RE-INVENTING THE WASTE SUPPLY CHAIN ACCORDING TO CLIMATE CRISIS

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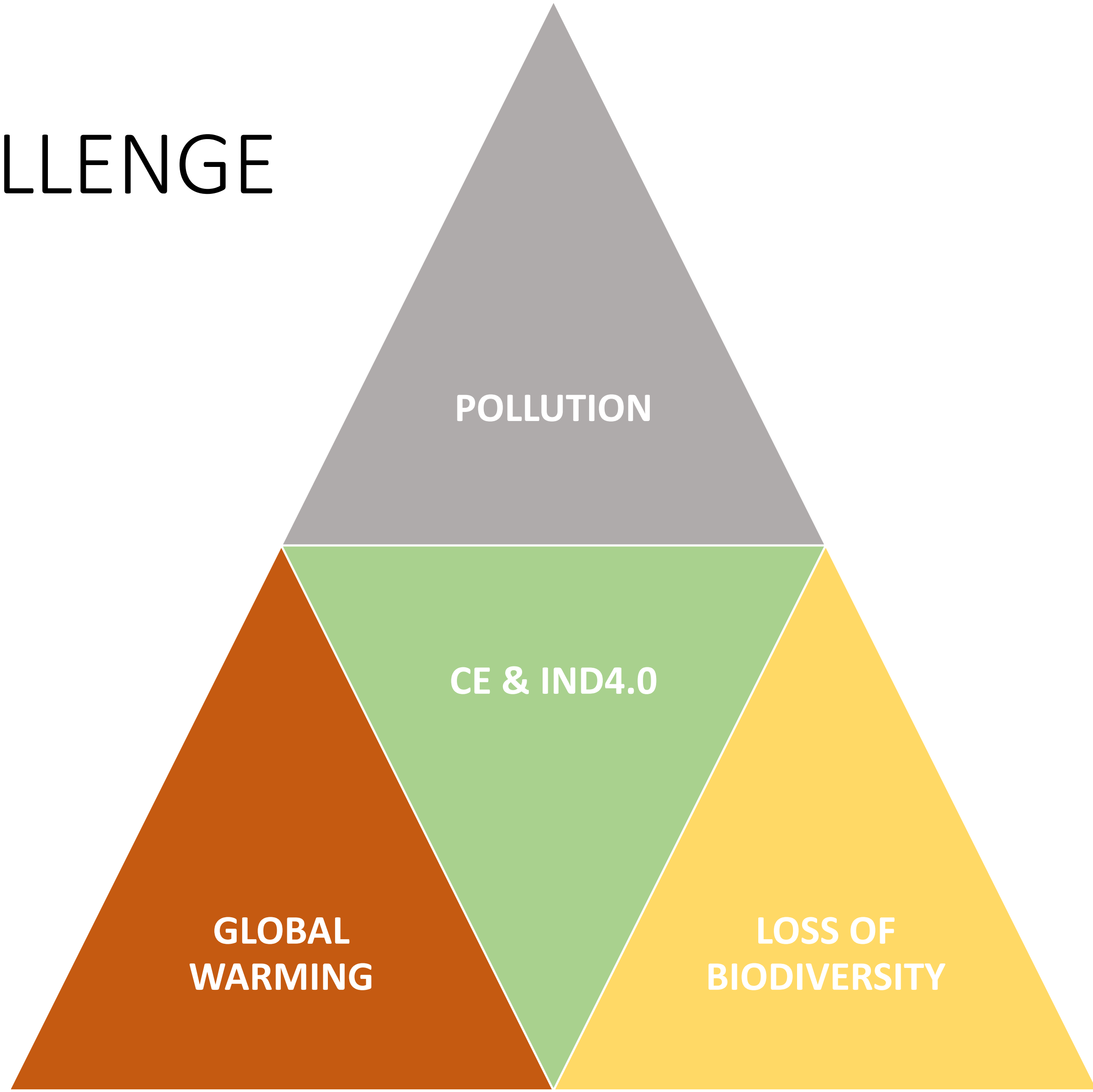
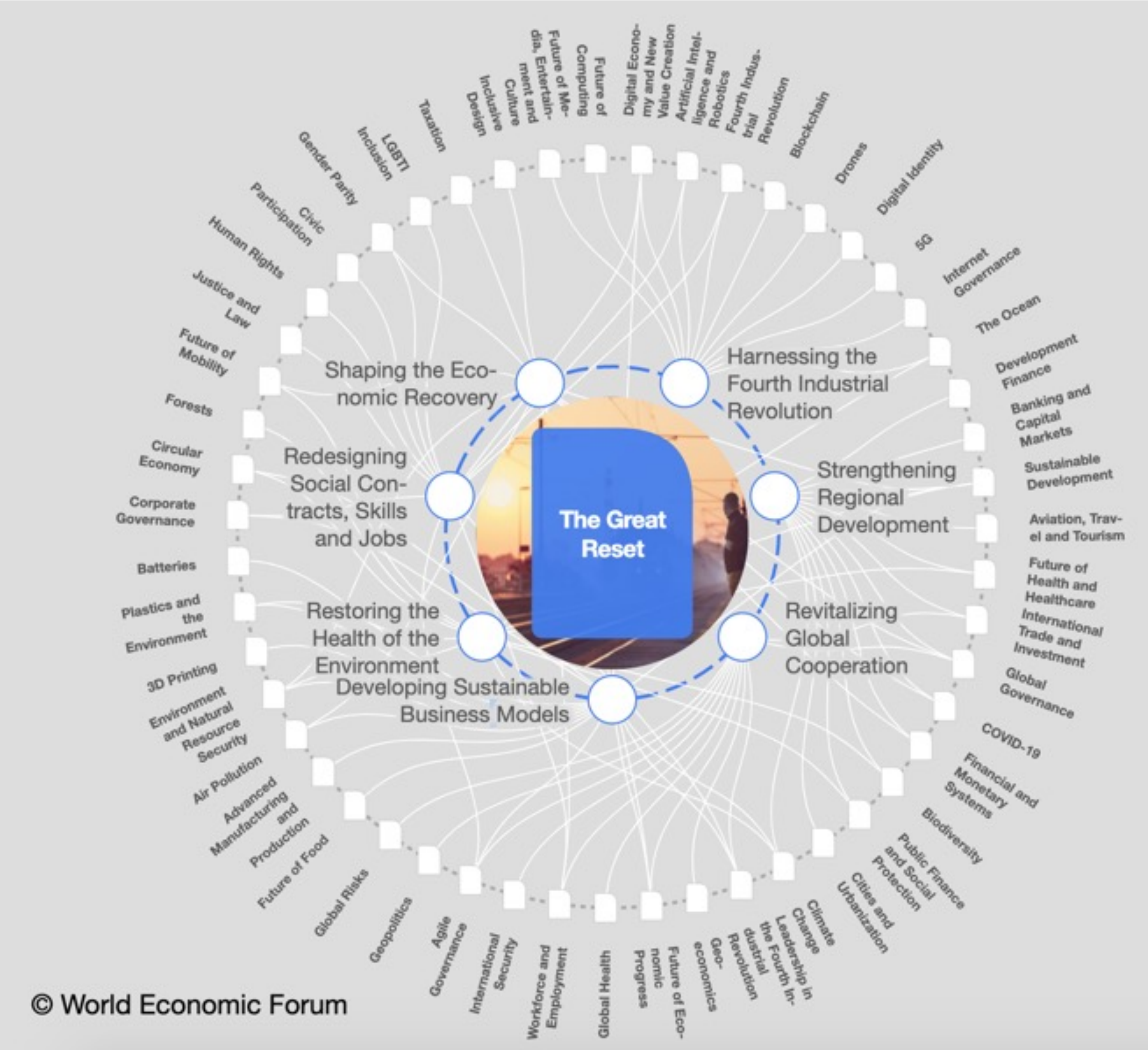
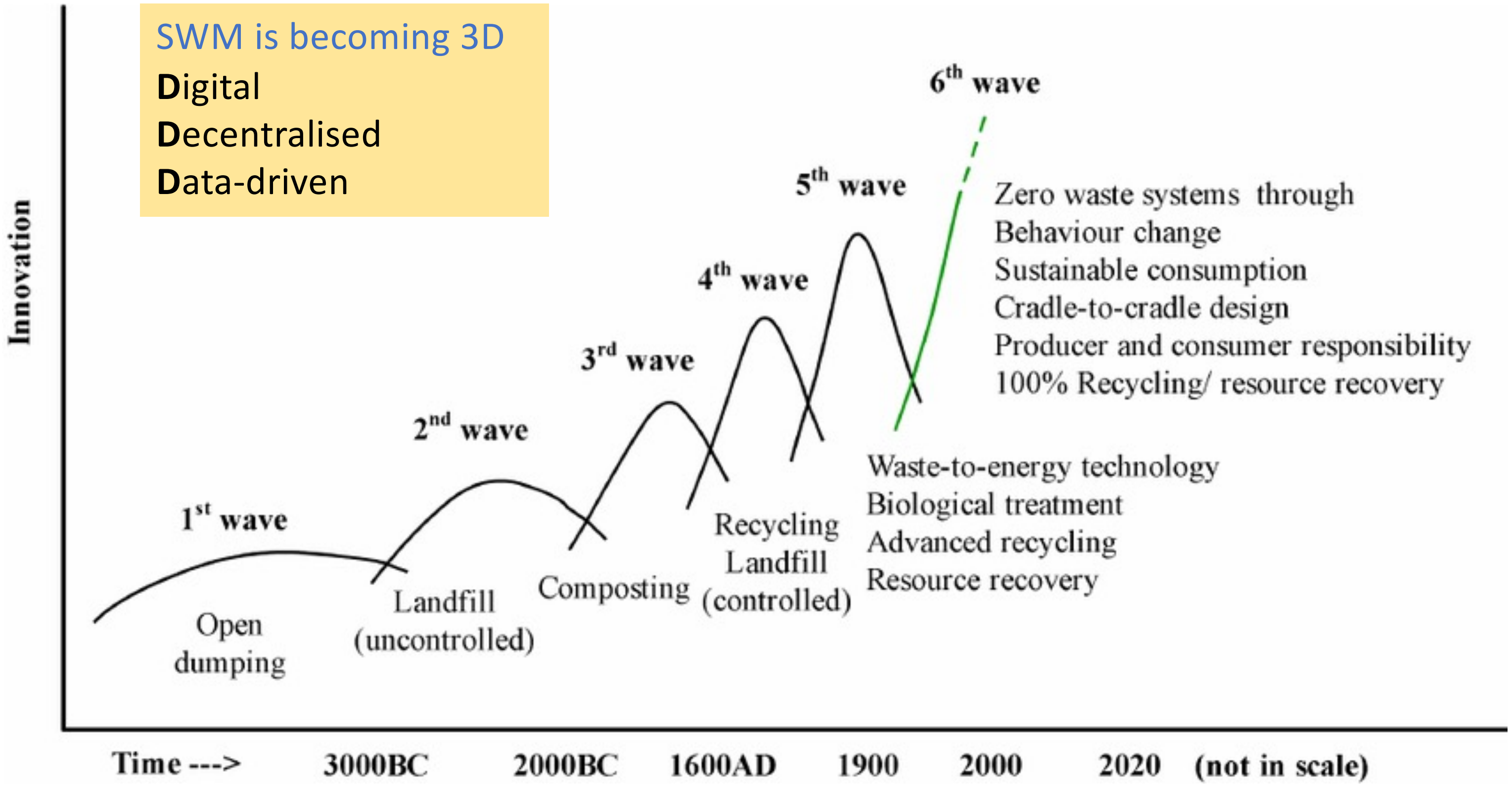
A TRIPLE CHALLENGE





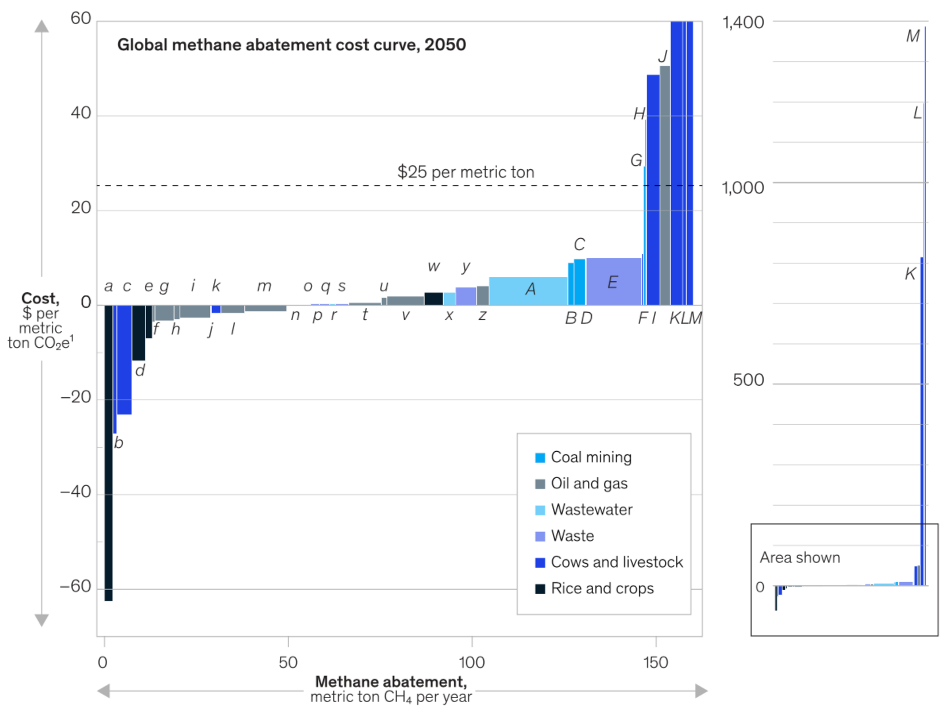
The Great Reset

The evolution of waste management



Source: Zaman & Lehman, Challenges and Opportunities in Transforing a City into a "Zero Waste City", Challenges **2011**, 2, 73-93; doi:10.3390/challe2040073

About 90 percent of methane emissions tracking to these levers could be abated at a cost of less than $25 per metric ton of CO_2e, according to our analysis.



Global methane abatement cost, 2050, $ per metric ton CO_2e[1]

a. Dry direct seeding	−$62	n. Genetic selection and breeding	$0	A. New treatment connection	$6
b. Anaerobic manure digestion	−$27	o. Varietal rice selection	$0	B. Coal methane to flare	$9
c. Animal health monitoring	−$23	p. Landfill gas to feedstock	<$1	C. Coal methane to heat	$10
d. Rice paddy water management	−$12	q. Landfill gas to power	<$1	D. Coal methane to power	$10
e. Straw management in rice	−$7	r. Operational improvement	<$1	E. Mechanical biological treatment	$10
f. Blowdown capture	−$3	s. Landfill gas to flare	<$1	F. Plug flow digestors	$11
g. Replace pumps	−$3	t. Downstream leak detection and repair	<$1	G. Coal methane to feedstock	$29
h. Replace compressor seal or rod	−$3	u. Early replacement of devices	$2	H. Small scale dome digestors	$39
i. Replace with instrument air systems	−$3	v. Replace with electric motor	$2	I. Animal feed-mix optimization	$49
j. Install plunger	−$2	w. Sulfate fertilizers	$3	J. Other	$50
k. Feed grain processing	−$2	x. Advanced technologies	$3	K. Animal feed additives	$88
l. Vapour recovery units	−$2	y. Composting	$4	L. Covered lagoon and anaerobic digesters	$205
m. Upstream leak detection and repair	−$1	z. Install flares	$4	M. Animal growth promoters	$1378

CLIMATE CHANGE & WASTE MANAGEMENT

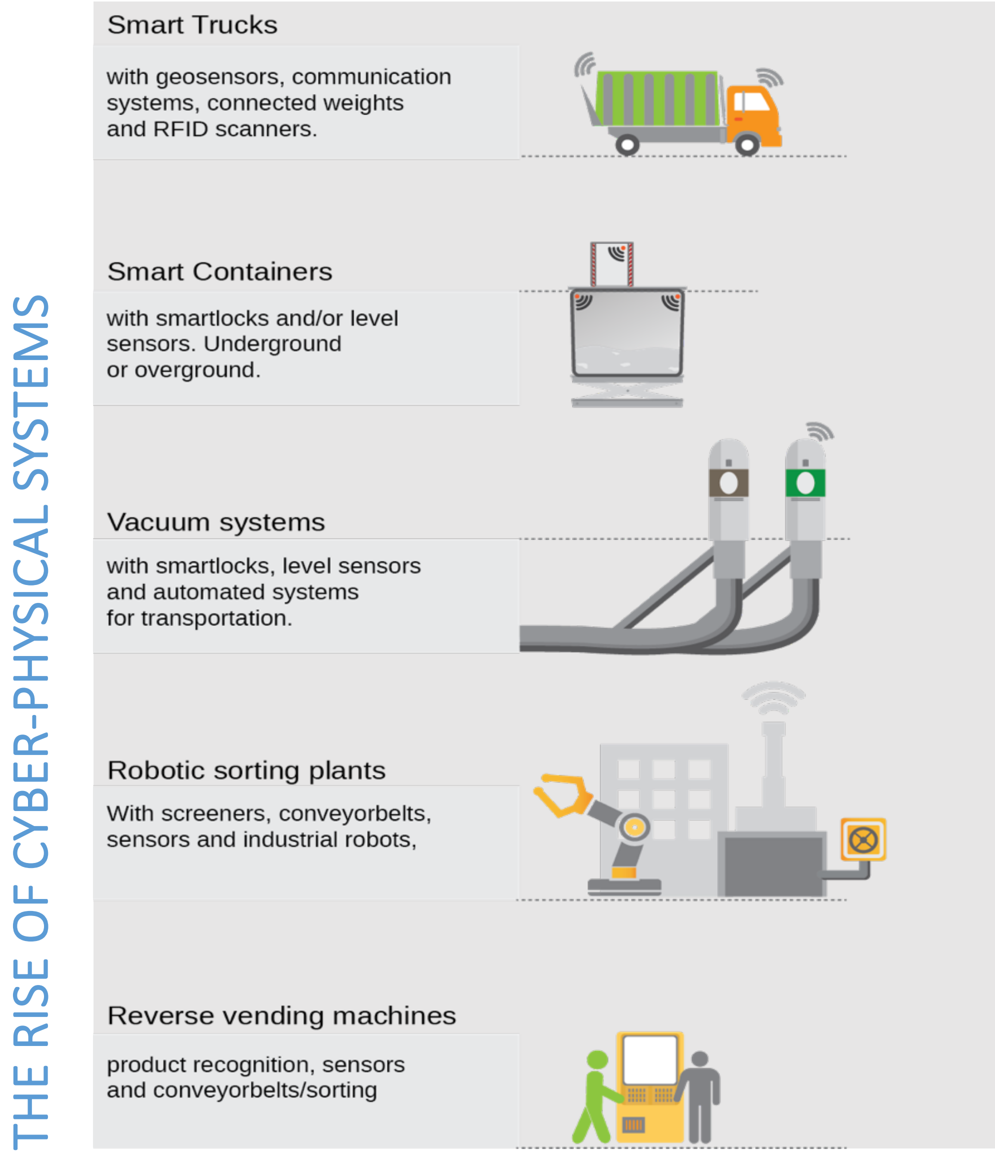
The solid-**waste sector could** achieve a 39 percent reduction in sectoral emissions by 2030 and a 91 percent reduction by 2050.

Source: Mc Kinsey, Curbing methane emissions: How five industries can counter a major climate threat 9/2021, https://www.mckinsey.com/business-functions/sustainability/our-insights/curbing-methane-emissions-how-five-industries-can-counter-a-major-climate-threat

THE WASTE SUPPLY CHAIN IS RE-INVENTED

It is allready happening, faster than we think

ENABLERS



Source: Mavropoulos & Nielsen, Industry 4.0 and Circular Economy, Towards a Wasteless Future or a Wastefull Planet? Wiley Publications, 2020

Source: https://roboat.org/use-cases

SAMSUNG Medical Center is the first hospital that is using the rolling out of robots that automatically dispose of medical waste from operating rooms

Source: https://www.kedglobal.com/newsView/ked202109160004

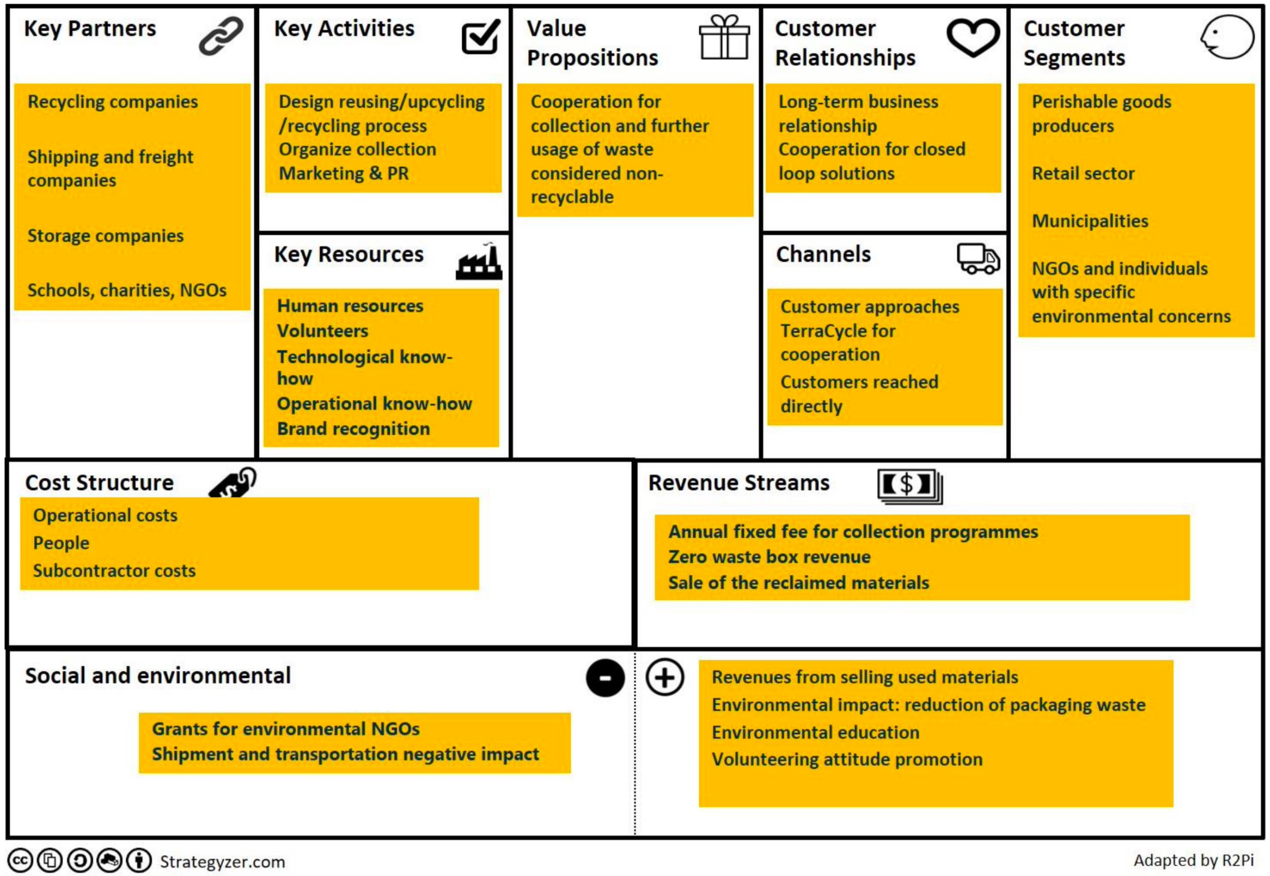
	Recognition	Purity	Recovery
Results	> 95 %	[82-100%] Average 97%	[4-93%] Average 67%
Lessons Learned	• High number of items in the classifier increases efficiency • Periodic classifier updating	• What the robot attempts to pick, it picks it with high efficiency • Mistakes are due to: - Recognition errors - Grasping of other materials together with targeted one	• High gap between recognition and sorting attempt due to: - Waste distribution - Flow rates • Grasping difficulties with long shaped waste • Material jams in collection hoppers and conveyer
Actions	• Weekly classifier updating	• Mechanical modification of the plant to avoid clogging in the conveyer and hoppers; damages in the robot; … • A.I. software grasping strategy improvement for particular materials • Ecoparc4 waste sorting process adjustment to favour steady waste distribution	

Figure 4. Training test results for aluminum, film, HDPE, cardboard, textile and wood [15].

Source: Wilts et al, Artificial Intelligence in the Sorting of Municipal Waste as an Enabler of the Circular Economy *Resources* 2021, *10*, 28. https://doi.org/10.3390/resources10040028

The rise of recycling platforms

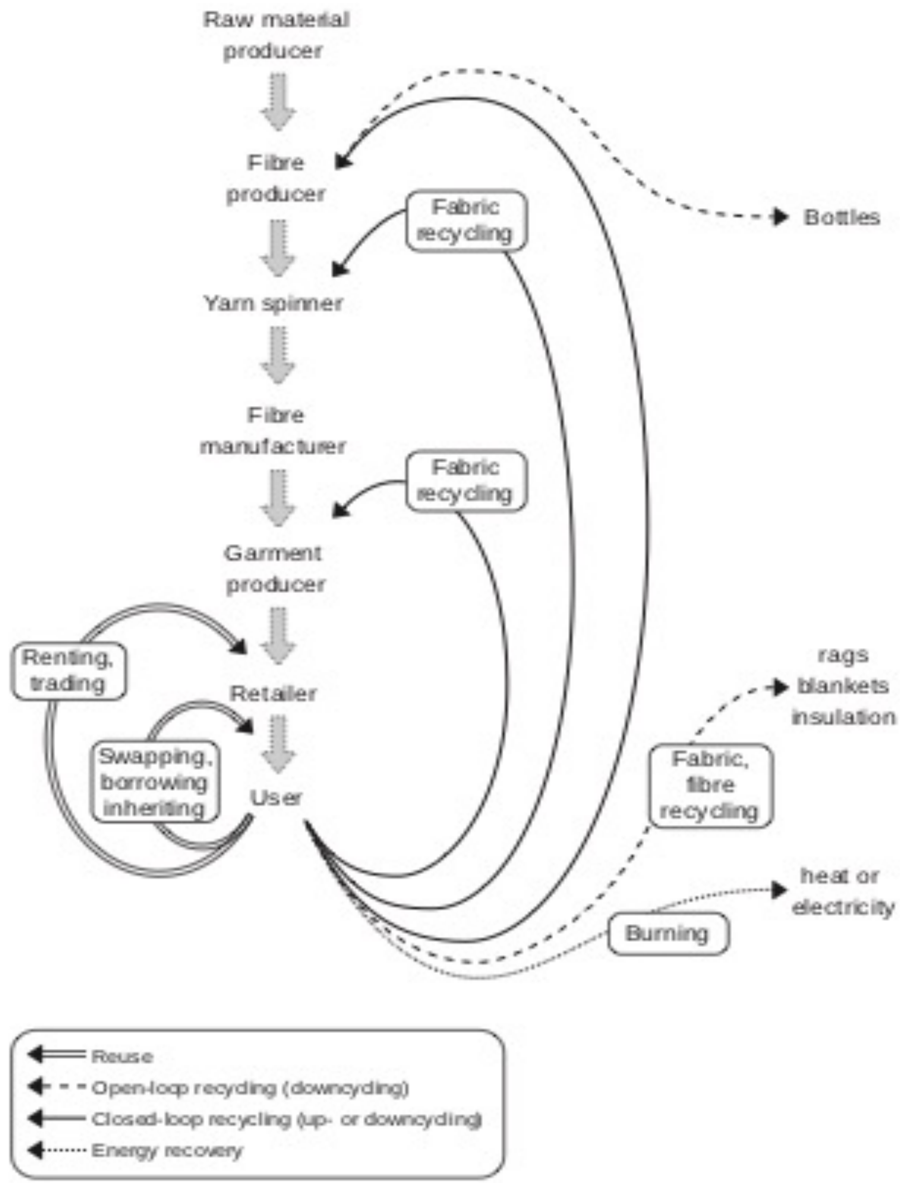
FIGURE 21 TERRACYCLE BUSINESS MODEL CANVAS



CE will be either digital or dead

The operation of the system depends on the assumptions

a. that textiles sent to recycling are free of environmental burden and that reused products and products made from recycled materials replace products made from virgin fibres.
b. There is a smooth functioning of five closed loops (two reuse loops on the left side and three closed loops on the right side), two recycling open loops (on the right side) and an energy recovery linear end.
c. In total, the system's function depends on the smooth function of eight sub-systems, eight markets and prices, and eight technological linkages

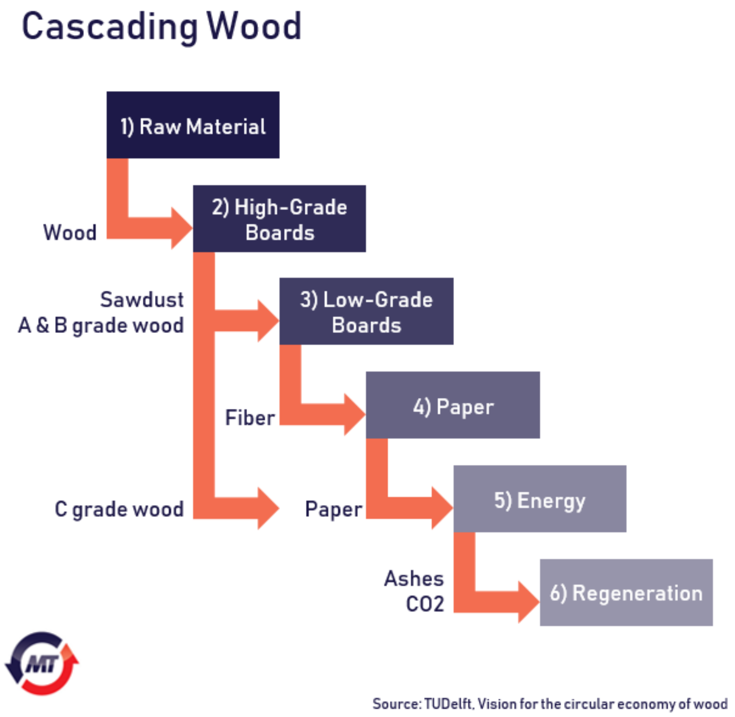


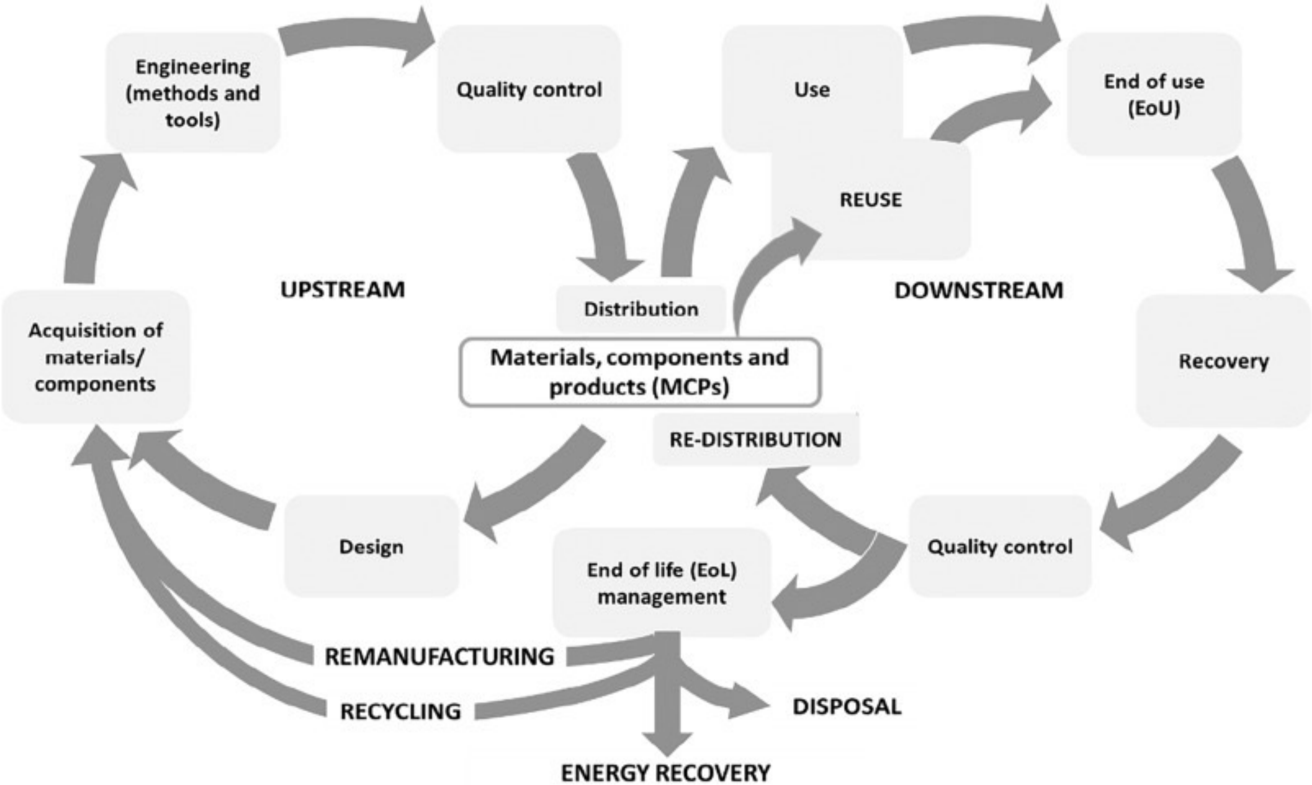
Usual misconceptions on recycling

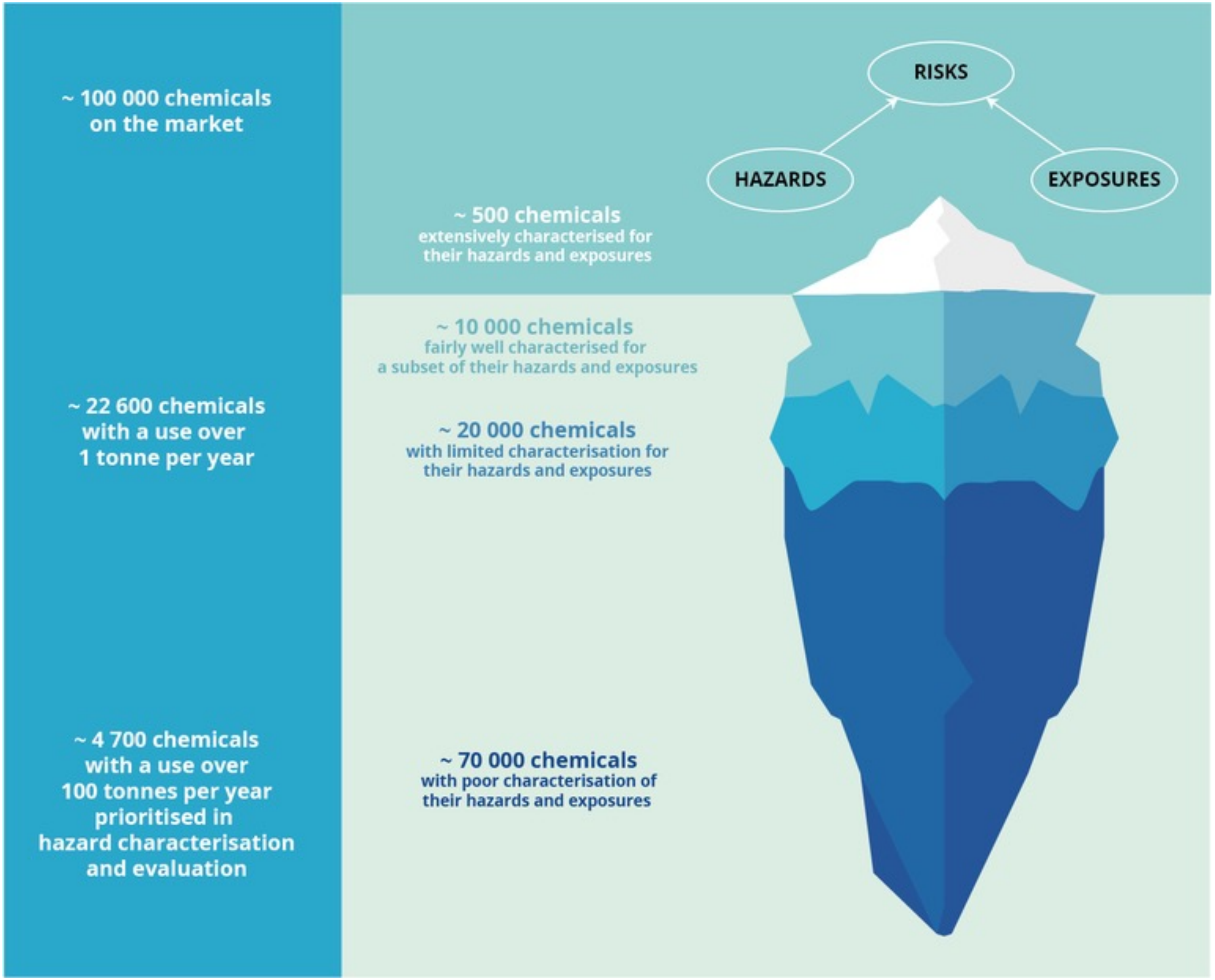
Misconceptions about recycling	
Recycling means displacement of primary materials	Market conditions will determine the fate of the recovered materials - recycling does not automatically bring the benefits of the displacement of primary materials, which are the main benefits.
Recycling materials multiple times is better than once	Cascading effects and chemical pollution undermine the recycling benefits and at a certain point the inclusion of virgin materials is definitely required, even for materials like aluminium and steel.
Closed loops are better than open ones	This is also a confusing argument because the logistics of the closed loop and the exact type of substituted materials finally determine the preference order.
Recycling is a decentralized activity with small financial cost and huge financial benefits	This is completely misleading for municipal recycling in middle and high- income countries. The cost of source separation programs and the cost pf reprocessing materials in Material Recovery Facilities (MRFs) are usually 4-5 higher than the revenues from the sales of recyclables.

Source: Mavropoulos & Nielsen, Industry 4.0 and Circular Economy, Towards a Wasteless Future or a Wastefull Planet? Wiley Publications, 2020

Huston we have a problem: cascading

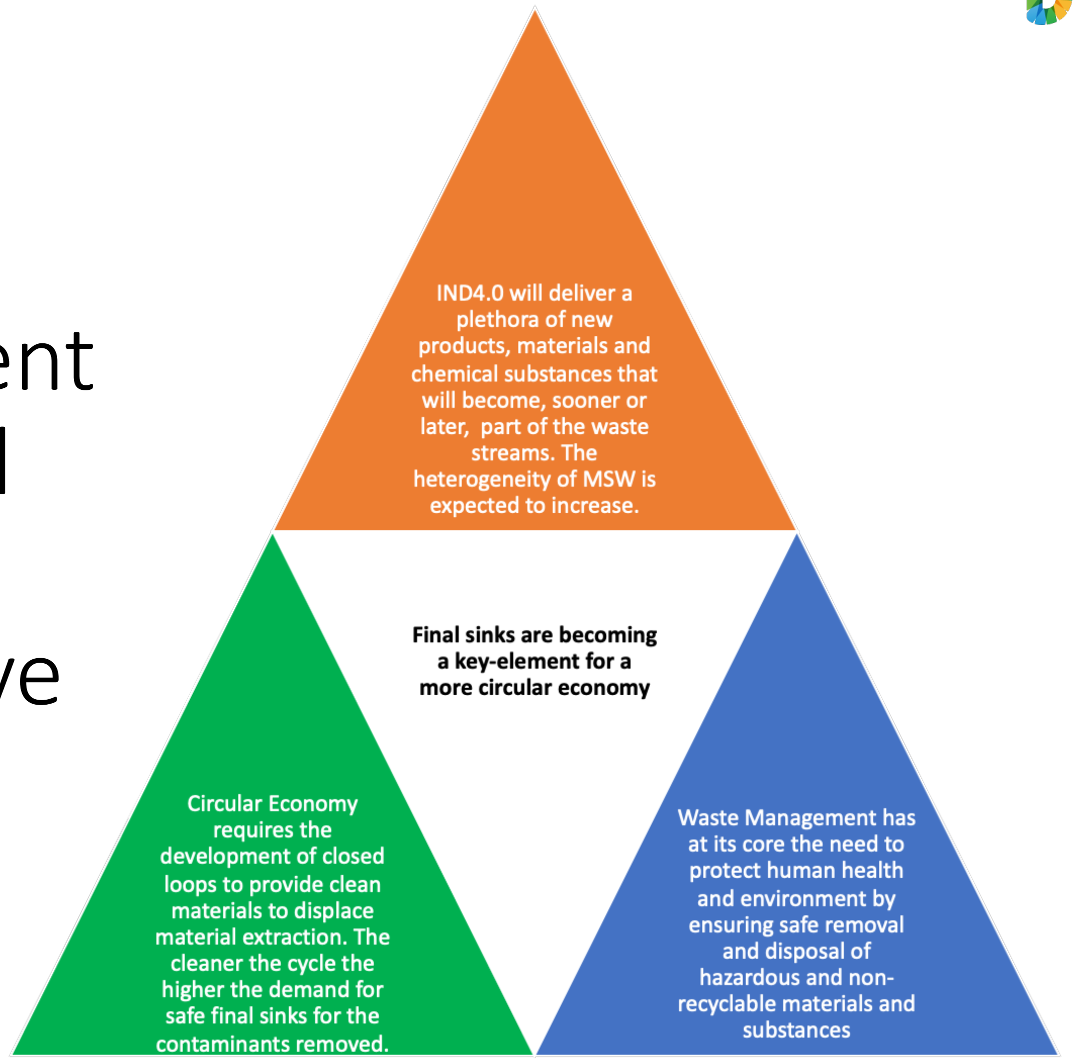




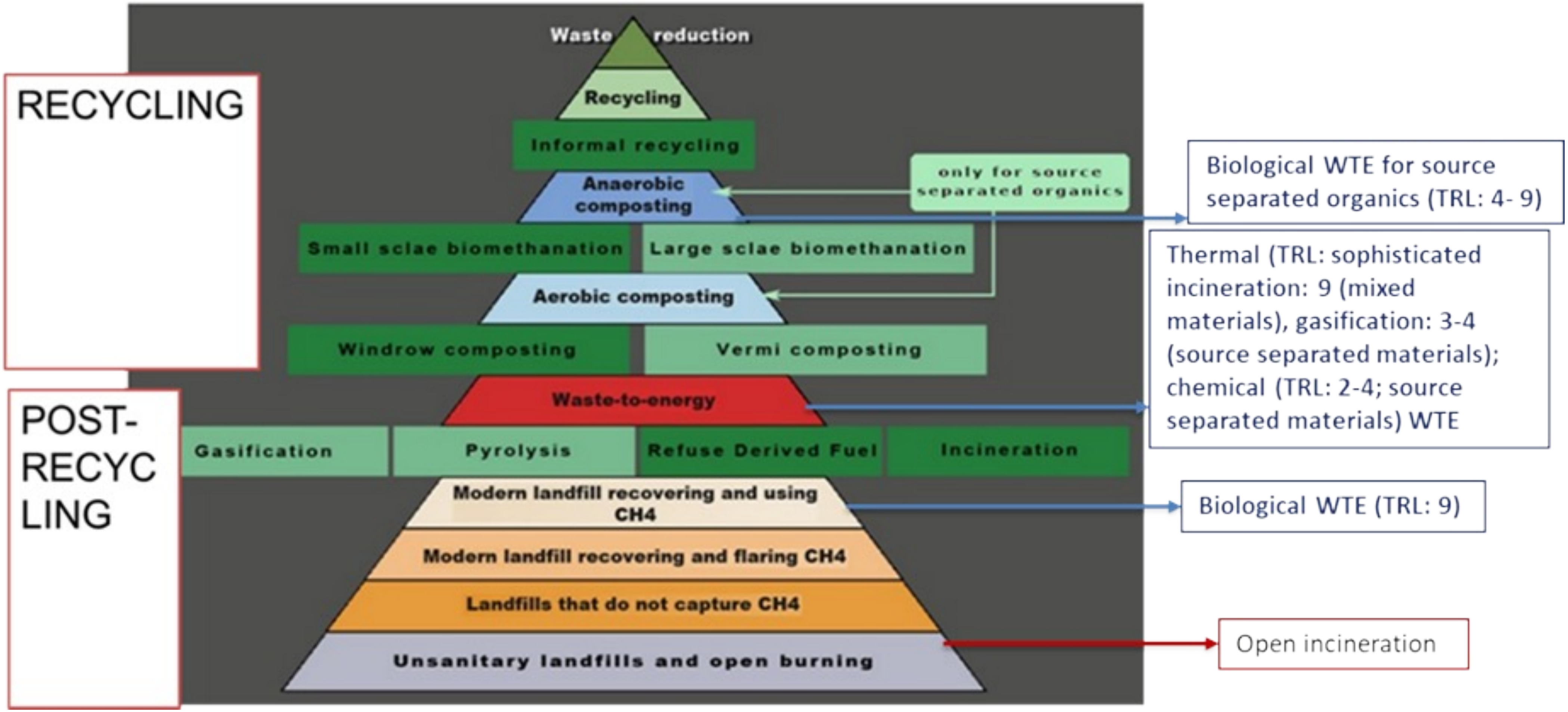


Source: European Environmental Agency

Safe waste management and availability of final sinks become a key-precondition to achieve Circularities



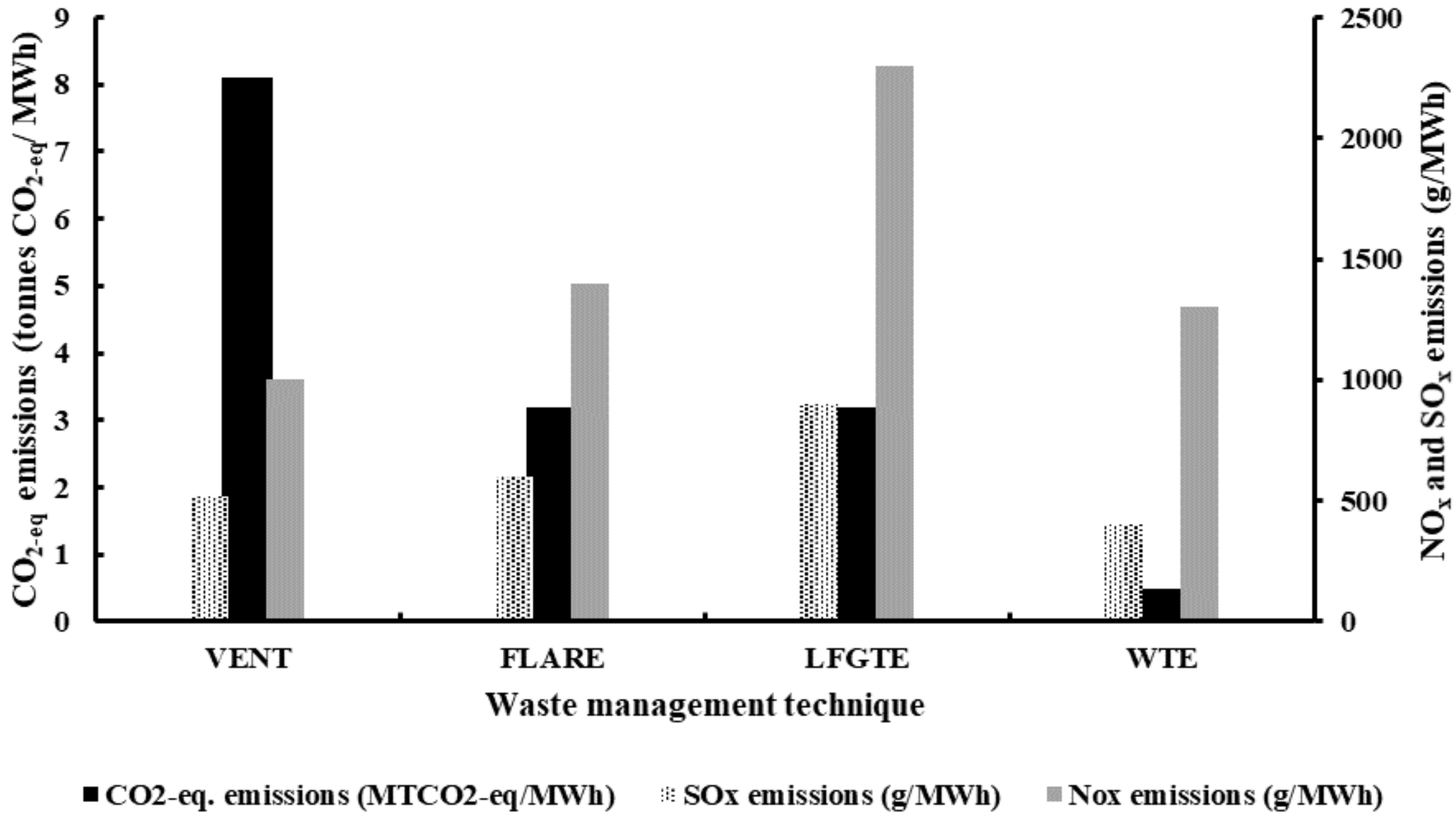
Source: Mavropoulos & Nielsen, Industry 4.0 and Circular Economy, Towards a Wasteless Future or a Wastefull Planet? Wiley Publications, 2020



Source: Themelis, Diaz Barriga and Estevez and Velasco, “WtE Guidebook 2013 for the Application of WtE Technologies in Latin America and the Caribbean”

Circular Economy & Final Sinks	Sanitary Landfills	Waste to Energy plants
Main role	• Containment of contaminants for a certain period • Final sink for non-recyclables, for low calorific value streams, for non-incinerated hazardous waste and ashes from incinerators • The only way available for poor countries and emergencies	• Destruction of hazardous substances and chemical pollutants • Homogenization of heterogeneous MSW that allows recovery of important metals • Substantial reduction of volume
Secondary features	• Biogas to energy production • Storage of materials for future utilization based on technology and markets developments	• Contribution to energy production • Analytical tool for the biogenic fraction of waste
Main problem	• Integrity and long-term behavior of containment systems • Leachate collection and treatment is necessary to avoid water and soil pollution	• Advanced air pollution systems required to ensure public health protection • Ash treatment is an important element for resource recovery

Source: Mavropoulos & Nielsen, Industry 4.0 and Circular Economy, Towards a Wasteless Future or a Wastefull Planet? Wiley Publications, 2020



Source: https://www.ieabioenergy.com/wp-content/uploads/2013/10/40_IEAPositionPaperMSW.pdf

Arguments put forward against	***Arguments put forward in favour***
WtE reduces recycling/composting, acting as a disincentive or even barrier to circular economy or zero waste practices. Turning unsorted and usable trash into a valuable fuel commodity means communities are less likely to choose to reduce, reuse and recycle it.	WtE can be part of a holistic waste management strategy if it processes non-recyclable waste only. The EU countries reduce landfilling of wastes, by a combined effort of recycling/composting and WtE. In the United States of America, counties and municipalities that utilize WtE consistently show an increased recycling rate, in parallel to WtE practice.
WtE raises environmental concerns, exacerbating climate change, emitting toxic emissions, and giving rise to air pollution.	Today's technology allows WtE projects to operate with limited to no polluting effects. In addition, WtE plants must comply with stringent environmental standards, such as the EU Industrial Emissions Directive. The latter also sets standards for non-EU countries. WtE and incineration are different processes. Incineration does cause emissions, however WtE facilities equipped with sophisticated Air Pollution Control (APC) systems have far less severe impacts on air pollution.
WtE raises public health concerns for the population, emitting carcinogenic pathogens.	Today's technology allows WtE projects to operate with limited to no polluting effects and WtE plants must comply with stringent regulatory requirements. The only proven alternative to landfilling of materials that cannot be recycled is WtE. Landfilling relates to methane emissions, a potent greenhouse gas, and it is well documented that WtE saves 0.5 to 1 tonne of CO_2 equivalent per tonne of waste.
WtE raises societal concerns and communities are opposed to them in their neighborhoods. In some countries, popular protests have taken place over the location of WtE plants reflecting serious concerns by residents on the impact to their health.	WtE plants monitor their emissions continuously, and report these on site and/or online. Many WtE plants around the world are built in the middle of residential or industrial sites to facilitate the use of heat for district or industrial heating or cooling.

Source: UN Economic and Social Council, Guidelines on Promoting People-first Public-Private Partnerships Waste-to-Energy Projects for Non-Recyclable Waste for the Circular Economy

WtE with Carbon Capture?

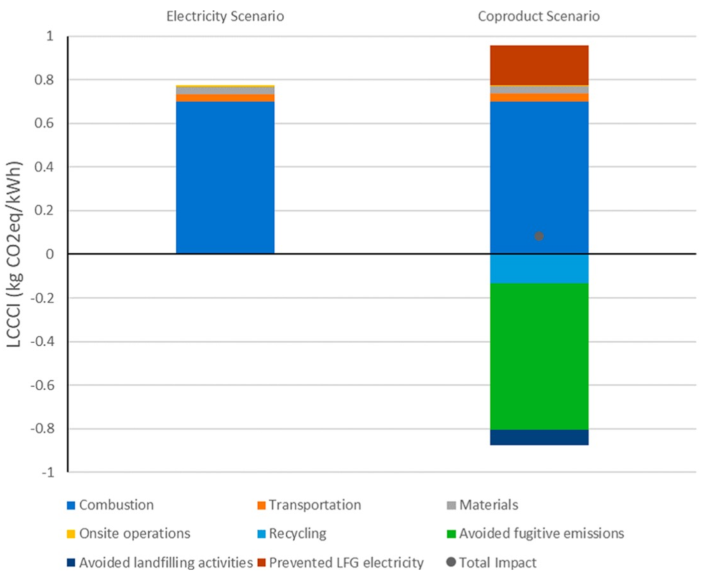


Figure 2. Total LCCCI and contributions by process for electricity from WTE from the baseline LCA results of the Electricity (left) (0.775 kg CO_{2eq}/kWh) and Coproduct (right) (0.0824 kg CO_{2eq}/kWh, depicted by a black dot) Scenarios.

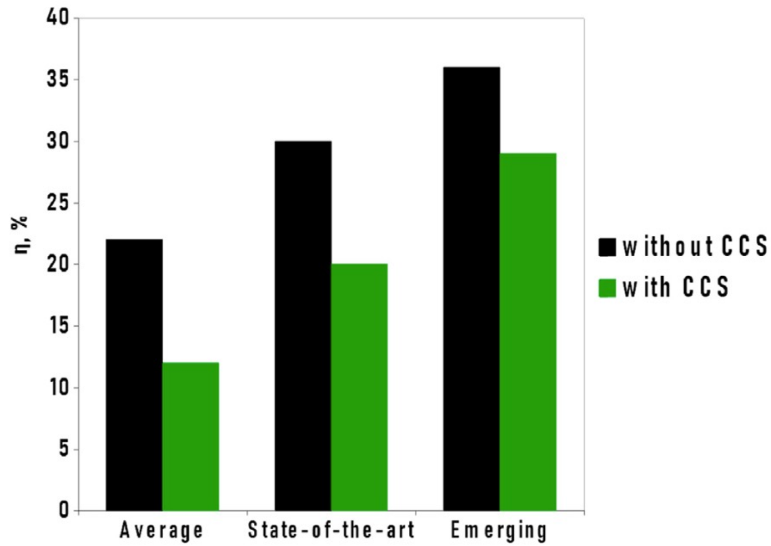


Fig. 4. Efficiency of WtE plants with and without CCS in dependence of development level, data source: Sathre et al. [89].

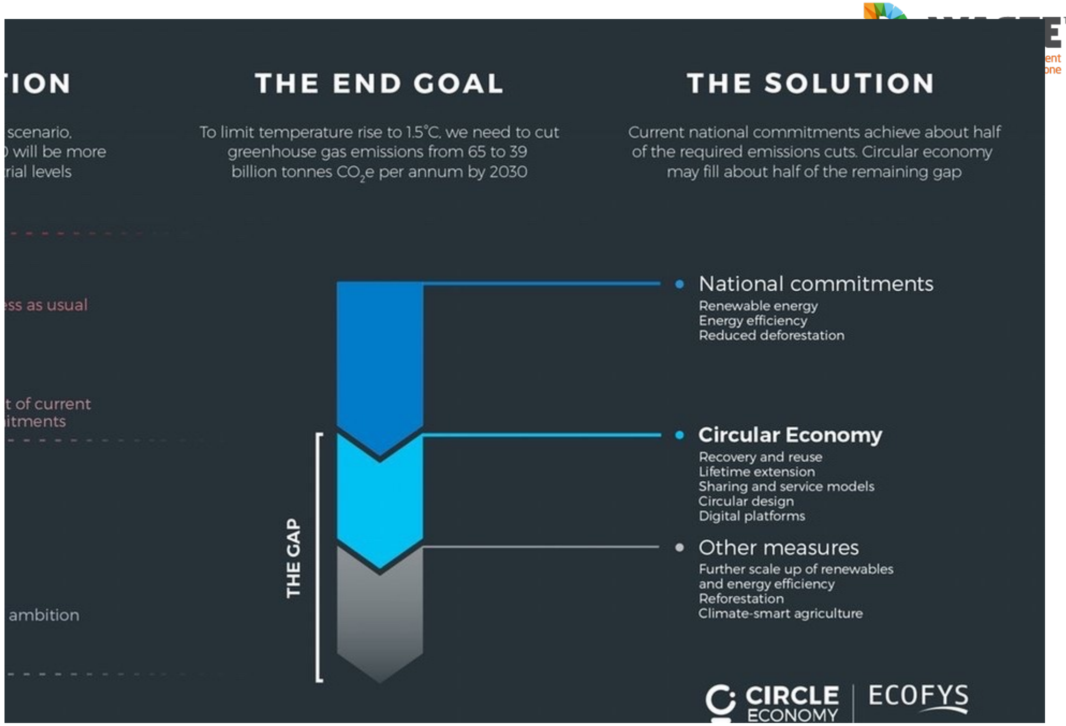
Source: Pfadt-Trilling et al, Climate Change Impacts of Electricity Generated at a Waste-to- Energy Facility
Environ. Sci. Technol. 2021, 55, 1436−1445

Source: Wienchol et al, Waste-to-energy technology integrated with carbon capture e Challenges and opportunities, Energy 198 (2020) 117352

Instead of conclusions

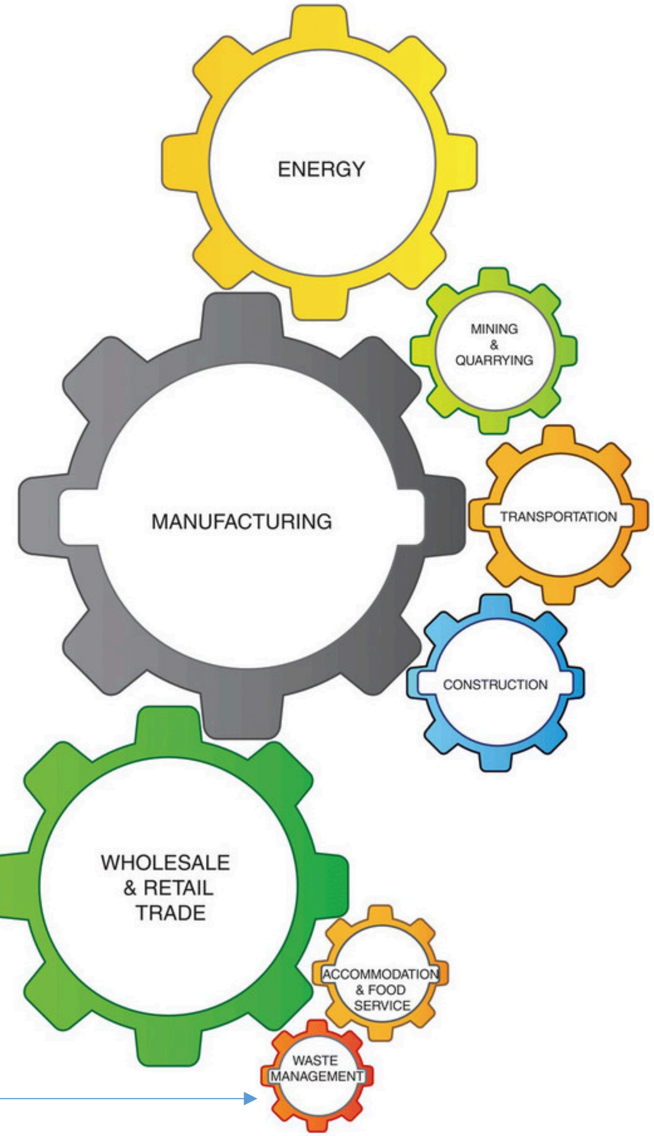
CE is a condition to manage global warming

3 billion tons of metals and minerals will be needed by 2050 to scale up wind, solar and geothermal power and energy storage to reach a below 2°C future



The importance of domino effects

SWM as a Catalyst



Source: Mavropoulos & Nielsen, Industry 4.0 and Circular Economy, Towards a Wasteless Future or a Wastefull Planet? Wiley Publications, 2020