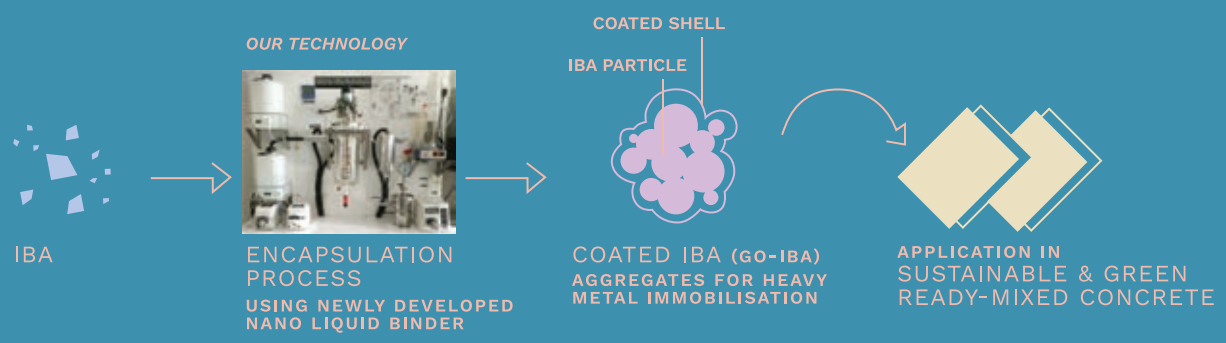
Just as PUB reclaimed used water to develop NEWater, the NEA is studying how to produce "NEWSand": an environmentally sustainable product made from incineration ash that can be commercialised. Finding ways to use incineration ash, as well as non-incinerable waste and industrial residues, will not only extend the lifespan of our only landfill but also avail Singapore of a new source of construction materials.

As ash contains heavy metals, strict standards are being developed to allow NEWSand to be used in non-structural concrete, road base and sub-base. This is in view of the fact that much of land-scarce Singapore has been or will be designated as water catchments. Treated incineration ash that meets these standards will be allowed for unrestricted use in both moulded and unmoulded forms, without polluting our water resources.

The standards will be validated through a demonstration project for incineration ash treatment and a field trial for treated ash. The Land Transport Authority has identified a suitable site for field trials, in which treated ash will be used to lay the road base and sub-base layers. Groundwater samples will be collected and tested for changes in environmental characteristics and compared against samples of groundwater from a nearby control site made from conventional road building materials.

The design and results of the field trial will be reviewed by a Technical Expert Panel comprising experts in toxicology, public health, environmental health, incineration ash treatment methods, civil engineering and hydrogeology.

FROM ASH TO CONSTRUCTION MATERIALS



Overview of process to convert IBA into construction aggregates

Photo: Republic Polytechnic, Singapore

In the future, ash left behind from burning incinerable waste could be used to build our infrastructure.

Researchers from Republic Polytechnic are developing a solution to turn incineration bottom ash (IBA) into construction aggregates that can be added to produce ready-mixed concrete.

Their goal is not only to divert IBA from landfilling, but also address rising market demand for high quality aggregates. They believe their product could be a sustainable substitute for mined aggregates on the market.

THEME 3

Environmental remediation

Where trash from around the island once accumulated, we believe our past landfills can be rehabilitated and turned into reusable land for future development. Therefore, one of the focus areas under the CTWL initiative is to investigate and characterise these closed landfill sites, and use them as test-beds for technologies and techniques that could make them usable land again.

THEME 4

Digital and data-driven management systems

There is a need for systems to help monitor and assess the effectiveness of the initiatives we implement across the entire waste management value chain.

We want to harness Information and Communications Technology (ICT), such as data analytics, to inform policy formulation and infrastructure planning in waste management and resource recycling.

WASTE-TO-ENERGY

Even as we try to maximise material resource recovery from our waste, Waste-to-Energy (WTE) remains a key strategy to extract value from residual waste that cannot be effectively reused or recycled. It also harnesses the energy content to produce electrical energy, while reducing the volume of residual waste and prolonging the lifespan of our precious Semakau Landfill.

To build up Singapore's capabilities in energy and value recovery from waste, the NEA launched the $25 million WTE R&D programme in 2014.

The programme has two aims.

AIM 1

Boost energy recovery efficiency of WTE processes and methods

Today, Singapore's WTE plants are not only energy self-sufficient, but also supply excess electricity to the national grid. Finding more efficient WTE incineration processes with higher electricity output will help them meet a greater share of Singapore's energy needs.

For example, one approach is to use oxygen-enriched air. A team from NTU's Nanyang Environment and Water Research Institute's (NEWRI) Singapore Membrane Technology Centre is developing membranes that can efficiently produce oxygen-enriched air. They are also modelling the feasibility of using the membranes to enhance the current incineration processes. The challenge lies in extracting oxygen molecules from the air in a cost-effective and energy-efficient manner.

WTE Research Facility at Tuas South
Photo: Nanyang Technological University, Singapore

(From left) Chief Executive Officer of NEA, Mr Tan Meng Dui; Minister for the Environment and Water Resources, Mr Masagos Zulkifli; and President of Nanyang Technological University, Professor Subra Suresh, holding pieces of concrete made with slag produced from the waste gasification processes. This highlights the potential of turning waste into material for useful applications, which contributes to closing the waste loop.

AIM 2

Explore alternative WTE technologies

Alternative WTE technologies like gasification provide more renewable energy options and/or higher value products from waste with minimal waste residues.

The WTE R&D programme aims to develop alternative, novel methods suited to our local context. For instance, Singapore's municipal solid waste streams are highly heterogeneous and have high moisture content. Therefore, foreign technologies may not be immediately applicable in our situation.

By understanding our solid waste composition, we will be better able to generate useful by-products like better quality syngas, while increasing the amount of energy and resources recovered.

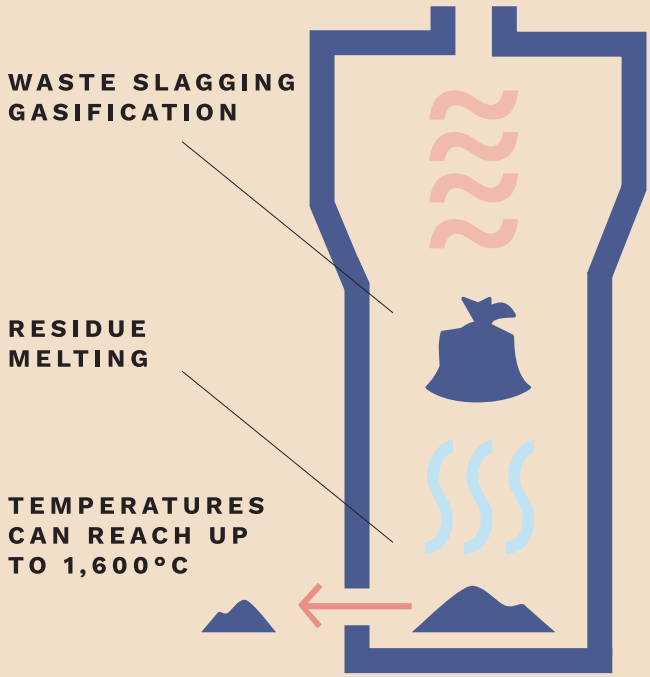
However, testing prototypes at existing WTE facilities is not feasible due to the disruption it would cause; neither are the facilities designed to accommodate such trials. Recognising this problem, the NEA contributed $12 million to co-fund the construction of a WTE Research Facility (WTERF) with NTU's NEWRI. The Residues and Resource Reclamation Centre of NEWRI was tasked with the execution and project management of the WTERF construction and operation.

The $40 million WTERF provides local researchers and industry players with a physical, open platform for pilot testing. Its plug-and-play features support experimentation and test-bedding at scale, bridging the gap between laboratory research and commercial deployment.

The WTERF is the first of its kind in Singapore, employing high-temperature slagging gasification as its underlying technology, and was officially opened in May 2019.

HOW DOES SLAGGING GASIFICATION WORK?

COMPACT SHAFT-TYPE FURNACE



The process takes place in a compact shaft-type furnace with combined functions for waste gasification in an upper part and residue melting in a lower part, in a reducing atmosphere with the use of auxiliary fuel, e.g. coke or biomass charcoal. The melting zone temperatures can reach up to 1,600°C to melt incombustible fractions (ash and metal) in waste to form slag which can be used as aggregates, and metal granulates that can be recycled.

Charting our next R&D steps

Even as new technologies emerge from the CTWL R&D Initiative and WTE R&D programme, we must think ahead and identify new areas to study next. Only then can we remain at the forefront of science and technology.

We will look at how science and technology can help us create circular, sustainable systems of production, consumption, and waste and resource management within our economy.

Our key objectives are to:

- Develop viable substitutes for conventional materials
- Develop scalable technologies to separate waste into its constituents and turn them into resources and energy at lower economic and environmental costs
- Generate new, viable applications for resources generated from waste

› Integrate waste and resource streams systematically

With these principles in mind, research areas relevant to Singapore include:

SUSTAINABLE MATERIAL SUBSTITUTES

Inventing easily recyclable substitutes to commonly used materials will make recycling and upcycling of waste cheaper and more convenient. This could be in the form of specially formulated non-metal nanostructures (made of paper, for example) that could replace metal electronic circuits and wiring.

NEW APPLICATIONS FOR RESOURCES HARVESTED FROM WASTE

One promising area is nutraceutical extraction, which involves extracting valuable substances with medical or health benefits from food waste.

Through research, we can identify useful substances within common types of food waste, and develop techniques to hygienically and efficiently extract and convert them into products fit for human consumption.

For instance, bioactive compounds can be extracted from vegetable and food wastes, such as skins, stems, seeds and residues from oils, juices and sugar extraction. These compounds can then be turned into high-value nutraceuticals and functional foods like health supplements and food additives.

INTEGRATING WASTE AND RESOURCE STREAMS

Industrial symbiosis is a form of brokering, where companies are brought together in mutually profitable transactions. This involves finding ways to use the waste from one company as raw materials for another.

Research in this field explores better ways of converting waste from one industry into usable materials for another, or discovering new, industrial-scale uses for existing waste streams currently not recycled or reused.

Increasingly, we are focusing on the food-water-waste-energy nexus, to find ways each sector can benefit from the other. This includes extracting nutrients from our waste for use in fertilisers in agriculture and horticulture.

By test-bedding such synergistic innovations at scale, we hope to translate these into real, commercially viable solutions.

Going forward, there will be ample opportunities to pilot circular zero waste solutions suited for local conditions, and integrate them with other systems to maximise district-level synergies.

Integrating these solutions into future housing estates and town centres will show how R&D helps fashion our living spaces into places where we can live and work in a sustainable, eco-friendly fashion.

Our R&D journey continues

By working closely with academia and industry, we will guide our R&D efforts to create economic opportunities for our companies and jobs for our people.

In this way, we can successfully adopt a circular economy approach to fulfil our vision of a Zero Waste Nation where Singaporeans can thrive and prosper.

Chapter 7

Towards A Zero Waste Nation, Together

Our zero waste vision is an endeavour that will require people in Singapore to come together. From individuals to households and industries, everyone has a part to play as we make our transition towards a Zero Waste Nation.

2019 was designated as the Year Towards Zero Waste to rally Singaporeans to care for our environment and treasure our precious resources

To become a Zero Waste Nation, we need to change the way we live, work and play. This includes curbing excessive consumption habits in all aspects of our lives, harvesting trash for treasure, consciously choosing sustainable products and services, and reusing resources for as long as possible.

The Government has set the direction of this transformation and taken significant steps to chart its course. We have facilitated the setting up of infrastructure to collect, sort and recycle different types of items and materials, and have stepped up education to change attitudes and behaviours towards reducing, reusing and recycling.

But the Government cannot do this alone. We need to partner businesses, individuals and organisations to come up with innovative and effective solutions. Over the years, MEWR and the NEA have worked closely with partners to undertake collective action for sustainable development. As we embark on this transformational journey together, we want to uncover broader perspectives, listen to diverse views and bring together different segments of society to co-create environmental solutions.

CO-CREATING SOLUTIONS WITH SINGAPOREANS

Since 2018, MEWR and the NEA have sought the views of the public and other relevant stakeholders on the Zero Waste Masterplan.

These stakeholders include:

Industry stakeholders
In 2018, the NEA consulted over 250 companies to gather ideas and views on possible measures to address priority waste streams.

Households
More than 5,000 households were engaged through two door-to-door surveys, conducted between June 2018 and February 2019. One was a biennial survey, which focused on households' experience with recycling services and infrastructure. The other was commissioned specially for the Year Towards Zero Waste to get a deeper understanding of households' recycling behaviour.

Non-Governmental Organisations (NGOs)
A dialogue was held with NGOs, youths and other partners in February 2019 to seek their views on MEWR's zero waste plans and to explore collaborations.

General public
More than 1,300 people participated in a public consultation in March 2019 on how Singapore can pursue sustainable consumption and production, and build a strong 3R (reduce, reuse and recycle right) culture. In April 2019, MEWR conducted two focus group discussions with 90 participants. The discussions were co-organised with NGOs Zero Waste SG and LepakInSG, and centred on ways to reduce waste and to encourage people to recycle right.

At the focus group discussion on 18 April 2019, participants discussed ways to reduce our consumption of resources and encourage more to adopt a zero waste mindset

Through the various engagement sessions, we found that people generally agreed that it was important to make the 3Rs a norm in Singapore. Many participants felt that convenience was a key factor in nudging people to put these principles into practice. Many also felt that more education was needed to raise awareness on waste issues, and also called on businesses to promote sustainable consumption.

CATALYSING GROUND-UP INITIATIVES

To effectively promote a zero waste lifestyle, MEWR and the NEA work closely with schools, businesses, community groups, NGOs and civil society groups to rally the ground and raise awareness on waste issues through their networks. Some of these individuals and groups are carrying out research that complement studies by the Government. Others are facilitating dialogues and gathering feedback, and have been galvanising the local community to adopt greener habits.

Here are some initiatives undertaken by our partners:

SEC plastic study and "One Less Plastic" campaign

The Singapore Environment Council (SEC) conducted a nine-month study on "Consumer Plastic and Plastic Ecosystem in Singapore", which focused on three segments of the plastic ecosystem:

- Upstream producers' responsibilities including packaging
- Consumer lifestyles including recycling behaviour
- Downstream processes including waste management

Reusable bags were given out by four supermarket chains, DBS and SEC as part of the "One Less Plastic" campaign
Photo: SEC One Less Plastic Campaign

The study, released in August 2018, found that Singapore uses about 1.76 billion plastic items each year. This prompted SEC to launch a month-long "One Less Plastic" campaign in December that year, to encourage shoppers to swap single-use plastic bags for reusable bags.

Project Recycling

The Climate Action SG Alliance, a group of corporate and civil society leaders, produced a series of videos to educate the public on how to recycle right and to debunk myths surrounding recycling. Three videos – "Breaking Up with Plastic", "What Can and Cannot be Recycled" and "Follow the Trash" – were shared on social media channels.

Industry efforts

Getting businesses on board to support Singapore's drive to reduce waste and operate sustainably is best done by an organisation that understands their needs and constraints.

Students from Mee Toh School showcased their project "The SORT-CERER" at the North East Clean and Green Singapore 2018. The project aims to encourage recycling through a simple game and has won the best project at the North East G!nnovation Challenge 2018.

Since 2001, this role has been played by the Waste Management and Recycling Association of Singapore (WMRAS) – the national trade body for local waste disposal and resource recovery companies.

WMRAS and its 160 member companies have been encouraging green practices in the community through talks on waste reduction and recycling. It also holds the biennial WMRAS Excellence Awards to recognise member companies that promote environmental sustainability.

WMRAS conducts regular outreach sessions to educate the youth about Singapore's waste ecosystem
Photo: WMRAS

In 2017, WMRAS Academy started a Professional Course in Waste Management and Resource Recovery in collaboration with Australia's Griffith University for industry workers to learn about sustainability, waste reduction, recycling and the latest environmental technologies.

Schools and youth

Beyond these specific initiatives, MEWR and the NEA have been encouraging schools and

youths to organise ground-up initiatives to promote environmentally-friendly practices.

Since March 2019, MEWR, together with the National Youth Council, has been engaging youth leaders on our environmental policies and programmes. Through their lens, we hope to better understand youth perspectives on sustainability, empower them to lead more ground-up initiatives and to build a more environmentally-conscious and gracious Singapore.

Meanwhile, the NEA works closely with schools to promote active learning and participation in environmental initiatives by providing funding support. The NEA also organises platforms to showcase exemplary student projects and facilitates networking among schools.

Scan this QR code for a list of the NEA's funding schemes:

For example, as part of the Youth for the Environment Day in April 2019, the NEA launched the Towards Zero Waste Challenge, where schools were encouraged to avoid the use of disposables when organising events. Under the programme, schools received an electronic guide on how to conduct Zero Waste events and other related activities.

Many schools and Institutes of Higher Learning have also organised their own ground-up initiatives to encourage staff and students to reduce waste. For example, in Bukit View Secondary School's canteen, no plastic straws are provided and reusable cutleries and containers are made available for staff to pack food. Canteen stall vendors also impose a small charge on disposable packaging to further discourage its use. At the National University of Singapore (NUS), infographics on recycling are set as wallpapers and screensavers on computer screens in the lecture theatres. Other campus-wide initiatives at NUS include a 10-cent plastic bag tax, and Bring Your Own (BYO) schemes like Project Box and Project Tumbler that reward patrons for bringing their own reusables for takeaways.

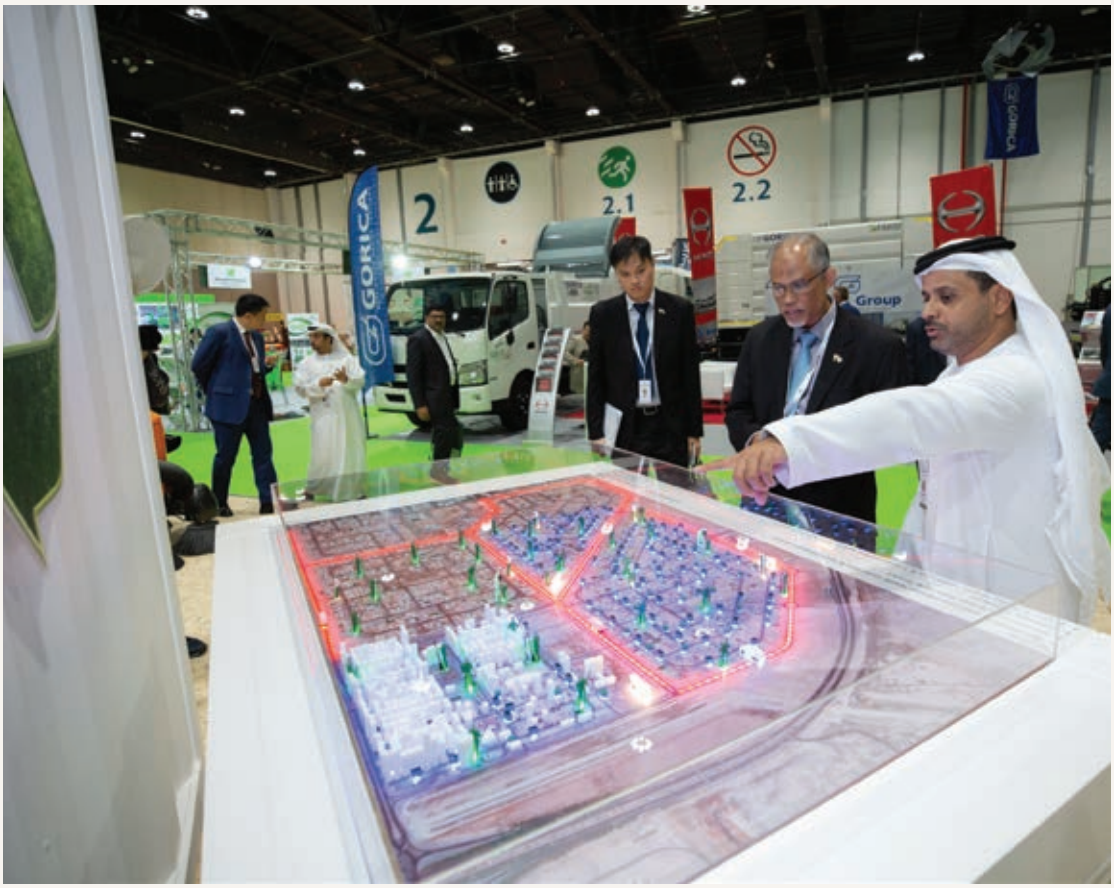
A "Towards Zero Waste Grant" was set up in 2019 to fund ground-up projects that drive waste reduction and recycling, or encourage households to recycle more and recycle right.

Recycle @ North West, an initiative by the North West Community Development Council, hopes to drive Active Recycling through educating residents on proper recycling techniques and bonding the community through a common platform to sort recyclables
Photo: North West Community Development Council

PARTNERSHIPS BEYOND BORDERS

The environmental challenges that we face are not unique to Singapore. Common challenges include a mounting waste problem, greater resource constraints and climate change. We can learn from the experience and expertise of other countries, while sharing ours as well.

Singapore welcomes partnerships with countries and institutions that share the vision of a global circular economy where resources are used efficiently, proper recycling and clean recyclables support economic activity, and innovation and technology push the boundaries of resource recovery.



Minister for the Environment and Water Resources, Mr Masagos Zulkifli, visited the Abu Dhabi Waste Management Center (Tadweer) to learn about Abu Dhabi's waste management plan and systems, and public outreach efforts

Such partnerships are becoming increasingly important as our world becomes more globalised and interconnected. The movement of materials will inevitably cross national boundaries, and international cooperation is key to leveraging the opportunities from sustainable production, consumption and waste management. As a responsible member of the international community, Singapore will continue to uphold the rules-based approach to addressing environmental challenges and fulfil our international commitments.

This is why we have partnered countries like China, Japan, South Korea, the Netherlands, Oman, Jordan and the United Arab Emirates. We have signed Memorandums of Understanding, engaged them in policy exchanges and worked together on industry workshops and demonstration projects. Singapore hopes to promote greater collaboration on policies, best practices and technologies to strengthen our capacity to drive the shift towards a Zero Waste future.

One example is the Sino-Singapore Tianjin

Eco-city (SSTEC), the second Government-to-Government project between Singapore and China. It was designated by China's Ministry of Environment and Ecology as one of China's 16 Zero Waste pilot cities/areas in April 2019. Singapore's contributions enabled SSTEC to meet key environment-related performance indicators on waste reduction and recycling, among others. Having been designated a pilot Zero Waste city, further novel zero waste environmental solutions and initiatives will be explored using a circular economy approach. The aim is to establish a replicable zero waste reference model for other Chinese cities/areas.

Another good example is the Singapore-Japan E-waste Management Forum organised by the NEA and the Ministry of the Environment of Japan. The forum was held in June 2019 and saw 150 industry leaders and delegates exchange ideas and information on electrical and electronic waste management strategies.

Pneumatic Waste Conveyance System (PWCS) collection bins at a residential development in the SSTEC
Photo: Eco-city Administrative Committee

SUSTAINED 3P PARTNERSHIPS

The Year Towards Zero Waste has triggered the momentum for action, and we will continue to build on our partnerships with the 3P (private, public and people) sectors. We believe in expanding our democracy of deeds, where Singaporeans actively contribute and shape our future.

As part of our sustained engagement efforts, MEWR is convening a Citizens' Workgroup to co-create solutions with Singaporeans, to improve the way we recycle at home. One of the key objectives is to reduce the contamination rate of the blue recycling bin, which is currently at 40%. The Citizens' Workgroup will include Singaporeans from diverse backgrounds. Members will be given access to data as well as subject matter experts who can share their expertise and help with the piloting and implementation of solutions.

We will continue to align our efforts with those of other Government agencies, adopt a science-based approach and work with businesses, international partners, civil society groups and individuals to co-create solutions for a sustainable Singapore.

Together, we can move closer towards our vision of becoming a Zero Waste Nation.

Zero Waste Masterplan

to Achieve a Sustainable, Resource-Efficient and Climate-Resilient Singapore

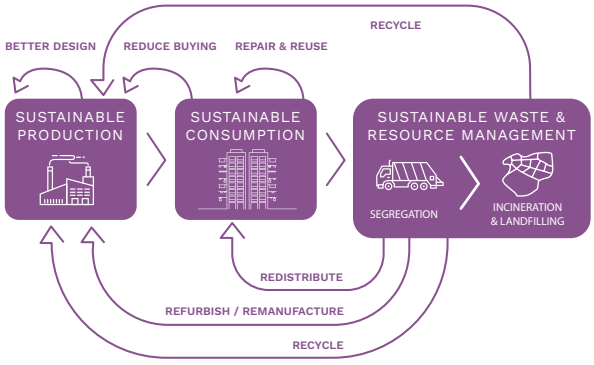
STRENGTHENING THREE RESILIENCES

Climate Resilience
Address existential threats of climate change especially rising sea levels

Resource Resilience
Ensure safe and secure supply of critical resources like food and water

Economic Resilience
Ensure the future Singapore economy remains competitive by overcoming carbon and resource constraints

To achieve this, we will adopt a circular economy approach



GOVERNMENT TAKING THE LEAD

Three Priority Waste Streams

- Food waste
- E-waste
- Packaging waste, including plastics

Resource Sustainability Act

Mandatory packaging reporting in **2020**

Extended Producer Responsibility for e-waste by **2021**

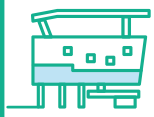
Mandatory food waste segregation for treatment from **2024**

Extended Producer Responsibility for packaging, including plastics, **no later than 2025**

Our Targets

1. Extend Semakau Landfill's lifespan **beyond 2035**
2. Reduce amount of **waste sent to landfill per capita per day by 30%** by 2030
3. By 2030, achieve a **70% overall recycling rate**:
   81% non-domestic recycling rate
   30% domestic recycling rate

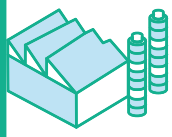
PUSHING BOUNDARIES THROUGH RESEARCH AND INFRASTRUCTURE

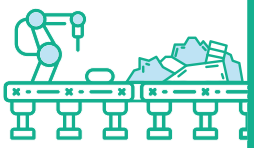


Pneumatic Waste Conveyance Systems

TuasOne Waste-to-Energy Incineration Plant

Pilot Mechanical Biological Treatment facility





Tuas Nexus
Comprising Integrated Waste Management Facility and Tuas Water Reclamation Plant to harness synergies across the water-waste-energy nexus

NEWSand
Use of incineration bottom ash in construction materials

$45 million
Closing The Waste Loop R&D Initiative
8 projects worth almost $20 million funded as of 2019

$25 million
Waste-to-Energy Programme
Prototype testing at $40 million Waste-to-Energy Research Facility

TRANSFORMING THE ENVIRONMENTAL SERVICES INDUSTRY

More than **2,000 firms**

30,000 workers to benefit from the Environmental Services Industry Transformation Map by 2025

Gov-PACT innovation calls

$30 million Productivity Solutions Grant (PSG)

Regulatory Sandbox

INCUBATE partnerships

CO-CREATING SOLUTIONS WITH THE COMMUNITY

#RecycleRight campaign

New design for recycling bin labels

Citizens' Workgroup on household recycling

More than **250 companies** consulted

Over **5,000 households** surveyed on recycling

More than **1,300 people** participated in public consultation

SINGAPORE'S WASTE FLOWS (2018)

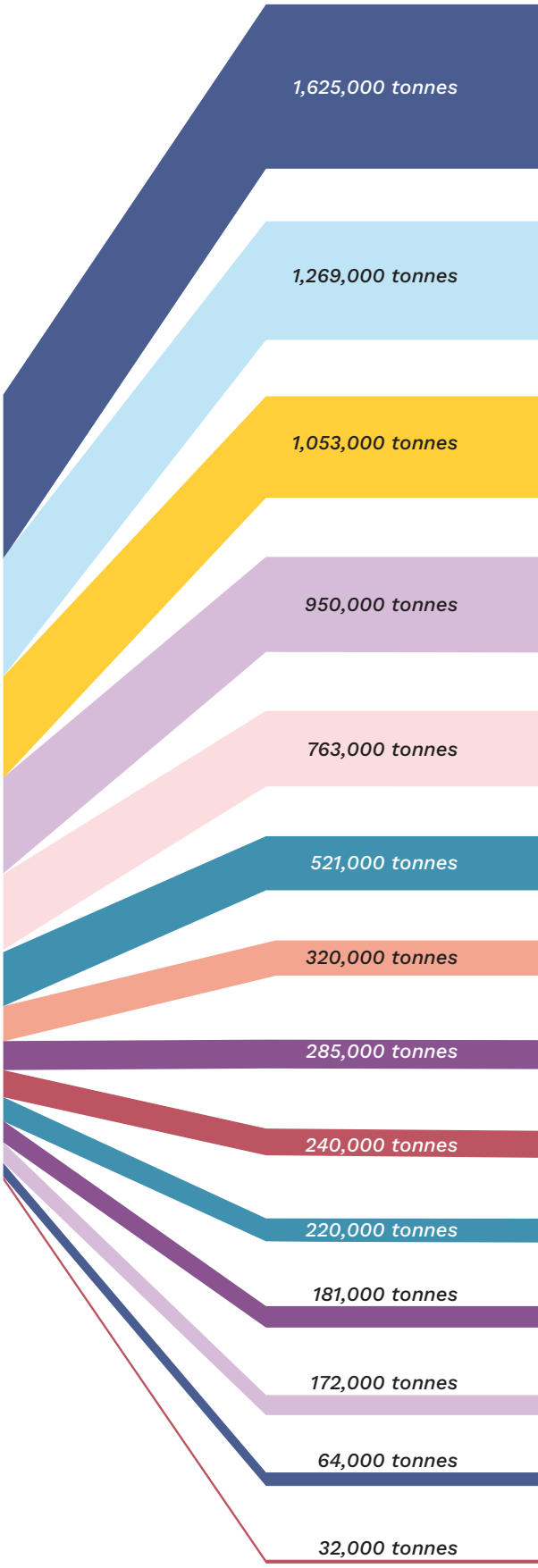
DOMESTIC

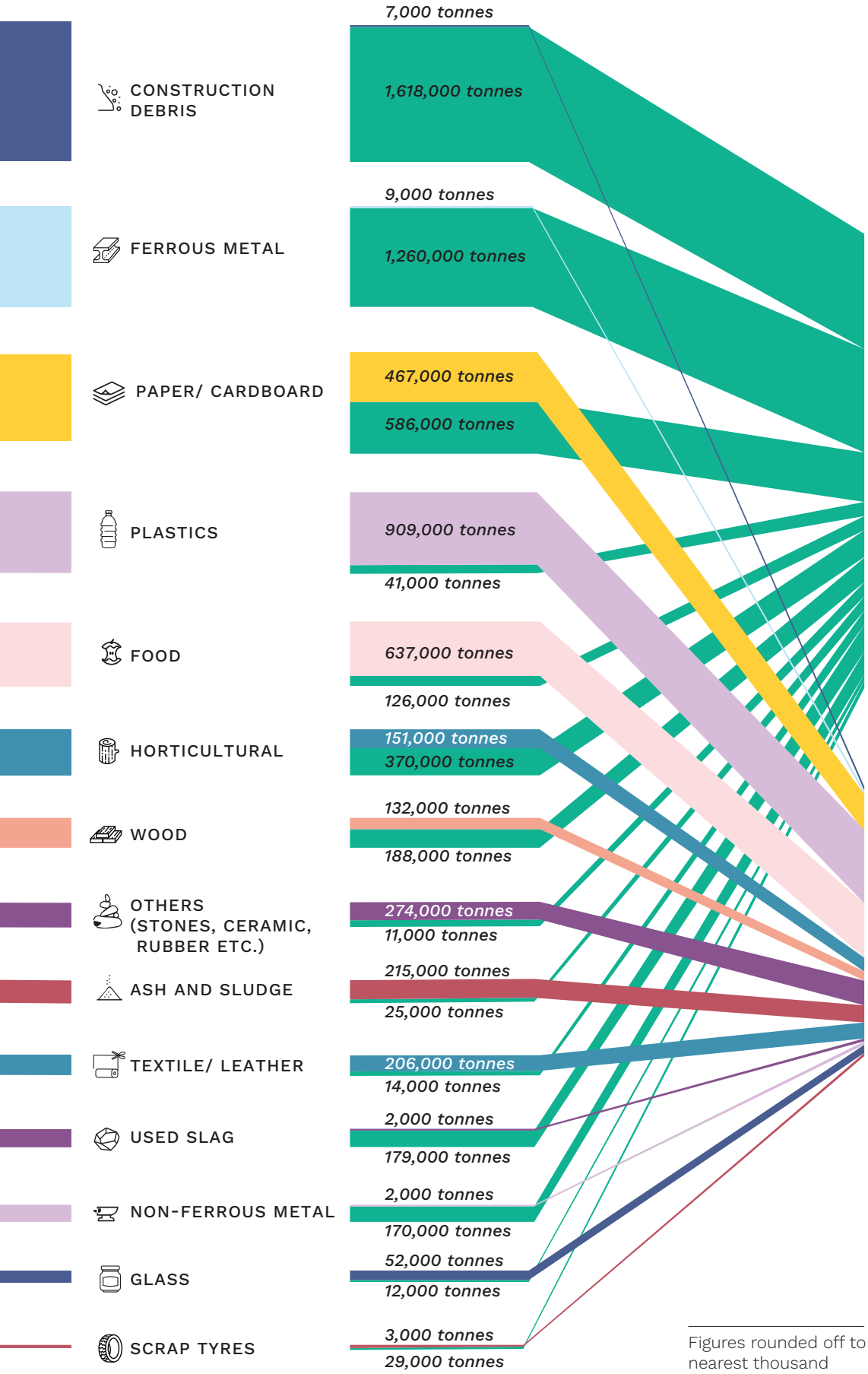
+

NON-DOMESTIC

TOTAL WASTE GENERATED

7,695,000 TONNES





TOTAL WASTE RECYCLED
4,629,000
tonnes

TOTAL WASTE DISPOSED OF

INCINERABLE WASTE
2,838,000
tonnes

NON-INCINERABLE WASTE
228,000
tonnes

Figures rounded off to nearest thousand

In support of

Ministry of the Environment and Water Resources
SINGAPORE

National Environment Agency
Safeguard · Nurture · Cherish

TOWARDS ZERO WASTE