Disruptive Technologies for Development

World Bank Learning Event June 25-27, 2018 World Bank Singapore Office

https://www.thegpsc.org/

How can Disruptive Technologies drive a circular economy in a sustainable future?

Professor Seeram Ramakrishna, *FREng*

Chair of Circular Economy Taskforce, National University of Singapore

A World's Most Influential Scientific Mind (Thomson Reuters)

Member of World Economic Forum Committee on Future of Production-Sustainability

Singapore in 2065

Expect smart technologies, healthcare innovations and upgraded infrastructure

AS A professor at the National University of Singapore, it is natural for me to imagine Singapore in 2065. By then all my mentees would be basking in the glory of their mentees, and I would be 100 if I am still alive. It is a gamble for anyone to predict the future. Yet we cannot resist! How Singapore will be in 2065 depends very much on how the world turns out to be, and which innovations Singapore absorbs along the way.

Like Singapore, Moore's Law – which predicted the future of integrated circuits, the heart of computing and smart devices – turned 50 this year. The co-founder of Intel Gordon Moore famously made an empirical observation in 1965 about how the number of transistors that could fit on a single silicon chip would double every two years thereby increasing computing power and speed. Intel's latest chip offers 3,500 times more computing performance, is 90,000 times more energy efficient and costs about 60,000 times less compared to its first generation chip. We now have personal computers, smartphones and the Internet. By 2065 I wish to see more technologies using this law which will lower the cost of living and make rapid improvements in living standards.

Fifty years from now, economic growth facilitated by innovations in finance, commerce and political governance will enable people around the world to be glocal (i.e. global as well as local) in their mindsets and workplaces. They would be more concerned about the sustainability of the world for future generations, influenced by clean water shortages and undesirable consequences caused by climate change. How will these end points impact Singapore in its transformation to 2065?

According to Emporis, which lists the world's top skylines, Singapore with 4,562 tall buildings is ranked third behind New York (6,091) and Hong Kong (7,794). I imagine that by 2065, Singapore's skyscrapers will increase and be three times taller than the current ones with automated carpark systems and smart home appliances. They will be smarter and enable us to find the nearest and cheaper carparks, efficiently water green spaces, ensure security, save energy and handle waste with robots.

Lush green spaces in Singapore will grow and be recognised the world over for their uniqueness. Singapore will turn waste into a resource, and even export it to the world. Carbon footprinting of products and services will become the vogue, and building materials and construction methods reimagined to lower the carbon footprint.

Singapore will be monitoring polluting particles and gases to facilitate higher standards of healthy, urban living. Finance and international trading aspects of the economy will grow further. All electric transportation will go mainstream and information sent to our smartphones so we can share rides and find cost-effective parking spots and dining places. Drones will deliver food, groceries and purchases where and when we need them. Urban farming and nutritious diets will be favoured by Singaporeans. E-shopping will be the new normal. We will have our energy needs met at least up to a quarter by renewable sources.

Owing to our robust electricity system we may become the biggest data centre of the region and perhaps the world. We may be supplying clean water, clean energy and nutritious food to the region. We will be mitigating the rise of the sea level while leveraging on opportunities with the emergence of new shipping and trading routes via the Arctic.

The World Health Organisation expects that one in four people in the world will be above 65. As people pay more attention to health and well-being, they are likely to use more medicines and medical devices in addition to pursuing healthy lifestyles. As much as a quarter of our body weight is likely to be various medical devices! Aside from healthcare innovations, Singapore will have upgraded amenities, infrastructure (smart technologies-enabled walkways, building access, public transportation and roads), healthcare facilities, and opportunities for learning and skills upgrading.

Singapore in 2065 could be a key global node for finance, healthcare, sustainable technologies, dining, entertainment and space tourism. It will be a leading example of a livable city with high quality, smart infrastructure.

Professor Seeram Ramakrishna is the director of the Centre for Nanofibers & Nanotechnology at the National University of Singapore.

New Engineering Jobs in 2050
Co-Robot Engineers
Smart Electronics Engineers
Cyber Engineers
Virtual Reality Engineers
Organ/Tissue Engineer
Smart grid engineer
3D Printing or Additive manufacturing engineer
Digital manufacturing engineer
Machine/Human Interface Engineer
AI engineer or AI App Developer
Urban factory designers
Life Cycle Engineering Engineer or Green Engineer
Sub-terrain Engineers
Deep ocean engineers
IoT Engineers
Battery engineer
Electric vehicle engineer
Wind and Solar Power Engineer
Biologics Engineers
Urban Farmer
Food Engineer

New Engineering Jobs in 2100
Mind (Mentalist) engineer
Idea engineer
Brain engineer
Gene engineer
Synthetic Meat and Food Engineer
Food design engineer
Climate Engineer
Ozone Engineer
Space Traffic Engineer
Maintenance Engineer for Intelligent Machines
Urban farmer
Deep ocean engineer
Digital currency engineer
Biomedical Implants engineer
Wearables Engineer
Health Engineer
Medical Imaging Engineer
Media Engineer
Solutions Engineer
Medical Diagnostics Engineer

The past three centuries' growth model is the Linear Economy

- **Mine, Make, Use, Dispose**
- **Convenience and consumption**
- **Unsustainable & damaging to ecosystem**

Why a slice of cheesy pizza sends reward signal to brain

Eating food with high levels of fat and carbohydrates activates an ingrained reward system in human brains which releases dopamine, a new study has found.

The study, which was published earlier this month by Germany's Max Planck Institute for Metabolism Research, found that foods which combine both high fat and carbohydrate levels in particular further reinforce the observed neuronal effect.

The researchers, who were from the institute and Yale University in the United States, pointed out that the combination of high fat and carbohydrate levels in foods rarely occurs in nature.

Unprocessed food is either high in fats, as exemplified by nuts, or high in carbohydrates, as exemplified by potatoes. A notable exemption to the rule is the breast milk consumed by all mammals.

Researcher Marc Tittgemeyer explained that humans had consequently most likely evolved to "react intensely" to nutrition which was both high in fat and carbohydrates, experiencing a pleasant dopamine rush, because mother milk was necessary for the survival of infants.

The researchers invited 40 participants to play a computer simulation game where they would bid money to secure a reward of food with different calorie qualities.

At the same time, magnetic resonance imaging (MRI) technology was used to observe how the food on offer triggered brain activity in the players of the game.

Both in terms of the money offered in the game and the MRI results obtained, participants showed a strong conscious and neuronal preference for food which was simultaneously heavy in fat and carbohydrates.

Dr Tittgemeyer warned, however, that what might once have been a useful survival mechanism has now become a serious health risk to human societies which enjoy an abundance of food, including naturally rare variants with high fat and carbohydrate levels. The result was a rapid[illegible]incidence of [illegible]esity and related diseases.

"We did not evolve to say 'no' all the time. As a consequence, we usually do not stop eating when we are already satiated," he said.

The findings suggest that the reward signal sent to the brain when fatty and carbohydrate-heavy food is consumed is more powerful than the sensation of satiation experienced during eating.

The institute hopes to build on this insight in the development of future therapies to treat obesity.

XINHUA

The
mac


Google
NEVER
SETTLE

Everest, the world's highest rubbish dump

http://www.tribuneindia.com/news/world/mount-everest-turns-into-world-s-highest-rubbish-dump/606728.html


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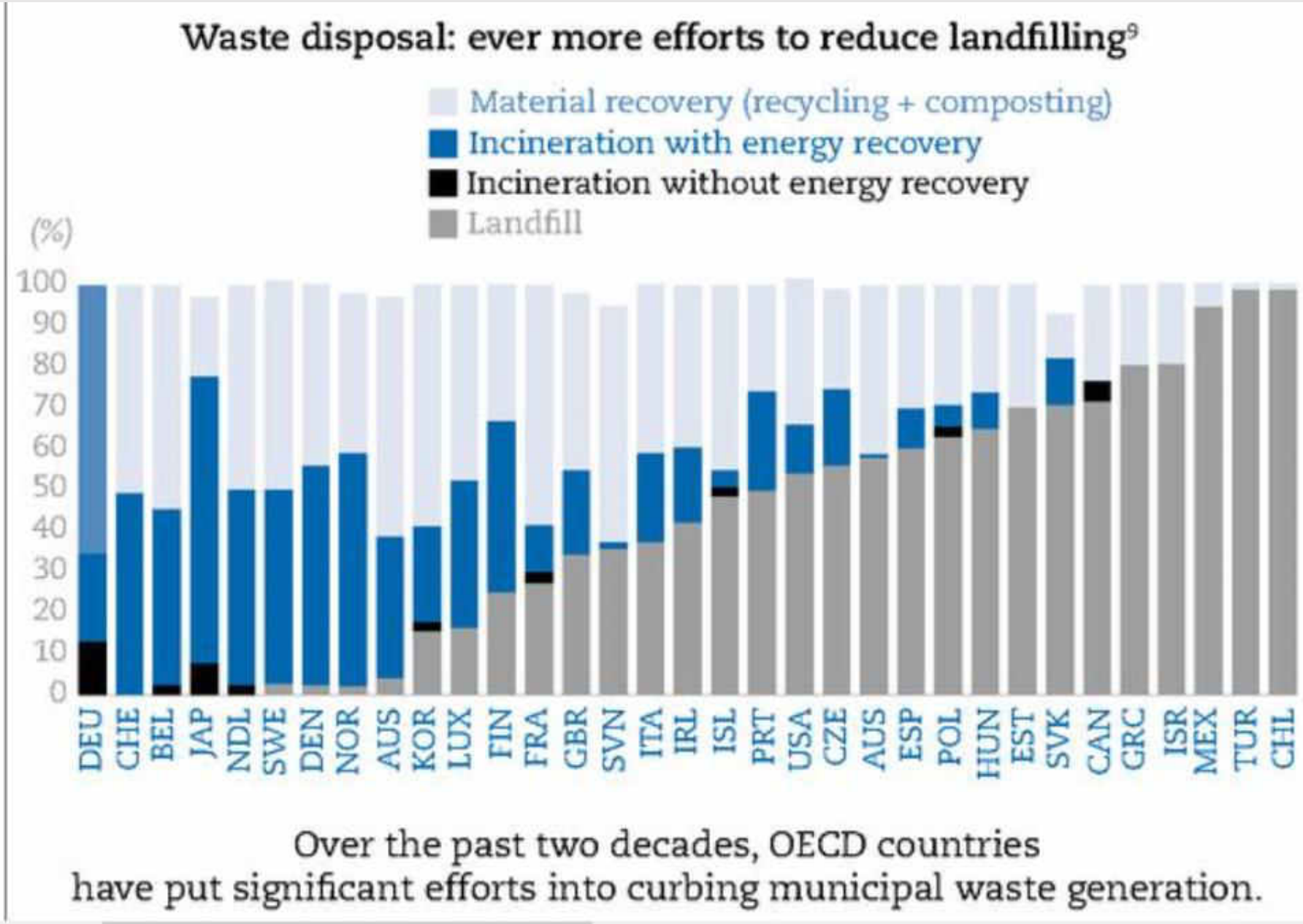
北京时间

http://www.keepeek.com/Digital-Asset-Management/oecd/science-and-technology/oecd-science-technology-and-innovation-outlook-2016_sti_in_outlook-2016-en



Over the past two decades, OECD countries have put significant efforts into curbing municipal waste generation.

requirements f

- While governi play a leading r transition to lo private sector v innovation effo
- The Internet c and sensors wi monitoring of c ecosystems an
- Participatory will generate la data that could practices and c support of mor

https://www.romper.com/p/how-to-buy-wildfangs-i-really-care-jacket-because-its-statement-is-more-than-worth-it-9556650

Sustainable future is in circular economy

In **circular economy** we keep resources in use for as long as possible, extract the maximum value from them while in use, then recover and regenerate products and resources at the end of each service life.

✓ **"Circular Economy saves trillions of dollars to the world economy"**

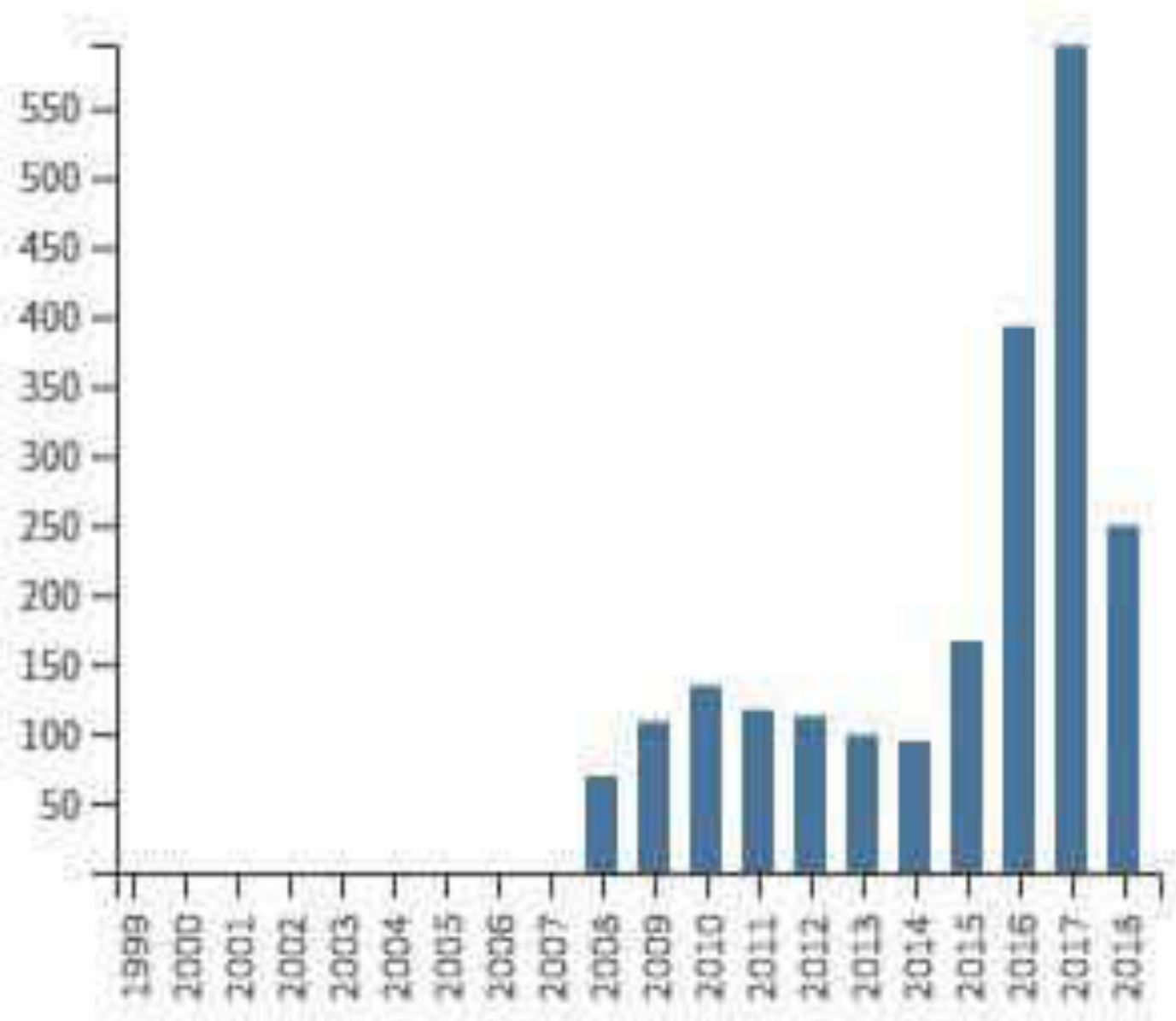
Major Consulting Firms

Source: World Economic Forum

Circular Economy, CE

Decarbonizing Industry & Economy

Circular Economy Research Publications trend worldwide



Accenture, Deloitte, EY and McKinsey & Company estimate that CE saves trillions of dollar to the economies

- Resources (energy, materials, water) efficiency
- Lowering energy demand
- Use of renewable energy
- Elimination of toxic chemicals usage
- Elimination of waste through the superior selection of materials, processes and business models
- Designing products with environment in mind

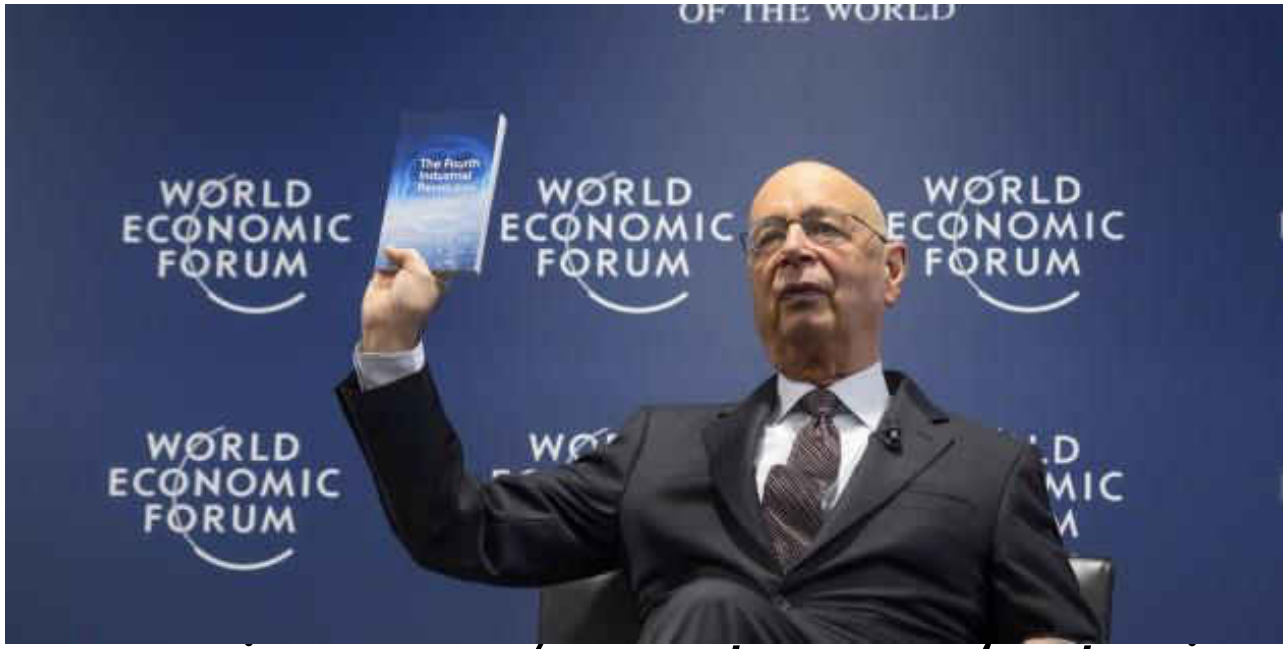
To achieve these

by leveraging

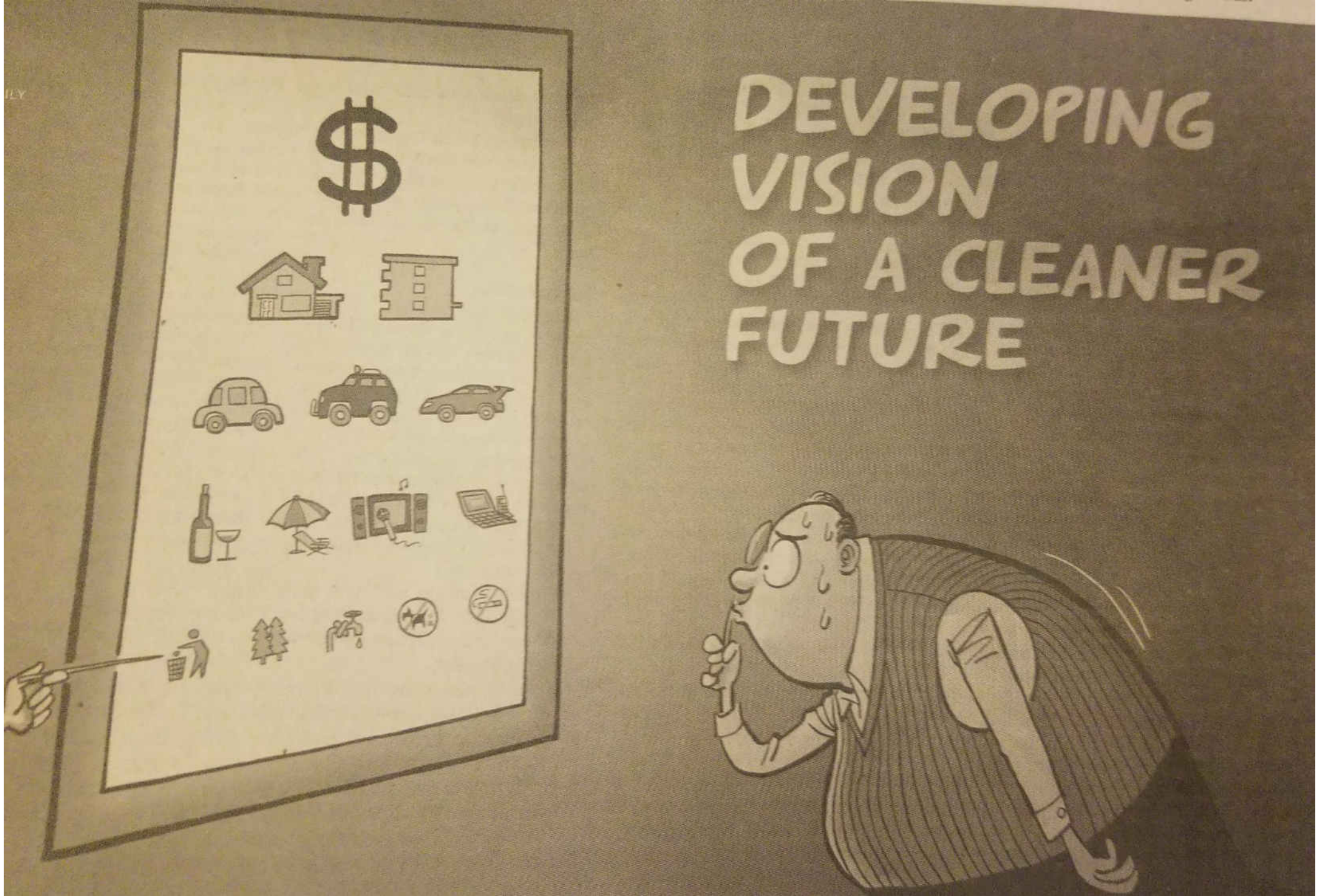
Industry 4.0

Zero Waste Manufacturing: A Paradigm for a Circular Economy in Singapore, Piya Kerdlap, Seeram Ramakrishna, Jonathan Sze Choong Low

Industry 4.0 is a confluence of emerging technologies- Internet of Things (IoT), big data analytics, machine learning, artificial intelligence (AI), cloud computing, robots, automation, materials informatics, nanotechnology, 3D printing, biotechnology, wearables, and mind-inspired technologies, with transformative effects on production systems, business models, employment and economy.



http://www.europeanbusinessreview.com/smart-manufacturing/


DEVELOPING VISION OF A CLEANER FUTURE

Singapore is proactively taking diverse measures to transition towards circularity

- ✓ Gross Energy efficiency improved by 13% between 2000 and 2016
- ✓ Growing renewable sources in energy mix
- ✓ Replaced the carbon-emissions based vehicle scheme with the vehicle emissions scheme with expanded range of pollutants (cleaner transportation)
- ✓ Carbon tax on large emitters from next year

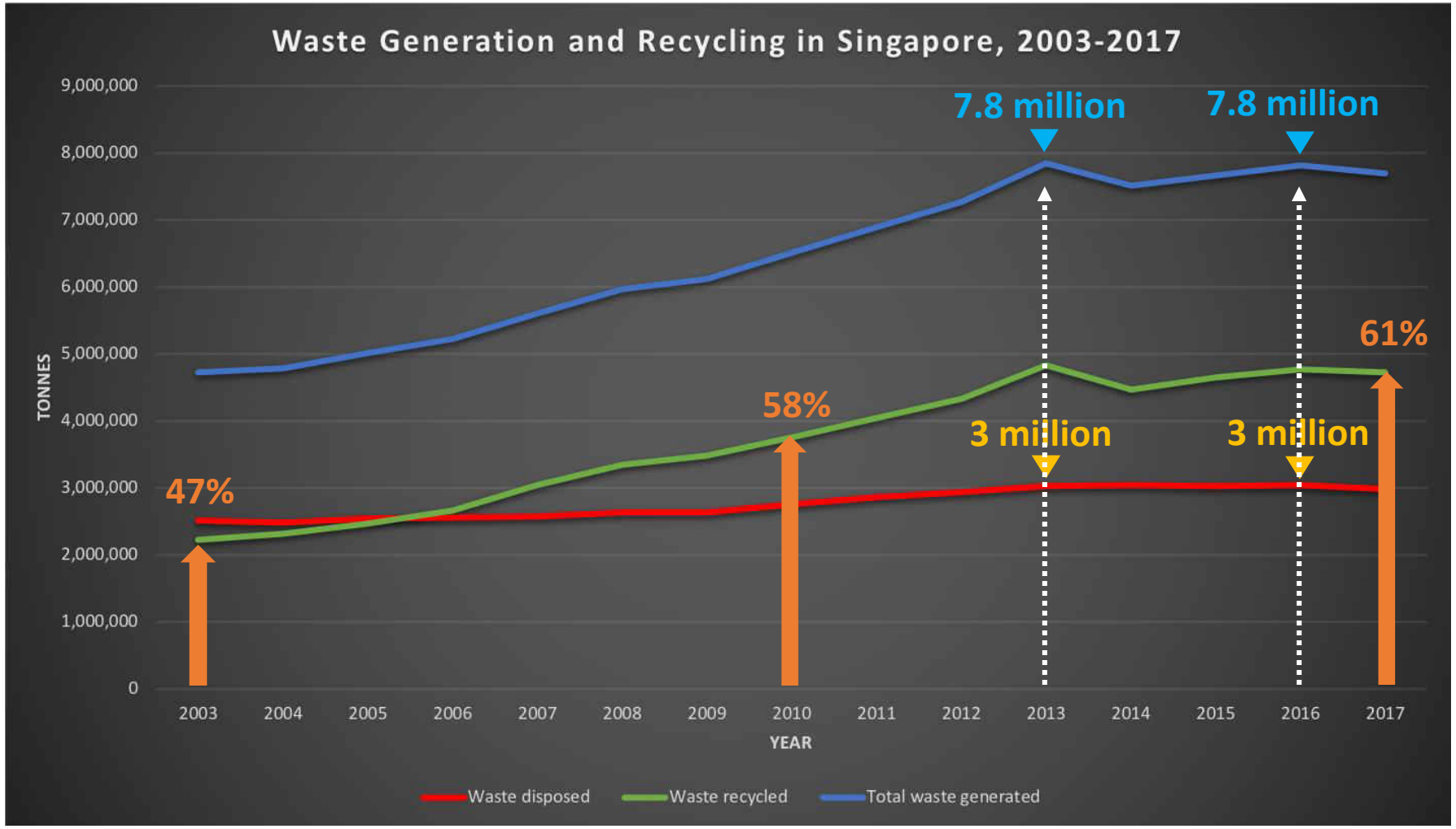
Example, Keppel Corporation is integrating sustainability principles throughout the supply chain which extends overseas so as to cut its carbon emissions by 28.8 per cent from 2010 levels by 2030. Initial measures led to an estimated $37 million in cost savings and an avoidance of approx 77,000 tons of carbon emissions in 2017.


COVER STORY Floating solar special report

At the heart of floating solar: Singapore

Floating PV | Singapore operates the world's largest testbed for floating PV, comparatively testing and evaluating 10 different floating PV installations from around the world, and held the first floating solar conference globally in October 2017. Writing exclusively for *PV Tech Power*, Thomas Reindl of the Solar Energy Research Institute of Singapore (SERIS) reports on a form of solar power whose huge potential is starting to be realised

Waste Reduction Challenges

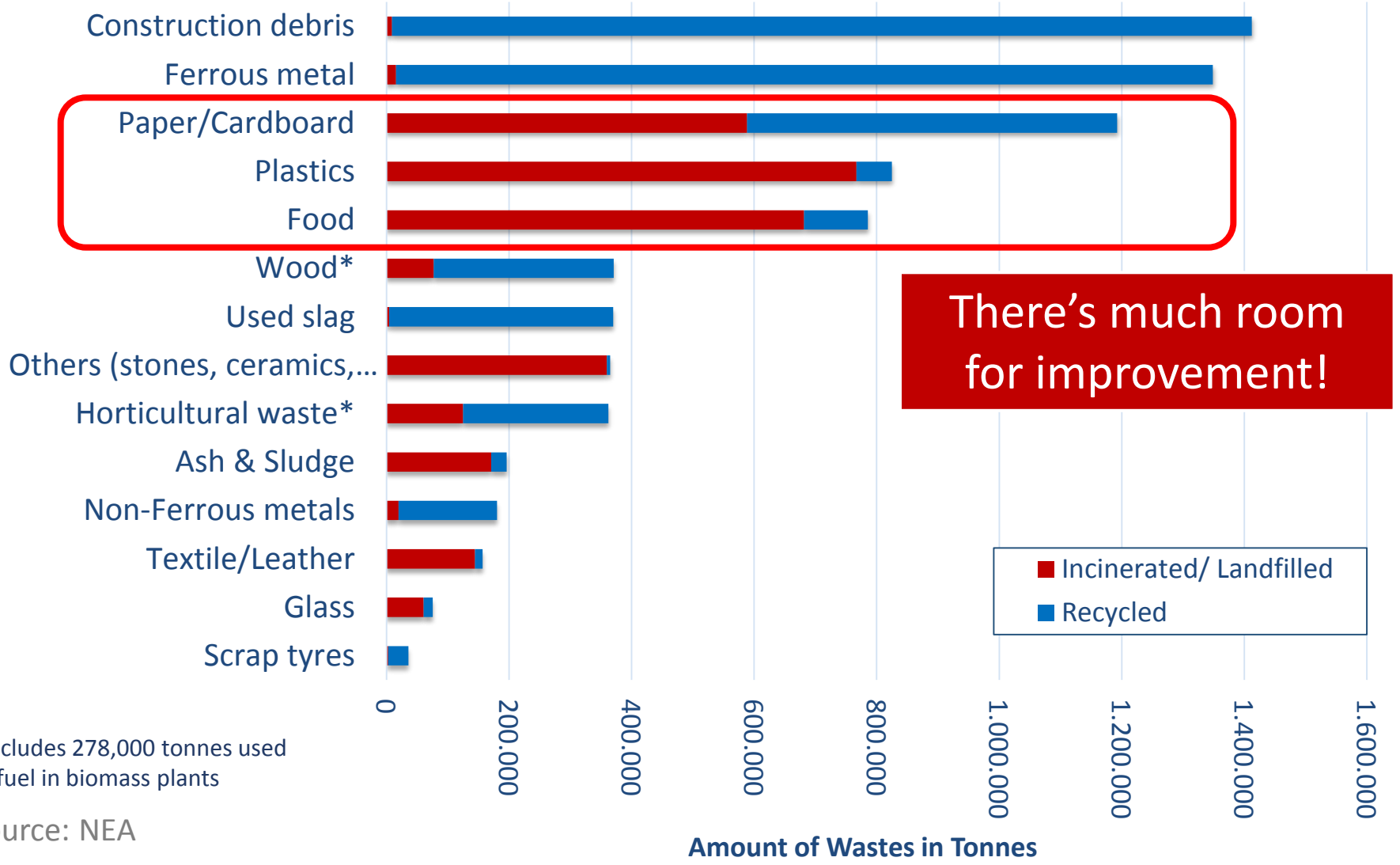


Relatively over the years, the recycling rate has increased…

but the overall amount of waste that is generated and goes to the incinerator has not improved that much.

Piya Kerdlap et al, A State-of-the-Art Review of Zero Waste Manufacturing Technologies for Enabling a Circular Economy in Singapore, Journal of Cleaner Production

Singapore Waste Statistics for 2015



*Includes 278,000 tonnes used as fuel in biomass plants

Source: NEA

e-waste generated per person

Hong Kong 21.7 kg

Singapore 19.5 kg

Japan 17.3 kg

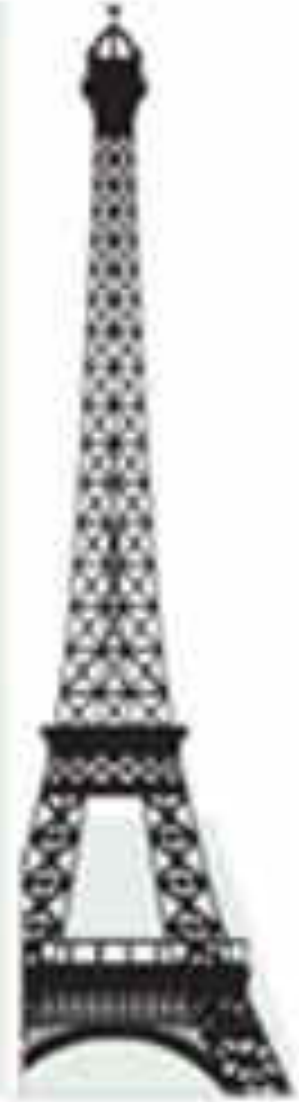
South Korea 15.9 kg

https://www.straitstimes.com/singapore/environment/singapores-mountain-of-e-waste

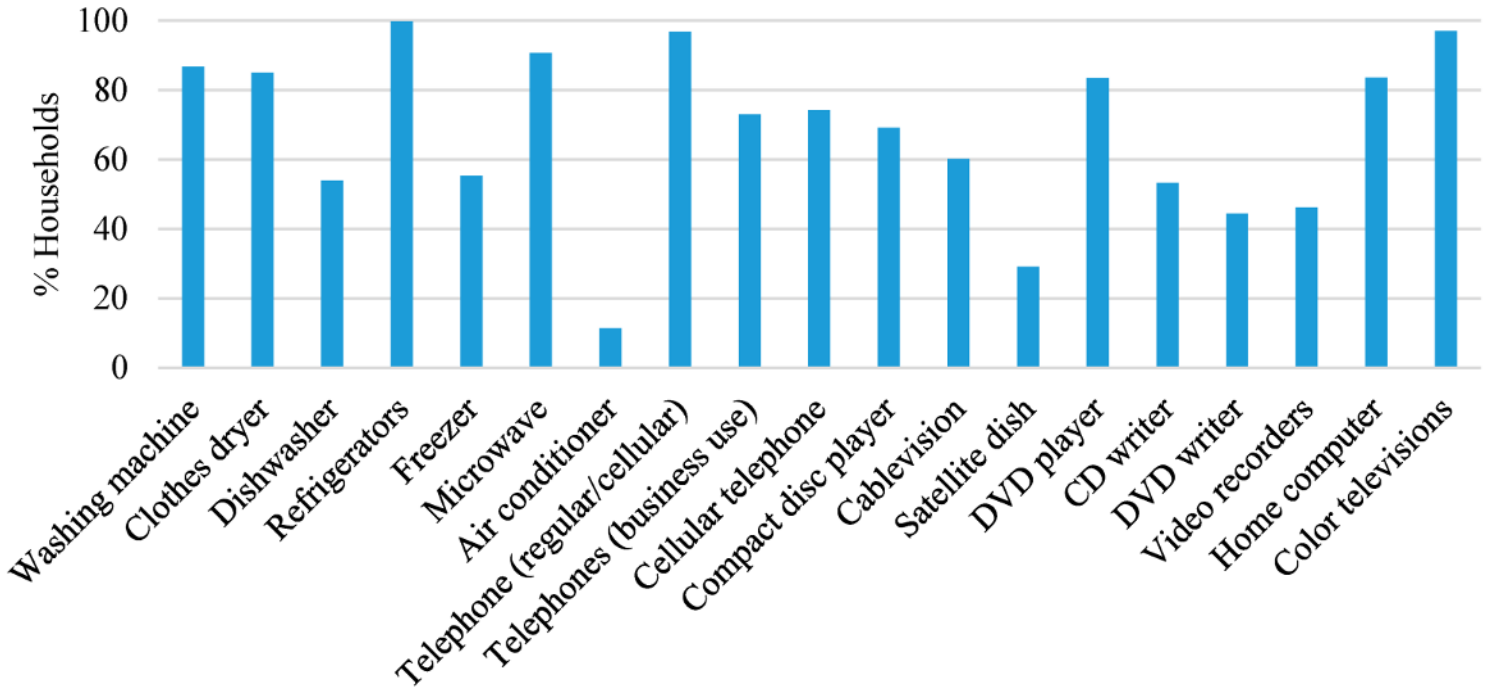
In 2016, **44.7** million metric tonnes of e-waste were generated.

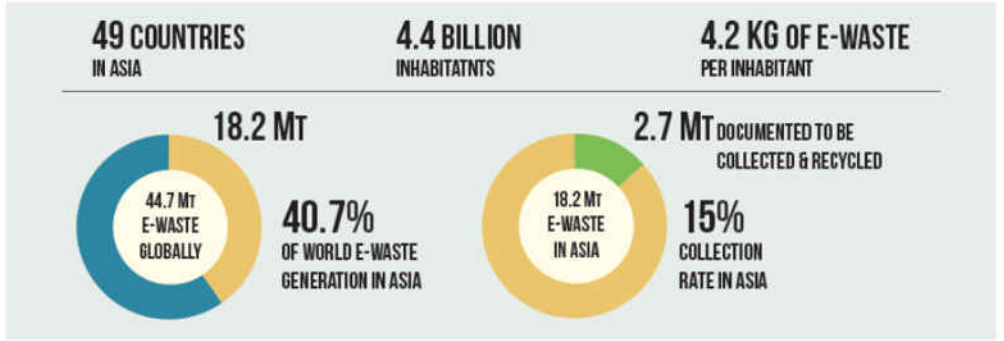
This is an equivalent of almost

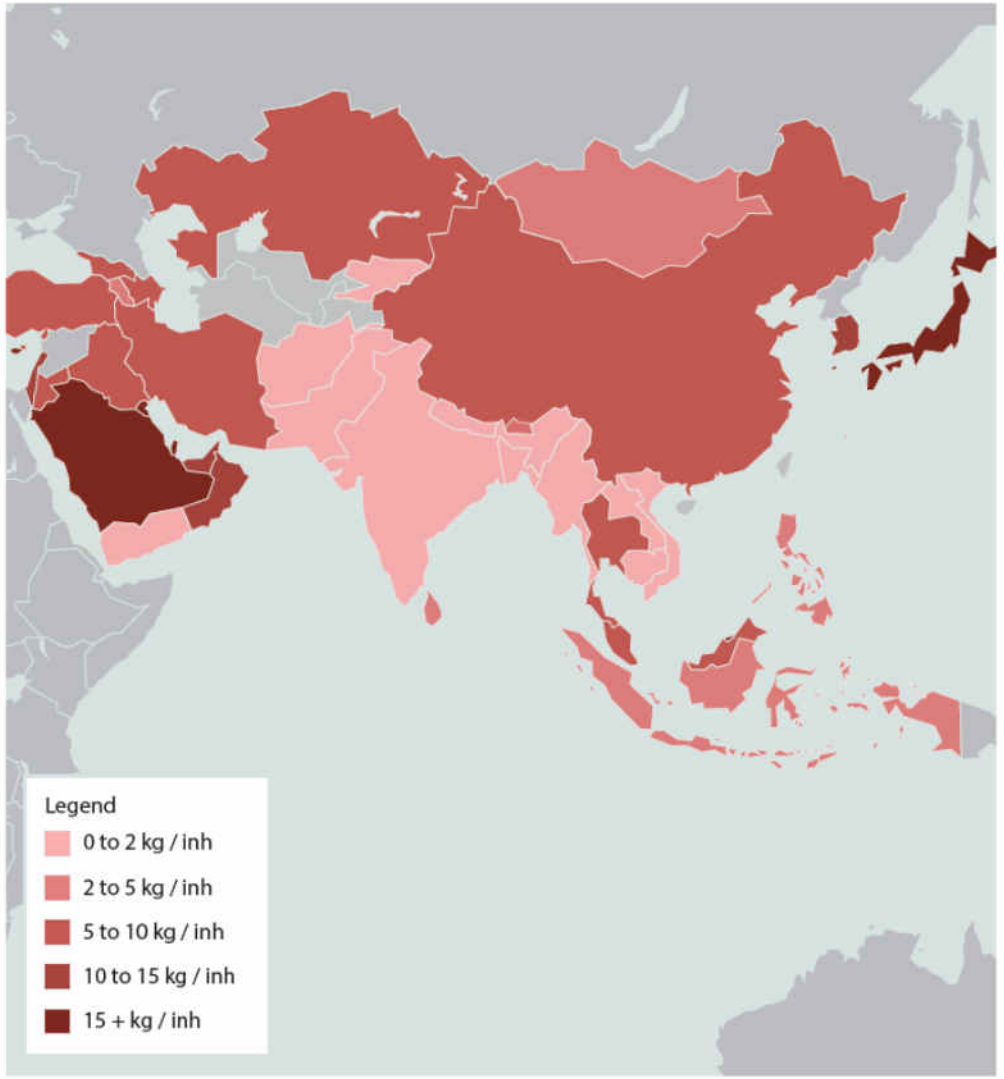
4,500 Eiffel towers.



UN statistics compare e-waste per inhabitant for countries in Asia







http://www.mdpi.com/2079-9276/5/4/35/htm

What happens to e-waste in Singapore

- A 2017 global report estimates that the world generated 44.7 million tonnes of e-waste in 2016 – equal in weight to almost

9 Great Pyramids of Giza.

Singapore

- About **60,000**

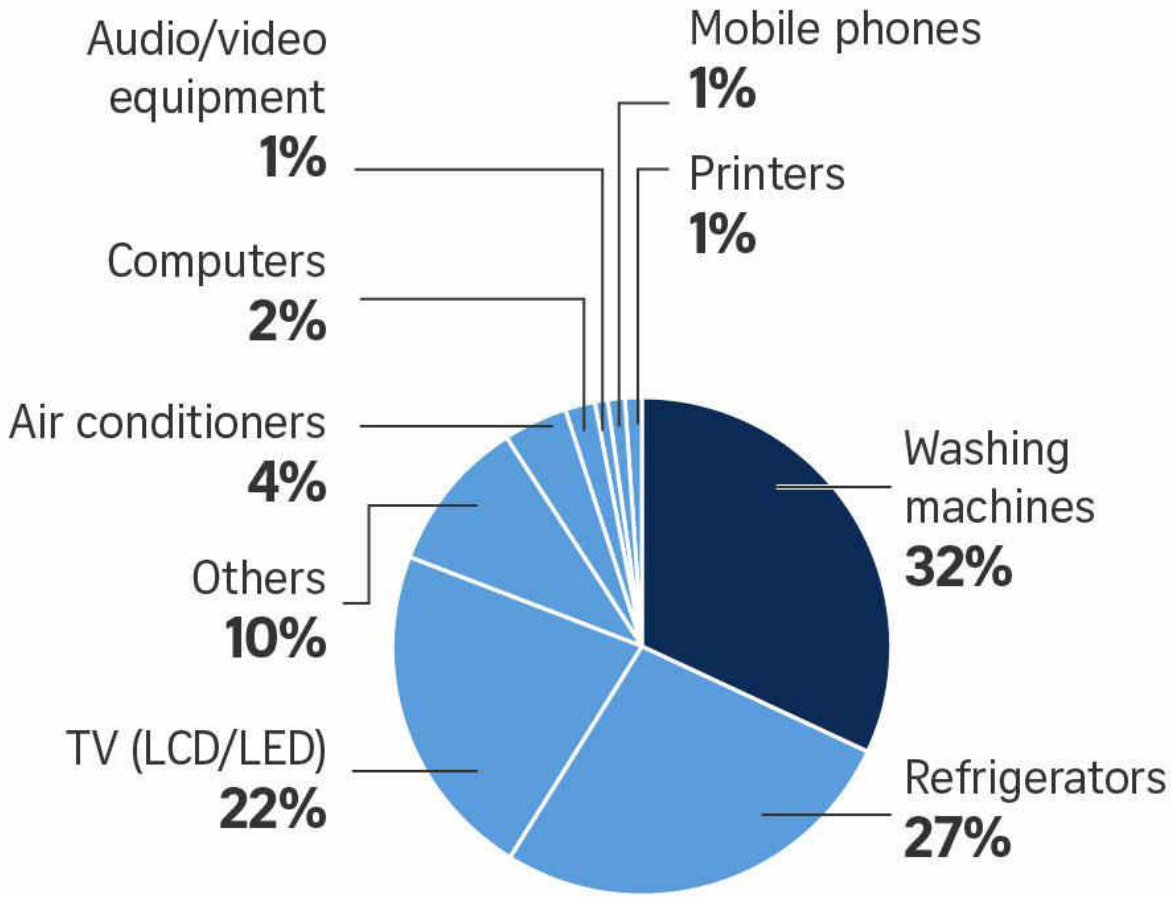
tonnes of e-waste are generated a year. This is equivalent to the weight of

220 Airbus A380 airplanes.

- About **11kg**

of e-waste – equal in weight to 73 mobile phones – is discarded by each person a year.

Types of e-waste (by weight)



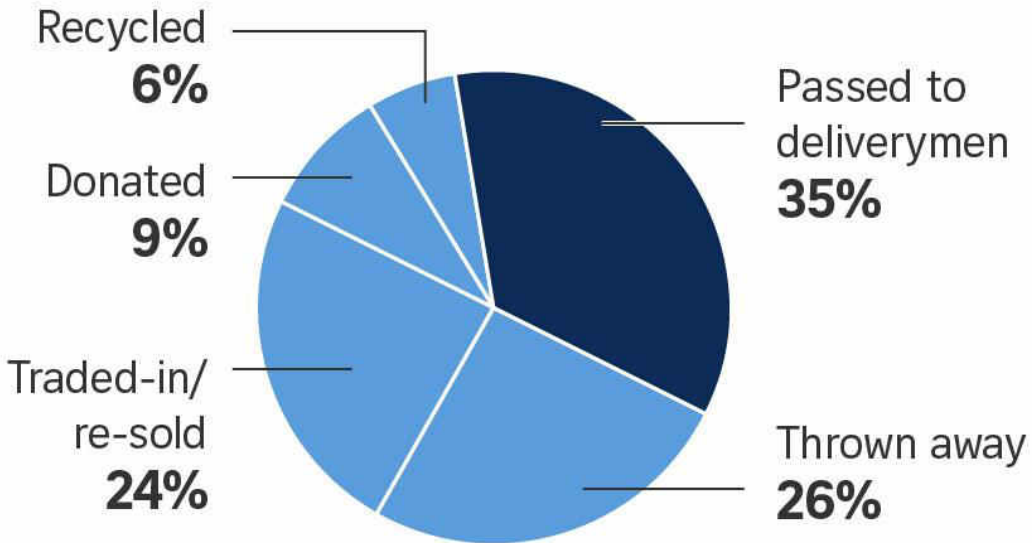
AN NEA SURVEY FOUND 60% OF CONSUMERS SAID THEY DON'T KNOW OR ARE UNSURE OF HOW TO RECYCLE THEIR E-WASTE. E-WASTE IS NORMALLY:

AN NEA SURVEY FOUND 60% OF CONSUMERS SAID THEY DON'T KNOW OR ARE UNSURE OF HOW TO RECYCLE THEIR E-WASTE. E-WASTE IS NORMALLY:

- **Traded-in/ re-sold**
- **Thrown away**
- **Passed to deliverymen**

Public education is important

Disposal pattern (by weight)



CHANNELLING E-WASTE TO REPUTABLE E-WASTE RECYCLERS WILL BENEFIT THE ENVIRONMENT AND THE PUBLIC, AS THIS:

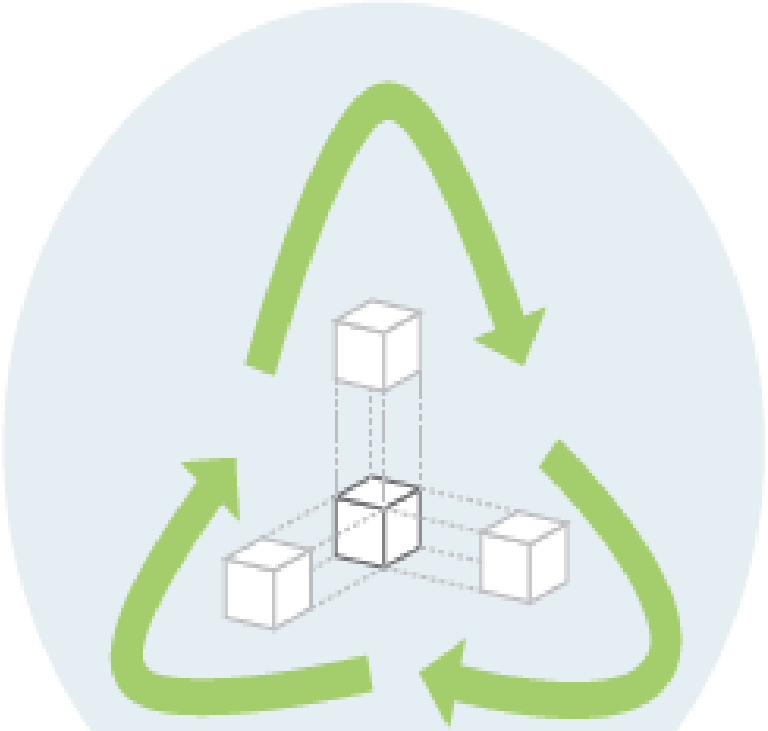
- Keeps valuable resources out of the waste of the stream.
- Conserves our planet's finite resources.
- Ensures harmful substances are not released into the environment.
- Grows our green economy and local employment opportunities.
- Helps fight climate change.
- Reduces strain on Singapore's waste disposal facilities and frees up land for better quality of life for residents.

Source: NATIONAL ENVIRONMENT AGENCY
STRAITS TIMES GRAPHICS

NEA to introduce Extended Producers Responsibility (EPR) regulations by 2021. EPR will compel producers of electrical and electronic equipment to ensure their used products are collected and recycled or disposed in environmentally responsible ways.

Circular Economy requires a balance between the Government, businesses and the public.

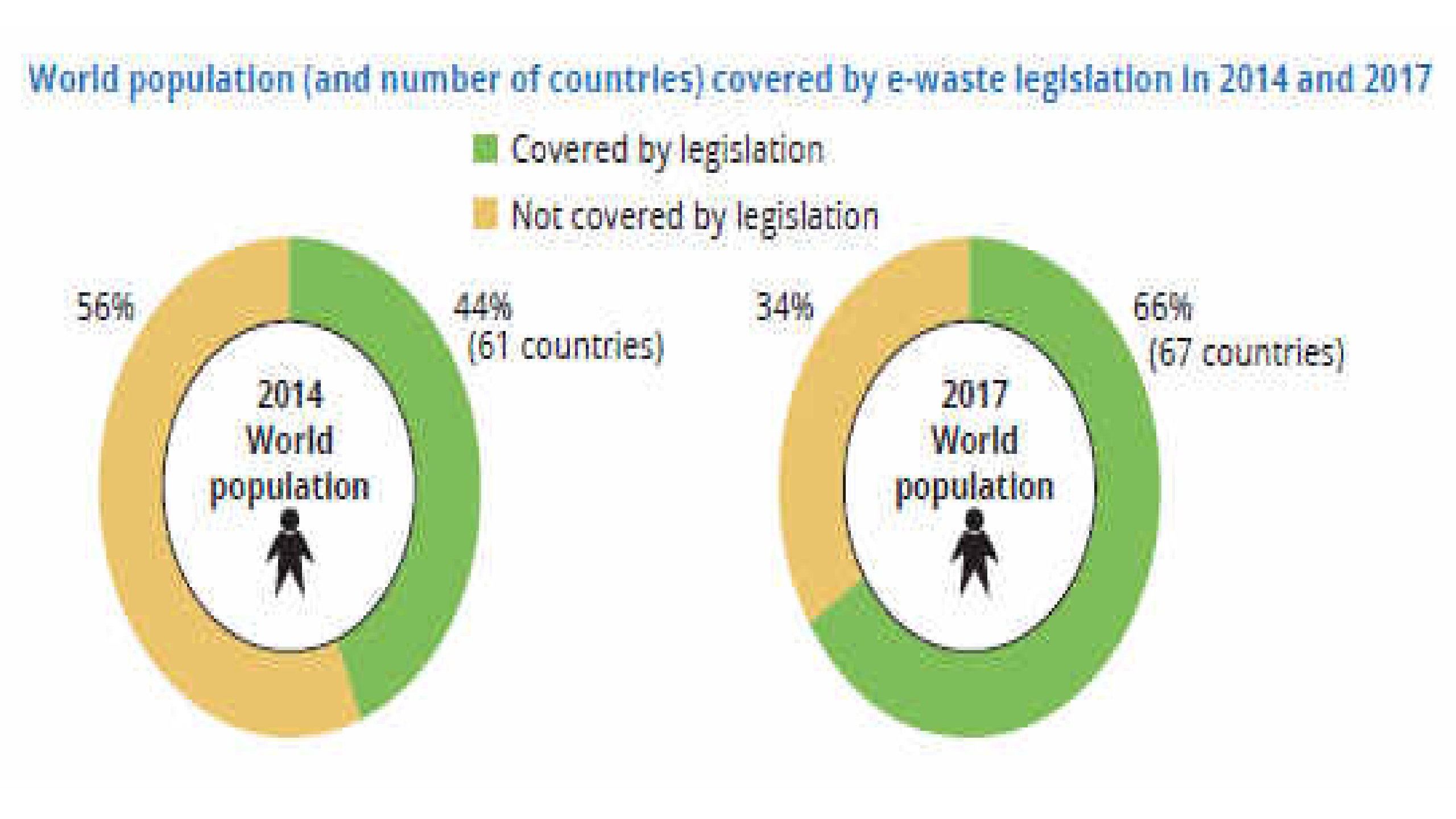
Illustration 8.1: The primary objectives of the EPR principle



Improve design

Achieve high utilization rate

Collection, treatment, reuse & recycling

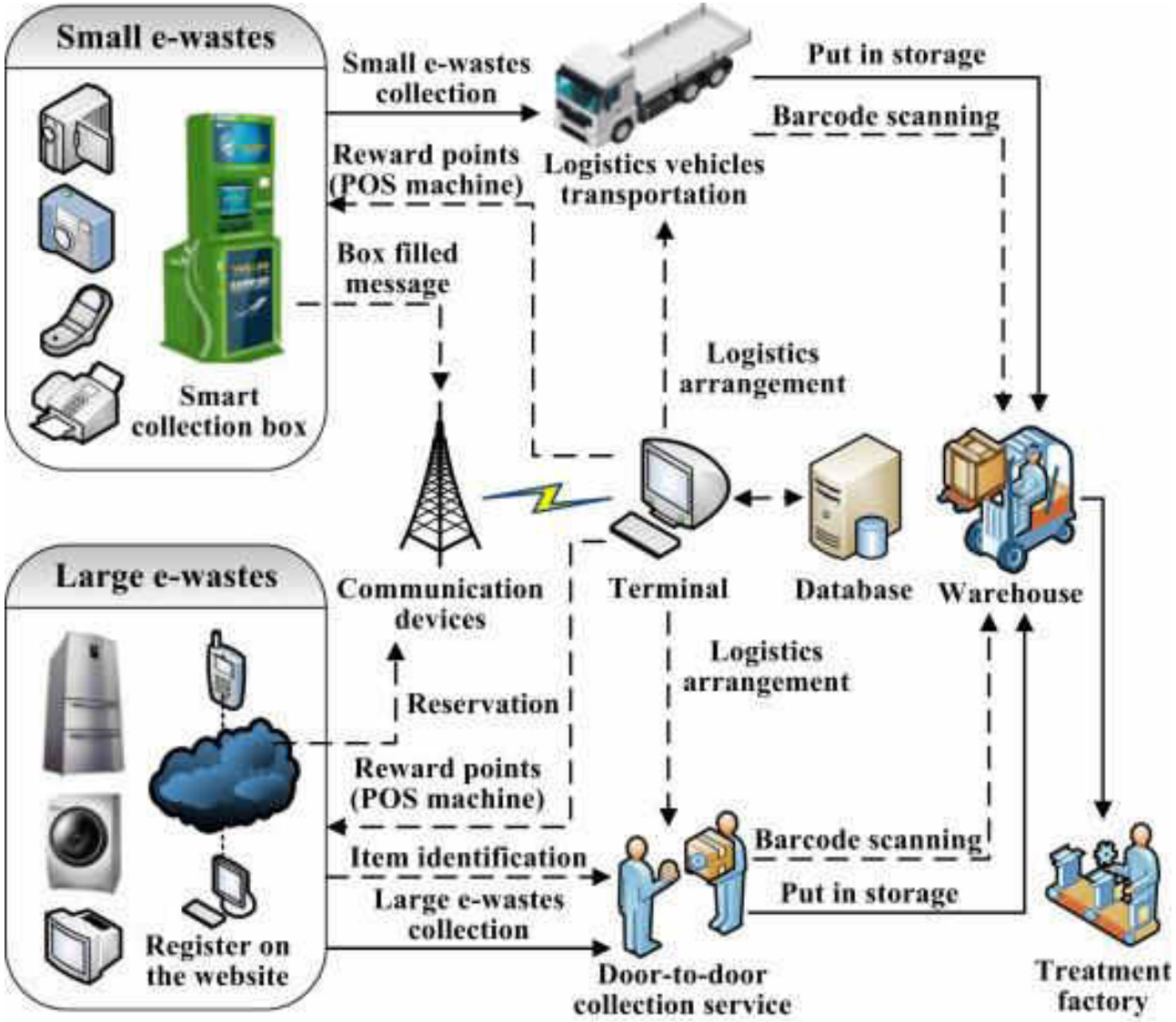

World population (and number of countries) covered by e-waste legislation in 2014 and 2017
Covered by legislation
Not covered by legislation
56%
44%
(61 countries)
2014
World
population
34%
66%
(67 countries)
2017
World
population

Circular Economy

- **Extended Producers Responsibility**
- **Designing products for circular economy as opposed to built in obsolescence**
- **Urban mining**

Circular Economy

- **Extended Producers Responsibility**
  - ✓ **Automation and Robotics**
  - ✓ **Sensors & IoT**
  - ✓ **Data Analytics, AI**



https://doi.org/10.1016/j.rser.2016.04.078

https://waste-management-world.com/a/rise-of-the-machines-why-robots-will-transform-waste-sorting-methods

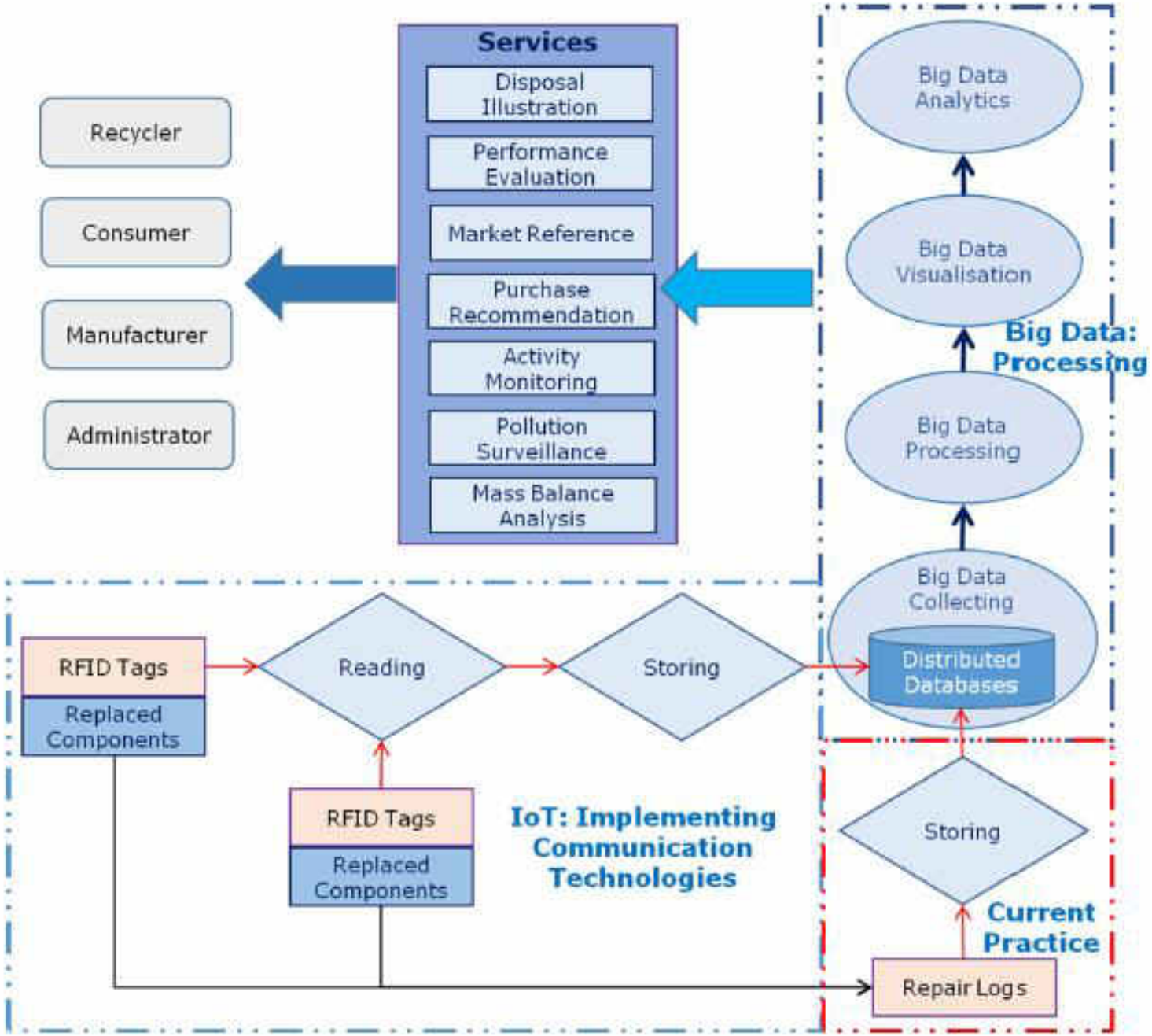


Fig. 4. The scenario of implementing the IoT and the Big Data technologies in monitoring the repair activities.

F. Gu et al. / Waste Management 68 (2017) 434–448

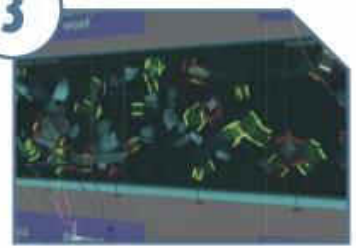
1

ZRR Sensor unit scans the waste stream.

2

ZenRobotics Brain control software analyses data and controls the robots.

3



ZenRobotics Brain identifies materials, objects and gripping points.

4

ZenRobotics Smart Gripper picks the desired objects.

5

Robots sort multiple fractions in one spot.

https://cleantechnica.com/2016/07/27/welcome-robotics-waste-recycling-management/

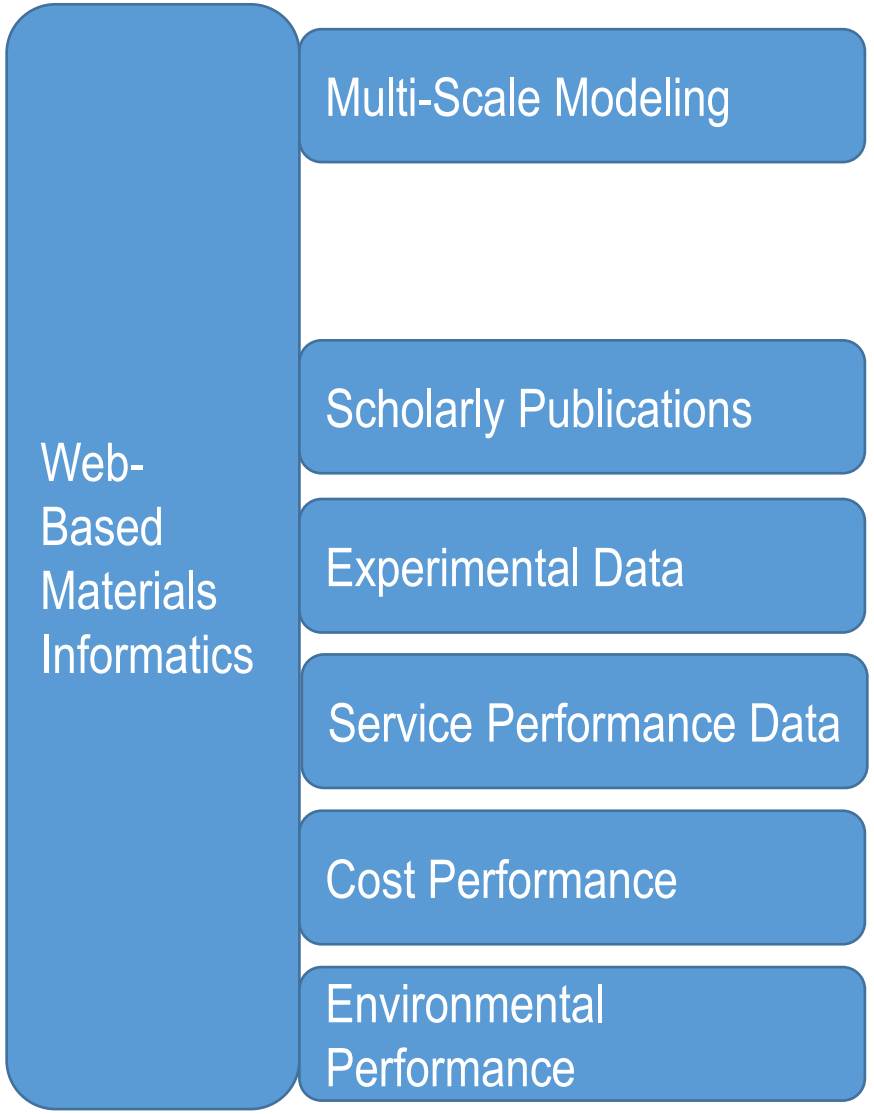
Circular Economy

- **Extended Producers Responsibility**

- **Designing products for circular economy**
  - ✓ Materials Informatics, Materials selection and substitution
  - ✓ Design products and processes by mimicking nature
  - ✓ Design for disassembly, recycling and waste reduction, and longevity of use

Materials Informatics employs digital technologies to accelerate materials, products and manufacturing innovations

- ❑ Microstructure Informatics
- ❑ Data Science and Analytics
- ❑ Data mining and quality
- ❑ Machine Learning/AI/Deep Learning
- ❑ Materials Knowledge Systems
- ❑ Cyberinfrastructure for materials data
- ❑ Spectral Methods for Microstructure-Property-Processing-Performance (s-p-p-p) Linkages
- ❑ Standards and codes
- ❑ E-collaboration networks



- ○ Density Functional Theory
- ○ Molecular Dynamics
- ○ Combinatorial materials science
- ○ Quantum Mechanics
- ○ Continuum Mechanics
- ○ Finite Element Modeling
- ○ Monte Carlo Model
- ○ Analytical Equations, theory
- ○ Empirical Equations

- ○ Life Cycle Cost, LCC
- ○ Life Cycle Assessment, LCA
- ○ Life Cycle Engineering, LCE

Seeram Ramakrishna et al (2017) Materials Informatics, Journal of Intelligent Manufacturing, https://doi.org/10.1007/s10845-018-1392-0

Designed for the Environment: Allbirds are machine washable and meant to be worn without socks. Made of a very fine merino wool.

allbirds

Allbirds founders Joey Zwillinger, left, and Tim Brown

The City as a Laboratory

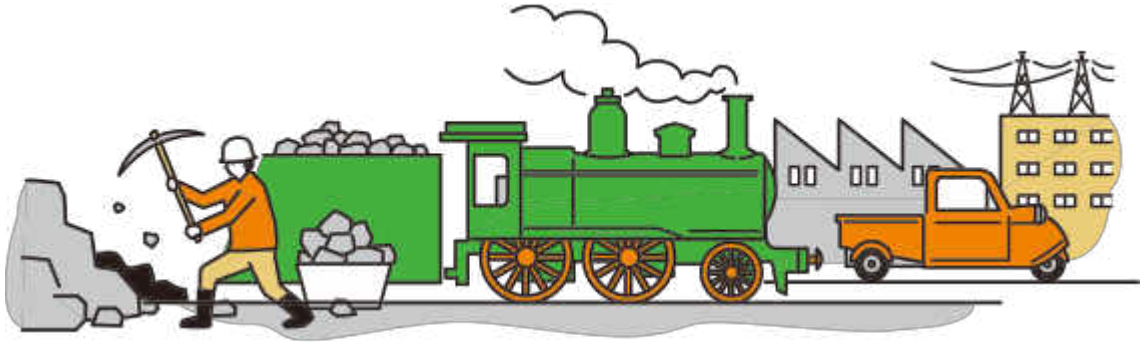
City-scale research and innovation for urban challenges

British
High Commission
Singapore

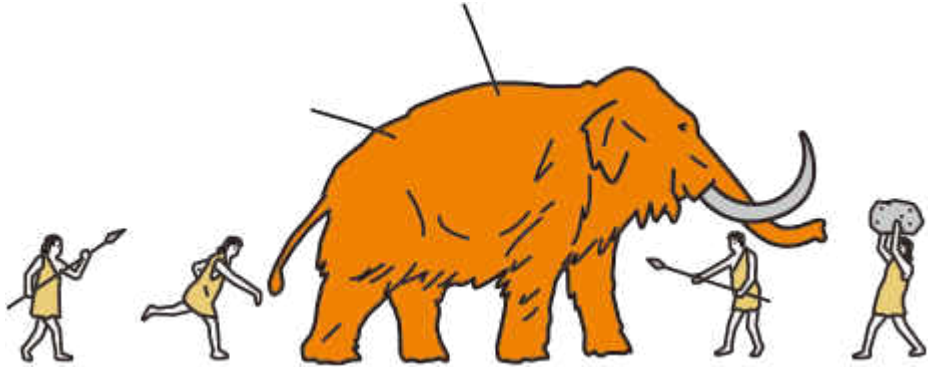
stella.toh@newcastle.ac.uk


70%
Percentage
of the world's
greenhouse-
gas emissions
that cities are
responsible for,
even though
they cover only
2% of the world's
land mass

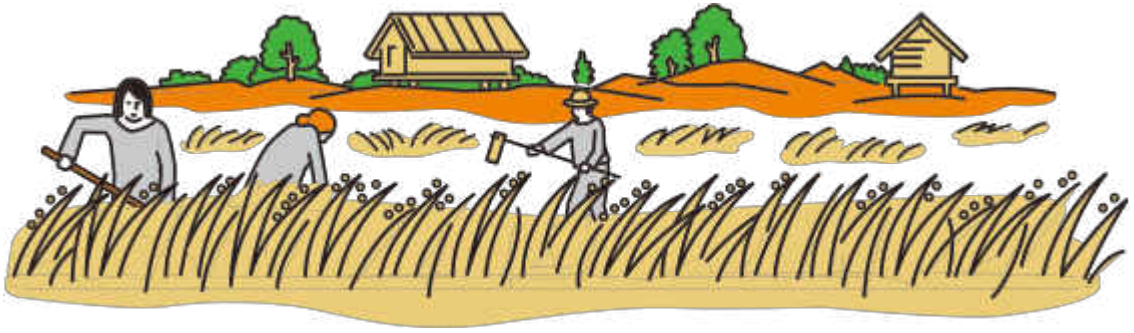
Information Society 4.0



Industrial Society 3.0



Hunter-gatherer Society 1.0

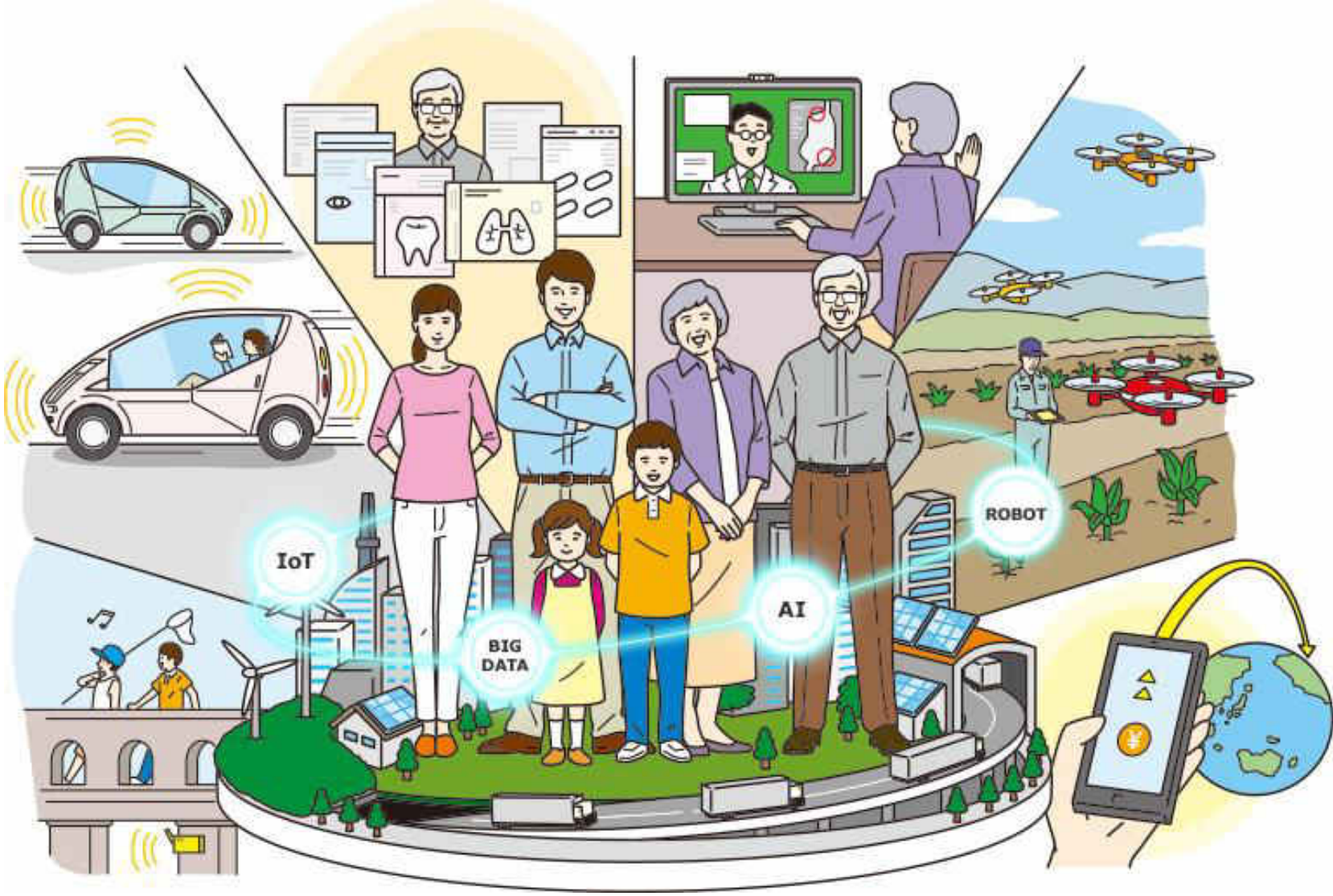


Agrarian Society 2.0

https://www.japan.go.jp/abenomics/productivity/society5_0/index.html

Society 5.0

Physical space and cyberspace to be seamlessly integrated into every aspect of life



https://www.japan.go.jp/abenomics/productivity/society5_0/index.html

Ban Single-use Plastic

BEAT PLASTIC POLLUTION | WORLD ENVIRONMENT DAY | UN environment

isha

RALLY FOR RIVERS
INDIA'S LIFELINES

NATIONAL POLICIES FOR CIRCULAR ECONOMY

- ✓ ban single use plastics
- ✓ encourage switching to new packaging materials with lowest carbon foot print
- ✓ restrict the use of hazardous substances in the products and processes
- ✓ product take back strategies to ensure successive lives

- **Set targets for waste collection and recycling rates**
- **Set targets for proportion of recycle materials content in new products**
- **Set targets for sustainable materials (& regenerative resources) content in products**
- **Set targets for lowering the carbon emissions per unit of manufacturing value add**

Circular Economy

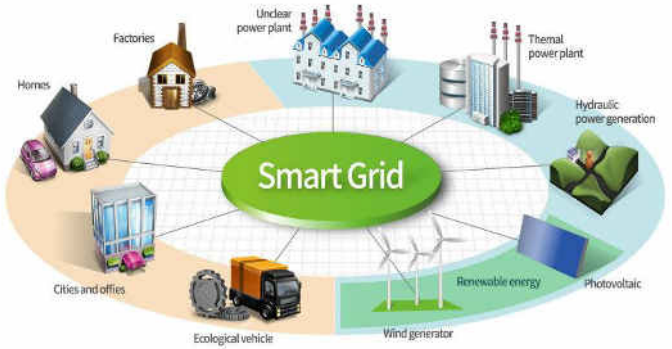
- Extended Producers Responsibility
- Designing products for circular economy

- Urban mining

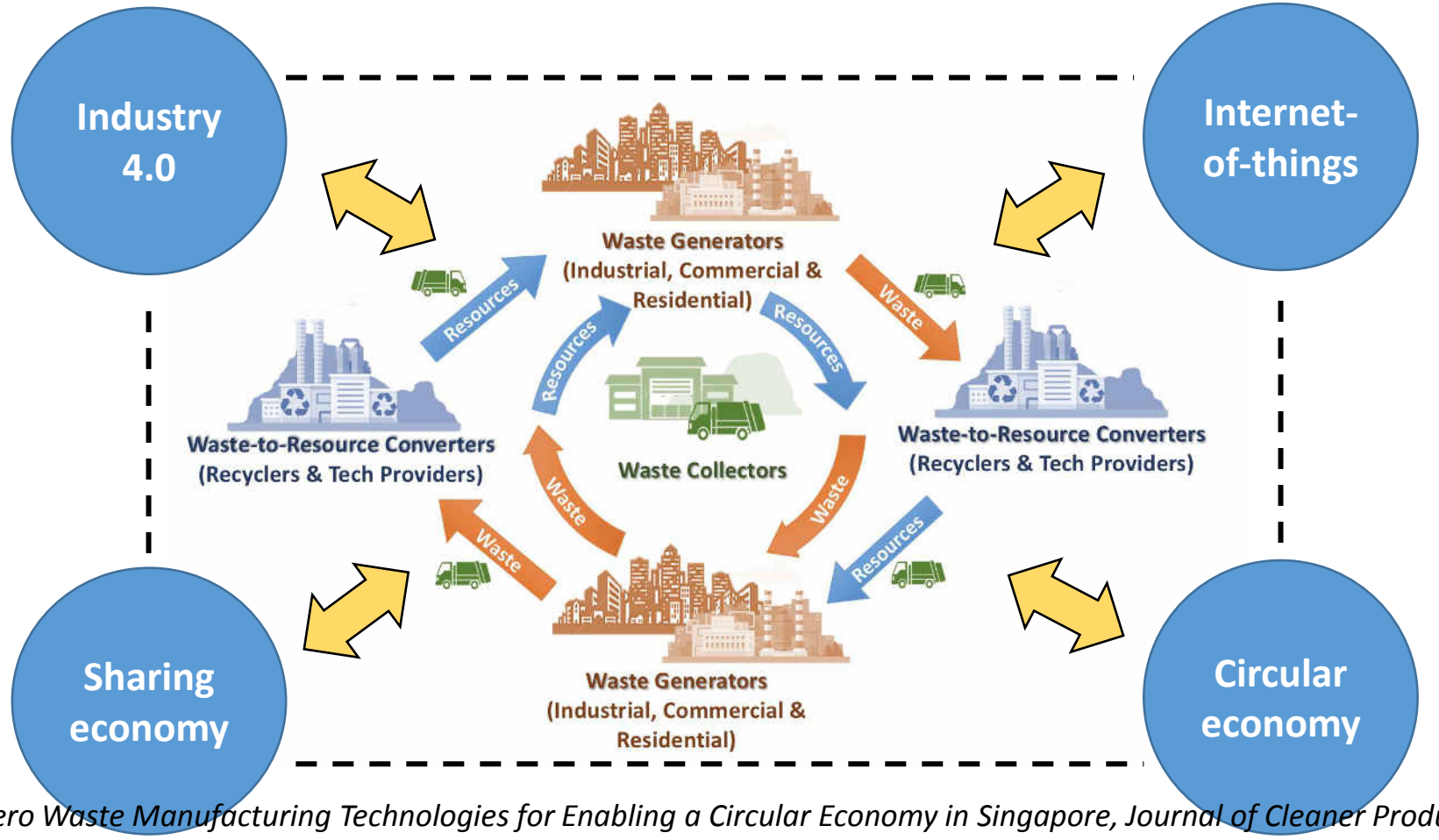
  - Environmentally benign processes

  - Industrial symbiosis

Circular Economy is in need of disruptive innovations and new business models



Wasted Food = Wasted Money & Nutrients



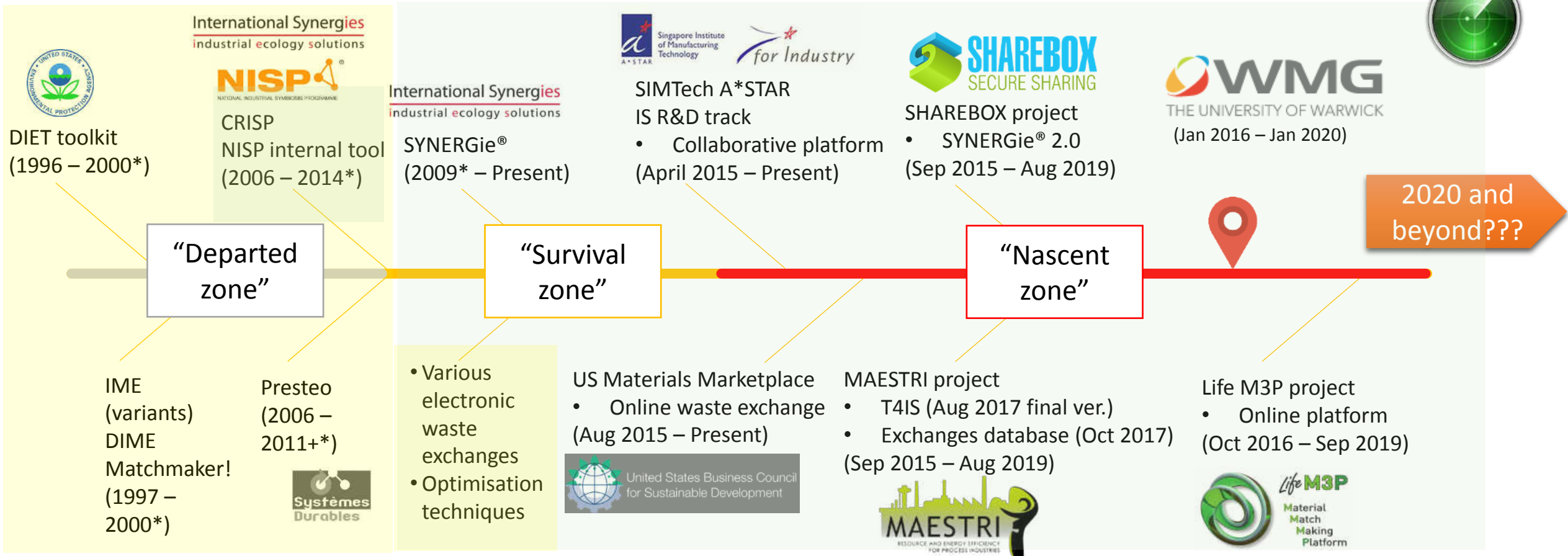
Piya Kerdlap et al, A State-of-the-Art Review of Zero Waste Manufacturing Technologies for Enabling a Circular Economy in Singapore, Journal of Cleaner Production

Circular Economy Disruptive Technologies

Theme	Waste generators	Waste collectors	Waste to resource converters
Design for zero waste	Additive manufacturing, products with modular designs	Products designed for disassembly that enable easy collection of components	Products that can be refurbished to increase chances for reuse or recover valuable parts and materials
Smart waste audit and reduction planning	Software for automated waste auditing and reporting processes	Digital tools for predicting composition and volume of waste generated to be collected	N/A
Smart waste collection	Smart bin technologies that monitor fill levels, composition of waste, and do onsite segregation	Software tools for efficient waste collection and management of waste collection assets (trucks)	N/A
High-value mixed waste processing	N/A	N/A	Industrialized segregation and sorting technologies at waste processing facilities
Collaborative platform for industrial symbiosis	Online network tools that connect waste producers with waste converters		
Waste to resource conversation and recycling	N/A	N/A	Remanufacturing, paper, plastic, e-waste recycling technologies, food waste to energy technologies

Piya Kerdlap et al, A State-of-the-Art Review of Zero Waste Manufacturing Technologies for Enabling a Circular Economy in Singapore, Journal of Cleaner Production

Collaborative Platform for Industrial Symbiosis



Source: Zhiquan Yeo, 2018

GAP: LIFE CYCLE IMPACT EVALUATION TOOL

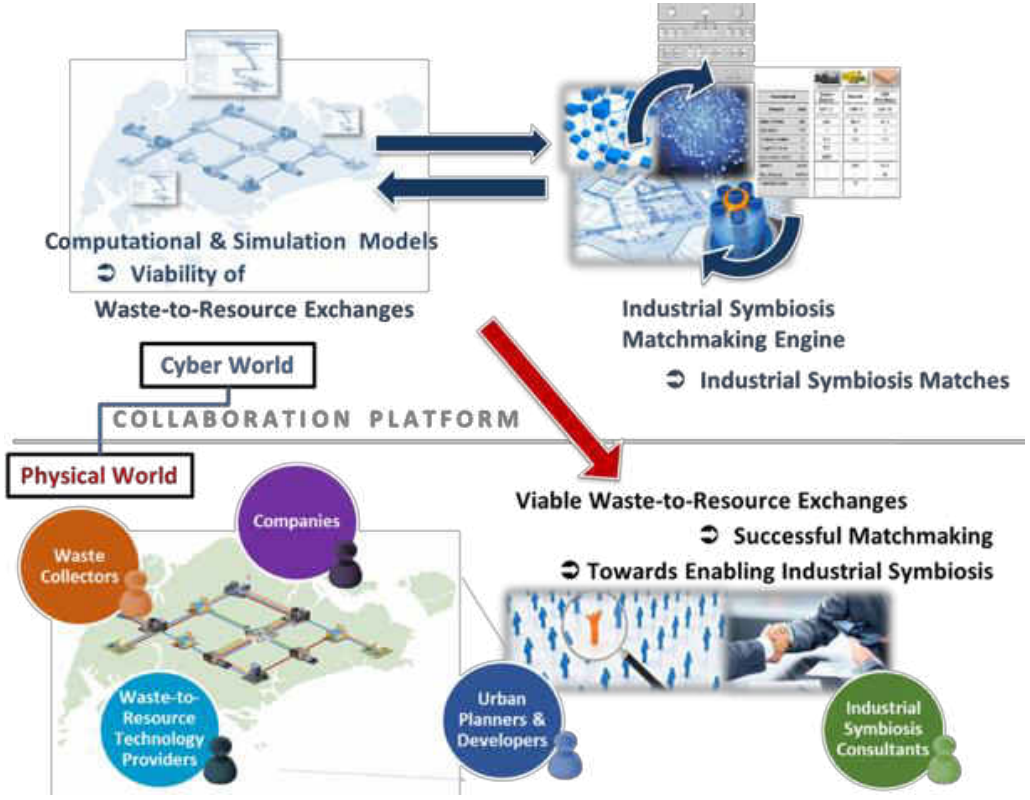
*approximate timeline

Note:
Ongoing projects have start and end dates
Current ongoing activities do not have end dates

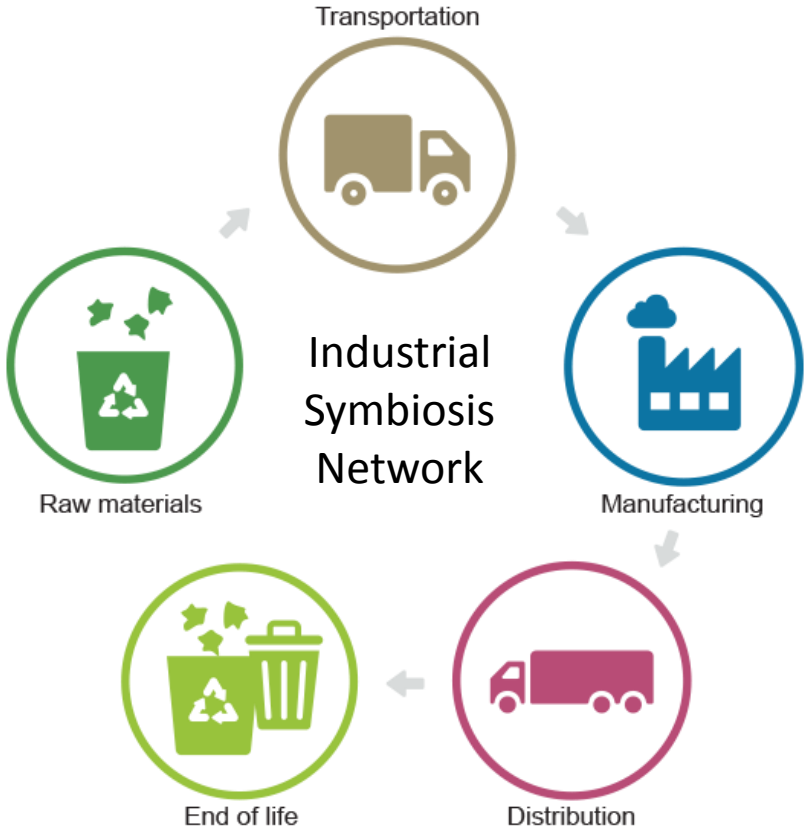
Piya Kerdlap et al, A State-of-the-Art Review of Zero Waste Manufacturing Technologies for Enabling a Circular Economy in Singapore, Journal of Cleaner Production

Integration of platforms

Waste-to-Resource Matching Platform



Life Cycle Analysis Engine



Piya Kerdlap et al, A State-of-the-Art Review of Zero Waste Manufacturing Technologies for Enabling a Circular Economy in Singapore, Journal of Cleaner Production

Summary

- Singapore committed to reduce carbon emissions by 36 percent from 2005 levels by 2030
- Singapore envisions its future as a zero waste nation. This implies that every person, family, precinct, industry, business and service is rooted with circular culture.
- Thus implying all forms of resources including water, energy and materials are recovered and reused repeatedly. New economy is as waste free as possible with lowest carbon footprint.
- Circular Singapore underpins the transition from the safest, efficient and prosperous city to smart, healthy and livable city.
- **Singapore to invest in long-term breakthrough research in addition to supporting test bedding opportunities for innovative solutions**.

How can Disruptive Technologies drive a circular economy in a sustainable future?

	Industry 4.0	Circular Economy	Environment
Pollution control (Transportation)	Data Analytics, IoT, AI	Efficient Supply chain	Lower emissions
Plastics (& Bio-based substitutes)	Knowledge Platform	Waste to Resource	Lower waste disposal
Wood and Paper	Knowledge Platform	Waste to Resource	Lower waste disposal
Construction materials	3D Printing, Nanotech	Waste to Resource	Lower carbon foot print
Water	IoT, Data Analytics	Waste water reuse	Energy efficient
Solid waste	Data Analytics	Waste to Resource	Lower waste disposal
Clean energy gen, storage, supply	IoT, AI, Data Analytics	Lower consumption	Lower energy losses
Energy efficiency (processes, systems, etc.)	Real Time Monitoring	Lower consumption	Lower energy losses
Food (& faux meat)	Data Analytics	Waste to Resource	Lower wastage
Agriculture, Urban Farmed Products	Data Analytics	Efficient Supply chain	Lower pollution
Beverages	Data Analytics	Waste to Resource	Lower wastage
Textiles (wearables, biotech leather, etc.)	Data Analytics	Waste to Resource	Lower pollution
Services	AI, Data Analytics	Efficient delivery	Lower pollution
Value chains, material flows, and products	AI, Data Analytics	Efficient delivery	Lower pollution
Electricals & Electronics	Knowledge Platform	Product re-routing	Co2 savings

CleanEnviro Summit Singapore

Transforming Tomorrow's Cities with Clean Environment Solutions

6–12 July 2018 | Sands Expo & Convention Centre | Marina Bay Sands, Singapore

www.cleanenvirosummit.sg

https://www.cleanenvirosummit.sg/programme/clean-environment-leaders-sum

Clean Environment Leaders Summit (CELS)
Leaders-Experts Forum (LEF)
Clean Environment Convention (CEC)
Clean Environment Regulators Roundtable (CERR)
Business Forums
- E-Waste Business Forum
- TWRP-IWMF Forum

Site Visits
NEA Innovation Pavilion
Co-located Events

safeguard both public health and the environment? How can policy makers put in place citizen-centric environmental solutions for a sustainable future? Howcan governments and companies nudge individuals and businesses to cultivate environmental stewardship?

Panellists

Dr Amy Khor
Senior Minister of State, Ministry of Health and Ministry of the Environment and Water Resources, Singapore

Ms Kristalina Georgieva
CEO, World Bank

Dr Walter R. Stahel
Founder-Director,
Product-Life Institute, Geneva

Mr James Shaw
Minister for Climate Change, New Zealand

Dr Marcus Gover
Chief Executive Officer,
WRAP UK

Professor Seeram Ramakrishna
Chair, Circular Economy Taskforce,
National University of Singapore
Moderator

Session 2: Business Innovation, Models, Best Practices
10 July 2018
10.30am – 11.45am

Panel Discussion: Innovative business concepts in pursuit of environment sustainability
How can innovative business concepts contribute to environment sustainability and yet provide a competitive advantage? How can businesses develop resource efficiency and engage in ethical consumption?

Let us hope for the better future

https://www.telegraph.co.uk/film/wall-e/review/