## 十二

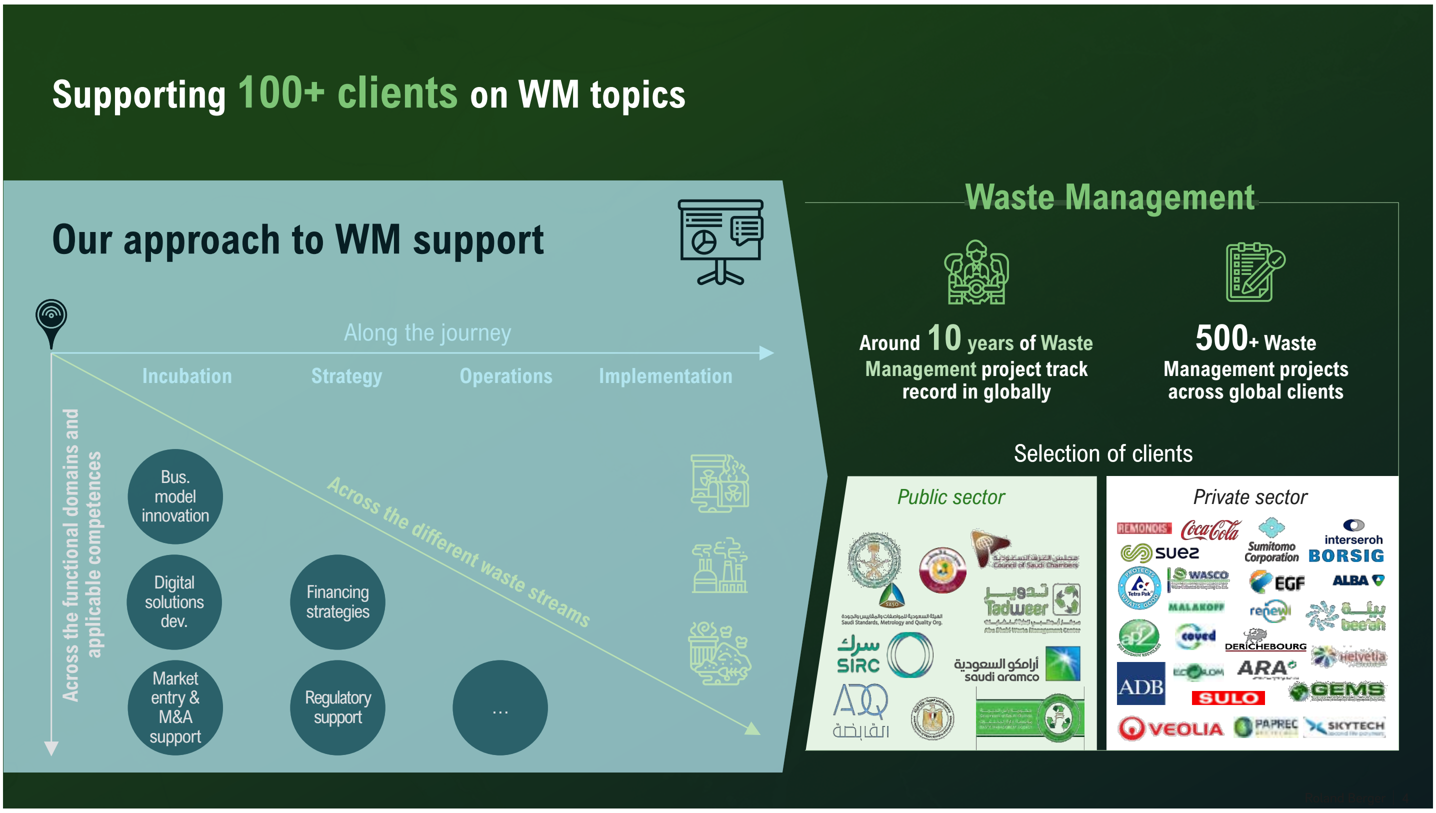
### 十個基本組成廢棄物管理部門轉型的關鍵推動力

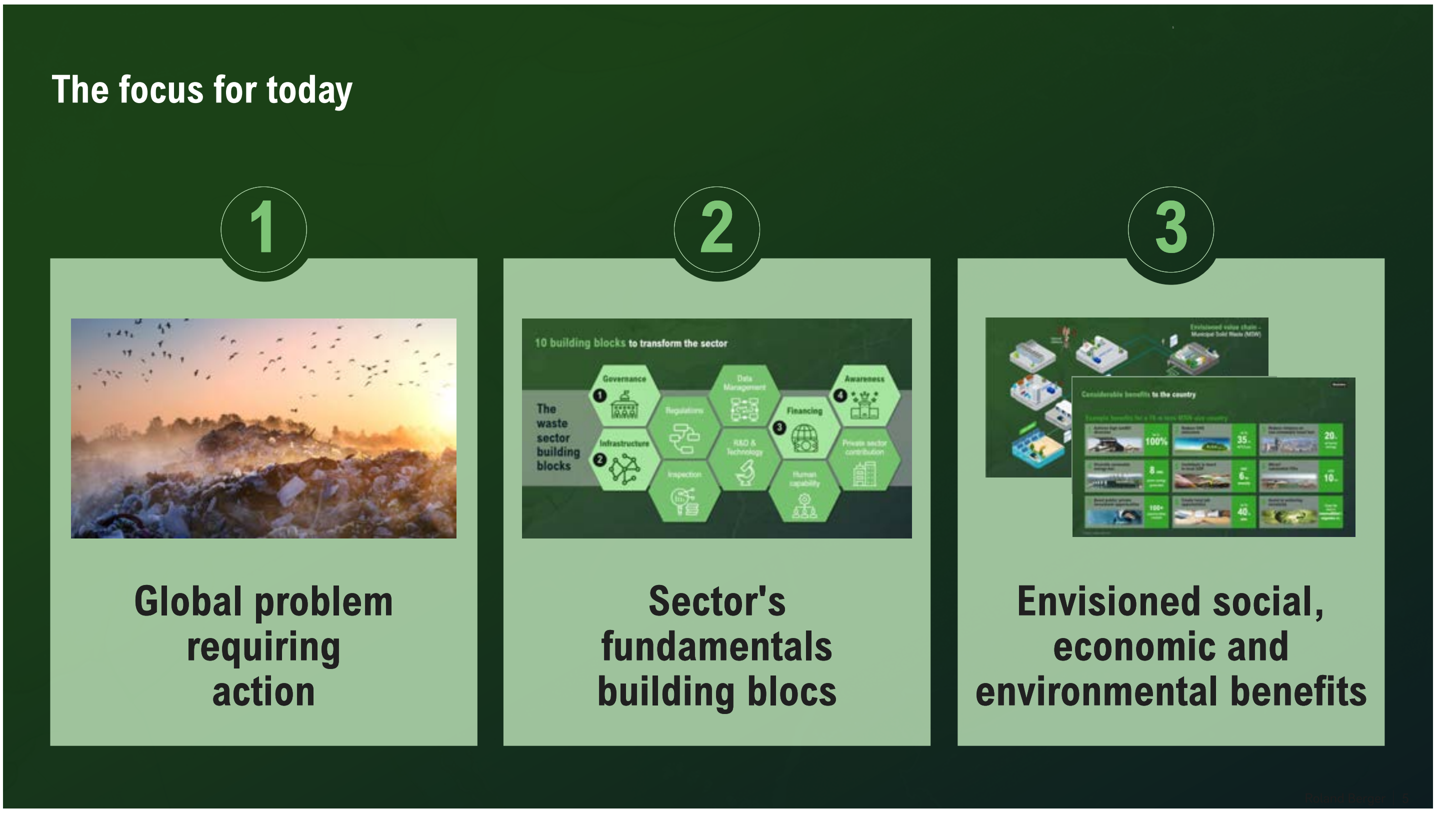
**(Ten Fundamental Building Blocks as Key Enabler of a Lean WM Sector Transformation)**

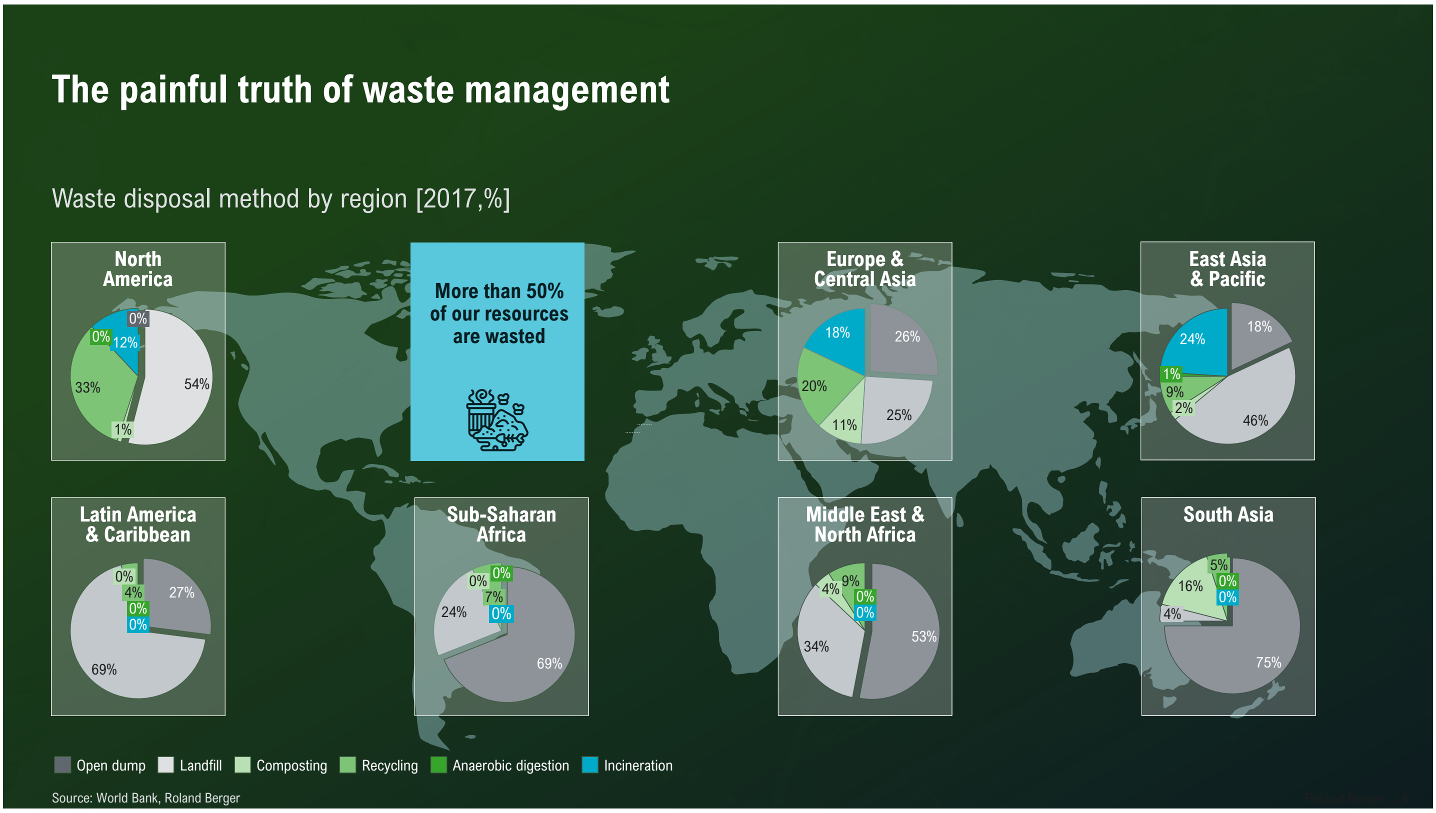
為幫助各國實現循環並遠離垃圾掩埋場，會中定義了10座基本的廢棄物管理建築。主要區別在於治理，應根據當地生態系統選擇最合適的結構。所有利益相關者都可以為有效轉型發揮作用。公共和私營部門應協調合作，共同創建合適的生態系統，在投資、監管改革和社會支持之間實現良好平衡。成功實現轉型的國家達到減少須補貼的情況、企業財務永續、環境和社會效益兼顧的理想狀態。


Roland Berger at a glance
Founded in 1967 in Germany by Roland Berger
51 offices in 34 countries, with around 2,400 employees
Nearly 220 Partners currently serving
~1,000 international clients


… with global practice focused on Waste Management
Waste Management
Automotive
Chemicals
Pharma
Civil Economics, Energy, Infrastructure
Construction
Consumer Goods & Retail
Corporate Finance
Digital
Energy & Utilities
Industrial Products & Services
Executive Communications
Financial Services
Information Management
Infrastructure
Operations
Sustainability
Aerospace & Defence

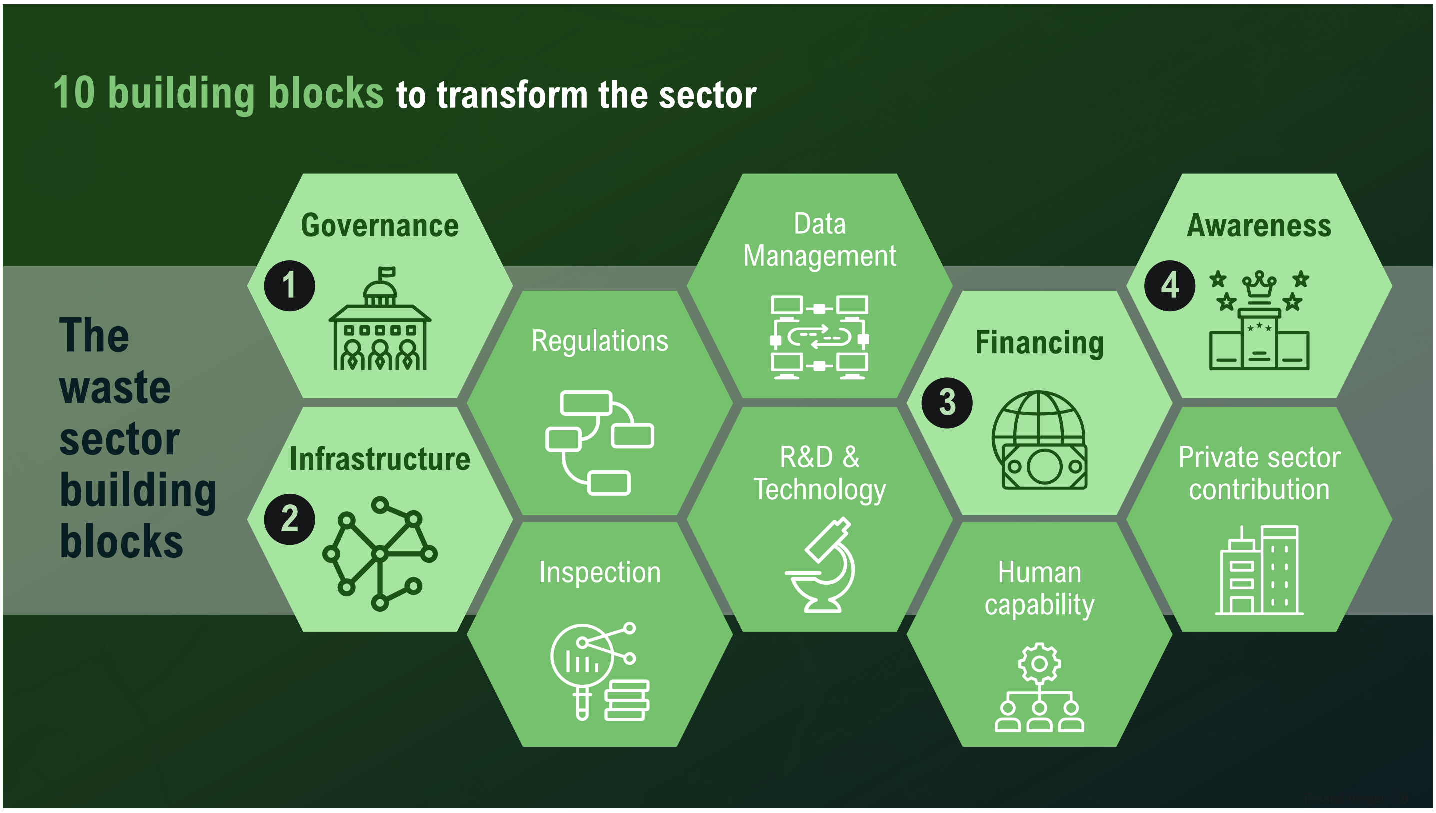

Supporting 100+ clients on WM topics
Our approach to WM support
Along the journey
Incubation
Strategy
Operations
Implementation
Across the functional domains and applicable competences
Across the different waste streams
Bus. model innovation
Digital solutions dev.
Market entry & M&A support
Financing strategies
Regulatory support
...
Waste Management
Around 10 years of Waste Management project track record in globally
500+ Waste Management projects across global clients
Selection of clients
Public sector
Private sector

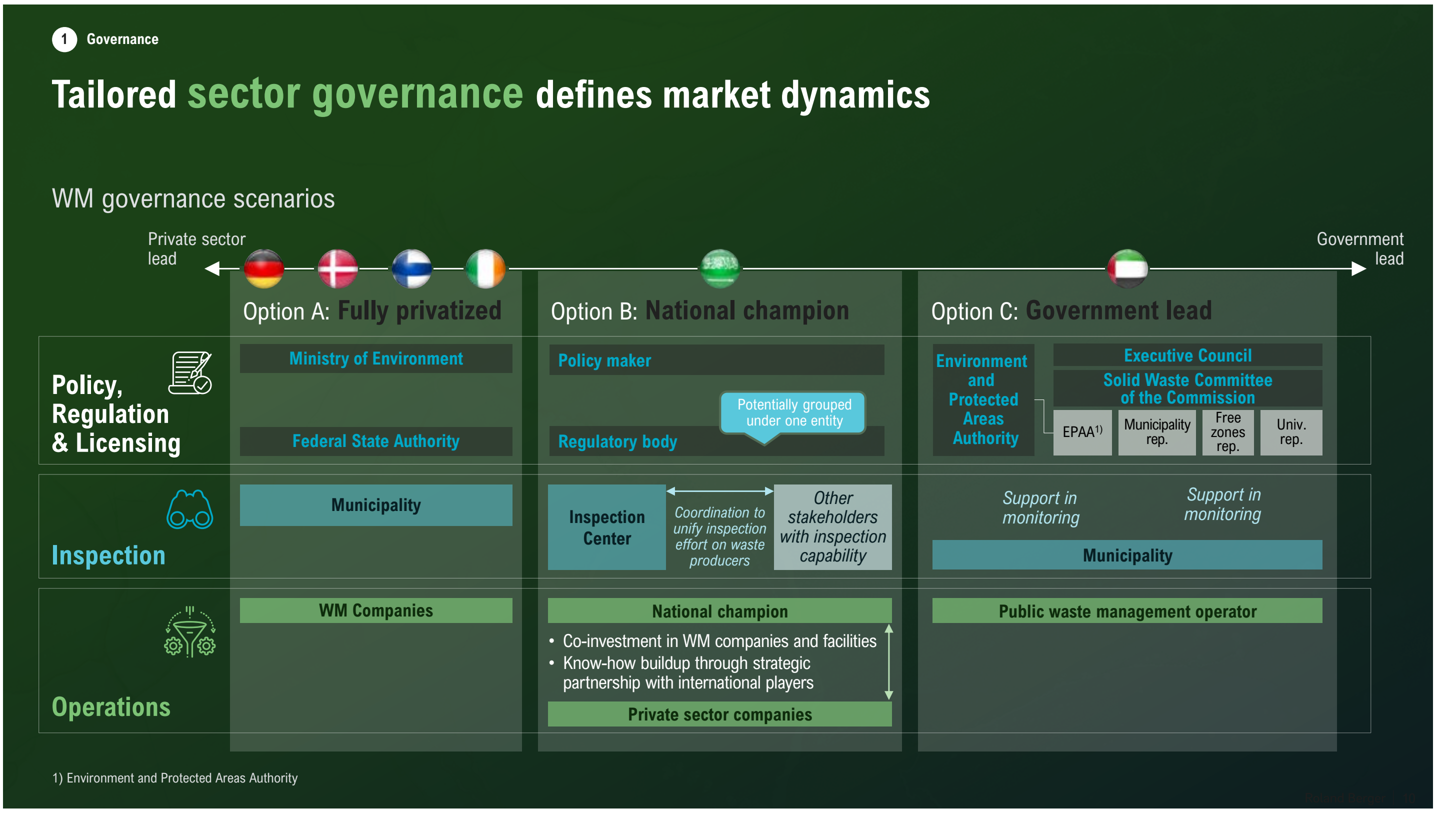

The focus for today
1
Global problem requiring action
2
10 building blocks to transform the sector
Sector's fundamentals building blocs
3
Envisioned social, economic and environmental benefits


The painful truth of waste management
Waste disposal method by region [2017,%]
North America
0%
0%
12%
33%
54%
1%
More than 50% of our resources are wasted
Europe & Central Asia
18%
26%
20%
25%
11%
East Asia & Pacific
18%
24%
1%
9%
2%
46%
Latin America & Caribbean
0%
4%
0%
0%
27%
69%
Sub-Saharan Africa
0%
0%
7%
0%
24%
69%
Middle East & North Africa
4%
9%
0%
0%
34%
53%
South Asia
5%
0%
0%
16%
4%
75%
Open dump
Landfill
Composting
Recycling
Anaerobic digestion
Incineration
Source: World Bank, Roland Berger


Yes, this is Linear Economy
Linear economy
Take raw materials
Products & Parts
Make
Product Sales & Transport
Use/ Consume
Dispose
Current challenges
GLOBAL WARMING
accelerated through GHG emissions generated in production
POLLUTION LEVELS
rising at an accelerated rate
LANDFILL WASTE
from disposal of material consumed products
RESOURCE EXHAUSTION
from consumption of earth's finite natural resources

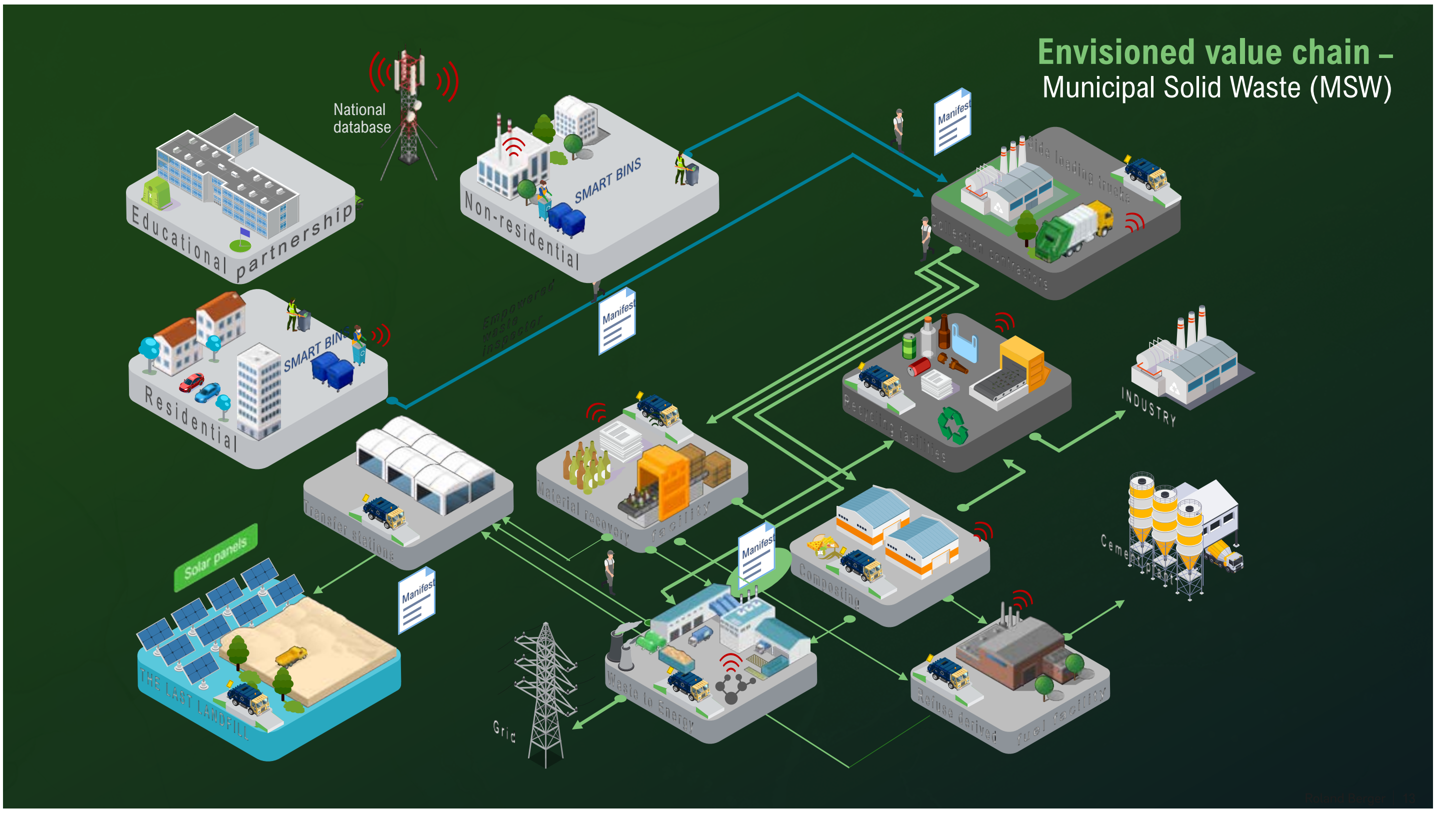

Municipal Solid Waste is 1 out of 70+ waste streams
Waste
Municipal Solid
Paper
OCC
Mixed paper[1]
ONP
HGDP
Plastic
PET
HDPE
PVC
LDPE
PP
PS
Other[2]
Metal
Aluminum
Steel
Organic
Food remain
UCO
Glass
Colored
Non-colored
Textile
Wood
Composites[3]
Portable batteries
Sludge
Construction & Demolition
Dredging
Trees
Dirt rocks
Other[4]
Insulators
Asbestos
Other[5]
Rocks
Concrete
Brick
Tiles
Asphalt
Cement
Recyclables
Wood
Plastic
Glass[6]
Metal
Iron
Copper
Aluminum
Steel
Wall-cover
Paint
Varnishes
Paint paper
Contaminated soil
Industrial
Hazardous
Oil & Gas
Oil, oily sludge & oily wastewater
Grease (mech. shop)
Process chemicals[7]
Marine waste[8]
Lubricants & solvents
Oil mud cutting
Sulfur
Contaminated sand & seas
Metal & Mining
Copper slag
Lead slag
Iron & Steel slag
Arsenic speiss
Bismuth Residue
Scorodite
Jarosite
Mill scale
Electric arc furnace dust
Spent Pot liner
Refractory Bricks
Aluminum dross
Solid copper tailings
Zinc tailings, titanium waste
Other[10]
Calcium based sludge
Red Mud
Gypsum[9]
NORM
Other
Ash[11]
Paint
Non-hazardous[12]
Sludge
Medical
Hazardous
Infectious
Human body parts & tissue[13]
Blood-soaked bandage
Surgical gloves
Syringe
String
Masks
Needle
Pharmaceutical
Drugs & Medicines
Chemotherapy products
Radioactive
Nuclear medications
Radioactive isotopes
Non-hazardous[12]
Oxygen tanks
Electrical & Electronic Eq.
HH appliances[14]
Metal[15]
Plastic
Glass
Ceramic
Equipment[16]
Batteries
Steel
Chemicals
Paper
Plastic
PCB
Metal[17]
Rubber
Glass
Plastic
Textile
Chemicals
Mercury
Beryllium
Arsenic
Cadmium
Antimony
Gases
ICT – Data & digital
Agricultural
Plants
Greens – agri.
Fruit/ veg. residues
Wood & timber
Animal
Skins
Manure
Fat
Bowels
Blood
Bones
Meat
Dead animal
Milk & cheese prod.
Chemicals
Pesticide
Glyphosate
Acephate
Deet
Propoxur
Metaldehyde
Boric Acid
Diazinon
Malathion
Containers
PP
HDPE
Aluminum
End-of-Life Vehicle
Batteries
Lead acid
Plastic
Metal
Acid
Li-ion
Plastic
Metal
Organic solution
Tires
Rubber
Steel
Carbon black
Polymer Fibers
Metal
Steel
Aluminum
Copper
Other
Plastic
PP
PVC
Textile
Glass
Wood
Chemicals
Lubricants
Electronics


10 building blocks to transform the sector
The waste sector building blocks
Governance
1
Regulations
Data Management
Financing
3
Awareness
4
Infrastructure
2
R&D & Technology
Private sector contribution
Inspection
Human capability


1 Governance
Tailored sector governance defines market dynamics
WM governance scenarios
Private sector lead
Government lead
Option A: Fully privatized
Option B: National champion
Option C: Government lead
Policy, Regulation & Licensing
Ministry of Environment
Federal State Authority
Policy maker
Potentially grouped under one entity
Regulatory body
Environment and Protected Areas Authority
Executive Council
Solid Waste Committee of the Commission
EPAA1)
Municipality rep.
Free zones rep.
Univ. rep.
Inspection
Municipality
Inspection Center
Coordination to unify inspection effort on waste producers
Other stakeholders with inspection capability
Support in monitoring
Support in monitoring
Municipality
Operations
WM Companies
National champion
• Co-investment in WM companies and facilities
• Know-how buildup through strategic partnership with international players
Private sector companies
Public waste management operator
1) Environment and Protected Areas Authority


1 Governance
Informal sector, opportunity vs. risk
Challenges of uncontrolled informal waste sector
Value leakage outside formal market
Impact on financial viability of formal activities
Chemical, biological and physical health risks
Safety and security risks
Traffic hazards risks
Children's physical development risks
Possible solutions to handle the informal waste sector
Accepting
Consolidating & Formalizing
Employing
Banning

For each waste stream
2 Infrastructure
Building the infrastructure
Plant specifications
Capacities
Timing
Technology
Emissions
Manpower
Output quality
Land area
...
Operating enablers
Land availability
Logistics & utilities
Feedstock
Offtake
...
Regulatory overarching enablers
Inspection
Scavenging prevention
Export/ import spec.
Sorting at the source
Recycling incentivizing
Min. recycling content
...
Financial incentives
Gate fees
Grants
Import tax exemption
CAPEX support
Obligations
Penalties
Guarantees
...
Engagement
Partnership
Contracting – EPC/ O&M
Public Private Partnership (PPP)
Joint Venture (JV)
Scope
On cluster/ park level
On facility level
On waste stream level

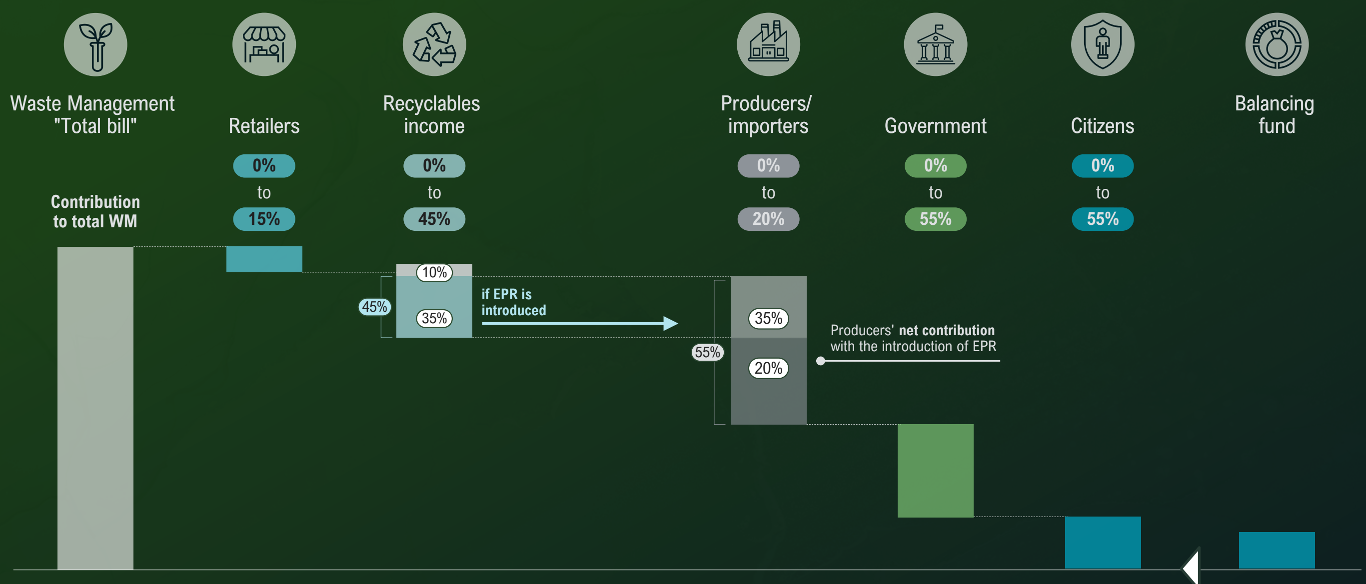



Envisioned value chain –
Municipal Solid Waste (MSW)
National database
Educational partnership
SMART BINS
Non-residential
Residential
Manifest
Solar panels
INDUSTRY
Grid

3 Financing

Illustrative financing scenario and ranges

## Who will pay for it? It's an OpEx game




xx Financing agents' net contribution share of total WM bill [%]

4 Awareness

## Public awareness enables WM sector

### Awareness guidelines

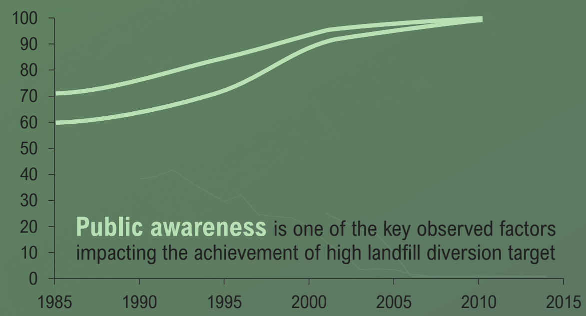
**Awareness should be targeting everyone**
Students, public, companies, governmental

**Walk the talk**

**Start early on**
From early age at nurseries and school

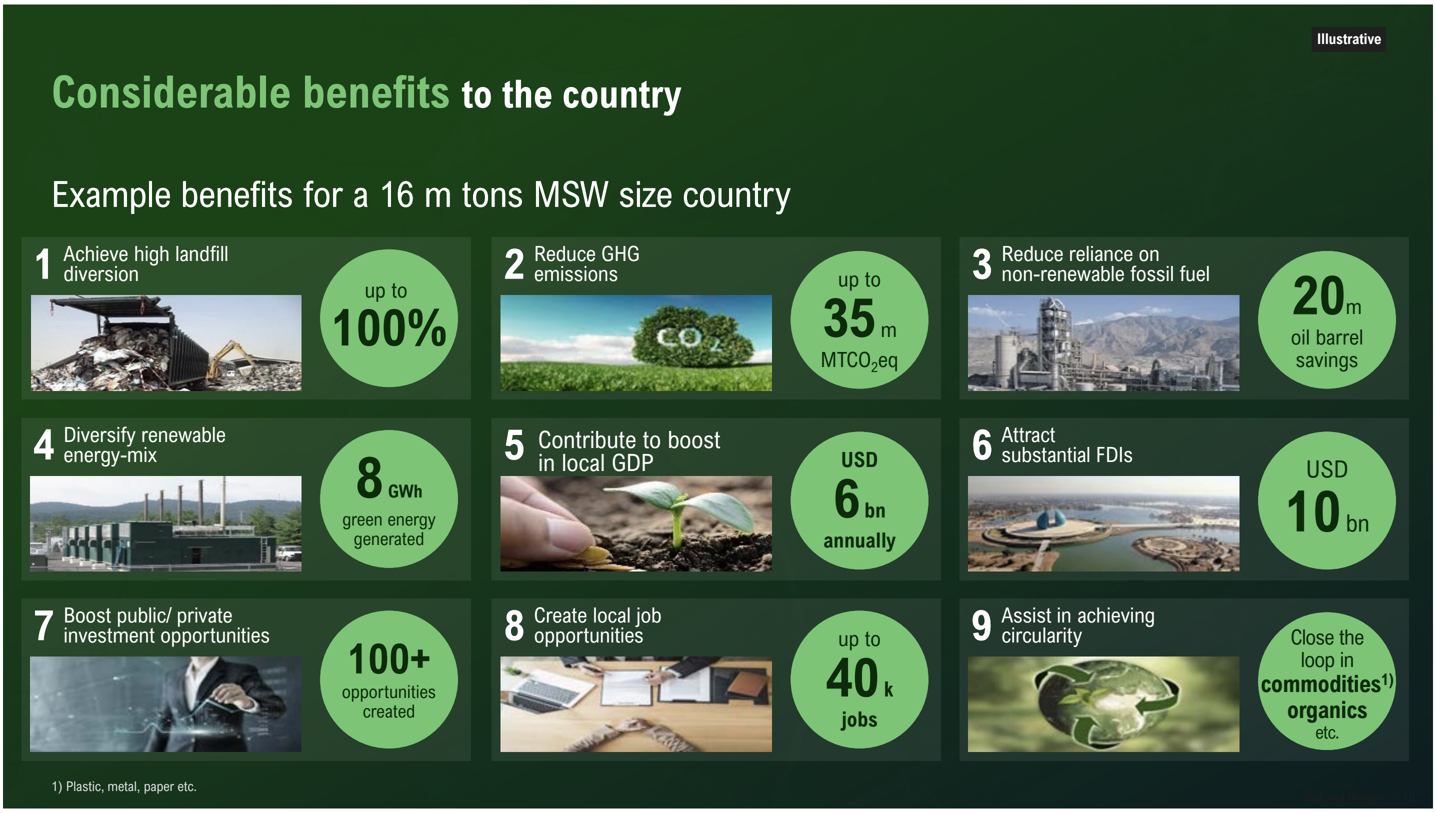
**Ongoing process**
Always research global innovation and new best practice

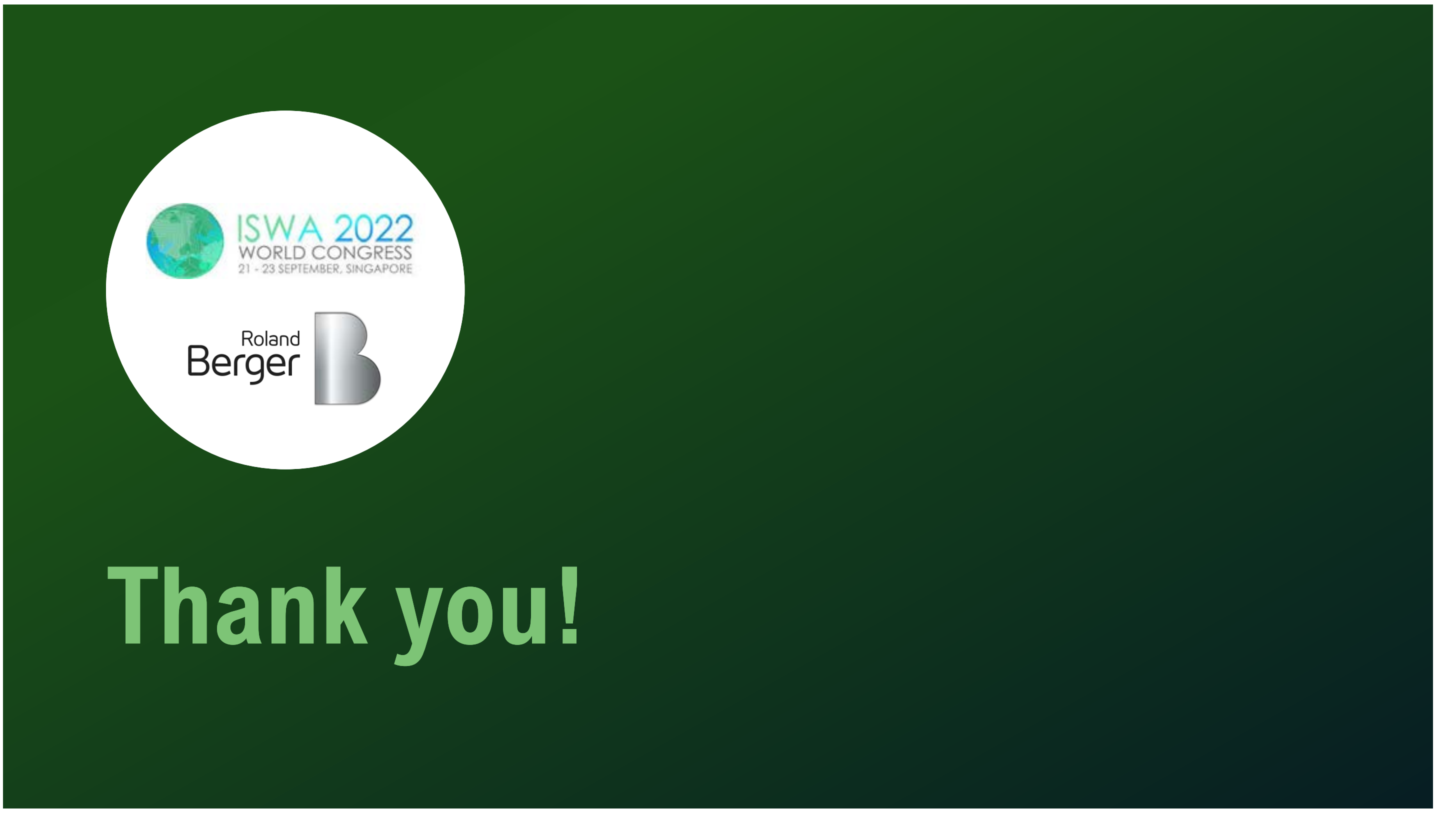
**Evolution of landfill diversion in best practice countries [1990-2021, %]**




**Public awareness** is one of the key observed factors impacting the achievement of high landfill diversion target

The first action towards achieving circularity is **reducing waste generation**


Illustrative
Considerable benefits to the country
Example benefits for a 16 m tons MSW size country
1 Achieve high landfill diversion
up to 100%
2 Reduce GHG emissions
up to 35 m MTCO2eq
3 Reduce reliance on non-renewable fossil fuel
20m oil barrel savings
4 Diversify renewable energy-mix
8 GWh green energy generated
5 Contribute to boost in local GDP
USD 6 bn annually
6 Attract substantial FDIs
USD 10 bn
7 Boost public/ private investment opportunities
100+ opportunities created
8 Create local job opportunities
up to 40 k jobs
9 Assist in achieving circularity
Close the loop in commodities1) organics etc.
1) Plastic, metal, paper etc.


ISWA 2022
WORLD CONGRESS
21 - 23 SEPTEMBER, SINGAPORE
Roland Berger
Thank you!

## 十三

### 整合式的環境計畫如何支持地方朝循環經濟轉型

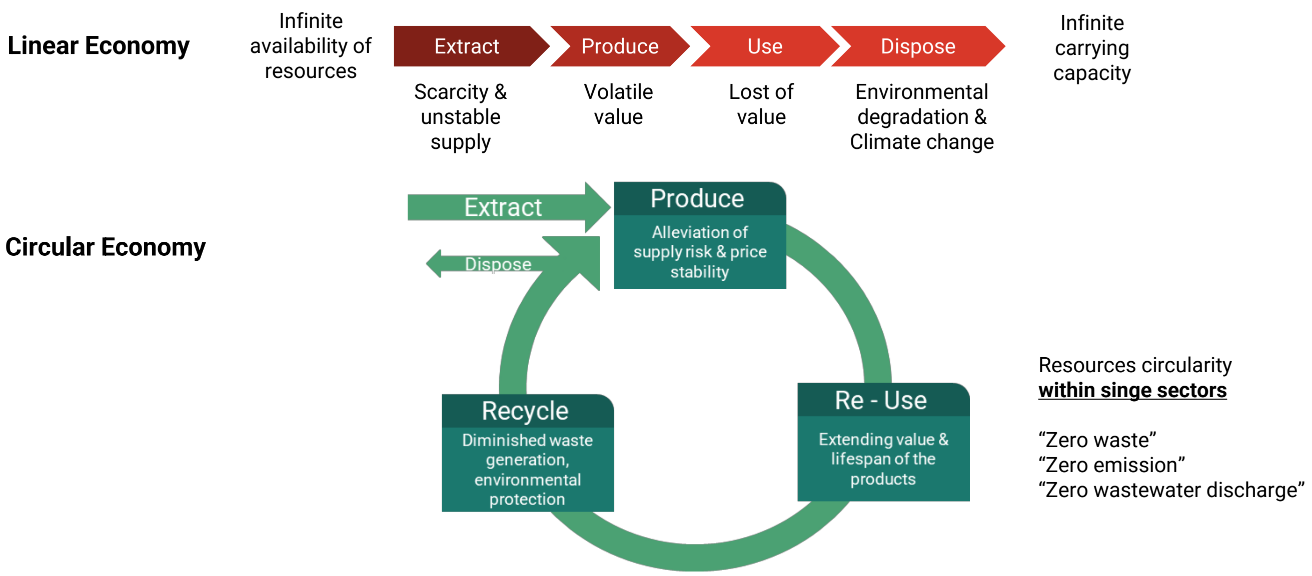
### (How Integrated Environmental Projects Can Support Transition Towards Circular Economy on A Local Level)

儘管在循環經濟範圍內跨部門資源管理的優勢已獲得認可，但仍缺失規劃的實用工具。為了彌合這一差距，開發一種易於部署規劃管理的工具。該工具可幫助決策者更好地了解資源整合管理的好處，並計算來自不同部門的已識別有機廢棄物的回收潛力，進行成本效益分析，最後提供永續性評估。


Naue

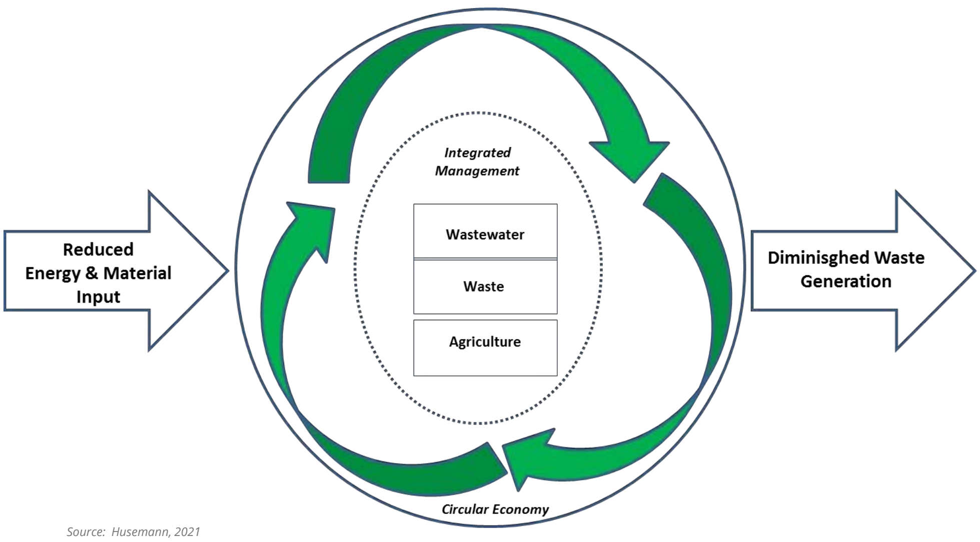
# How Integrated Environmental Projects Support Transition Towards Circular Economy on a Local Level

## Linear vs. Circular Economy (CE)





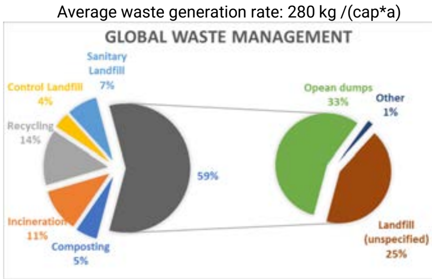

## Cross-sectoral Synergies as a Way Toward CE Transition




Source: Husemann, 2021

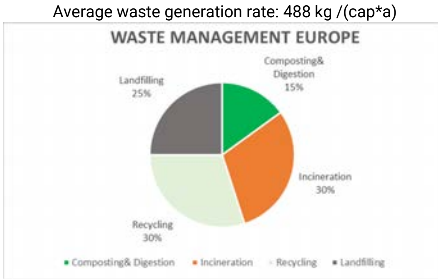
## Waste Management Status Quo

Average waste generation rate: 280 kg /(cap*a)

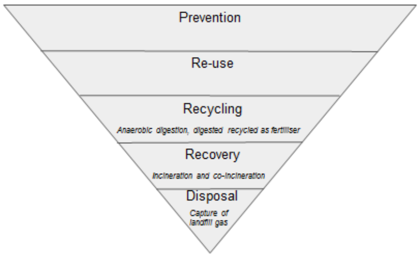



*Source: Adopted from World Bank, 2018*

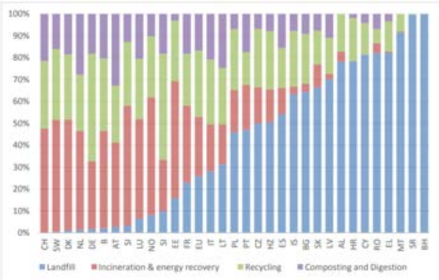
Average waste generation rate: 488 kg /(cap*a)



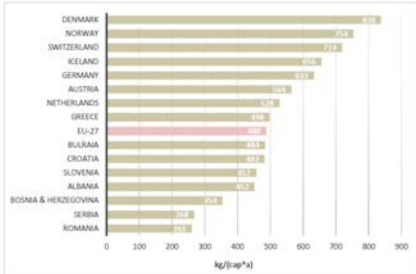

*Source: Adopted Eurostat data from 2018*




*Source: Adopted from EU, 2017*



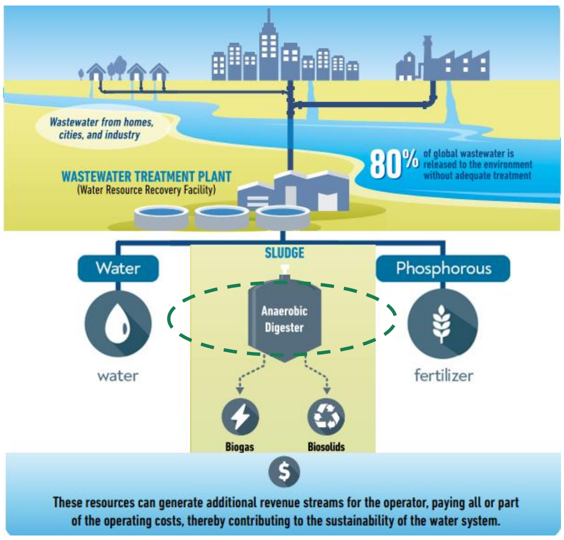

*Source: Adopted Eurostat data from 2018*




*Source: Adopted Eurostat data from 2018*

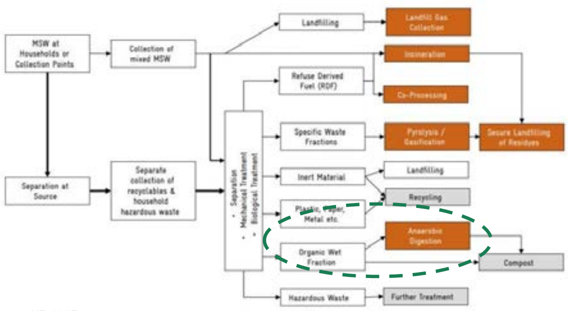


## Waste(water) as a Resource in CE



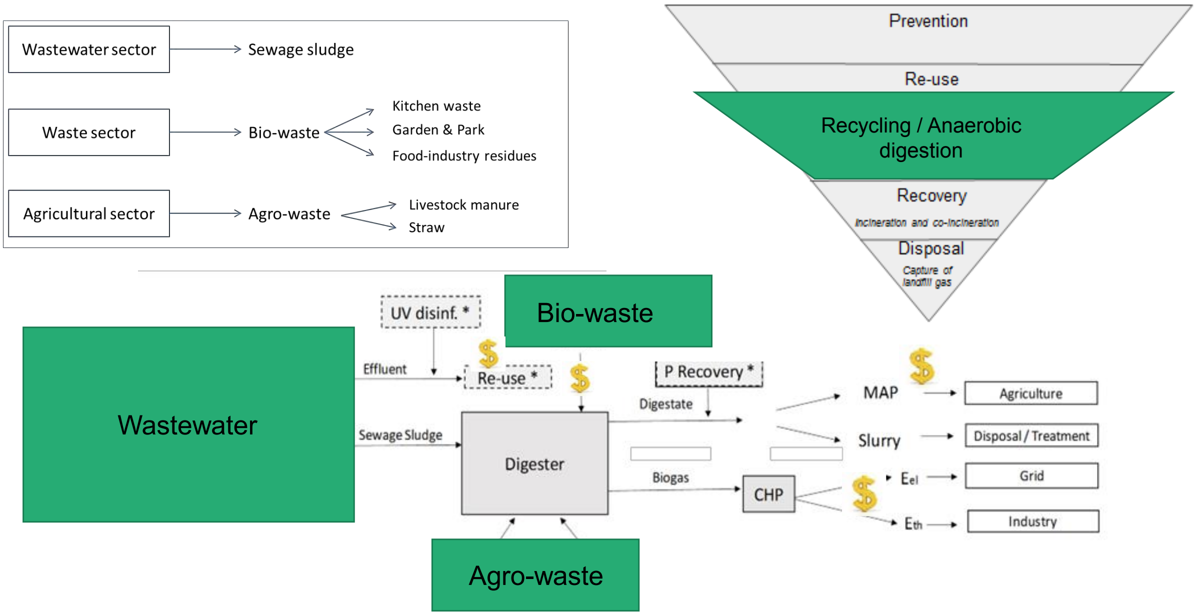

*Source: Adopted from Rodriguez, D. J. et al., 2020 & World Bank, 2018*


*Source: Adopted from World Bank, 2018*




*Source: GIZ, 2017*

## Integrated projects and CE






## Project Planning - Decision Support Tool (DST)

Input data → DST → Added value generated

Wastewater & organic "waste" flows

***Excel based tool***

Recovered energy, wastewater and Phosphorus and its preliminary cost estimation

| Type of WWT | Selection | Default | Mandatory |
|---|---|---|---|
| Decentralized WWTP | | | Yes |
| SBR | | | Yes |
| CW | | | Yes |

| Recovery/Reuse of Substances | Selection | Default | Mandatory |
|---|---|---|---|
| Phosphorus recovery | | | Yes |
| Wastewater reuse | | | Yes |

| Prices | Price | Default | Mandatory |
|---|---|---|---|
| Electricity price | | | Yes |
| Heat price | | | Yes |
| Feed in tariff sewage sludge | | 84 €/MWh | No |
| Feed in tariff agricultural residues | | 157 €/MWh | No |

| Financial Data | Value | Default | Mandatory |
|---|---|---|---|
| Loan | | | Yes |
| Equity | 100% | 100% | No |
| Interest rate | | 6% | No |

| Tariffs | Value | Default | Mandatory |
|---|---|---|---|
| Domestic wastewater | | | Yes |
| Industrial wastewater | | | Yes |

| Waste water | Value | Default | Mandatory |
|---|---|---|---|
| Daily domestic wastewater flow | | | Yes |
| Daily industrial wastewater flow | | | Yes |
| Specific waste water production | | 143 m3/d | No |
| Central WWTP capacity | | | Yes |
| CW Capacity | | | Yes |

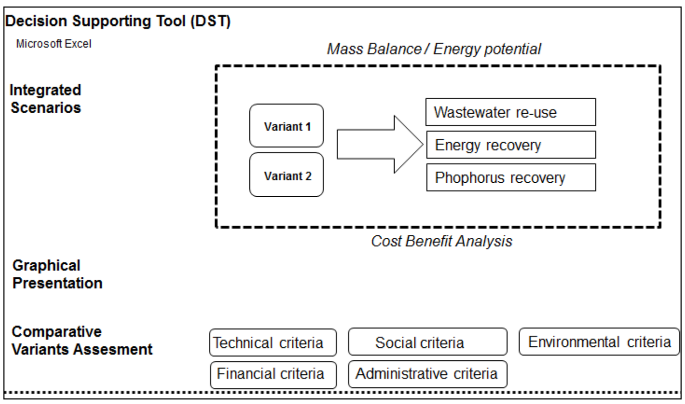
| Crops | Value | Default | Mandatory |
|---|---|---|---|
| Corn | | t/a | No |
| Whole cereal | | t/a | No |
| Barley | | t/a | No |
| Grass | | t/a | No |
| Sugar beet | | t/a | No |
| Rapeseeds | | t/a | No |
| Sunflower | | t/a | No |

| Livestock manure | Value | Default | Mandatory |
|---|---|---|---|
| Cow manure | | t/a | No |
| Cow liquid manure | | t/a | No |
| Pig manure | | t/a | No |
| Poultry | | t/a | No |
| Horses excrements | | t/a | No |

| Bio-waste | Value | Default | Mandatory |
|---|---|---|---|
| Green cut | | t/a | No |
| Kitchen Waste | | t/a | No |

| Food-industry residues | Value | Default | Mandatory |
|---|---|---|---|
| Brewer's grains | | t/a | No |
| Cereal distillers | | t/a | No |
| Potato stillage | | t/a | No |
| Fruit distillers | | t/a | No |
| Raw glycerine | | t/a | No |
| Rapeseed press cake | | t/a | No |
| Potato pulp | | t/a | No |
| Z-press cutlets | | t/a | No |
| Molasses | | t/a | No |
| Apple pomace | | t/a | No |
| Milk | | t/a | No |
| Whey | | t/a | No |

Calculate!




*Source: Husemann, 2021*

# DST - Integrated Scenarios & Variants

Naue

Semi-Decentralise (sequence batch reactor - SBR)?
Decentralised wastewater treatment (CW)?

Phosphorus recovery ?

Effluent recovery?

| Type of WWT | Selection | Default | Mandatory |
|---|---|---|---|
| Decentralized WWTP | | | Yes |
| SBR | | | Yes |
| CW | | | Yes |

| Recovery/Reuse of Substances Selection | Default | Mandatory |
|---|---|---|
| Phosphorus recovery | | Yes |
| Wastewater reuse | | Yes |

| Prices | Price | Default | Mandatory |
|---|---|---|---|
| Electricity price | | | Yes |
| Heat price | | | Yes |
| Feed in tariff sewage sludge | | 84 €/MWh | No |
| Feed in tariff agricultural residues | | 157 €/MWh | No |

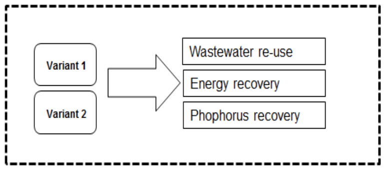
| Financial Data | Value | Default | Mandatory |
|---|---|---|---|
| Loan | | | Yes |
| Equity | 100% | 100% | No |
| Interest rate | | 6% | No |

| Tariffs | Value | Default | Mandatory |
|---|---|---|---|
| Domestic wastewater | | | Yes |
| Industrial wastewater | | | Yes |

In total 16 integrated Scenarios

| | | | Effluent recovery | Phosphorus recovery | Effluent recovery | Phosphorus recovery | Effluent recovery | Phosphorus recovery | Effluent recovery | Phosphorus recovery |
|---|---|---|---|---|---|---|---|---|---|---|
| SBR | CW | | no | no | yes | no | no | yes | yes | yes |
| | | | a | | b | | c | | d | |
| no | no | 1 | Scenario a-1 | | Scenario b-1 | | Scenario c-1 | | Scenario d-1 | |
| yes | no | 2 | Scenario a-2 | | Scenario b-2 | | Scenario c-2 | | Scenario d-2 | |
| no | yes | 3 | Scenario a-3 | | Scenario b-3 | | Scenario c-3 | | Scenario d-3 | |
| yes | yes | 4 | Scenario a-4 | | Scenario b-4 | | Scenario c-4 | | Scenario d-4 | |

*Mass Balance / Energy potential*

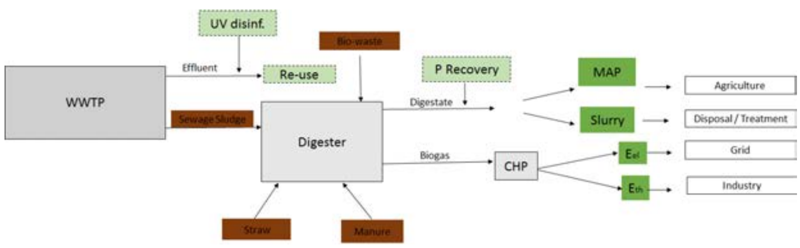



*Cost Benefit Analysis*

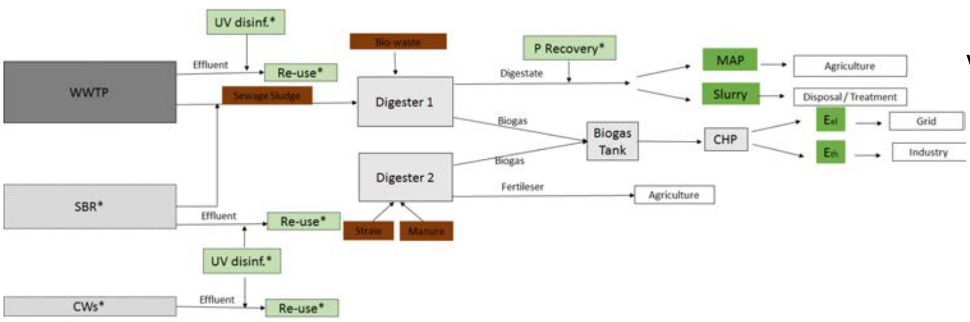


# DST - Variants of the Scenarios

Naue



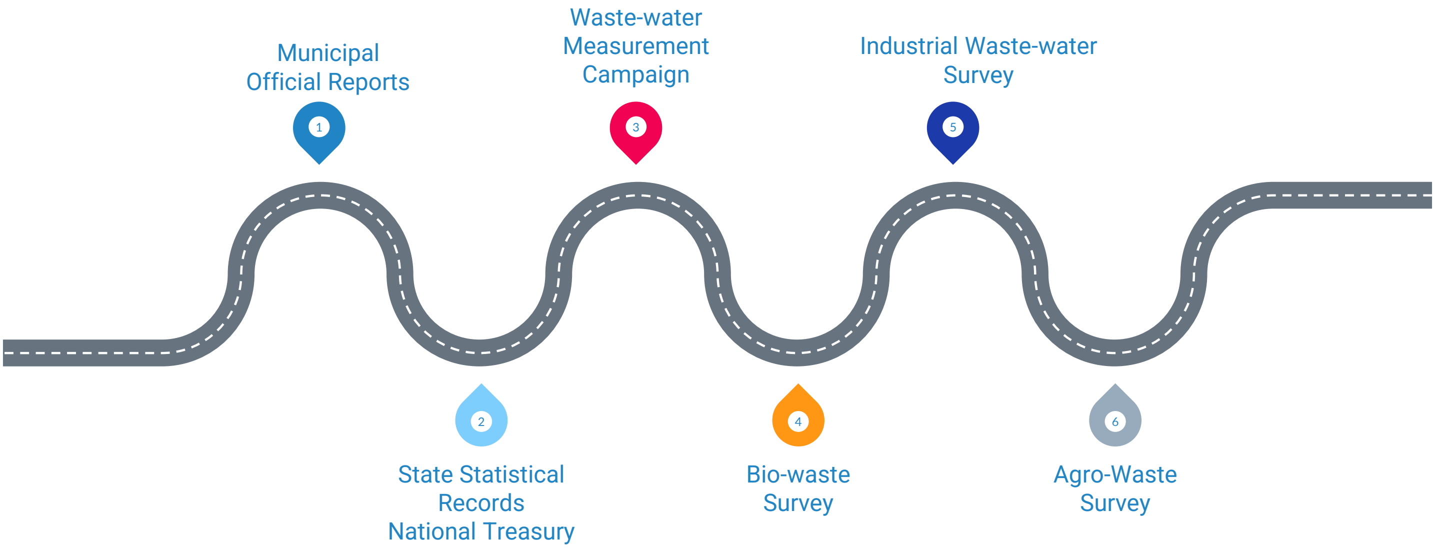

Variant 1 - centralised approach




Variant 2 - modular approach

## Data Collection

Naue








## DST - User Input Exempel

Naue

| | | | Effluent recovery | Phosphorus recovery | Effluent recovery | Phosphorus recovery | Effluent recovery | Phosphorus recovery | Effluent recovery | Phosphorus recovery |
|---|---|---|---|---|---|---|---|---|---|---|
| SBR | CW | | no | no | yes | no | no | yes | yes | yes |
| | | | a | | b | | c | | d | |
| no | no | 1 | Scenario a-1 | | Scenario b-1 | | Scenario c-1 | | Scenario d-1 | |
| yes | no | 2 | Scenario a-2 | | Scenario b-2 | | Scenario c-2 | | Scenario d-2 | |
| no | yes | 3 | Scenario a-3 | | Scenario b-3 | | Scenario c-3 | | Scenario d-3 | |
| yes | yes | 4 | Scenario a-4 | | Scenario b-4 | | Scenario c-4 | | Scenario d-4 | |

| Type of WWT | Selection | Default | Mandatory |
|---|---|---|---|
| Decentralized WWTP | Yes | | Yes |
| SBR | No | | Yes |
| CW | Yes | | Yes |

| Recovery/Reuse of Substances | Selection | Default | Mandatory |
|---|---|---|---|
| Phosphorus recovery | Yes | | Yes |
| Wastewater reuse | No | | Yes |

| Prices | Price | Default | Mandatory |
|---|---|---|---|
| Electricity price | 70 €/MWh | | Yes |
| Heat price | 40 €/MWh | | Yes |
| Feed in tariff sewage sludge | 84 €/MWh | 84 €/MWh | No |
| Feed in tariff agricultural residues | 157 €/MWh | 157 €/MWh | No |

| Financial Data | Value | Default | Mandatory |
|---|---|---|---|
| Loan | 90% | 100% | Yes |
| Equity | 10% | 0% | No |
| Interest rate | 7% | 6% | No |

| Tariffs | Value | Default | Mandatory |
|---|---|---|---|
| Domestic wastewater | 0.26 €/m3 | | Yes |
| Industrial wastewater | 0.37 €/m3 | | Yes |

Measurement Campaign & Industry Survey

Agro-survey

Waste survey

| Waste water | Value |
|---|---|
| Daily domestic wastewater flow | 16,302 m3/d |
| Daily industrial wastewater flow | 4,471 m3/d |
| Specific waste water production | 143 m3/d |
| Central WWTP capacity | 145,500 P.E |
| CW Capacity | 10,000 P.E |

| Crops | Value |
|---|---|
| Corn | 36,826 t/a |
| Whole cereal | 12,825 t/a |
| Barley | 2,180 t/a |
| Grass | 3,800 t/a |
| Sugar beet | 114,000 t/a |
| Rapeseeds | 500 t/a |
| Sunflower | 1,554 t/a |

| Livestock manure | Value |
|---|---|
| Cow manure | 200 t/a |
| Cow liquid manure | t/a |
| Pig manure | 1,850 t/a |
| Poultary | 1 t/a |
| Horses excrements | t/a |

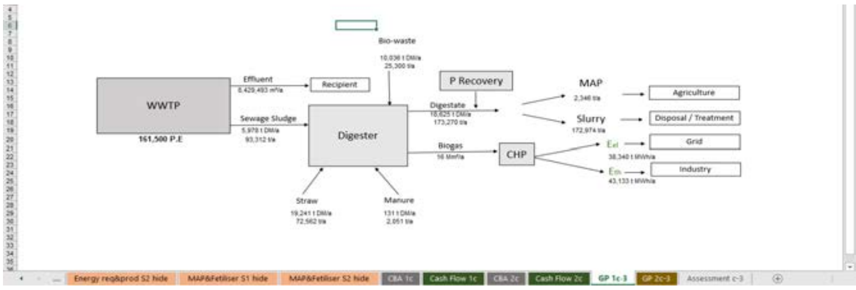
| Bio-waste | Value |
|---|---|
| Green cut | 300 t/a |
| Kitchen Waste | 25,000 t/a |

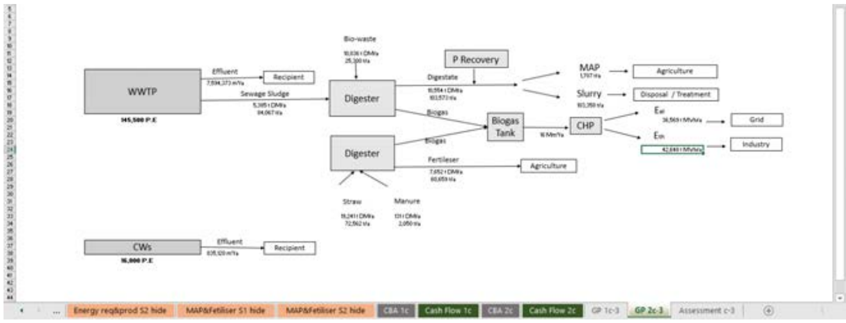
| Food-industry residues | Value |
|---|---|
| Brewer's grains | t/a |
| Cereal distillers | t/a |
| Potato stillage | t/a |
| Fruit distillers | t/a |
| Raw glycerine | t/a |
| Rapeseed press cake | t/a |
| Potato pulp | t/a |
| Z-press cutlets | t/a |
| Molasses | t/a |
| Apple pomace | t/a |
| Milk | t/a |
| Whey | t/a |

Calculate!

## DST Results

Naue






## DST - CBA and Cash Flow

Naue

| Investment Costs | Results |
|---|---|
| Investment costs WWTP | 17.437.500 € |
| Investment costs SBR | 2.550.000 € |
| Investment costs Digester 1 | 4.893.896 € |
| Investment costs Digester 2 | 12.061.898 € |
| Investment costs Constructed Wetland | 5.120.000 € |
| Investment costs MAP recovery | 785.700 € |
| Investment costs disinfection WWTP | € |
| Investment costs disinfection SBR | € |
| Investment costs disinfection Constucted Wetland | € |
| **Total** | **42.848.992 €** |

| O&M Costs | Results |
|---|---|
| Labour | 244.800 €/a |
| WWTP and digester Electricity | 576.443 €/a |
| MAP production | 829.350 €/a |
| WWTP effluent disinfection | €/a |
| SBR effluent dissinfection | €/a |
| CW effluent dissinfection | €/a |
| Transport and disposal of digestate | 962.253 €/a |
| Checmicals costs | 66.885 €/a |
| Maintenance costs | 856.980 €/a |
| **Total** | **3.536.710 €/a** |

| Revenues added value | Result |
|---|---|
| Revenues electricty | 3.077.421 €/a |
| Revenues theraml energy | 727.276 €/a |
| Revenues MAP | 512.107 €/a |
| **Total** | **4.316.804 €/a** |

| Revenues tariffs | Result |
|---|---|
| Revenues tariffs | **2.150.868 €/a** |

| Revenues fertiliser | Result |
|---|---|
| Revenues fertiliser | 606.592 €/a |

| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| Loan 0,9 | 38.564.093 | | | | | | | |
| Equity 0,1 | 4.284.899 | | | | | | | |
| Investment | -42.848.992 | | | | | | | |
| Annuity | | -3.362.193 | -3.362.193 | -3.362.193 | -3.362.193 | -3.362.193 | -3.362.193 | -3.362.193 |
| Operational Costs | | -3.536.710 | -3.536.710 | -3.536.710 | -3.536.710 | -3.536.710 | -3.536.710 | -3.536.710 |
| Income from Operation | | 4.923.396 | 4.923.396 | 4.923.396 | 4.923.396 | 4.923.396 | 4.923.396 | 4.923.396 |
| Income from Tarifs | | 2.150.868 | 2.150.868 | 2.150.868 | 2.150.868 | 2.150.868 | 2.150.868 | 2.150.868 |
| Sum of Cash-Flows | 0 | **175.361** | **175.361** | **175.361** | **175.361** | **175.361** | **175.361** | **175.361** |
| Sum of Discounted Cash Flow | 0 | **167.010** | **159.057** | **151.483** | **144.270** | **137.400** | **130.857** | **124.626** |

| Year | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
|---|---|---|---|---|---|---|---|
| Loan 0,9 | | | | | | | |
| Equity 0,1 | | | | | | | |
| Investment | | | | | | | |
| Annuity | -3.362.193 | -3.362.193 | -3.362.193 | -3.362.193 | -3.362.193 | -3.362.193 | -3.362 |
| Operational Costs | -3.536.710 | -3.536.710 | -3.536.710 | -3.536.710 | -3.536.710 | -3.536.710 | -3.536 |
| Income from Operation | 4.923.396 | 4.923.396 | 4.923.396 | 4.923.396 | 4.923.396 | 4.923.396 | 4.923 |
| Income from Tarifs | 2.150.868 | 2.150.868 | 2.150.868 | 2.150.868 | 2.150.868 | 2.150.868 | 2.150 |
| Sum of Cash-Flows | **175.361** | **175.361** | **175.361** | **175.361** | **175.361** | **175.361** | **175.** |
| Sum of Discounted Cash Flow | **118.691** | **113.039** | **107.656** | **102.530** | **97.647** | **92.997** | **88.** |

| Column1 | Column2 |
|---|---|
| **Discount Rate** | **5%** |

| Column1 | Column2 |
|---|---|
| **NPV** | **2.185.381** |

## CBA - Comparative Variants Assessment

Naue

| N0. | Criteria | No. | Sub-criteria | Type of criteria | Measurement unit | Variant 1 | Varinat 2 |
|---|---|---|---|---|---|---|---|
| 1 | Technical | 1.1 | Flexibility/modularity | Qualitative | [-] | xx | xxx |
| | | 1.2 | Operational complexity | Qualitative | [-] | xx | xx |
| | | 1.3 | Process stability & Robustness | Qualitative | [-] | xxx | xx |
| | | 1.4 | Infrastructure adaptation | Qualitative | [-] | xx | xx |
| 2 | Social | 2.1 | Public acceptance | Qualitative | [-] | xx | x |
| | | 2.2 | Employment Opportunities | Qualitative | [-] | xx | xx |
| 3 | Environmental | 3.1 | Landfilled residues | Quantitative | [t/a] | 172,974 t/a | 113,207 t/a |
| | | 3.2 | Energy consumption | Quantitative | [MWh/a] | 21,310 MWh/a | 21,139 MWh/a |
| | | 3.3 | Reagens consumption | Quantitative | [t/a] | 086,526 t/a | 080,463 t/a |
| | | 3.4 | GHGs emissions savings | Quantitative | [t CO2eq/a] | 76,681 t/a | 76,324 t/a |
| | | 3.5 | Recovered energy (gross) | Quantitative | [kWh/a] | 81,473 MWh/a | 79,754 MWh/a |
| | | 3.6 | Recovered materials | Quantitative | [t/a] | 2,346 t MAP/a | 1.757 t MAP/a; 56.795 t fertiliser/a |
| | | 3.7 | Re-used water | Quantitative | [m3/a] | 0 m³/a | 0 m³/a |
| 4 | Financial | 4.1 | CAPEX | Quantitative | [€] | 38,106,328 € | 41,175,416 € |
| | | 4.2 | OPEX | Quantitative | [€/a] | 3,792,320 €/a | 3,663,694 €/a |
| | | 4.3 | Revenues | Quantitative | [€/a] | 7,125,737 €/a | 7,126,391 €/a |
| | | 4.4 | NPV (Cumulative 20 years) | Quantitative | [€] | 1,198,199 € | -439,969 € |
| 5 | Administrative | 5.1 | Complexity of authorisation | Qualitative | [-] | xx | xxx |



## Integrated Projects - Safe Construction with Geosyntetics

Naue

## The Application of Geosynthetics in Environmental Engineering

“The need of **smarter, systemic, faster** climate adaption has to be supported by robust, environmentally friendly and resource-saving constructions in civil engineering” (EU Commission, 2021).

***Geotechnical solutions are durable, save $CO_2$ and improve the energy balance.***


Example: Water reservoirs


Example: Sewage sludge/Slurry lagoons


Example: Water channel


Example: Irrigation ponds



## Naue Guiding Principles


### CE and Sustainability

Naue focuses on innovation to create even more sustainable product developments:

- The **ClassicLine** consists of products made from synthetic, polymeric raw materials. The products are designed to meet the highest achievable standards for long-term durability.
- The **GreenLine** products are biodegradable. The material for these products comes from renewable raw materials (bio-based).
- Our **EcoLine** is made from or with recycled raw materials. The products are designed to be as close as possible to a 100% circular economy.

### Quality

We are particularly proud of the quality of our solutions and products.

We are certified in environmental management (ISO 14.001) and energy management (ISO 50.001). Quality management for the areas of development, production, sales and geosynthetic application technology has been certified according to ISO 9001 since 1994. This certification is confirmed by regular surveillance audits.

## Naue -  Full Service Provider

### Engineering services

With our well-trained engineers, we offer project-specific engineering planning.

### Software-Tools

**Naue Portal**
The Naue Portal is the basic building block for digital access to solutions.

**Naue SolutionFinder**
The Naue SolutionFinder is a genuine, multi-stage digital planning tool with individual consideration of your requirements and implied calculations.

**Naue DesignSuite**
We bundle our design tools and calculation software for all types of geotechnical tasks.

### Installation services

Naue has an experienced team to carry out installations for your sealing application.

### Naue Customer Center

With the CustomerCenter, we provide selected partners with a digital platform where you can view and process availability, prices and delivery conditions as well as your orders.

## Naue Application Examples

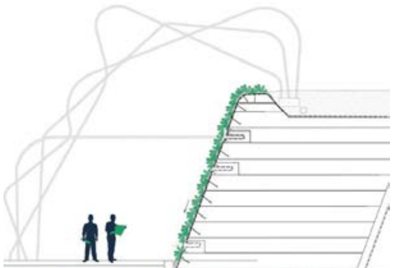
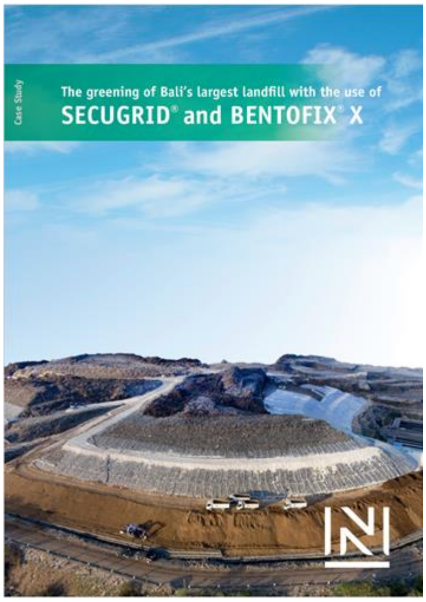
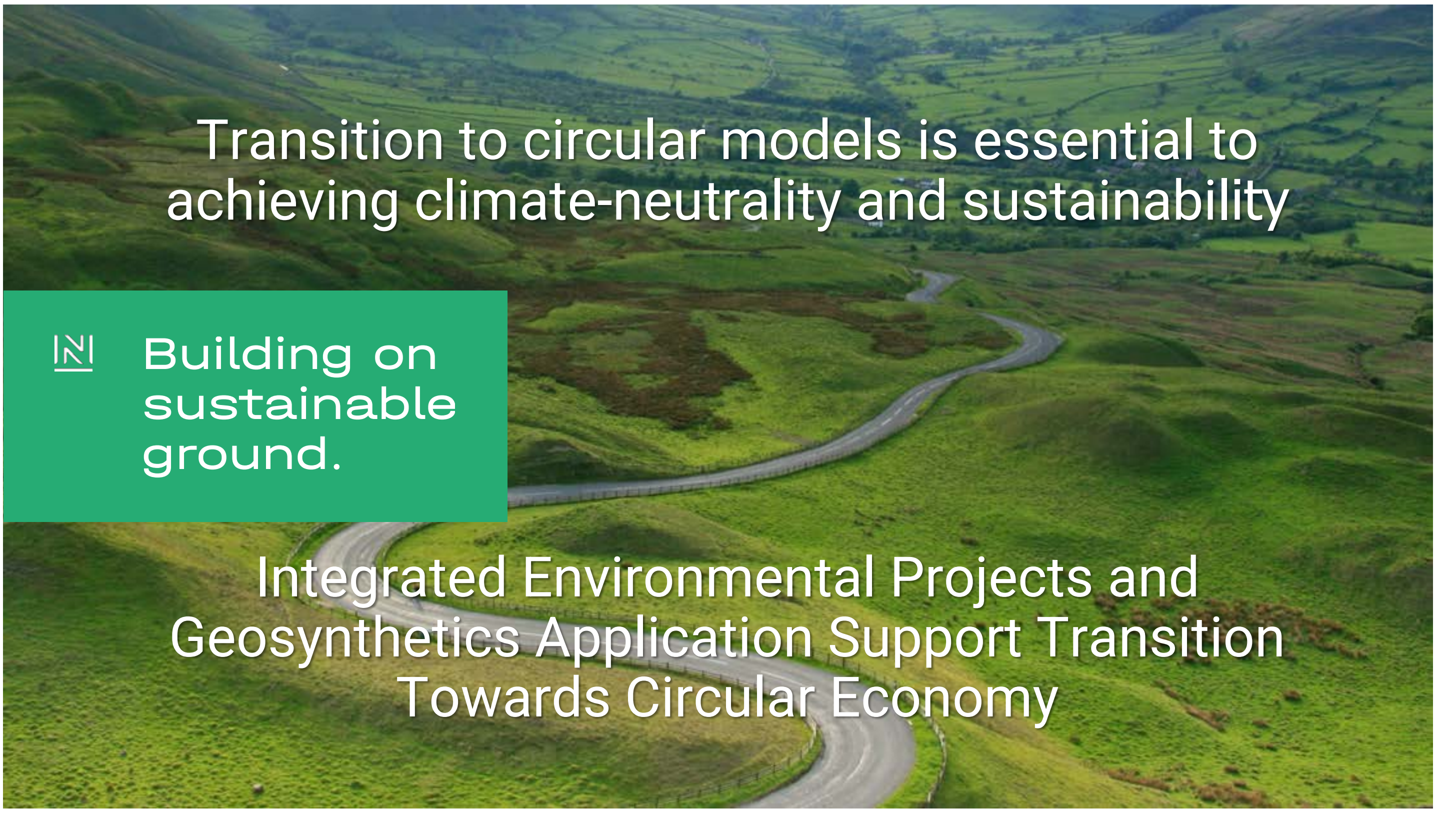


Fig. 6: Typical cross section of Combigrid® reinforced "Green Wall"




© 2022 Naue GmbH & Co. KG Dr. Jovana Husemann | ISWA World Congress Singapore | 21 September 2022 naue.com




**Dr. Jovana Husemann**
*Business Development Manager*

Naue GmbH & Co. KG

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Mob. +49 173 549 4730

Thank You.

Building on sustainable ground.

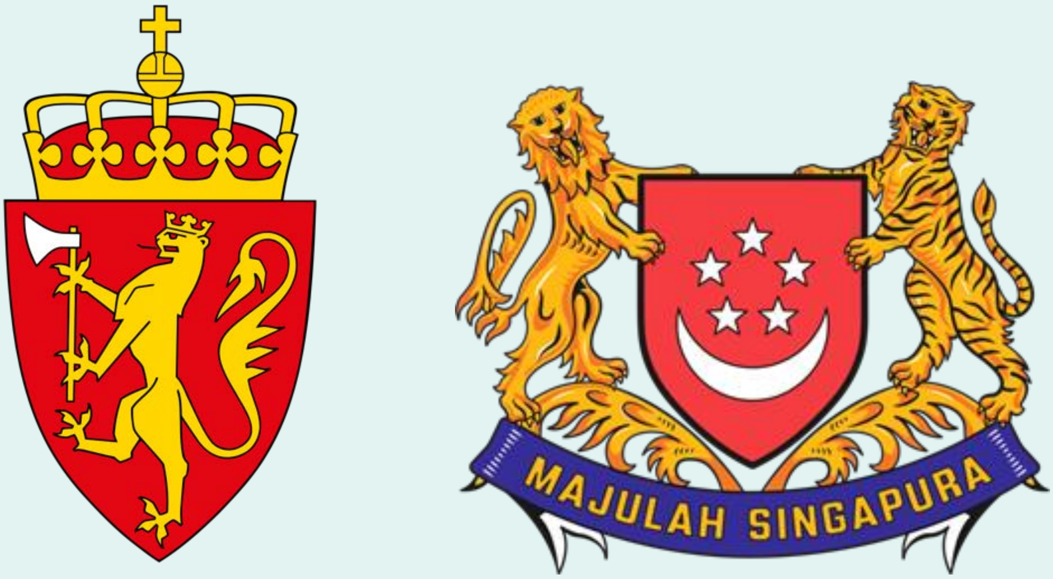
| 十四 |
| --- |
| 是什麼阻止了包裝的循環以及如何處理它<br><br>**(What Prevents Packaging from Circularity and How to Deal with It)** |
| 包裝業對於環境造成許多危害，因此Ola Roness經理領導一個業務和創新團隊，專責處理面臨的障礙和解決方案，將包裝業從線性經濟轉變為循環經濟。循環包裝由商業快速消費品生產商、包裝生產商、創新者、初創企業、研發組織組成，挪威政府也同時支持創新和發展，為循環經濟做出貢獻。 |

POPULATION

5,5 5,5

POPULATION




CIRCULAR PACKAGING CLUSTER


Departementene
Strategi
Noregs plaststrategi


zero
waste
masterplan


Population density 213th
Population density 3rd
CIRCULAR
PACKAGING
CLUSTER

Norwegian Innovation Clusters

Arena

Arena Pro

NCE
Norwegian Centres of Expertise

CIRCULAR PACKAGING CLUSTER

# Collaboration for innovation and solutions for circular barriers

# Our focus areas

**Renewable material use**

Increased use of sustainable materials from renewable, recycled and recyclable resources.

**Circular business models**

Develop sustainable, circular and profitable business models in practice.

**Recycling**

Facilitation of collaboration between the upstream and downstream side of the value chain.

**Innovation and commercialization**

Products and services which have user attractiveness, strengthen Norwegian production of sustainable packaging materials and packaging solutions.

# A circular economy is being pushed forward

Role of the cluster: Collaboration platform for development, innovation and competitiveness

REGULATIONS & DIRECTIVES

SYSTEMS

THE PLAYERS

INNOVATION
&
COLLABORATION

ATTIDUDES & BEHAVIOUR

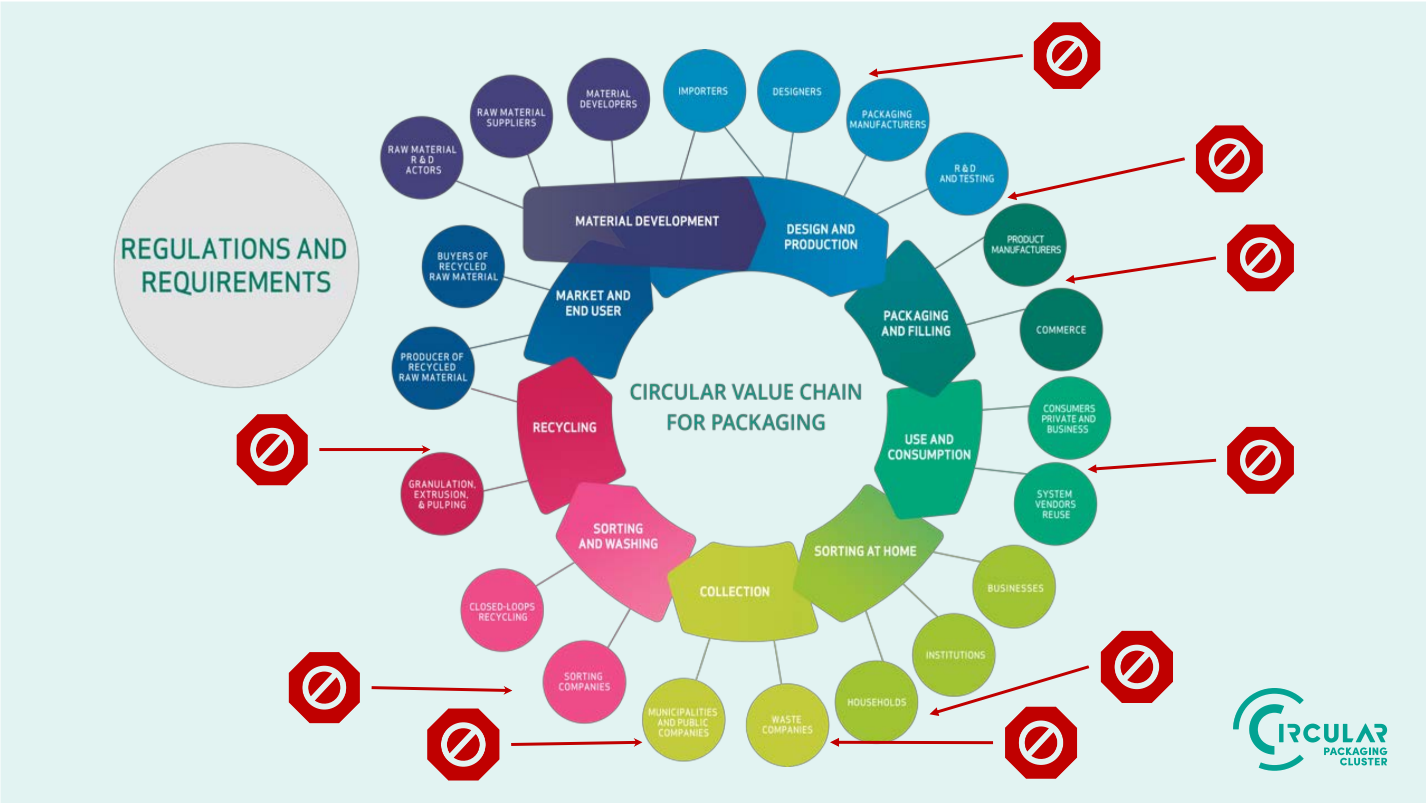
# Strategic platform

## Vision

We will create the world's most efficient and circular value chain for packaging.

## Mission

To facilitate collaboration and development in the packaging value chain to reduce circular barriers and promote innovation and market development within existing and new markets.




# Five challenges

Which currently limit circular development

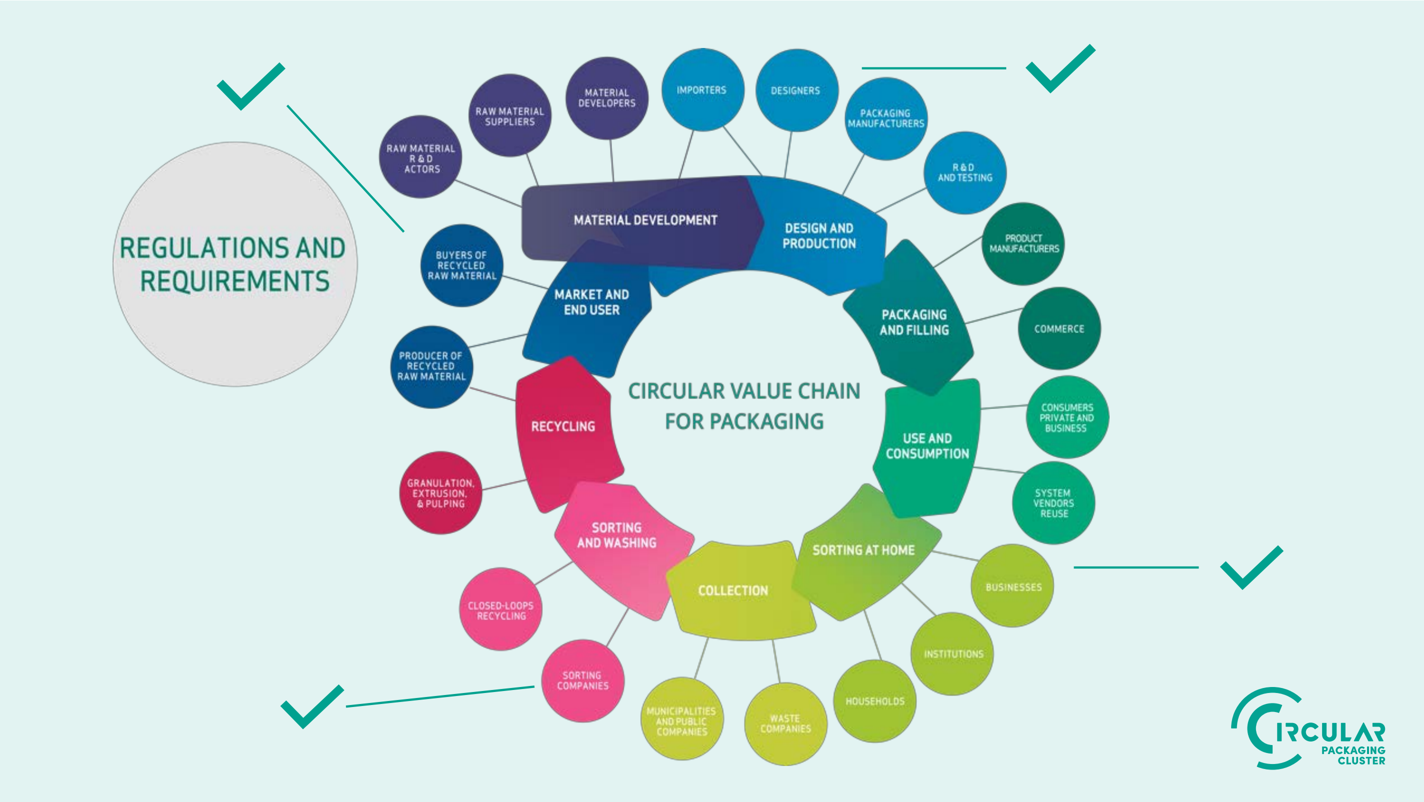
1 Systemic challenges

2 Commercial challenges

3 Competence-related challenges

4 Regulatory challenges

5 Product-related challenges




# Mapping of barriers

| | | |
|---|---|---|
| Desk Research | | 25 |
| Interviews | | 60 |
| Workshops | | 12 |

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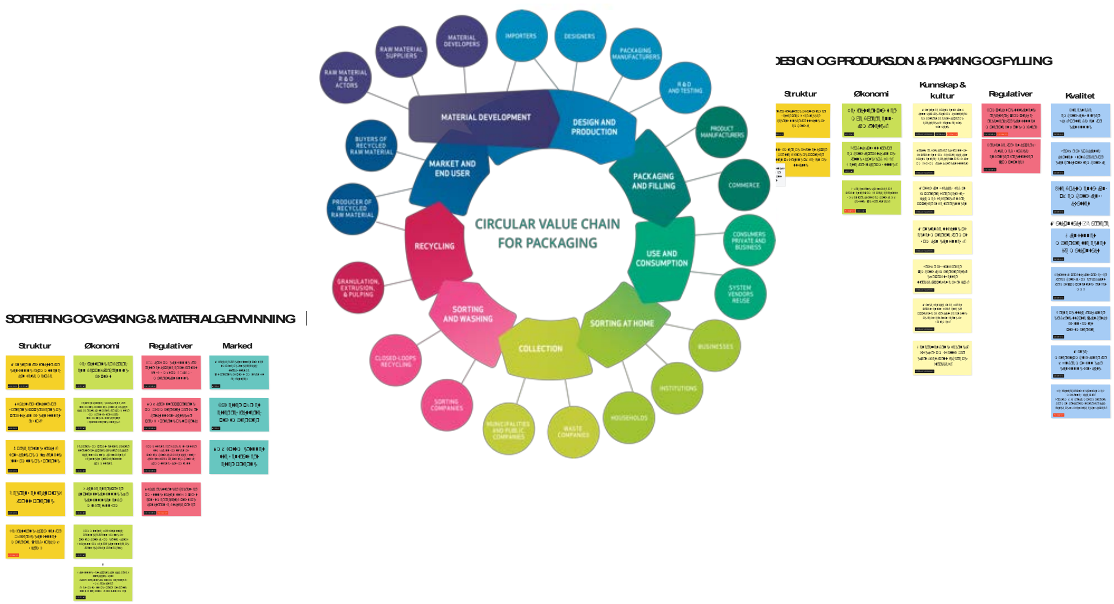
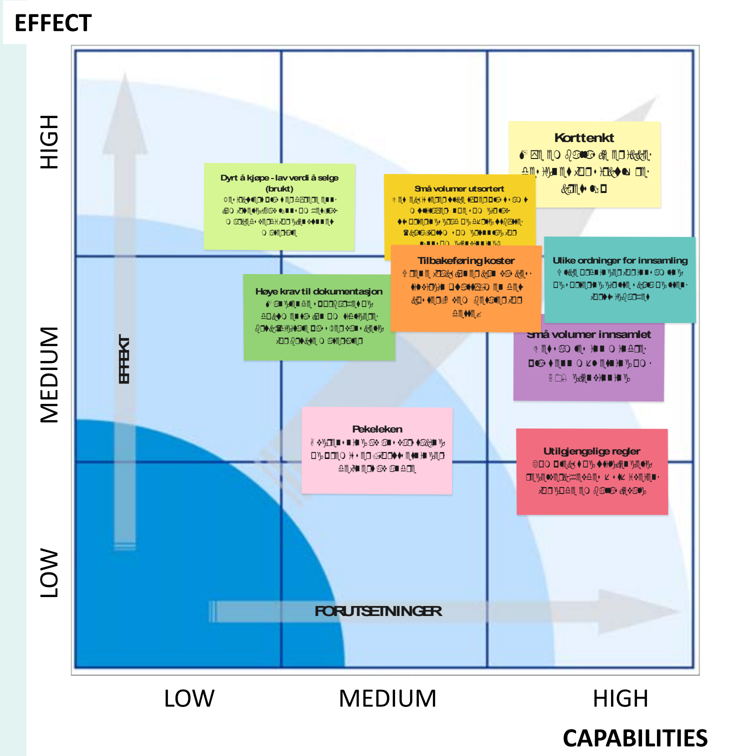
# Two main areas for barriers



1 LACK OF INCENTIVES AND CONSEQUENCES
2 INACCESSIBLE DIRECTIVES
3 DEMANDING DOCUMENTATION
4 NOT ENOUGH COLLECTED
5 TOO SMALL VOLUMES SORTED FOR RECYCLING
6 DIFFERENT REGIONAL SYSTEMS
7 THE BLAME GAME




## Lack of incentives and consequences

Much packaging is not designed for a circular value chain

1. Standardisation
2. Knowldege & Cooperation
3. Digital tools & calculators
4. Regulations

# Inaccessible directives

Complex and inaccessible regulations are claimed to stand in the way of good packaging choices

1. Updated and accessible digital source of national & international regulations + scouting
2. Dialogue ISWA and otther
3. Stronger use of directives for incentives and punishment

# Demanding documentation

Lack of traceability and documentation of previous use (digital passports) is currently difficult for used materials and makes recycling for food very difficult

1. Industry initiative for certification
2. Establish a circular initiative of standardisation
3. Early adaption of EFSA
4. Digital Tracing
5. Closed loops

# Not enough collected

Collection is a scale/efficiency thing. We collect less than recycling target.

1. Nordic system for collection
2. Coordinated B2B – B2C collection
3. Nordic system of symbols

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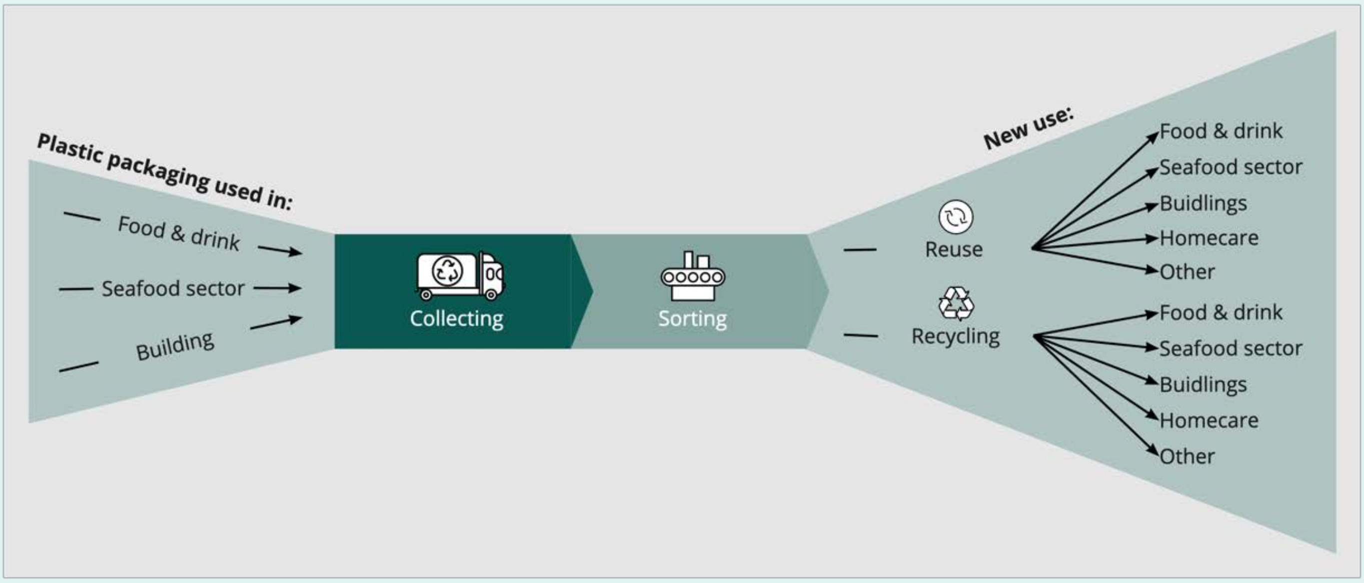
# Too small volumes sorted for recycling

There are too many different types of plastic as well as multilayers, which results in a low sorting rate and poor yield (scale/volume as basis for profitable recycling)

1. Introduce standards (fewer) of plastic materials
2. Mechanical sorting / automated / sensoric
3. R&D on tracing / digital passes for suitability / EFSA

CIRCULAR PACKAGING CLUSTER




# Different regional systems

Prevents scale and predictability

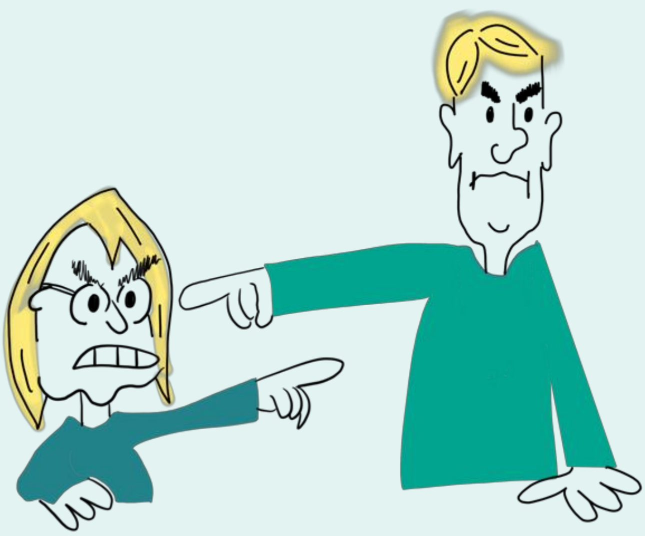
1. Nordic map for scale and fine-sorting
2. Interactive predictions

## The blame game

Unclear responsibilities and a complex value chain contribute to the pointing game, but are also used to avoid intrusive consequences for one's own business

1. Three year educational programme

2. Strengthening arenas for cooperation and co-creation



CIRCULAR PACKAGING CLUSTER

25. Aug 2022

på(fyll)©

Brief introuction

# CASE: PåFYLL

**Our mission**

We've made it our mission to face one of the biggest challenges for the future consumer market: the ever-growing pile of plastic waste.

**Our vision**

**In five years, we will have made zero-waste living easy and accessible for every individual in the Nordics.**

**What are we**

A data-driven service enabling the circular economy for the consumption of everyday home goods.

**How do we do it**

a) Circular refill system of your favourite household product

b) On-demand web shop accessible 24-7

c) Doorstep delivery and returns

d) Lifestyle insights to make zero-waste living easier

CIRCULAR PACKAGING CLUSTER


## 2,5 million tonnes

high-quality residual biological raw material is generated in Norway every year.

## 70 %

of residual raw material from Norwegian bio-industry can be used as input in new production, with greater value, and replace virgin and fossil input

## Business model // ResourcerGraph, a knowledge-graph for biological residual resources


ReSourcerGraph

document, map, and make available biological resources in an open interface. In this way, biological residual waste can be defined as resources in new productions.

The ResourcerGraph connects industrial data with market data and data from the natural sciences.

*Service under development: Analysis of resources*

## ReSourcer makes biological residual waste a valuable resource

We offer a lab as a service to industrial actors which need to document the content in their residual resources. Analysis and documentation makes the resources tradable as is, or after processing.

**Basic analysis**
Data sheet with the content of the biological resource

1 hour consultancy

*Price 2-4000NOK*

**Fertilizer analysis**
The resource as a fertilizer or as part of a organic fertilizer.

1 hour consultancy

*Price 7-10.000NOK*

**Feed analysis**
Qualify the bioresource as an input in production of animal-food.

1 hour consultancy

*Price 12-15.000NOK*

**Environmental data and LCA**
Can be offered AS an add-on service from Resourcer in cooperation with Green House.

*Price on request*


## ReSourcer creates business opportunities across different value chains.

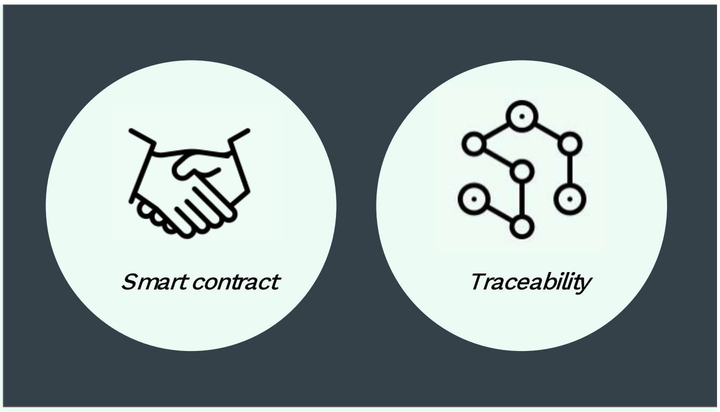
We develop an interface to present reports for municipalities, regions, industry-nettworks and consultancy-firms which works with mapping local resources in the circular bioeconomy.

**Biomap DIY**
Acess to tool for your own mapping of bioresources, including 1 year subscription.

*Price 95.000NOK per mapping*

*Service under development: Resource mapping*

## ReSourcer secure and facilitates transactions of bioresources.




Develop a facilitating service for transaction in industrial symbioses

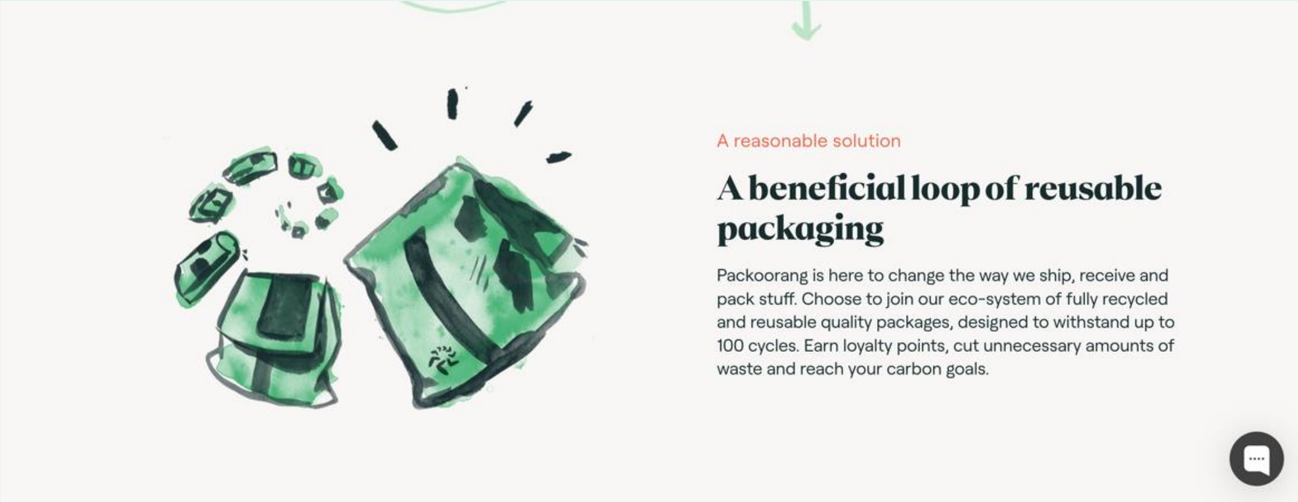
**Subscription**
Company profile with access to the platform..

*Price xxx pr year*
*alt. xx pr month*

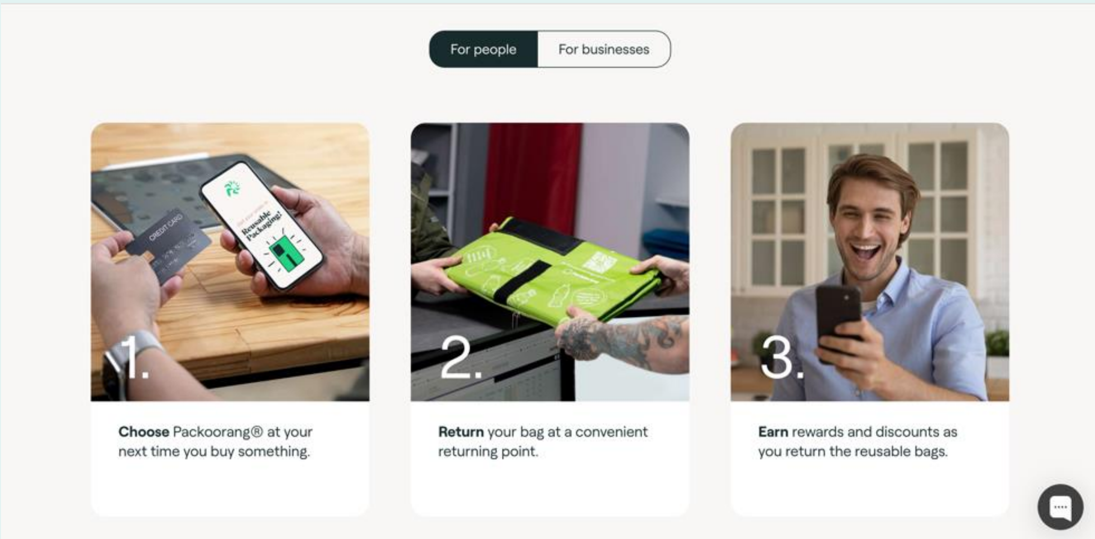
**Transaction fee**

*Price xx%*

# Packoorang




# Packoorang



# ISWA
# 21st September 2022

Circular Packaging Cluster

CEO Ola Ronæss

# 十五

## 未來燃料：向清潔和低碳燃料轉型

**(Future Fuels: A Transition to Clean and Low Carbon Fuels)**

講述生產未來燃料的原料（有機和無機）來源和技術，此外還提及未來燃料計劃背景下易出現的關鍵商業和法律問題，並闡述其溫室氣體減排潛力，並置於市場和監管場所，以更廣泛的脫碳和能源轉型背景下去探討，包括其在脫碳中的作用。

## YOUR SPEAKER TODAY

**Michael Harrison**

Senior Partner, Energy Resources and Infrastructure – Ashurst LLP

Michael acts on a broad range of matters across multiple industries and jurisdictions.

Michael works for corporations, financiers and governments on across the following sectors: energy and power, government procured infrastructure (including economic and social infrastructure), mining and natural resources, LNG, oil an gas, ports and shipping (infrastructure and operational), air and land transport (infrastructure and operational), steel, telecommunications, waste and water sectors.

In short, Michael works across all industries that are impacted by the energy transition. Michael is widely acknowledged as a leading specialist on net-zero emissions across all sectors, having acted for participants across each sector for most of his career.

Since the Paris Agreement, Michael has focused on assisting clients with understanding decarbonization and progress to NZE. He is the trusted advisor to Governments, Government Agencies and international corporations (including IOCs and international energy corporations) in this area.

In addition to roles for Government and Government Agencies, Michael is currently the lead partner advising on 12 decarbonisation projects, including in respect of carbon storage in the Bayu Undan field, and co-leading on the Antwerp@C CCS / CCUS Project.

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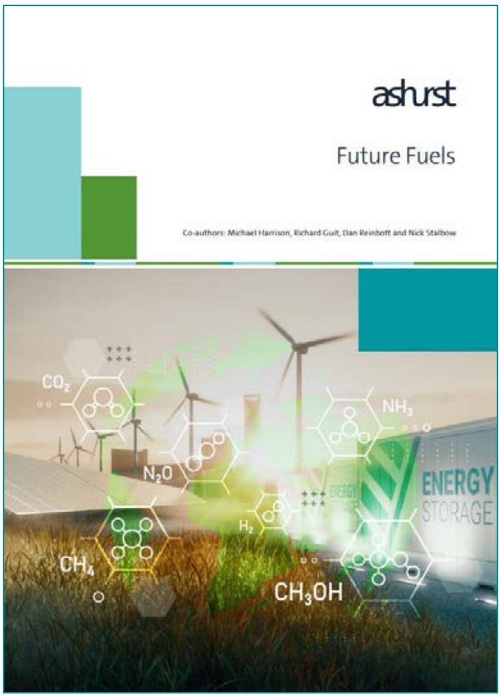
ashurst

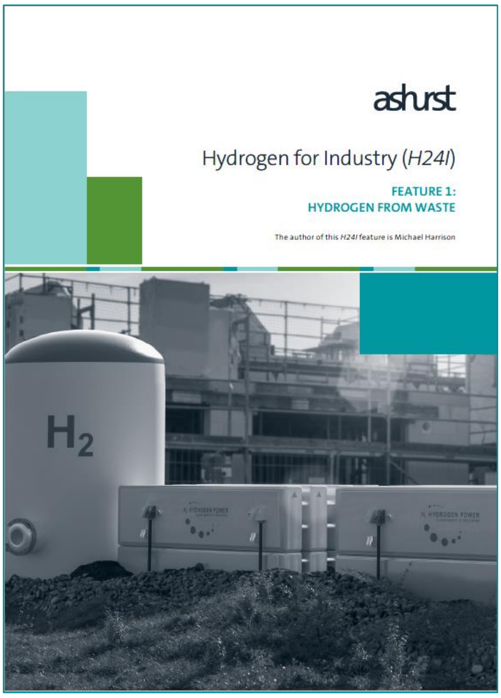
## FUTURE FUELS




- Before the session today, we would like to share a publication ***Future Fuels***;
- The purpose of the session today is not to repeat the subject matter of the Future Fuels article, rather we hope to tease-out key points in the development of the Future Fuel supply / value chains.

3

## HYDROGEN FROM WASTE




- Before the session today, we would like to share a publication ***Hydrogen from Waste***;

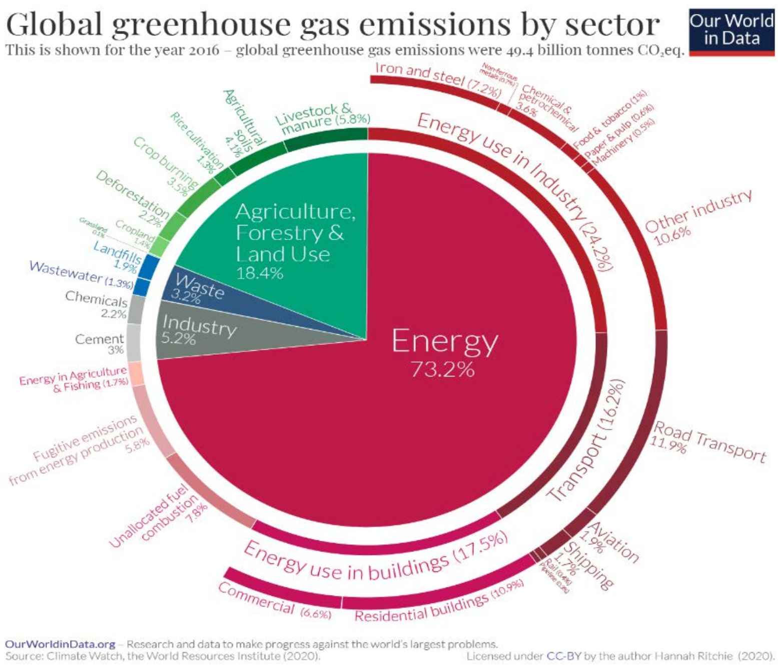
- As with the Future Fuels article, the purpose of the session today is not to repeat the subject matter of the ***Hydrogen from Waste*** publication, rather we hope to tease-out key points in the development of the ***Hydrogen from Waste*** supply / value chain.

First, some background.

4

## 1. FUTURE FUELS: A TRANSITION TO CLEAN AND LOW CARBON FUELS – GHG EMISSIONS ARISING

- GHG emissions globally – between 51 GT and 60 GT (IPCC) a year of CO2-e emissions globally (+/- 10% from 60 GT)
- While the mass of CO2-e emissions globally has increased since 2016, their proportionate source remains the same

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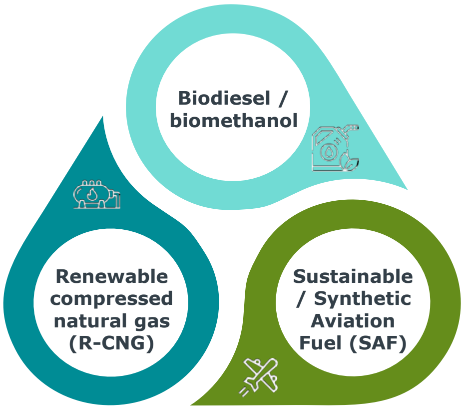
## 2. FUTURE FUELS: A TRANSITION TO CLEAN AND LOW CARBON FUELS

- **What are clean and low carbon fuels?**




- Each fuel has a lower carbon footprint than a fossil fuel derived fuel
- Not derived from a fossil fuel, derived from a carbon source that is recycled or renewable
- On combustion give rise to CO2, and are not GHG free, but less carbon intensive than fossil fuel alternatives
- Clean and low encompass cleaner and lower carbon fuels
- Clean or Low Carbon Methanol or carbon-neutral e-methanol (connoting the use of renewable energy) or sustainable bio-methanol

**More importantly as to choice of Future Fuel are:**

1. **energy density**
2. **availability and security of supply**
3. **GHG neutrality "from well to wake"**

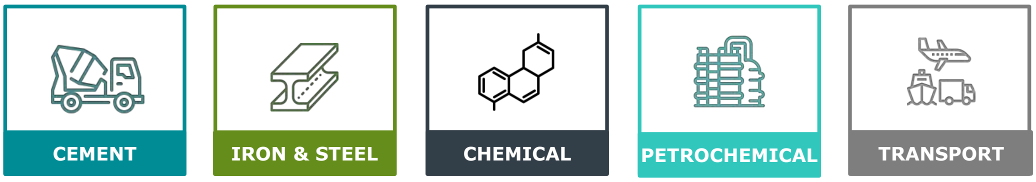


## 2. FUTURE FUELS: A TRANSITION TO CLEAN AND LOW CARBON FUELS

- **As yet there is no clear definition of clean or low carbon fuels:**
  - The one Future Fuel that gives rise to zero GHG emissions on use is **Green Hydrogen**;
  - Not all hydrogen is Green Hydrogen, and there is no standard definition of clean or low carbon hydrogen:
    - In the EU hydrogen produced from non-renewable electrical energy is low carbon if its carbon footprint is less than **36.4 g $CO_2$-e MJ** (4.37 kg per Kg of hydrogen);
    - In the UK hydrogen produced from non-renewable electrical energy is low carbon if its carbon footprint is equal to or less than **20 g $CO_2$-e / MJ** (2.4 kg CO2-e per Kg of hydrogen).

## 3. FUTURE FUELS: A TRANSITION TO CLEAN AND LOW CARBON FUELS

- **Policy Settings are key**;
- **Hydrogen and Bio-energy global focus;**
- **REE + H2** said to be the two legs of decarbonisation, and two of the six or seven means of achieving net-zero emissions;
- **Uses of H2 –** to decarbonise:




- **Law and regulation intensive to support policy settings**:
  - Allow production and use of H2 – principally, Blue and Green Hydrogen;
  - Address CO2 / GHG arising on production of Blue Hydrogen;
  - Value capture for CO2 / GHG capture on production, and HESS;
- Export of Blue Hydrogen and Green Hydrogen and hydrogen-based fuels (e.g. ammonia and methanol). Blue Hydrogen does not give rise of GHG emissions on use, Blue Ammonia and Blue Methanol both do.
- **Bioenergy** less intensive from new law and regulation perspective, but all bioenergy Future Fuels give rise to GHG emissions on use.



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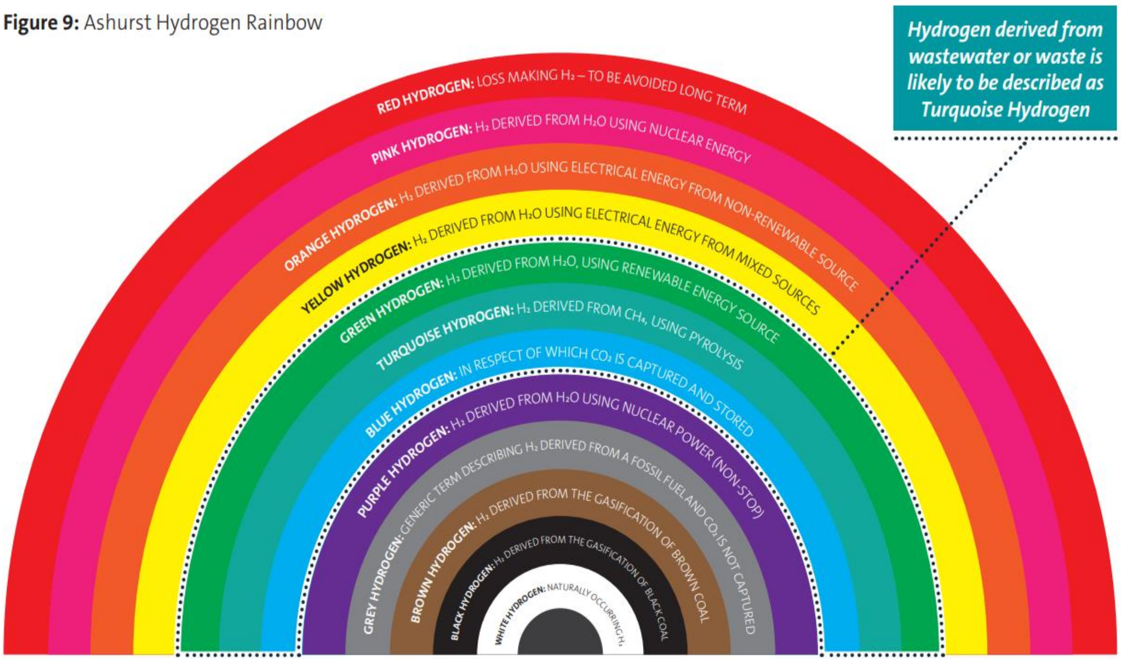
## 4. FUTURE FUELS: A TRANSITION TO CLEAN AND LOW CARBON FUELS

**Figure 9:** Ashurst Hydrogen Rainbow



## 5. FUTURE FUELS: A TRANSITION TO CLEAN AND LOW CARBON FUELS

## THE COLOURS OF HYDROGEN: HYDROGEN ON A PAGE

| Definitions | |
|---|---|
| Red Hydrogen | A reference to the fact that "early doors" hydrogen projects tend to be loss making. Also on occasion, used as an alternative to Pink and Purple Hydrogen, i.e., hydrogen produced using nuclear energy and steam arising from nuclear power generation |
| Pink Hydrogen | $H_2$ produced by splitting of $H_2O$ using nuclear power as the electrical energy source |
| Orange Hydrogen | $H_2$ produced by splitting of $H_2O$ using electrical energy from a non-renewable source |
| Yellow Hydrogen | $H_2$ produced by splitting of $H_2O$ using electrical energy from mixed energy sources |
| Green Hydrogen | $H_2$ produced by splitting of $H_2O$ using electrical energy from renewable electrical energy (REE), no GHG emissions on production or oxidation (use) |
| Turquoise Hydrogen | $H_2$ produced from thermal splitting of natural gas (form of pyrolysis) to produce "carbon black" (including $CO_2$), giving rise to GHG emissions on production and oxidation (use) |
| Blue Hydrogen | Grey or Brown (or Black) Hydrogen but $CO_2$ captured permanently using CCS / CCUS: logically, the means of production does not matter as long as $CO_2$ captured and stored |
| Purple Hydrogen | $H_2$ produced from steam arising from nuclear power generation |
| Grey Hydrogen | $H_2$ produced with fossil fuel as the feedstock, including from natural gas, coal and oil (but most often and typically natural gas), using established processes |
| Brown (or Black) Hydrogen | $H_2$ produced from coal |
| White Hydrogen | $H_2$ arising naturally on earth |
| Renewable Hydrogen | $H_2$ produced without any fossil fuel, but may not be GHG emission free if any carbon feedstock is used (biomass) |
| Clean Hydrogen or Low-carbon Hydrogen | Blue Hydrogen, Green Hydrogen and Turquoise Hydrogen, and possibly including Clean / Low-Carbon / Renewable-Carbon Hydrogen, and including any hydrogen produced using a process in which GHG emissions are captured |
| Cleaner Hydrogen and Nearly Clean Hydrogen | Blue Hydrogen produced using renewable energy and hydrogen produced using nuclear steam or nuclear Power |
| Blue Ammonia | $NH_3$ produced from Blue Hydrogen, $CO_2$ arising captured permanently using CCS / CCUS, and with the Blue Hydrogen combined with $N_2$ extracted from any source, and on oxidation (use), NO arise |
| Green Ammonia | $NH_3$ produced from the combination of Green Hydrogen and $N_2$ extracted from the air using electrical energy from REE source, the process requiring high temperature, and on oxidation (use) NO emissions arise |
| Turquoise Ammonia | $NH_3$ produced from the combination of Turquoise Hydrogen and $N_2$ extracted from any source using any energy source, the process requiring high temperature, and on oxidation (use), NO arise |



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## 6. FUTURE FUELS: A TRANSITION TO CLEAN AND LOW CARBON FUELS

## SCALE OF ELECTRICAL ENERGY TO PRODUCE STATED MASS OF HYDROGEN

| Electrical Energy (per unit expressed in watts hours) | Kilograms / tonnes of H2 |
|---|---:|
| 50 to 55 KWh | 1 kg |
| 1 MWh to 1.1 MWh | 20 kg |
| 2.5 MWh to 2.75 MWh | 50 kg |
| 5 MWh to 5.5 MWh | 100 kg |
| 10 MWh to 11 MWh | 200 kg |
| 50 MWh to 55 MWh | 1,000 (one tonne) |
| 100 MWh to 110 MWh | 2 tonnes |
| 500 MWh to 550 MWh | 10 tonnes |
| 2,500 MWh to 2,750 MWh | 50 tonnes |
| 5 GWh to 5.5 GWh | 100 tonnes |
| 50 GWh to 55 GWh | 1,000 tonnes |
| 500 GWh to 550 GWh | 10,000 tonnes |
| 5 TWh to 5.5 TWh | 100,000 tonnes |
| 50 TWh to 55 TWh | 1,000,000 tonnes (Mt) |
| 250 TWh to 275 TWh | 5 Mt |
| 500 TWh to 550 TWh | 10 Mt |
| 1,000 TWh to 1,100 TWh | 50 Mt |
| 3,750 TWh to 4,125 TWh | 75 Mt (close to current prod) |
| 5,000 TWh to 5,500 TWh | 100 Mt |
| 12,500 TWh to 13,750 TWh | 250 Mt |
| 25,000 TWh to 27,500 TWh | 500 Mt |

## 7. FUTURE FUELS: A TRANSITION TO CLEAN AND LOW CARBON FUELS

## BIOENERGY ON A PAGE

### BIOENERGY

**Biomethane**: is Biogas that has been processed and scrubbed (referred to as "upgrading") so that it can be used as pipeline gas (i.e., complying with the specification for hauling through the applicable natural gas pipeline, including the removal of $CO_2$, and other compounds and elements, such that the gas hauled through the pipeline is **$CH_4$**). **Biomethane** is a **Biofuel**.

**Biogas** and **Biomethane** can be used as a fuel (typically, as a gas that is combusted / oxidised to produce electrical energy or heat energy or both) or as a feedstock. Also, either may be referred to as **Renewable Natural Gas** (or **RNG**), or in compressed form, as compressed natural gas (**CNG**) and in liquified form as **Bio-LNG** or **R-CNG** or, less frequently, **Renewable LNG**.

**Biofuel** is a fuel derived or produced from **Biomass**, whether in gaseous, liquid or solid form. In addition to **Biogas** and **Biomethane**, for example, wood products (gaseous and solid biofuels), the following may be regarded as the most prevalent **liquid biofuels**:

- **Bio-ammonia**: being ammonia that is derived or produced using $H_2$ derived from a renewable source that is then combined with N to produce the compound $NH_3$;
- **Bio-butanol**: being butanol (i.e., a synthetic alcohol) that is derived or produced from the microbial fermentation of carbohydrates (typically from corn and from agricultural waste), and is similar to motor spirit, and as such may be used as a fuel for internal combustion engines. (It is a drop-in fuel.)
- **Bio-diesel**: being diesel (i.e., synthetic paraffinic compound) that is produced typically using transesterification of animal fats and vegetable oils;
- **Bio-ethanol**: being ethanol (i.e., synthetic alcohol) that is derived or produced the microbial fermentation of carbohydrates (including from corn and sugarcane, and lignocellulosic biomass);
- **Bio-kerosene**: being kerosene (i.e., synthetic paraffinic compound and another kind of methyl ester) that is derived or produced from animal and vegetable oils (containing fatty acids);
- **Sustainable** or **Synthetic Aviation Fuel** (**SAF**), is a synthetic paraffinic kerosene. Currently, most SAF is derived or produced from used animal fats and cooking oil and from the gasification of other organic waste streams (typically using some natural gas). As noted below, typically fatty acids and hydrogenated acids are used to produce synthetic paraffinic kerosene. If the feedstock is sourced from Biomass it is a Bio-kerosene;
- **Bio-LNG**: being Bio-methane that is liquified at a temperature of -161° C, with the liquified Bio-methane 1/600th the volume of gaseous Bio-methane; and
- **Bio-methanol**: being methanol (i.e., produced from $CO_2$ (captured or derived) and $H_2$ derived from Biomass) that is derived or produced from biochemical (fermentation) or thermochemical (including gasification and pyrolysis) technologies.

A **Biofuel** is an E-Fuel (an electro-fuel) if the electrical energy used to produce it is sourced from a renewable source. Hence the use of E-Diesel, E-Ethanol, E-Kerosene, E-LNG and E-Methanol.



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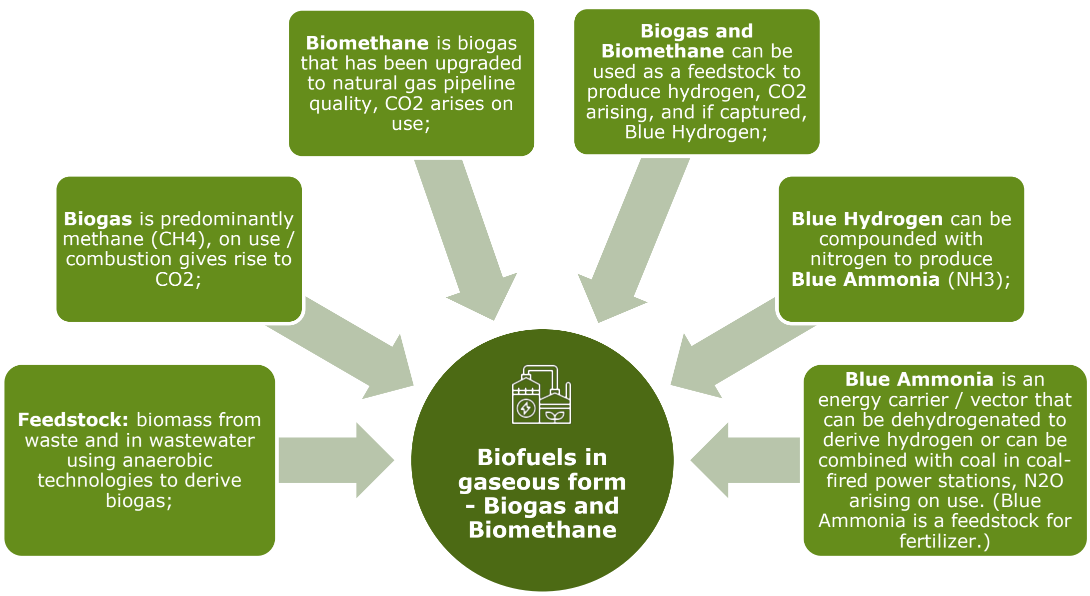
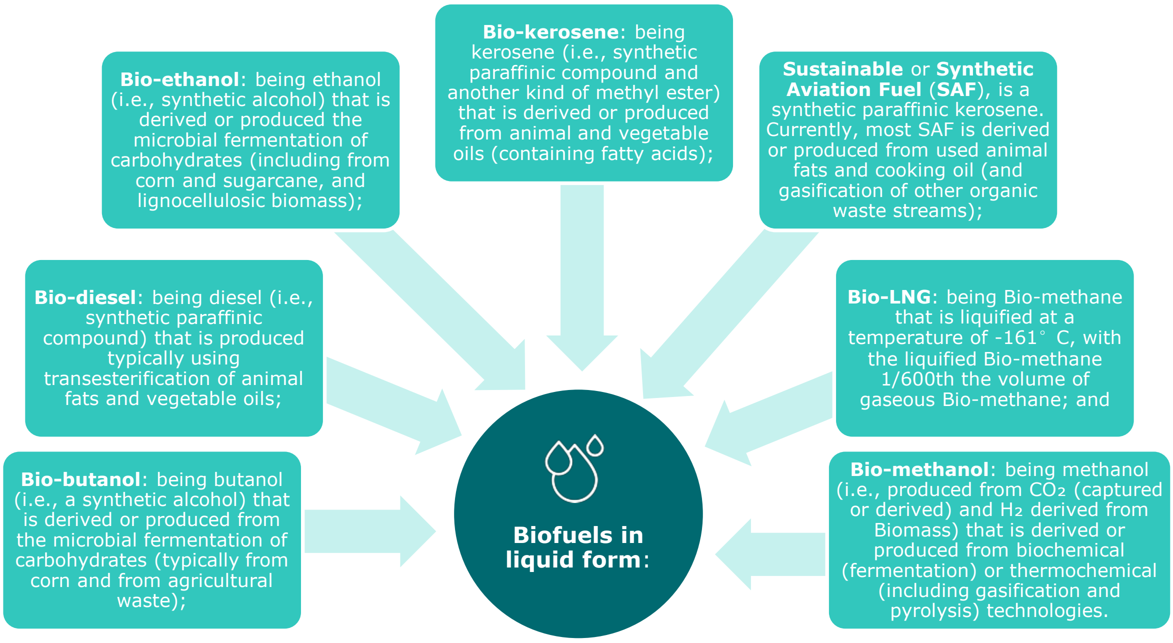
## 8: FUTURE FUELS A TRANSITION TO CLEAN AND LOW CARBON FUELS

- **Future Fuels** include biofuels, being fuels produced from biomass, i.e., comprising organic compounds, being Bioenergy, and if renewable electrical energy is used e-fuels or e-Future Fuels.

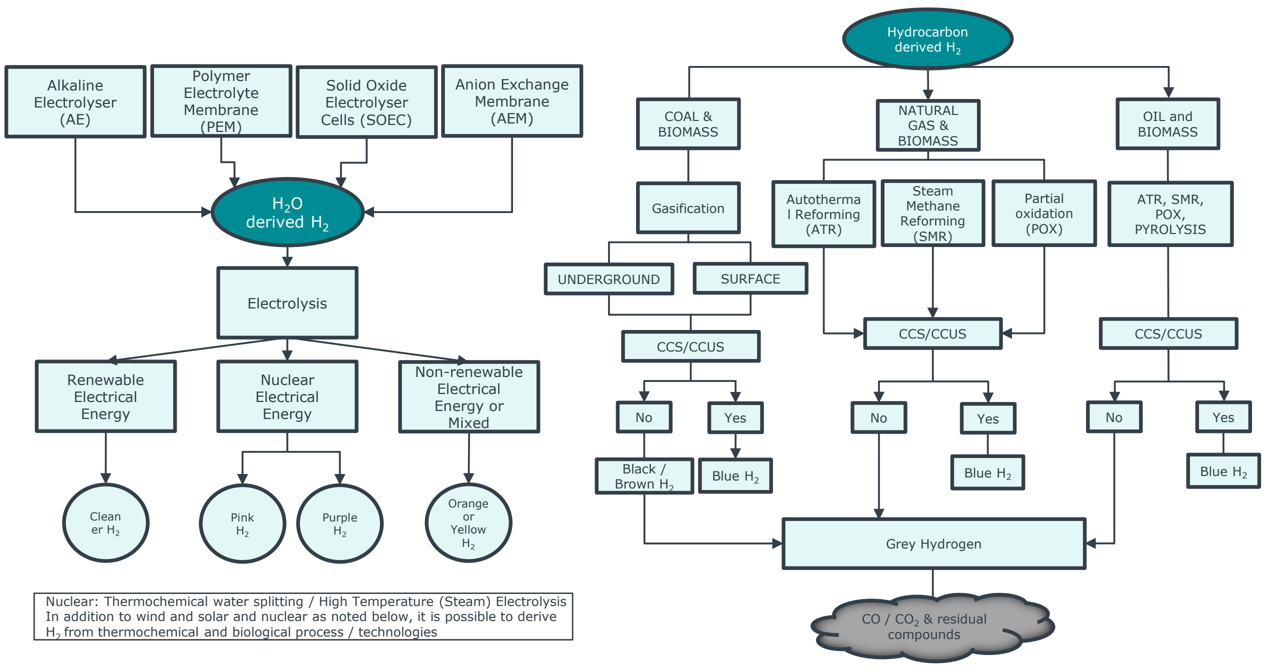


## 8: FUTURE FUELS A TRANSITION TO CLEAN AND LOW CARBON FUELS






## 9. FUTURE FUELS A TRANSITION TO CLEAN AND LOW CARBON FUELS TECHNOLOGIES USED FOR HYDROGEN PRODUCTION APPLICABLE FOR



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## 10: FUTURE FUELS A TRANSITION TO CLEAN AND LOW CARBON FUELS

- **Core of progress to achieving net-zero emissions:**
  The decarbonization of the electrical energy sector – electrify as much as possible.

### Hydrogen and Hydrogen Based Future Fuels

- **Green Hydrogen**: no biomass and no fossil fuels – no GHGs on use;
- **Green Ammonia**: no biomass and no fossil fuels, N2O arising on use;
- **Blue Hydrogen**: biomass or fossil fuel, with CO2 captured and stored or used, and no GHGs on use;
- **Blue Ammonia**: biomass or fossil fuel, with CO2 captured and stored or used, and N2O arising on use;
- **Turquoise Hydrogen**: biomass in solid waste or wastewater, with CO2 captured and stored or used, and no GHGs on use;
- **Turquoise Ammonia**: biomass in solid waste or wastewater, with CO2 captured and stored or used, and N2O arising on use; and
- **Green Methanol and Blue Methanol** (CH3OH) – both give rise to CO2 on use.

### Bioenergy Future Fuels arise from sourcing CH4 and H2 from biomass

- **Bio-ammonia**: being ammonia that is derived or produced using $H_2$ derived from a renewable source that is then combined with N to produce the compound $NH_3$
- **Bio-methanol**: being methanol (i.e., produced from $CO_2$ (captured or derived) and $H_2$ derived from Biomass) that is derived or produced from biochemical (fermentation) or thermochemical (including gasification and pyrolysis) technologies.
- **Bio-diesel**: being diesel (i.e., synthetic paraffinic compound) that is produced typically using transesterification of animal fats and vegetable oils;
- **Bio-kerosene**: being kerosene (i.e., synthetic paraffinic compound and another kind of methyl ester) that is derived or produced from animal and vegetable oils (containing fatty acids); and
- **Sustainable or Synthetic Aviation Fuel** (**SAF**), is a synthetic paraffinic kerosene. Currently, most SAF is derived or produced from used animal fats and cooking oil (and gasification of other organic waste streams).

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## 11: FUTURE FUELS A TRANSITION TO CLEAN AND LOW CARBON FUELS

| | |
|---|---|
| Hydrogen($H_2$) | Can be used as an energy carrier, including to power and propel vehicles, to undertake high-temperature processes in difficult to decarbonise sectors, and to blend with natural gas.<br>Also $H_2$ can be used as a feedstock to produce Ammonia or Methanol (two liquid energy carriers and feedstocks). |
| Ammonia ($NH_3$) | Can be used as an energy carrier, including to power and to propel vessels (marine bunkers) and to mix with another energy carrier to generate electrical energy, and can be used as the compound in which $H_2$ is carried, and from which $H_2$ can be extracted.<br>Also is used as feedstock for ammonium nitrate |
| Bioenergy | Is a generic term that includes the use of any $H_2$, $CH_4$ or $CO_2$ derived or produced from Biomass, including to produce Ammonia or Methanol, and other Biofuels. |
| Methanol ($CH_3OH$) | Can be used as an energy carrier to fuel vehicles and vessels. Also is used as a feedstock to produce polymers. |

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## 12: FUTURE FUELS A TRANSITION TO CLEAN AND LOW CARBON FUELS

**Hydrogen** (**$H_2$**) is derived from:

- fossil fuels or from another carbon intensive source (i.e., **Biomass**); or
- water.

**$H_2$** is either an energy carrier itself or a feedstock for the production of another energy carrier or another feedstock, for example, ammonia and methanol. As an energy carrier, on use $H_2$ combines with oxygen to produce water vapour (irrespective of the colour of the $H_2$).

- **Ammonia**: $H_2$ synthesised with nitrogen to produce the compound $NH_3$ – no carbon atoms in sight;
- **Methanol**: $CO_2$ synthesised with hydrogen to produce the compound $CH_3OH$ – the most simple alcohol.

On use, $NH_3$ combines with oxygen to produce $N_2O$ and $H_2O$ (depending on the temperature as water vapour or as steam), which is one of the Big Three GHGs or, as the IPCC calls them, the well-mixed GHGs.

On use, $CH_3OH$ combines with oxygen to produce $CO_2$ and $H_2O$.

The $H_2$ and $CO_2$ for $CH_3OH$ can be produced from fossil fuels or Biomass. If Biomass is used to derive or to produce $CH_3OH$ it will be bio-methanol. If renewable electrical energy is used as the source of electrical energy for the production of the methanol, the $CH_3OH$ is e-methanol. If both, the $CH_3OH$ is renewable methanol.

While $H_2$ has the highest energy (by mass) of any substance (other than nuclear fuels and anti-matter), its low density (by volume) means that to be transported the volume of gaseous $H_2$ needs to be reduced, whether by compression (including for transportation by pipeline or truck), by liquefaction (resulting in energy density of 70 kg/m³ at 1 bar), or by compounding. The two key means of compounding are:

- the production of $NH_3$, which has the advantage of high energy density (123 kg/m³ at 10 bar (at 10 bar or -33° C $NH_3$ is in liquid form). There is an existing trade in ammonia, as a result of which there are ammonia bulk carriers and existing storage and transportation systems. The key disadvantage in the use of $NH_3$ to carry $H_2$ is that it is energy intensive; or
- compounding of $H_2$ to form a Liquid Organic Hydrogen Carrier (LOHC), for example, methylcyclohexane (MCH), with energy density of 47 kg/m³, and perhydro-dibenzyl-toluene (PDBT), with an energy density of 57 kg/m³. The key advantage of LOHCs is that they are can be stored and transported safely at ambient temperatures. The key disadvantage of LOHCs is that the $H_2$ needs to be separated from the liquid, and this requires to the use of energy.

[**Note:** While it is possible to compound to form a hydride, as yet, this is not considered viable commercially.]

Each means of volume reduction adds cost to the delivered cost of $H_2$, critically energy use, and, in the case of liquefaction, in addition to the energy cost, the development of liquid hydrogen vessels and infrastructure both to liquefy (in the place of origination of $H_2$) and to re-gasify (at the point of delivery of $LH_2$)

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## 13. FUTURE FUELS A TRANSITION TO CLEAN AND LOW CARBON FUELS

## KEY COMMERCIAL ISSUES


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## Further questions



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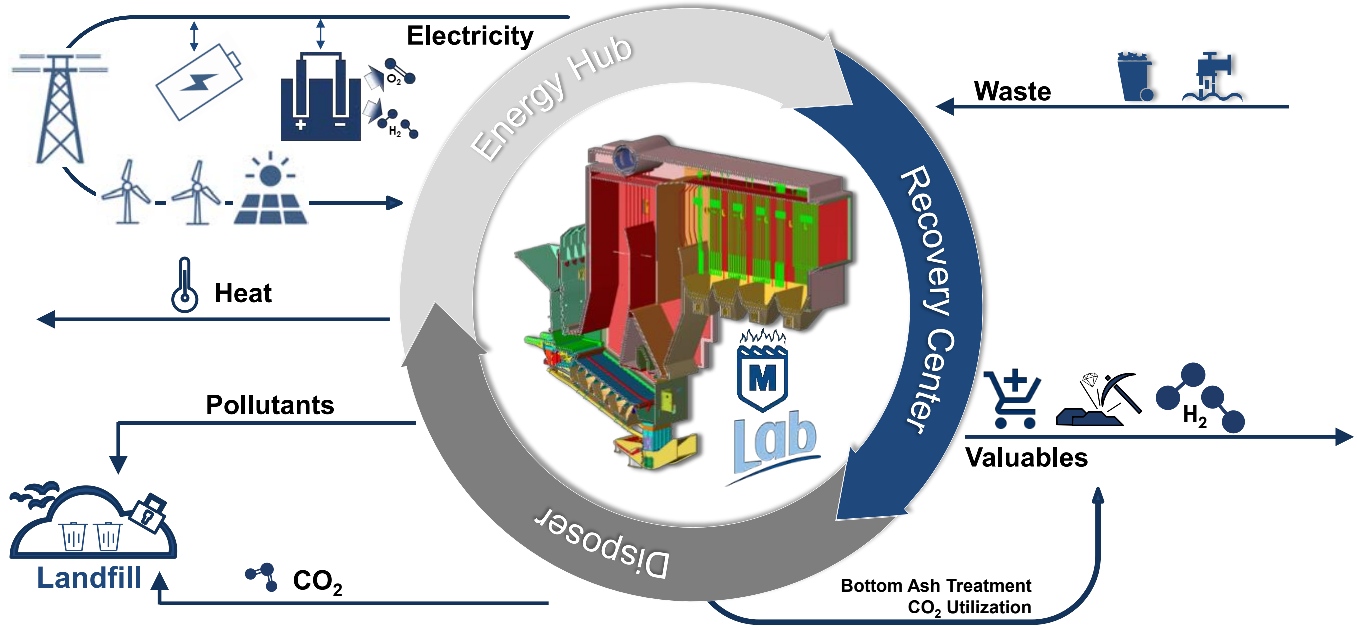
# 十六

## 廢棄物能源化的最新進展

## (Latest developments for Waste to Energy)

講述如何將廢棄物能源化的碳捕捉和甲醇產生等議題聯繫起來討論，以實現負碳排放。

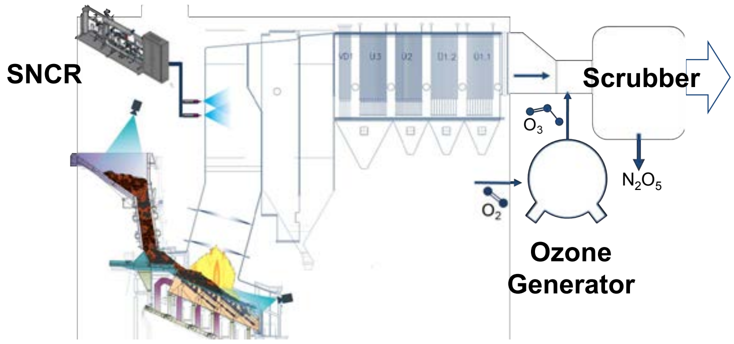
## WtE is a central component of modern circular economies

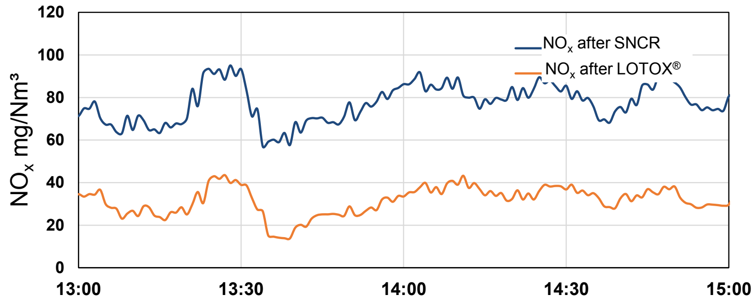





## Low Temperature Oxidation (LOTOX®) for $NO_x$ removal

- **High $NO_x$ selectivity:** $NO_x$ removal rates of > 90%. Low $NO_x$ levels < 50 mg/Nm³ are consistently achieved.
- **Easy to retrofit:** post-combustion technology for treating flue gas – containerized implementation possible.
- **Low CAPEX:** invest costs are significantly lower compared to other $DeNO_x$ processes (i.e. SCR).



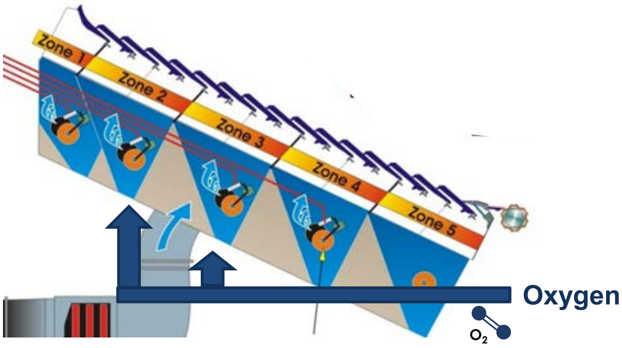




patent pending

## MARTIN Synthetic Combustion (SYNCOM) for enhanced combustion

- **Improved bottom ash quality:** Increased temperature of the burning bed leads to improved burnout (TOC < 0.5%) and less leaching of the heavy metals in bottom ashes.
- **Reduced flue gas flow:** due to the substitution of air ($N_2$+$O_2$) with pure oxygen the flue gas flow can be reduced significantly (up to 30%) leading to more compact plant design and higher efficiencies.


KRV Arnoldstein (AT) – 105,000 tpy





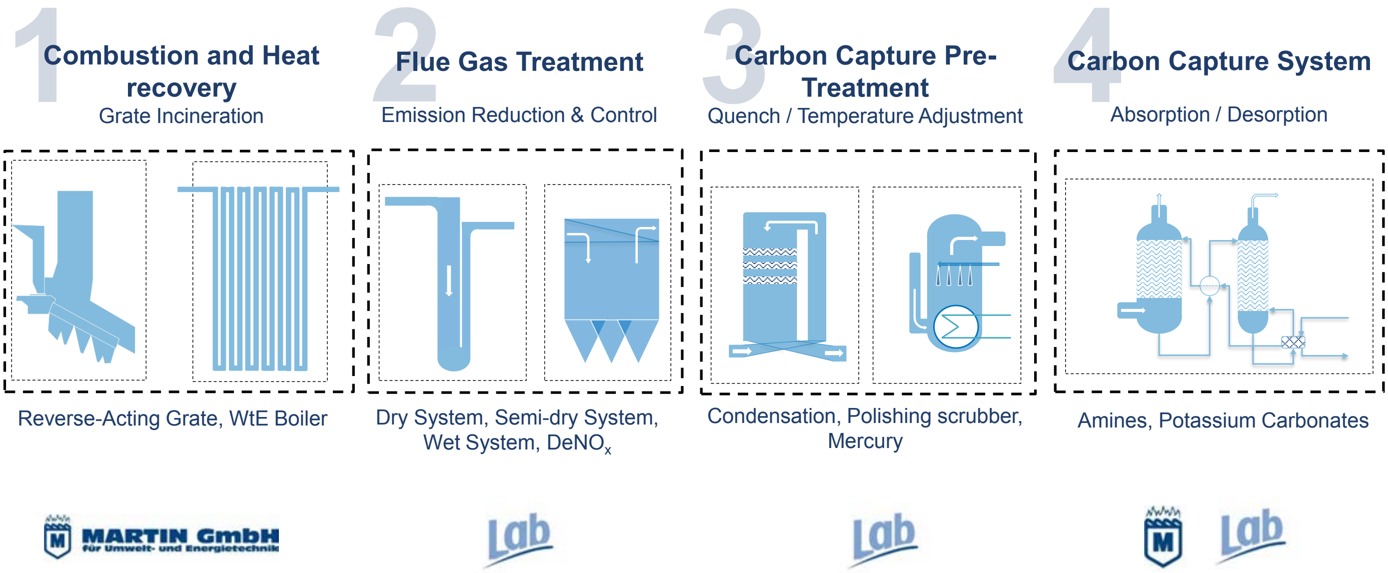

## Electrolysis for Hydrogen Production

- **Flexible electricity utilization:** hydrogen production enables flexible use of electricity – thus a participation in the electricity balancing market.
- **Production of hydrogen:** hydrogen can be broadly used for i.e. fuel stations or further syntheses.
- **Useful by-product:** Oxygen can be used in the combustion or by other processes like LOTOX.


**LIMECO (CH) – 95.000 tpy**
2,5 MW Electrolysis (250 m³/h $H_2$)

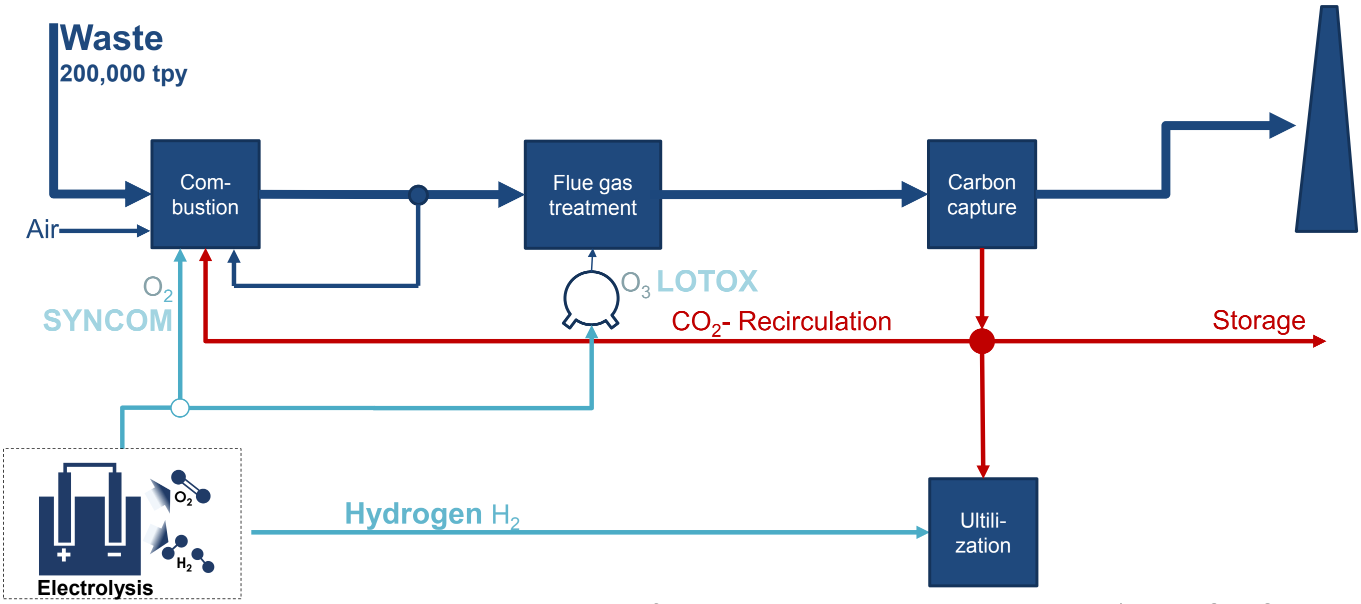

**AWG Wuppertal (DE) – 400,000 tpy**
1 MW Electrolysis (100 m³/h $H_2$)

# Optimized Integration of Carbon Capture Processes in WtE-Plants



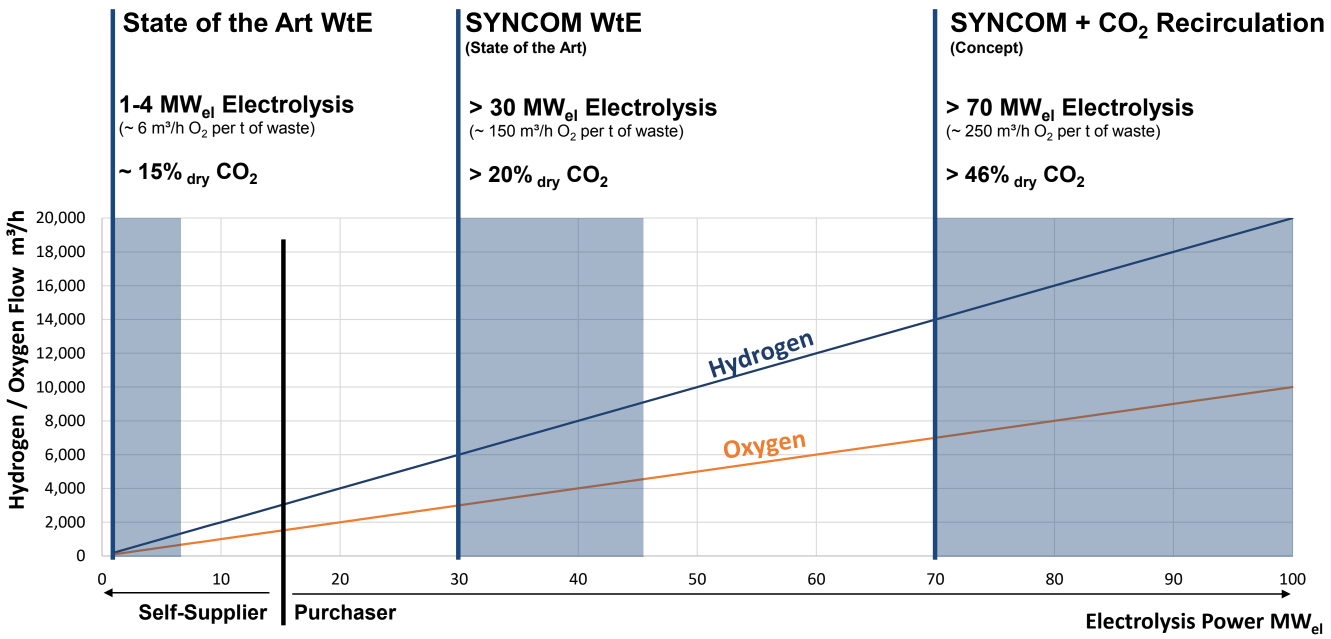



# Next Generation WtE – Integration of Electrolysis and Carbon Capture




Hydrogen for gas stations or advanced syntheses(i.e. MeOH, SynFuels …)

## Next Generation WtE – Integration of Electrolysis and Carbon Capture

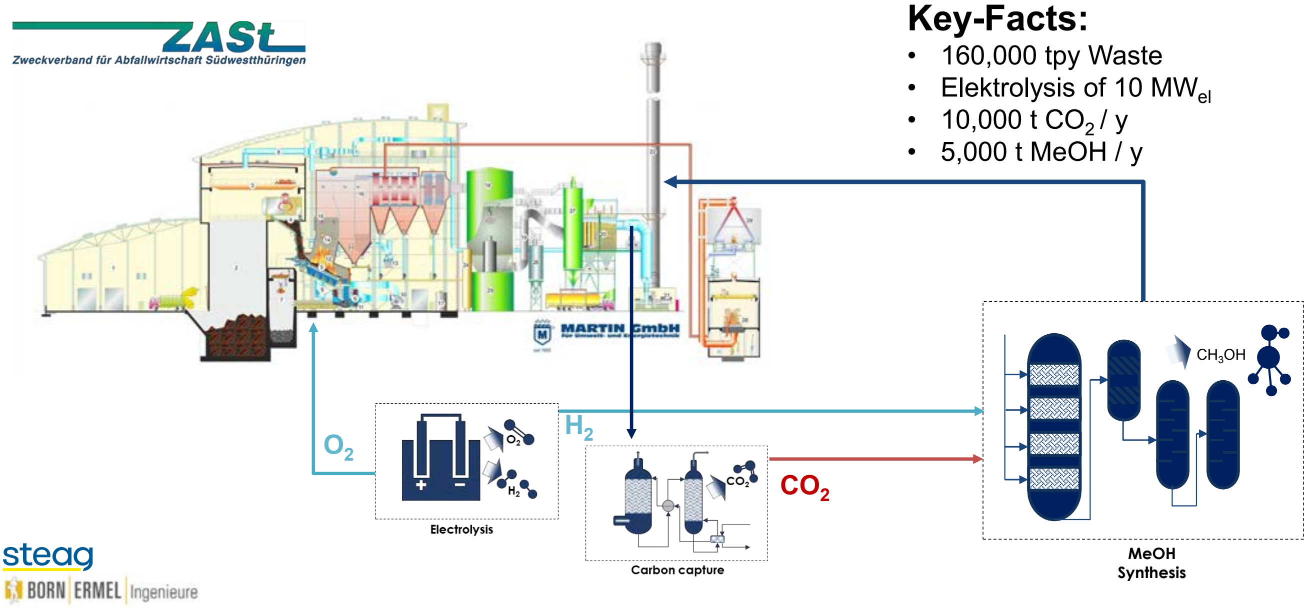


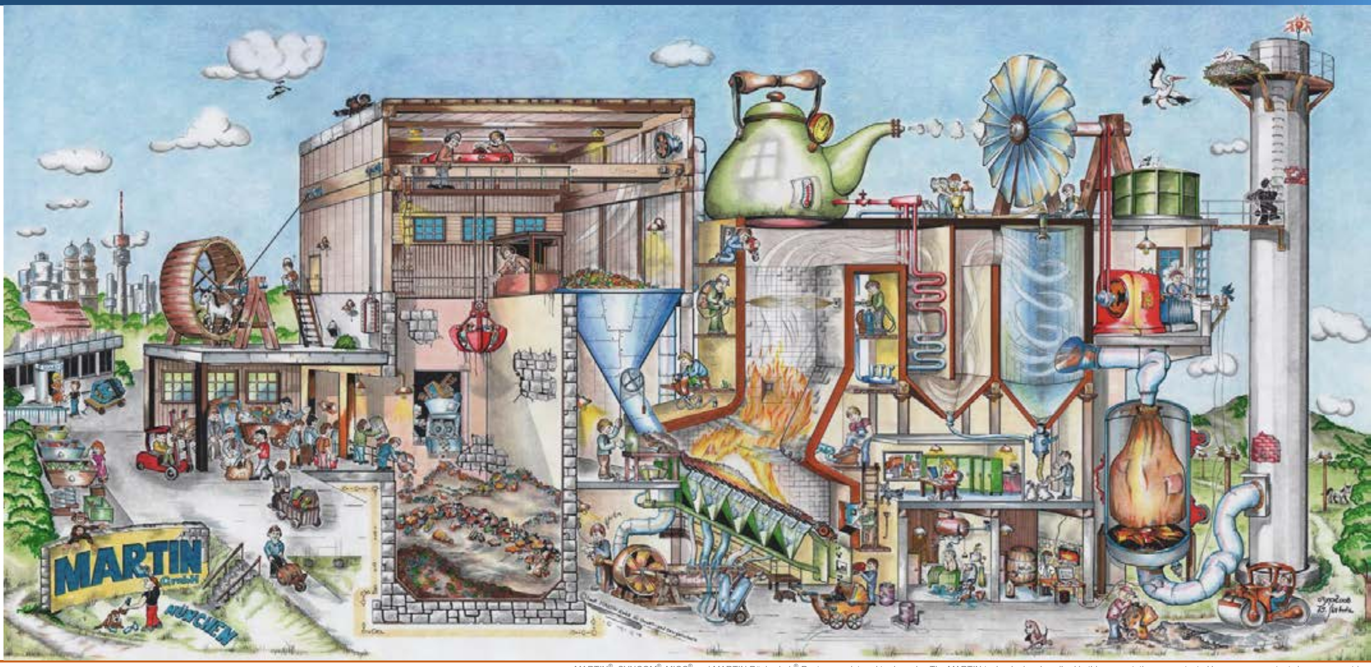



## Next Generation WtE: MeOH Syntheses Project (in planning)

**Key-Facts:**

- 160,000 tpy Waste
- Elektrolysis of 10 MW$_{el}$
- 10,000 t $CO_2$ / y
- 5,000 t MeOH / y




MARTIN
GmbH
MÜNCHEN

十七

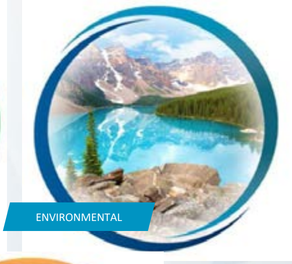
先進技術在廢棄物管理上的未來

**(The Future of Advanced Technology in Waste Management)**

隨著廢棄物回收的增加，未來的廢棄物管理將替新的先進技術提供機會，以先進的收集和分類技術產生更清潔、更均勻的廢棄物處理方式，並為化學循環等新技術奠定基礎。該技術可將廢棄物轉化為氫氣和二氧化碳，同時還能產生電能和熱能。目標是在進行碳捕捉的過程中能夠同時生產氫氣。

# What We Do

- **Renewable Waste-to-Energy** - *Waste-to-Energy combustion and steam generation*
- **Renewable Biomass** – *Biomass combustion and steam generation*
- **Environmental Technologies** - *Integrated, custom solutions for utility/industrial emissions control*
- **Ash and Material Handling** - *Bottom and fly ash material handling*
- **Cooling Systems** - *Custom engineered wet, dry and hybrid cooling solutions for power plants*
- **Steam Generation Technologies** - *Boilers to burn any fuel, from small package boilers to high-capacity boilers*
- **Boiler Auxiliary Equipment** - *Reliable components for cleaner, more efficient operations*
- **Technical Services and Parts** - *Solutions for modifying, improving, operating and maintaining equipment*
- **Construction** - *Field construction, construction management and maintenance services*



*A Leader and Innovator in the World's Energy Transition*




# Agenda

**Circular economy** – how does WtE fit into the EU future?

How can WtE reduce the **GHG emissions**?

What kind of **fuel** will be available for WtE plants in the future?

High costs - **New opportunities**

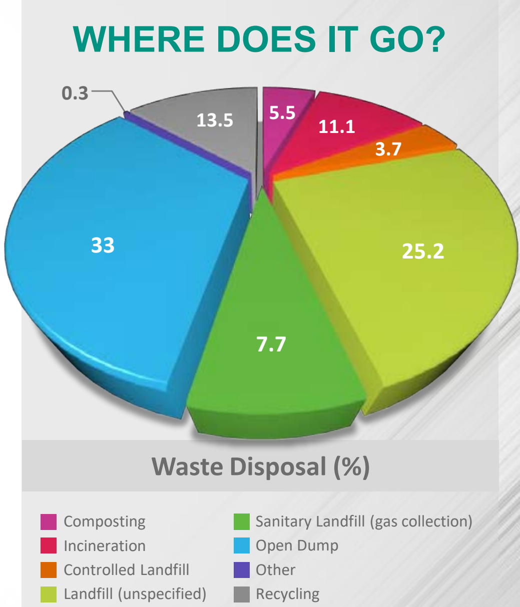
B&W transition towards a **net zero carbon** target:

- ***Oxy-combustion***
- ***Carbon Capture***
- ***Chemical Looping***

Toward a **sustainable future**

# Global Need for Safe Waste Management

- World population is **7.8 billion** and growing at a rate of 1.1% (200,000/day)
- Total municipal solid waste (MSW) generated per person, per day: **1.6 lbs (0.74 kg)**
- **500+ cities** with population over 1 million
- Universal impact
  - High-income countries: volume
  - Low-income countries: mismanagement (dumped/burned)

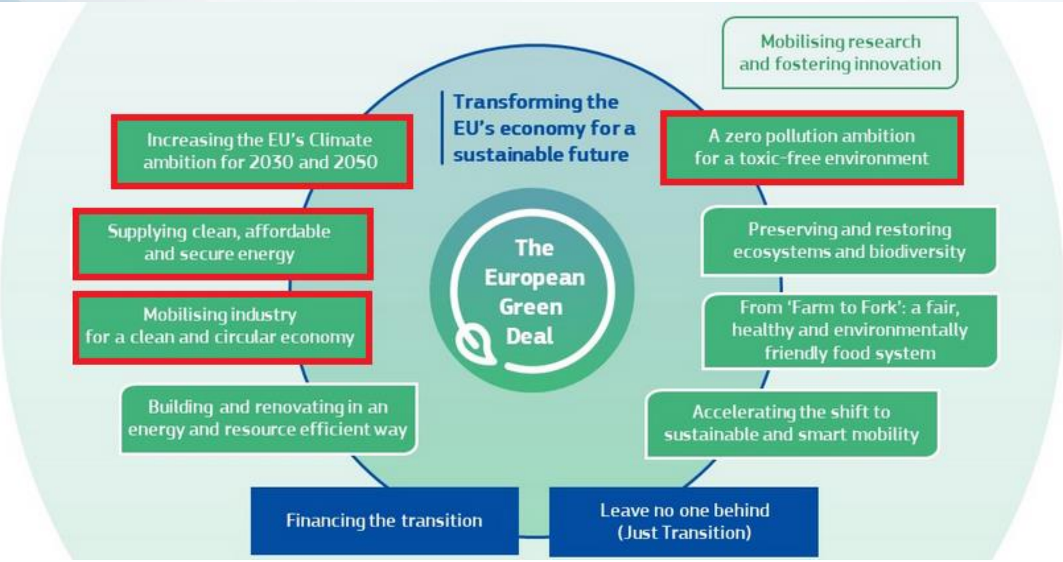



Source: *World Bank*




# EU policy goals = **Green deal**

## WtE contribution to the goals of the EU Green Deal




**Pollution prevention:**

Safe treatment of residual waste (landfill prevention)

**Secured energy:**

Dispatchable energy

Partly renewable

Does not rely on extra-EU imports of fuels

**Circular economy:**

Energy & material recovery

**Decarbonisation:**

Landfill diversion (< $CH_4$)

Prevents use of virgin fuel/material

# Towards a circular economy


- Current rates of resource depletion and waste generation are **unsustainable**
- **28 March** Denmark had used it annual part of natural resources in 2022!!
- Need to **de-couple** economic growth from increasing resource consumption.
- Radically **different business** models required




# Methane Emissions

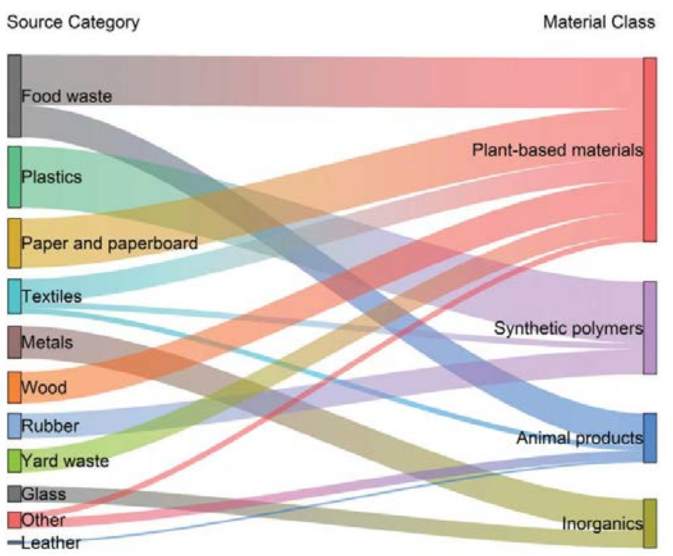
The GHGSat team used their ***satellites to spot methane*** plumes on 20 August and 13 October 2021, emanating from two landfill sites approximately six km apart, located just 18 km from the center of ***Madrid***.

The largest source released methane at a rate nearing 5000 kg per hour, with satellite imagery showing a cloud of greenhouse gas drifting towards nearby residences. ***Both landfill sites combined emitted 8800 kg of methane per hour = 77000 tons per year***

# Waste handling

## What will WtE plants burn post 2030

- Source separation – system with multiple waste bins. One bin for non-recycling = **residual waste**.
- Single source collection – 2 bins dry/organic - follow by centralized sorting process.
  Non-recycling = **out put from MBT**.
- **Industrial** mono waste steams
- **Composite material** from packaging wrapping materials
- **Contaminated waste;** hospital, food industry, medical industry)
- **Output from re-cycling industry** – low quality material from re-cycling operations







# What are the opportunities

- More homogeneous waste streams
  - **High costs - New opportunities**
- Waste streams – Non Recyclable **part** streams
  - Wood waste
  - Paper & cardboard
  - Plastic & rubber
  - Tires
  - Textile
- Chemical processes
  - Pyrolysis = **Oil**
  - Gasifications = **Syngas**
  - Advanced combustion = Chemical Looping = **Hydrogen**

# BrightLoop™ – the next generation of Chemical Looping

**The Babcock & Wilcox collaboration with our university partner The Ohio State University has:**

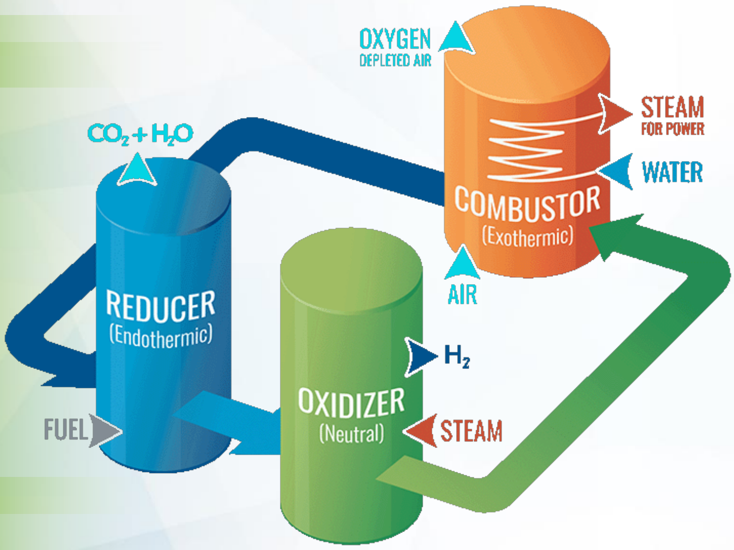
- Shown that Chemical Looping can effectively separate $CO_2$ while producing hydrogen, steam and/or syngas
- Demonstrated that Chemical Looping is ready for commercial scale-up





# The Technology

# A Particle Breakthrough Made It Happen

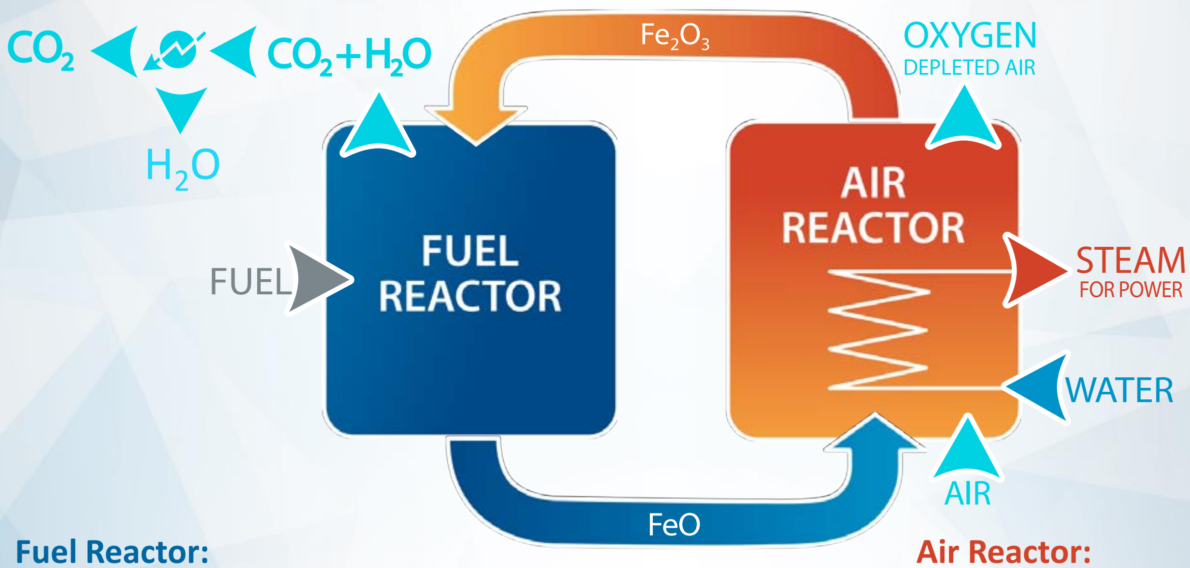



**A unique particle from Ohio State University**

- Use metal oxide particles to **carry oxygen**
- Oxygen carrier particles has shown an ability to sustain thousands of cycles – approx.
  **2 years operation**
- Makes Chemical Looping possible for practical implementation of carbon isolation and **$CO_2$ capture**
- Demonstrated **Hydrogen** production




# BrightLoop™ Combustion: Steam Generation

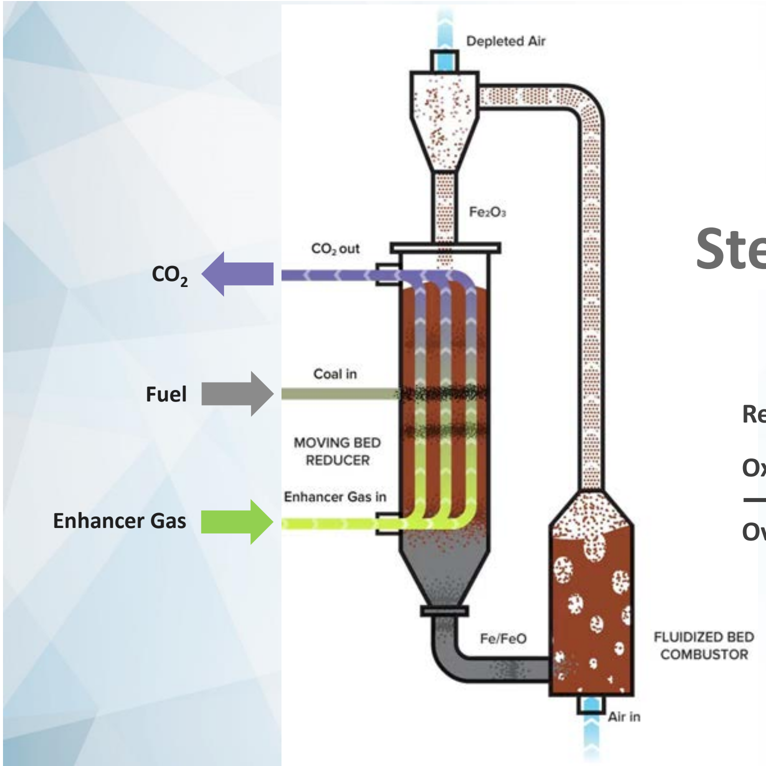



**Fuel Reactor:**

Fuel + $Fe_2O_3 \rightarrow CO_2 + H_2O + FeO$

**Air Reactor:**

$FeO + O_2$ (Air) $\rightarrow Fe_2O_3$ + Heat




# Steam-Only Generation

**Main reactions:**

**Reducer:** Fuel + $Fe_2O_3$ → FeO + $CO_2$ + $H_2O$

**Oxidizer:** Air + FeO → $Fe_2O_3$ + Spent Air

**Overall:** Fuel + Air → $CO_2$ + $H_2O$ + Spent Air

Animation by The Ohio State University

Tong, A., Bayham, S., Kathe, M., Fan, L.-S. Applied Energy Journal

Thomas, T. J., Fan, L.-S., Gupta, P., Velazquez-Vargas, L.G. U.S. Patent 7,767,191.



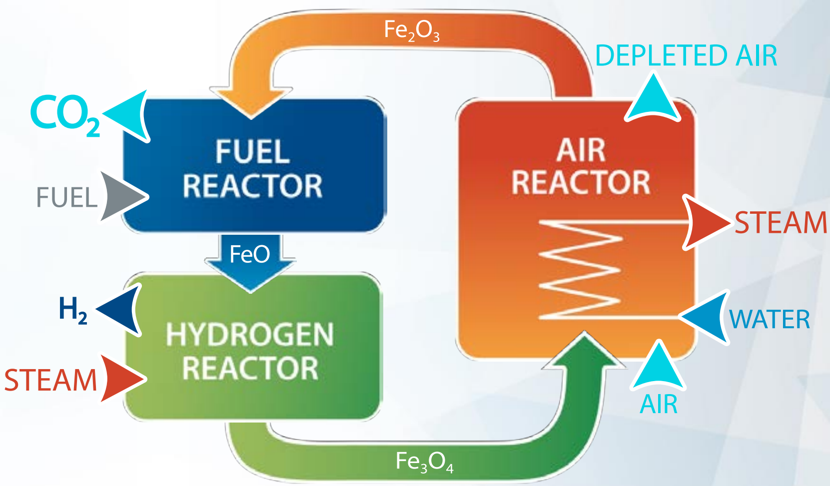

# BrightLoop™ Gasification: $H_2$ Generation

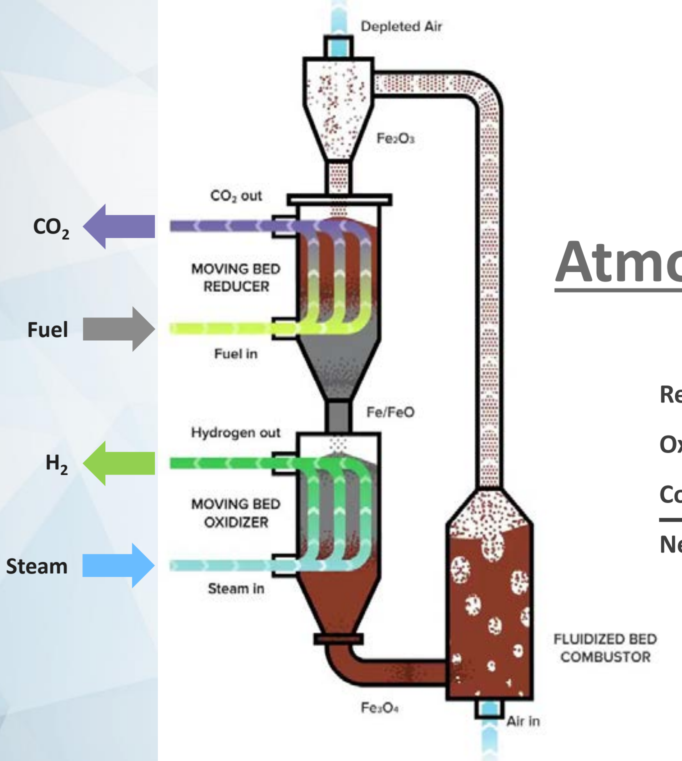
**Fuel Reactor:**
Fuel + $Fe_2O_3$ → $CO_2$ + $H_2O$ + 2 FeO

**Hydrogen Reactor:**
FeO + $H_2O$ → $Fe_3O_4$ + $H_2$

**Air Reactor:**
$Fe_3O_4$ + $O_2$ (Air) → $Fe_2O_3$ + Heat

Notes:
- $Fe_3O_4$ has lower oxidation than $Fe_2O_3$
- Equations are not balanced






# Atmospheric $H_2$ Generation

**Main reactions:**

**Reducer:** $C_xH_yO_z + Fe_2O_3 \rightarrow CO_2 + H_2O + FeO$

**Oxidizer:** $FeO + H_2O \rightarrow Fe_3O_4 + H_2 + Q$

**Combustor:** $Fe_3O_4 + O_2 \rightarrow Fe_2O_3 + Q$

**Net Reaction:** $C_xH_yO_z + H_2O + O_2 \rightarrow CO_2 + H_2 + Q$

Animation by The Ohio State University

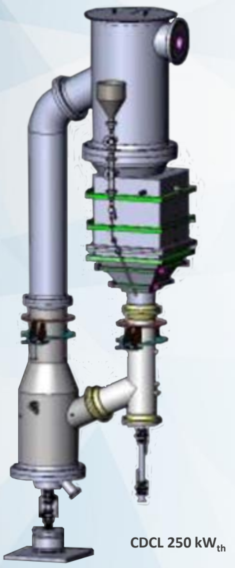
Tong, A., Bayham, S., Kathe, M., Fan, L.-S. Applied Energy Journal

Thomas, T. J., Fan, L.-S., Gupta, P., Velazquez-Vargas, L.G. U.S. Patent 7,767,191.





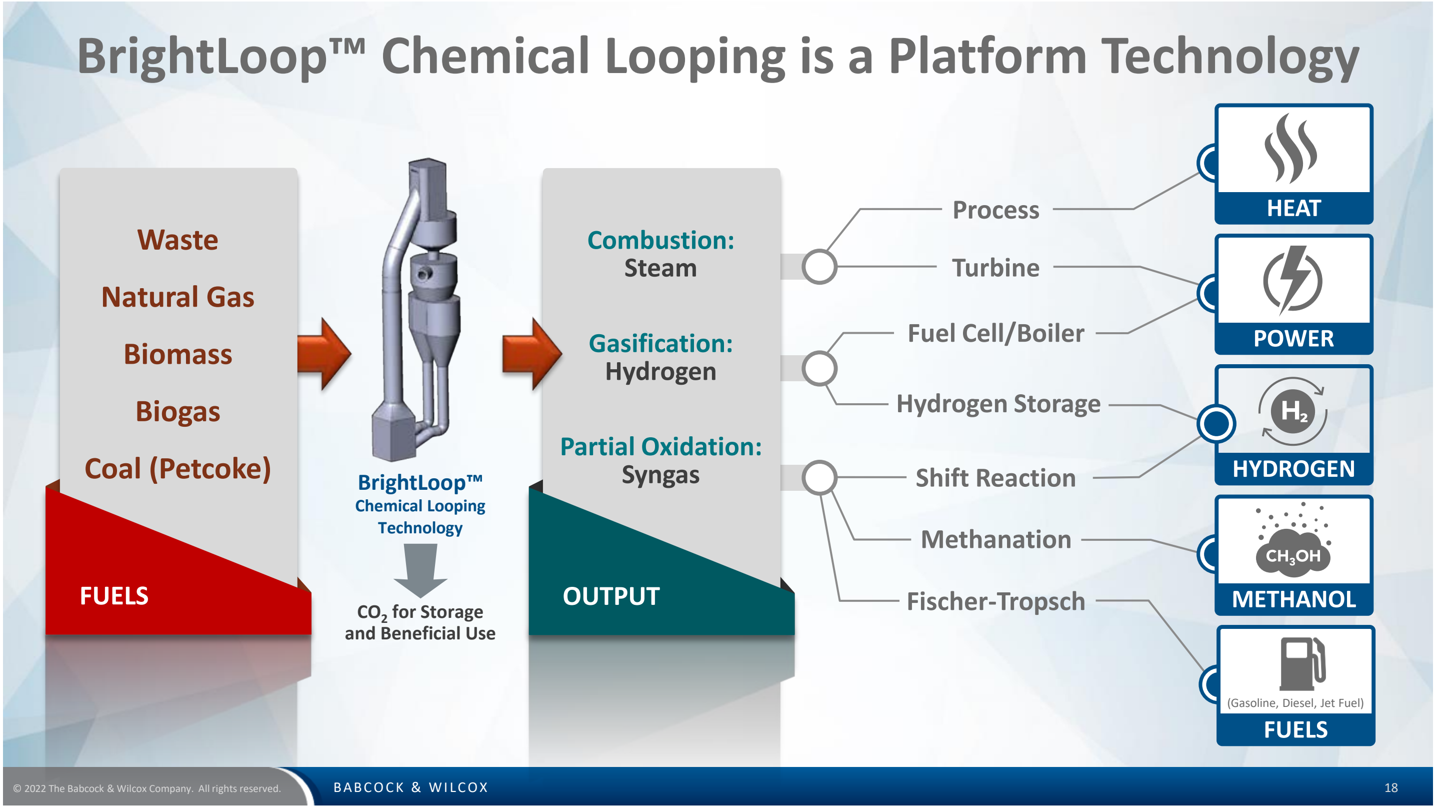
# Chemical Looping Combustion



CDCL 250 $kW_{th}$

- A flameless process using oxidation-reduction reactions to process fuel and produce energy for power generation and hydrogen
- Simultaneously produces a concentrated $CO_2$ stream for capture, storage or PtX
- Fuel impurities, such as sulfur, nitrogen and heavy elements report to the $CO_2$ stream.
- The $CO_2$ does not contain any nitrogen from air, the volume of gas to treat is reduced.
- Thus, any cleanup or environmental equipment is likely smaller and less expensive
- Lower cost, higher efficiency

*Process can convert carbon-based fuels—coal, biomass and natural gas—to electricity, hydrogen, syngas, chemicals, or liquid fuels*


BrightLoop™ Chemical Looping is a Platform Technology
Waste
Natural Gas
Biomass
Biogas
Coal (Petcoke)
FUELS
BrightLoop™
Chemical Looping
Technology
CO2 for Storage
and Beneficial Use
Combustion:
Steam
Gasification:
Hydrogen
Partial Oxidation:
Syngas
OUTPUT
Process
Turbine
Fuel Cell/Boiler
Hydrogen Storage
Shift Reaction
Methanation
Fischer-Tropsch
HEAT
POWER
H2
HYDROGEN
CH3OH
METHANOL
(Gasoline, Diesel, Jet Fuel)
FUELS
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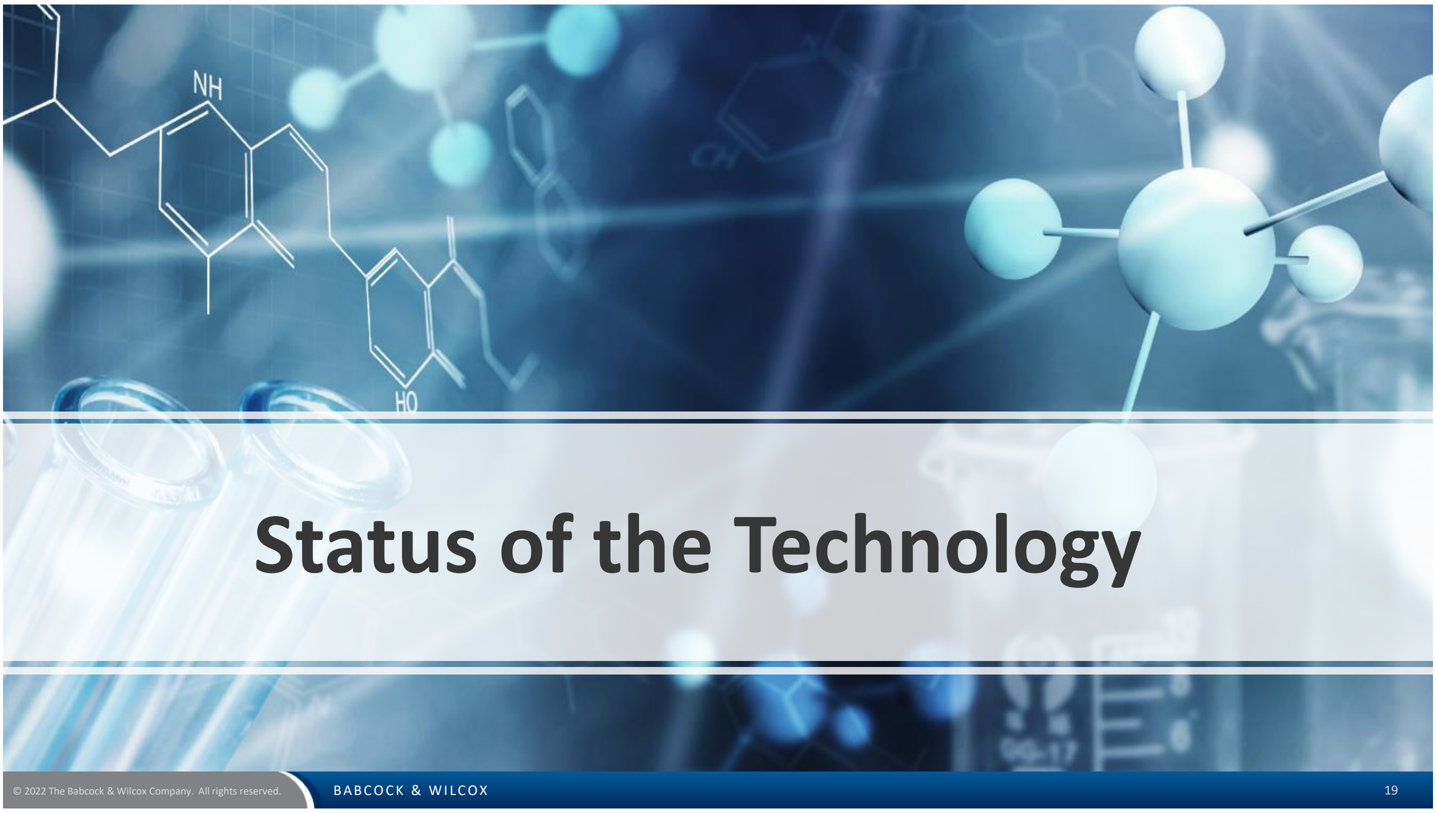
Status of the Technology
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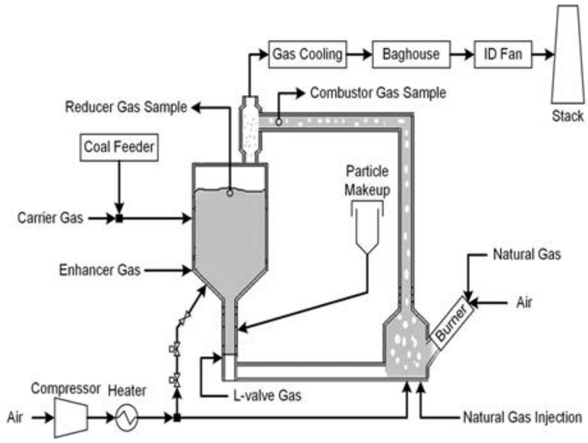


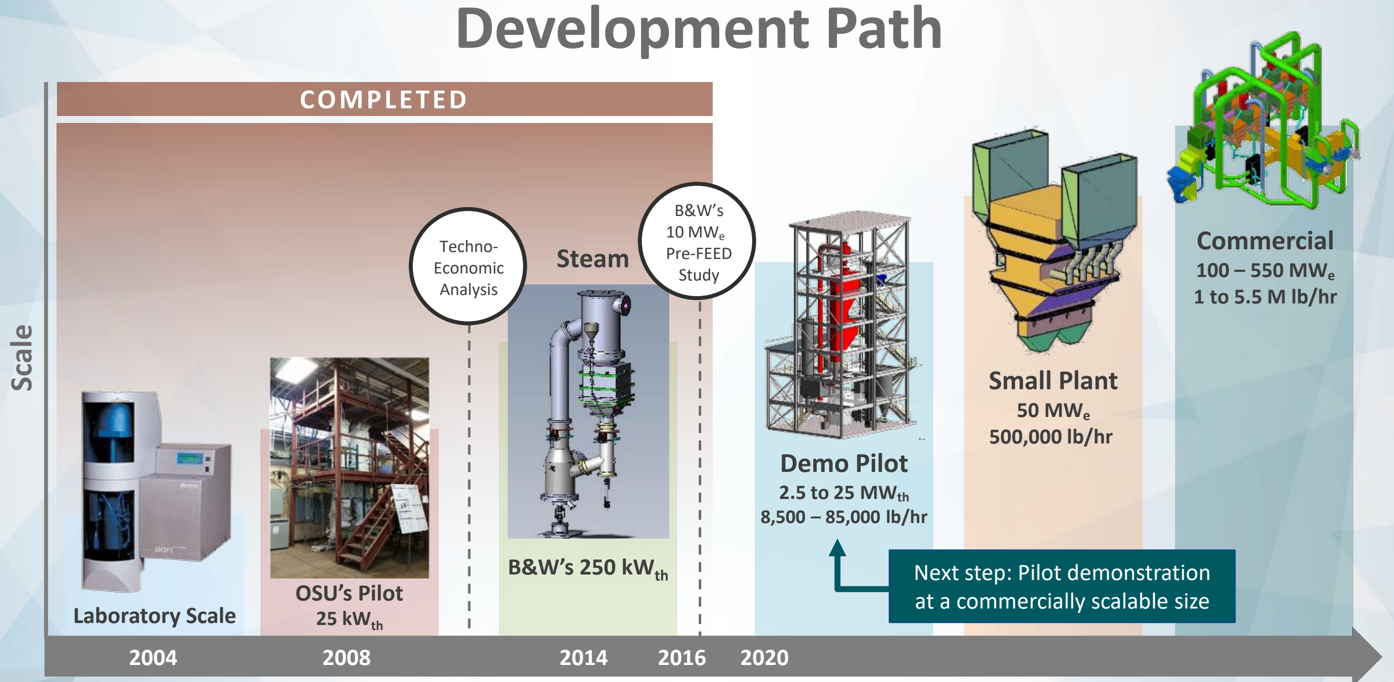

## 250 kW$_{th}$ CL Pilot Test Unit

### Specifications

- **Materials:** Refractory-lined carbon steel
- **Max Operating Temperature:** 1100 C°
- **Overall Height:** 9.7 m
- **Footprint:** 3 m x 3 m
- **Maximum Thermal Rating:** 250 kW$_{th}$
- **Design Feed Rate:** 16 kg/hr
- **Oxygen Carrier:** Iron based
- **Particle Diameter:** 1.5 mm




# Development Path



# BrightLoop™ Advantages

## $CO_2$ Capture

- $CO_2$ capture by design: no need for post-combustion $CO_2$ capture (amine scrubbing)
- ASU contributes to ~40% of CAPEX of $H_2$ or syngas plant
- Significant operating cost saving

## Emissions

- Contaminants report to the $CO_2$ stream
- Concentrated product streams result in more efficient and less expensive control equipment

## High Selectivity

- Moving bed design allows high purity of product from reaction equilibrium
- Compatible with $CO_2$ capture regulation

## Flexibility

- Base technology has wide range of products and applications

## Scalability

- Process maintains performance at small scale
- Not limited to ASU scales to be cost competitive

## Lower Capital Costs

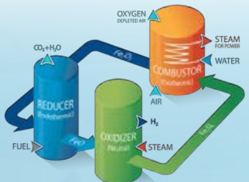
- All the above advantages result in lower costs when compared to competing technologies.




# Decarbonization Technologies are Ready

## ClimateBright™
DECARBONIZATION TECHNOLOGIES

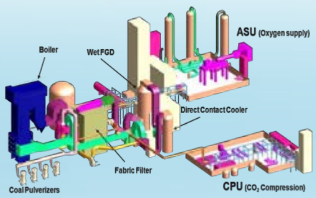
### BrightLoop™
CHEMICAL LOOPING




- Jointly developed with The Ohio State University
- Can simultaneously produce hydrogen
- Pilot testing complete on both syngas and coal at 250 $kW_{th}$ input
- Ready for scale-up to 4 x 2.5 $MW_e$

**FUELS:** Coal, pet coke, natural gas and waste streams

### OxyBright™
OXYGEN-FUEL COMBUSTION




- Pilot-scale testing complete (30 $MW_{th}$)
- 168 $MW_e$ full-scale design ready

**FUELS:** Natural gas and solid fuels (biomass, coal)

### SolveBright™
POST-COMBUSTION CARBON CAPTURE

- Pilot testing complete
- Post-combustion amine-based solvent process
- First solvent demonstrated at National Carbon Capture Center (NCCC) Southern Company's Plant Gaston
- Reference plant design ready

**FUELS:** Any combustion, gasification and industrial process that produces a flue gas stream with $CO^2$

### BrightGen™
HYDROGEN COMBUSTION

- Commercially ready and currently in operation
- A combustion technology that produces no $CO_2$
- Can be retrofitted to fire hydrogen

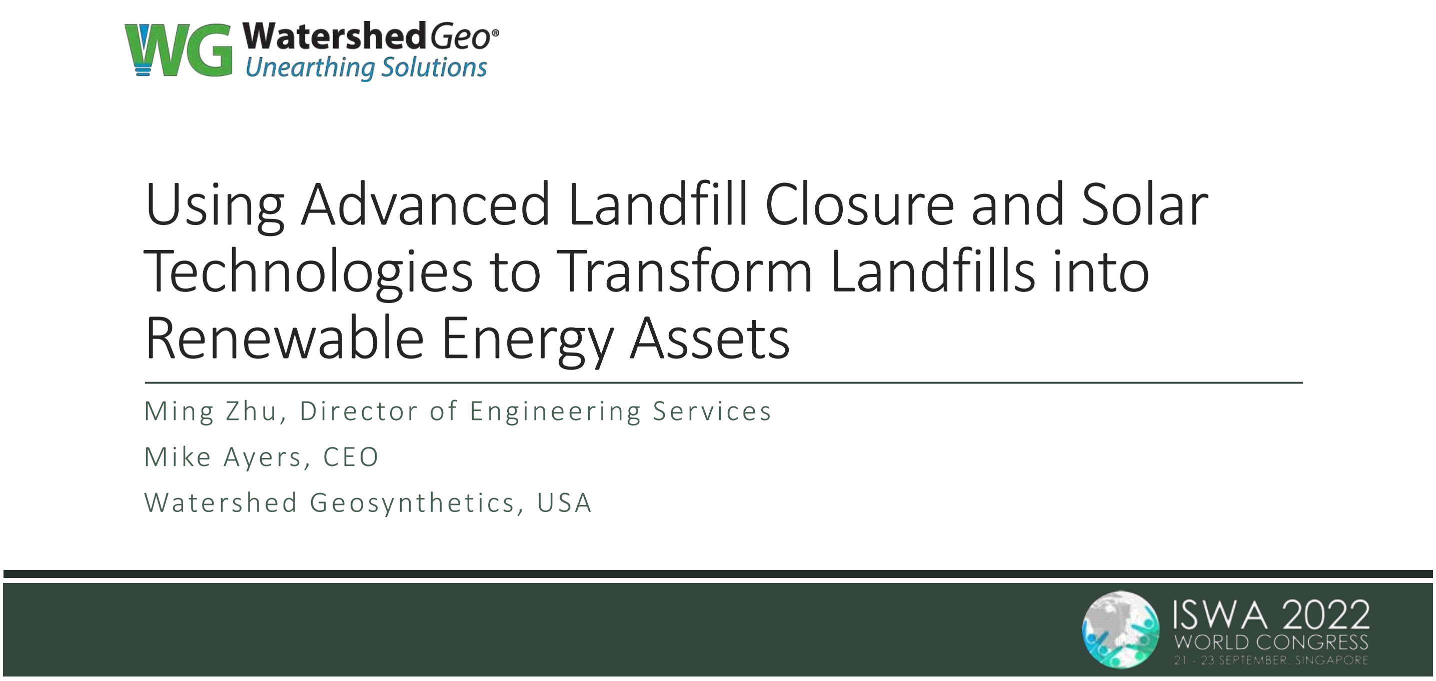
**FUELS:** Hydrogen, alone or in combination with natural gas, oil, or other gaseous fuels

B&W BABCOCK & WILCOX ENVIRONMENTAL

- B&W is at the forefront of developing $CO_2$ capturing technologies
- Multiple technologies ready for commercial demonstration
- 93 active patents related to carbon capture technology
- Positioned to provide critical solutions to meet global climate goals

*B&W has successfully tested three carbon capture technologies applicable to a wide range of fuels and processes*

| 十八 |
|---|
| 使用先進的垃圾掩埋場封場和太陽能技術將垃圾掩埋場轉變為可再生能源資產<br><br>**(Using Advanced Landfill Closure and Solar Technologies to Transform Landfills into Renewable Energy Assets)** |
| 近年來已實施一種新穎先進的解決方案推動垃圾掩埋場封場，並再利用垃圾掩埋場的空間進行太陽能開發，在此解決方案中，使用工程草坪的覆蓋層ClosureTurf®代替傳統的土壤覆蓋層；並使用無支架光伏(PV)太陽能系統PowerCapTM代替傳統的支架支撐光伏太陽能系統。這種先進的解決方案具備多項優勢，不須過多的現場維護、可快速安裝、可於更多區域發電，以及對垃圾掩埋場性能的影響最小，並可以將垃圾掩埋場封場的負債狀況轉化為長期的可再生能源資產。 |



## About Watershed Geo

WatershedGeo
Unearthing Solutions

- Based in Atlanta, Georgia, USA
- Founded in 2007 by civil engineers with landfill operation and management experience
- A technology company providing landfill closure solutions through development of innovative products
- Majority ownership by Shaw Industries Group, a Berkshire Hathaway Company (a Top 10 Fortune 500 company)
- Partner with Agru America for market development and structured geomembrane supply
- Both Shaw and Agru have offices worldwide, including Asia

Shaw　BERKSHIRE HATHAWAY INC.　agru STRUCTURED MEMBRANES

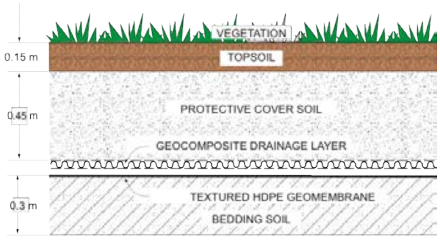


## Beneficial Reuse of Landfill for Solar Energy

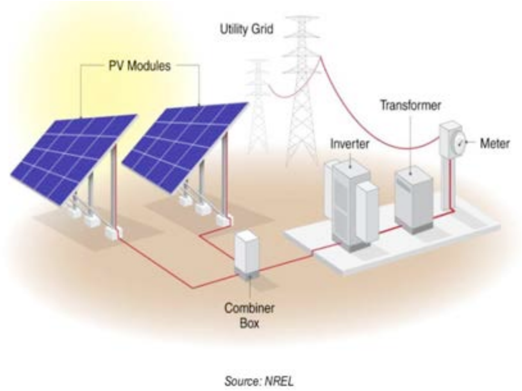
- Benefits of developing a solar farm on a closed landfill:
  - Reuse large space to provide a clean source of renewable energy
  - Prevent disturbing a “greenfield” and save natural areas
  - Save construction costs because the landfill already has infrastructure built in place (e.g., access roads, a stormwater management system, security fences, an electricity connection system, etc.)
  - Develop stronger public relationships through commitment to sustainability
  - Transform liabilities into renewable energy assets and generate revenue to offset landfill operation and maintenance costs

(Source: Watershed Geo)

## Traditional Solution




Vegetative Landfill Cover




Racking-Supported Photovoltaic (PV) Solar Panels



## Traditional Solution

A 2.7-MW solar farm constructed on a portion of a landfill in Somerville, Tennessee, USA
(Source: https://www.wastetodaymagazine.com/article/tennessee-landfill-solar-project-complete/)

## Challenges with Traditional Solution

Soil Erosion

Vegetation Overgrowth

Source: RBI Solar

Impact of Loading on Landfill
(e.g., settlement)

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## Challenges with Traditional Solution

Row Spacing and Shading

Difficulties with Installation on Slopes
(constructability and impact on landfill slope stability)

7

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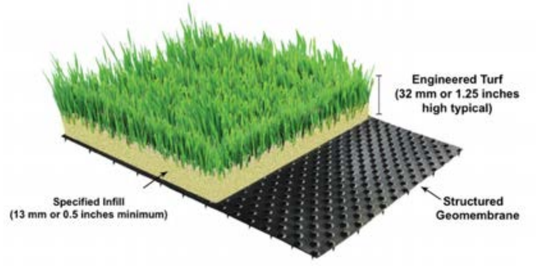
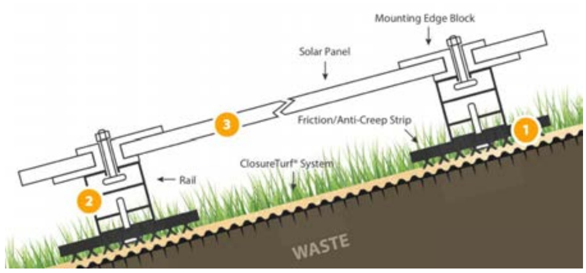
## Advanced Solution



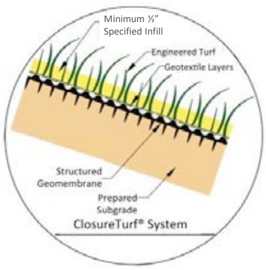

ClosureTurf®
Landfill Final Cover System

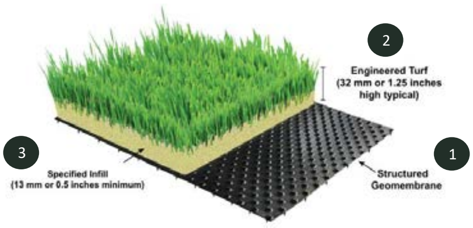
PowerCap™
Rackless PV Solar Panels



## What is ClosureTurf®

- ClosureTurf is a patented 3-component landfill final cover system:
  - A structured geomembrane: serves as the hydraulic barrier
  - An engineered turf: is made of synthetic grass blades tufted into a double-layer woven geotextile backing and provides ultraviolet (UV) and wind protection of underlying geomembrane
  - A specified infill (min. 0.5 in or 13 mm): provides additional ballast against wind uplift, UV protection of engineered turf geotextile backing, and improves trafficability



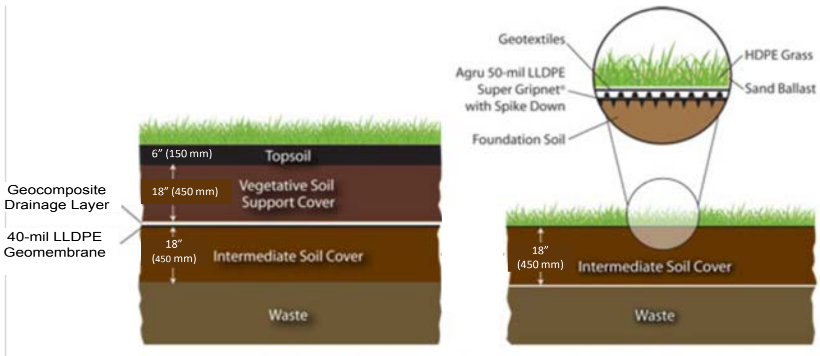


1 - Structured Geomembrane


2- Engineered Turf


3 - Specified Infill (Sand)

## Comparison with Traditional Soil Cover




Traditional Vegetative Cover ClosureTurf

- The soil layers in a traditional vegetative cover are replaced by the engineered turf and specified sand infill layers in ClosureTurf.
- By removing the soil layers, ClosureTurf provides more predictable and consistent performance that is less affected by changing weather and site conditions.
- ClosureTurf replaces the vegetative/protective soil layer, resulting in an additional airspace (typically 2 ft or 600 mm) for landfills that are permitted based on a maximum elevation of the final cover.



## ClosureTurf Project Map (USA)

WatershedGeo Unearthing Solutions ClosureTurf

- First ClosureTurf installation completed in 2009
- To date, 3,400+ acres (1,300+ hectares) of ClosureTurf installed or being installed at 90+ sites in the USA
- ClosureTurf sites including municipal solid waste (MSW) landfills, construction and demolition (C&D) landfills, industrial waste landfills, and coal combustion residuals (CCR) impoundments and landfills
- ClosureTurf installed in warm and cold climates, under severe weather conditions (hurricanes, storms, and high winds), and in seismic zones

## ClosureTurf Projects

**Baldwin County Municipal Solid Waste (MSW) Landfill,** Georgia, USA
Completed: 2017
ClosureTurf Area: 23 acres (9 hectares)

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## ClosureTurf Projects

**South Hilo Sanitary MSW Landfill,** Hilo, Hawaii, USA
Completed: 2019
ClosureTurf Area: 45 acres (18 hectares)

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## ClosureTurf Projects

**Mississippi Phosphates Corporation Site (US EPA Superfund Site)**
Pascagoula, Mississippi, USA
Currently Under Construction
ClosureTurf Area: 220+ acres (90+ hectares)

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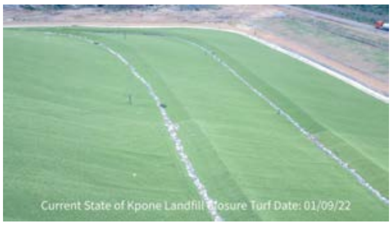
## ClosureTurf Projects

**Kpone MSW Landfill,** Tema, Ghana
Currently Under Construction
ClosureTurf Area: 35 acres (14 hectares)



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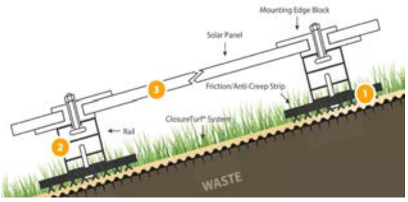
## What is PowerCap™

❖ PowerCap is a patent-pending PV solar panel system that is custom-designed for direct installation on ClosureTurf.




Friction Strip (backside)

Rail (with friction strip)

PowerCap™ Rackless PV Solar Panels

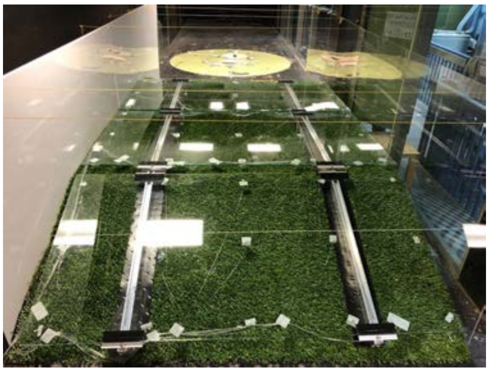


## PowerCap Installation

## Wind Tunnel Testing

Wind Tunnel Testing at Iowa State University

ClosureTurf



ClosureTurf and PowerCap



## PowerCap Projects

**A Confidential Site in Southeastern USA**
Project Completed: January 2019
PowerCap System Size: 39 KW, 120 panels
Side Slope: 3H:1V

## PowerCap Projects

**A Confidential Coal Ash Impoundment Site in Southeastern USA**

ClosureTurf Area: 309 acres (125 hectares) - Under Construction

Side Slope: 4H:1V

PowerCap System Size: 100MW (Under Design)




## Benefits of Advanced Solution

- **Easy Installation**: ClosureTurf installation is typically 2 to 3 times faster than traditional soil cover installation. The non-racking design of PowerCap makes it fast and easy to install too.
- **Minimal Impact on Landfill Performance**: PowerCap does not penetrate and is not mechanically connected to ClosureTurf. Therefore, it does "no harm" to the landfill cover. Both ClosureTurf and PowerCap are light systems and do not create significant settlement of the waste.
- **Minimal Maintenance**: ClosureTurf provides a stable foundation that requires minimal maintenance (e.g., no soil erosion repairs or grass cutting and no dust).
- **More Area to Use**: PowerCap allows installation of solar panels on landfill side slopes in addition to the top deck, increasing the footprint of solar farm for more solar power generation.
- **Increased Solar Panel Density**: Because of its low profile, PowerCap reduces shading and inner row spacing, increases panel density, and can provide 1 MW per 2 to 2.5 acres (0.8 to 1 hectares), compared to 5 to 7 acres (2 to 2.8 hectares) per MW for the traditional racking-supported solar system.

**Use of the advanced landfill closure and solar technologies can save closure construction and post-closure maintenance costs, generate additional revenue, and transform landfills into renewable energy assets!**

# THANKS!

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Mike Ayers, CEO
mayers@watershedgeo.com

WatershedGeo
Unearthing Solutions

ISWA 2022
WORLD CONGRESS
21 - 23 SEPTEMBER, SINGAPORE

## 十九

### 防止和去除有機廢棄物中的污染物

**(Preventing and Removing Contaminants from Organic Wastes)**

講述可回收的回收物中存在著污染物的問題，對於回收業者來說是一項巨大的挑戰。廢棄物生物處理工作小組(WGBTW)刻正制定一項如何防止或去除廢棄物中污染物的方案，預計於明(2023)年第一季度發布，該方案主要闡述污染物的類型、技術供應商如何設置相關廢棄物處理設施、污染防治的有效策略，以降低廢棄物中污染物的危害。

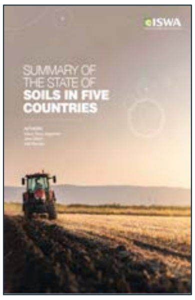
# Introduction

ISWA's Working Group on the Biological Treatment of Waste:

- Aims to discuss **topical issues** & disseminate **information**
- Our previous **soils project** highlighted the need to apply quality **compost** & **digestate** to increase **soil organic matter** levels
- Preventing & reducing **contamination** is an ongoing issue raised by WG members
- Currently developing an **issue paper** on contamination

www.iswa.org/biological-treatment-of-waste







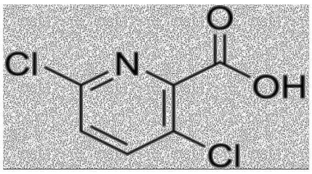
ISWA Working Group
Biological Treatment of Waste
ISWA

# What are contaminants?

**Undesirable items**, **substances** or **biological materials** in organic wastes and/or their recycled products that have potential to **adversely affect** the **recycling** process and/or the recycled end **product(s)**

*Examples:*

Plastics




Chemicals

Pathogens/weed seeds

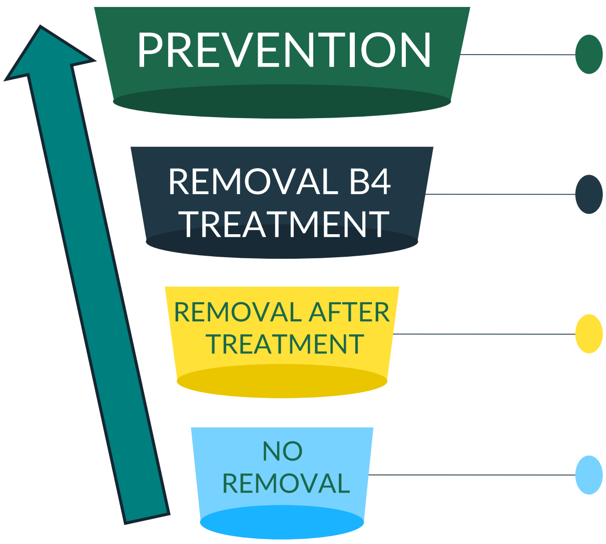
## Why are they important?

Can **adversely affect**:

- The composting or anaerobic digestion **process**
  - Damaging equipment
  - Impeding mixing
- **Safety** of operators, end users and/or the environment
- Processing **times** & **profitability**
- **Recycling rates**
  - Increasing disposal
- **Quality** of the end product
  - Restricts application
  - Potential to transfer into wider environment
  - Regulatory restrictions


ISWA Working Group
Biological Treatment of Waste
ISWA

## Contamination hierarchy




- Selecting feedstocks carefully
- Separate collections
- Good, consistent communication

- Screening
- Presses
- Cyclones

- Screening
- Wind sifters

- Disposal only

# Preventing & reducing contaminants at source

Segment according to source type:


C&I = Commercial & Industrial

- Collection scheme
- Collection tools
- Public awareness

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ISWA

# Collection schemes


PREVENTING 'MIS-THROWS'

Type of Scheme Affects **Behaviour**

**FOOD WASTE**

- **Door-to-door** or **kerbside** collections perform better than roadside containers
  - Quality control
  - Potential to 'reject' contaminated bins

**GARDEN WASTE**

- **Manned centralised** collection points
  - Recycling centres
  - Clear signage
  - Verbal instructions to people

**COMMERCIAL WASTES**

- Clear **instructions**
- Collection bins
  - Convenient location
  - Kept away from residual waste bins

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# Collection tools

- Clean
- Convenient
- Frequent

- Use of **compostable bags**/liners
- Kitchen caddies
- Dedicated bins outdoors
- Minimum of weekly collection

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ISWA

# Information


Milan, Italy

- **Consistent** messages
  - 'Ins' & 'outs'
  - 'How to'
- **Encourage** & make people feel good
- Clear **branding**
- Different communication **channels**
  - Signs
  - Social media
- **Repeating** messages

UK

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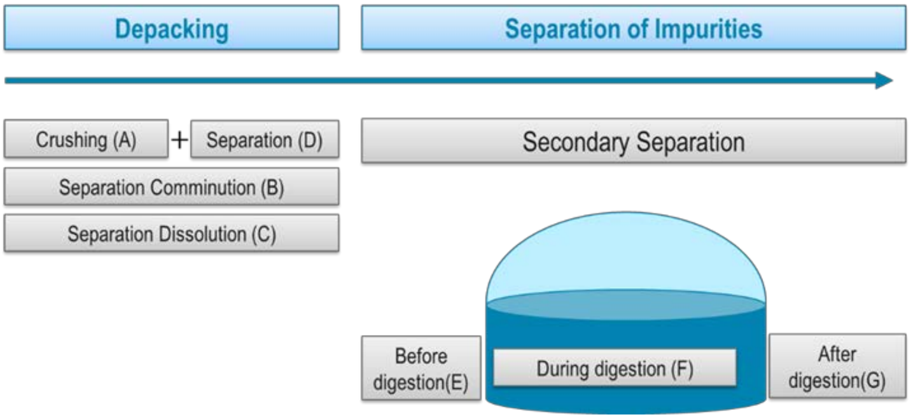
Biological Treatment of Waste
ISWA

# Managing food waste packaging at wet AD facilities

De-packaging of food waste at wet anaerobic digestion facility




- Supermarket food waste
- Arrives at facility still packaged
- Plastics need to be removed prior to digestion

Source: German Biogas Association

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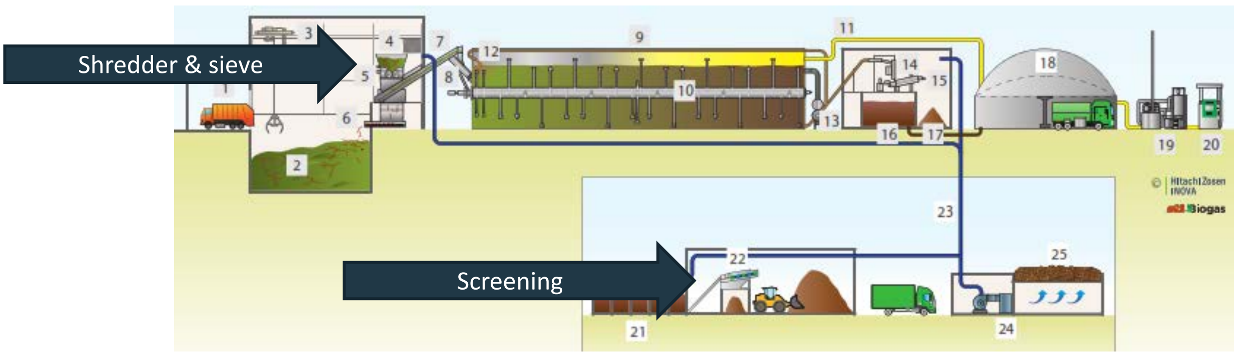
ISWA

# Removing contaminants at dry AD & composting

Example: Kompogas® dry AD, Högbytorp / Sweden
- Green waste, manures & food waste
- Contaminants due to 'mis-throws'




Source: Hitachi Zosen Inova

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# Overview & aims of the paper

**MAIN CHAPTERS**

1. Types of contaminants
2. Sources
3. Prevention strategies
4. Removal techniques

**AIMS**

- Reference document
- Hierarchy of options
- Describe examples

**PUBLISH Q1 2023**

PREVENTION

REMOVAL B4 TREATMENT

REMOVAL AFTER TREATMENT

NO REMOVAL

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# THANK YOU

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| 二十 |
| --- |
| 如何妥善處理食物廢棄物—集中式或分散式<br>**(How Food Waste Can be Handled Appropriately – by Centralized or Decentralized Approach)** |
| 食物廢棄物是城市固體廢棄物的主要來源，若處理不當，將產生溫室氣體排放。傳統的廚餘廢棄物處理設施為位於市中心的大型集中式設施或小型分散式設施。現在新興一種類似分散式的厭氧消化方法，先在廢棄物集中地實行預處理，之後運往社區進行水解和甲烷生成作用，使廢棄物轉化為能源，該方法可以降低運輸成本，減少交通壅塞，並作為當地社區的一種參與工具。 |

ISWA 2022
WORLD CONGRESS
21 - 23 SEPTEMBER, SINGAPORE

AEL Intl. Holdings Limited

**AEL (International Holdings) Ltd**

## How Food Waste Can be Handled Appropriately – by Centralized or Decentralized Approach

Jude.chow@aelintl.hk +852 2767 1222

Science Park Unit 105-106, Bio Informatics Centre (2W), Hong Kong

## Jude Chow

**Membership**

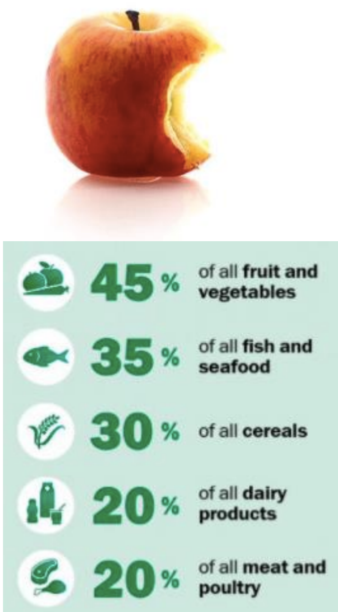
- ISWA Member since 2013
- Chairman Hong Kong Waste Management Association 2017 – 2019
- Chairman Environmental Council (FHKI) Since 2017
- Vice Chairman Federation of Hong Kong Industry Since 2019
- Committee Member, China Association of Urban Environment and Sanitation

**Think Tank**

- Committee Member, Greater Bay Area Task Force on Innovation and Technology: Trade Development Council
- Committee Member, Innovation and Technology Development Committee (FHKI)

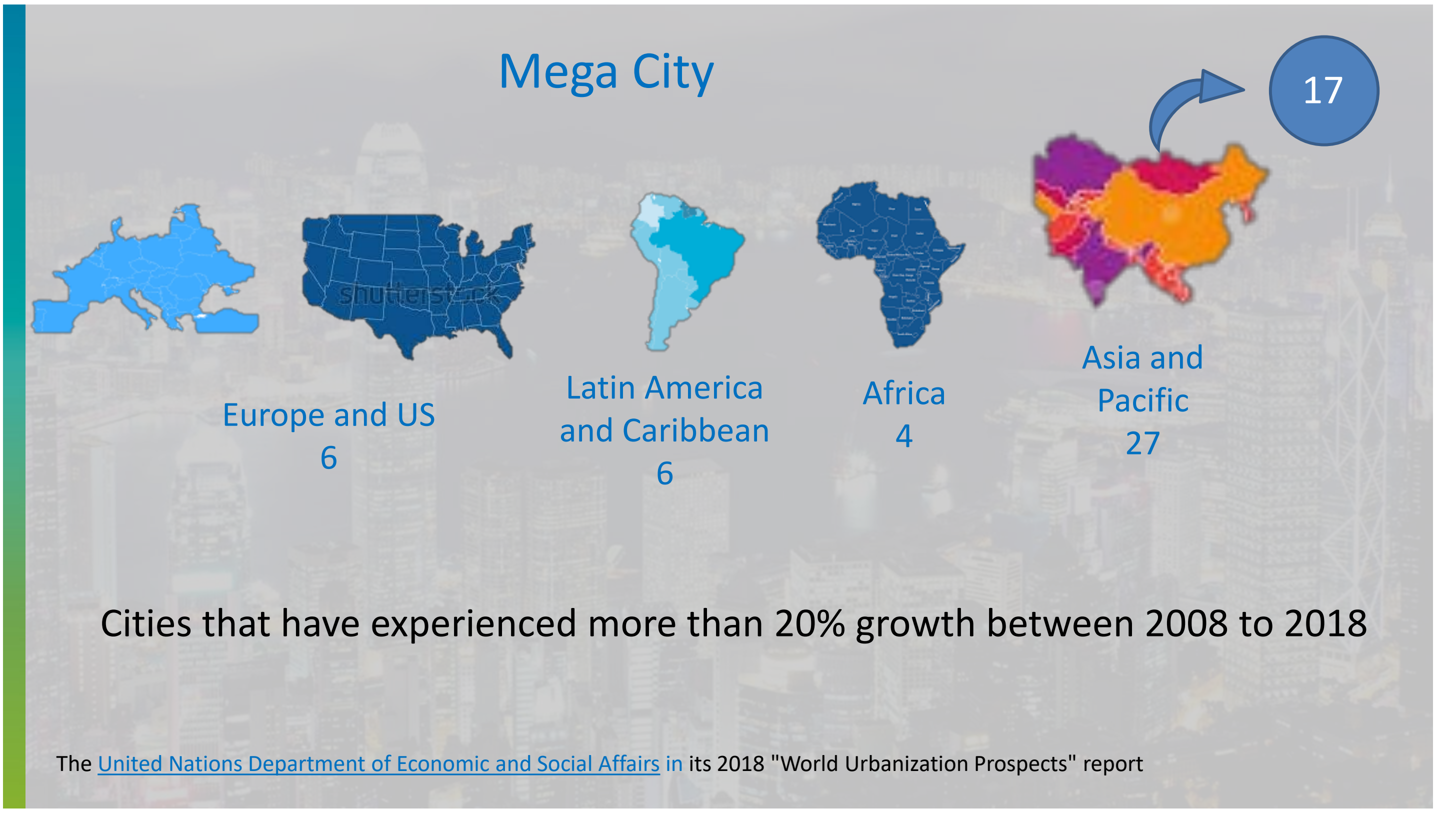
**Government Funding Committee / Environmental Award**

- Cleaner Production Partnership Program 2018-2022
- Enterprise Support Scheme (ESS) Assessment Panel's assessor, Innovation and Technology Commission.
- Awards Committee, The Hong Kong Awards for Environmental Excellence




"Roughly one-third of the edible parts of **food** produced for human **consumption**, gets **lost** or **wasted** glob ally, which is about 1.3 billion ton per year. "

Food and Agriculture Organization of United Nations – Report of Global Food Lost and Food Waste


Mega City
17
shutterstock
Europe and US
6
Latin America
and Caribbean
6
Africa
4
Asia and
Pacific
27
Cities that have experienced more than 20% growth between 2008 to 2018
The United Nations Department of Economic and Social Affairs in its 2018 "World Urbanization Prospects" report


Mega Cities Challenges
LOGISTIC AND TRAFFIC
ENERGY
FOOD SECURITY
CARBON EMISSION
SANITATION IN HIGHLY
POPULATED AREA
ODOUR
LABOUR SHORTAGE


## Driver for Sustainable Mega City Waste Management

SMART

- Big Data: On-Demand Collection
- Energy Efficiency

Sustainability

- Economic for stakeholders, SOCIETY,
- Natural Science
- Community Engagement

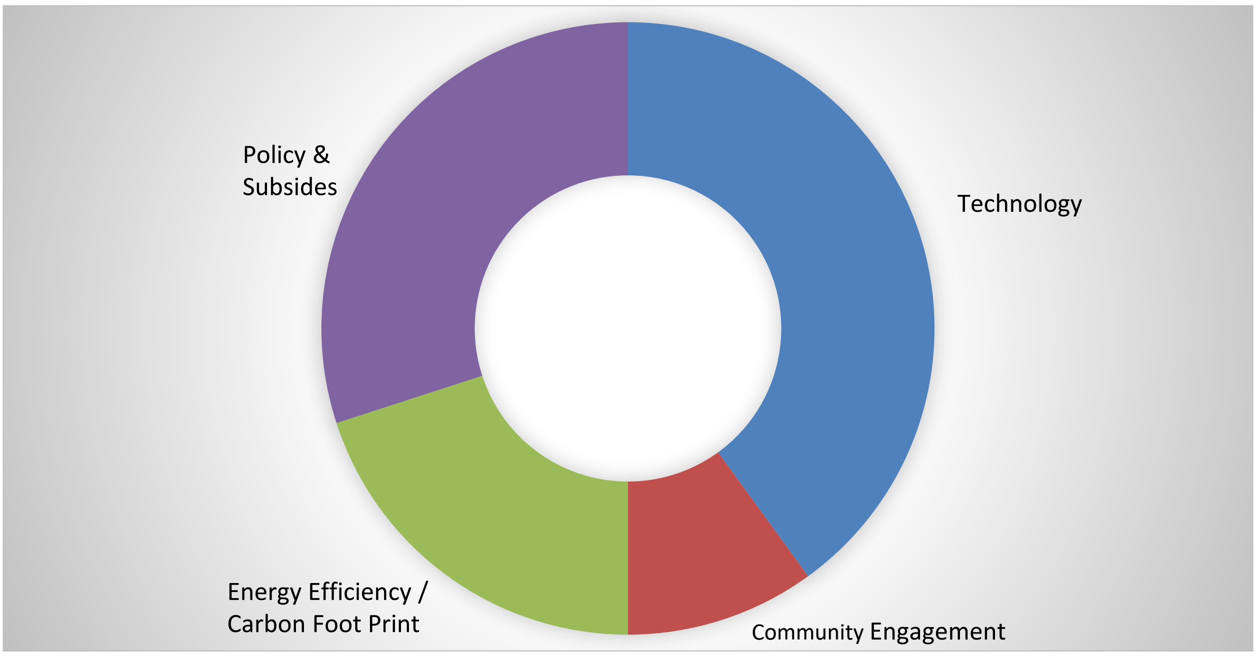
## Traditional Key Drivers for Waste Management

- Public Health
- Environmental Protection
- Resource Value of Waste
- Closing the loop / Circular Economy
- Institutional and responsibility issues
- Public awareness

David C Wilson (2007) Centre for Environmental Control and Waste Management Department of Civil and Environmental Engineering, Imperial College, London, UK

# Centralized Food Waste Treatment

# Consideration for Centralized Food Waste Treatment



## Conventional Centralized Food Waste Management

**1. Collection** → **2. Transportation** → **3. Treatment**

**1. Collection:** Require tedious manual separation of food waste and occupy lots of space for storing food waste

**2. Transportation:** Delivered either by refuse collection vehicles or tail gate trucks to centralized facilities

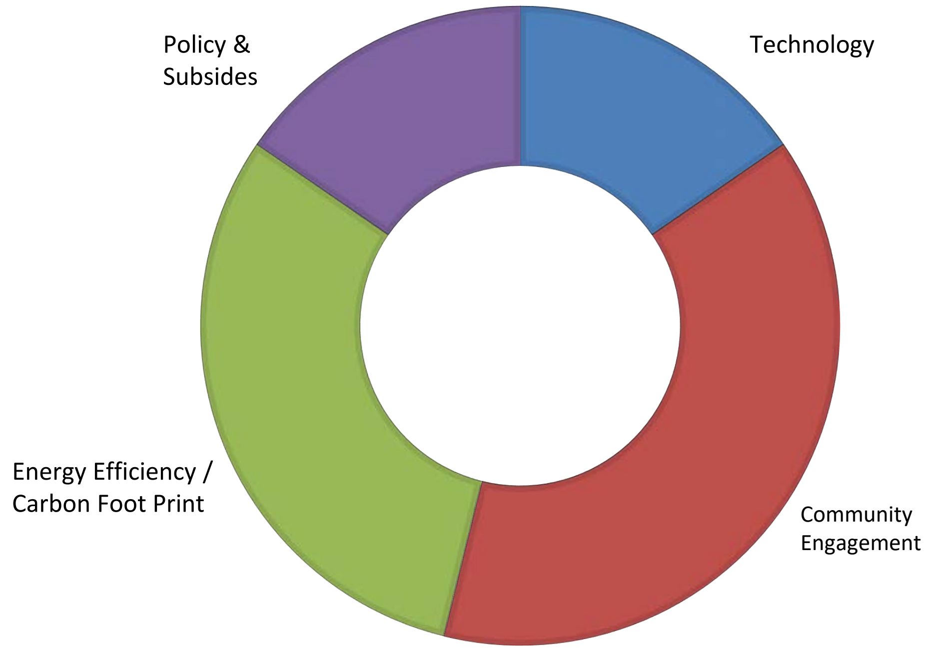
**3. Treatment:** Require complicated pretreatment before going through anaerobic digestion to produce biogas

**Key challenges:**

- Manual separation: labour-intensive
- Lots of space for storage
- Pretreatment: complicated & costly

## Decentralized Food Waste Treatment

## Consideration for Decentralized Food Waste Treatment



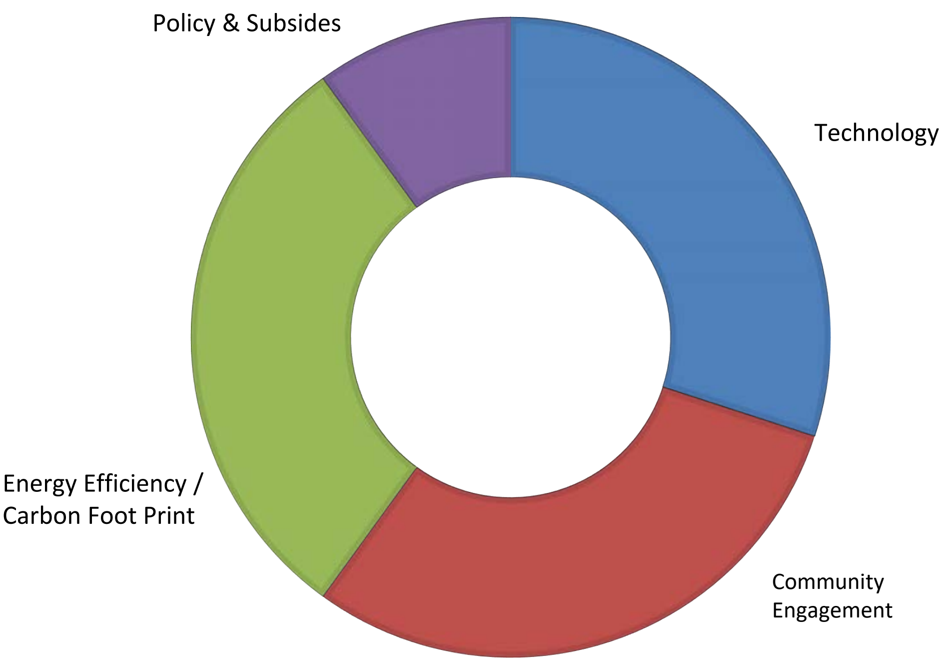

## Decentralized Food Waste Treatment

Compost
- Inconsistency in fertilizer quality
- Manual handling
- Odor and Sanitation
- Gardening Application

Animal Feed
- High capital investment for equipment
- Energy Intensive
- Farm Application

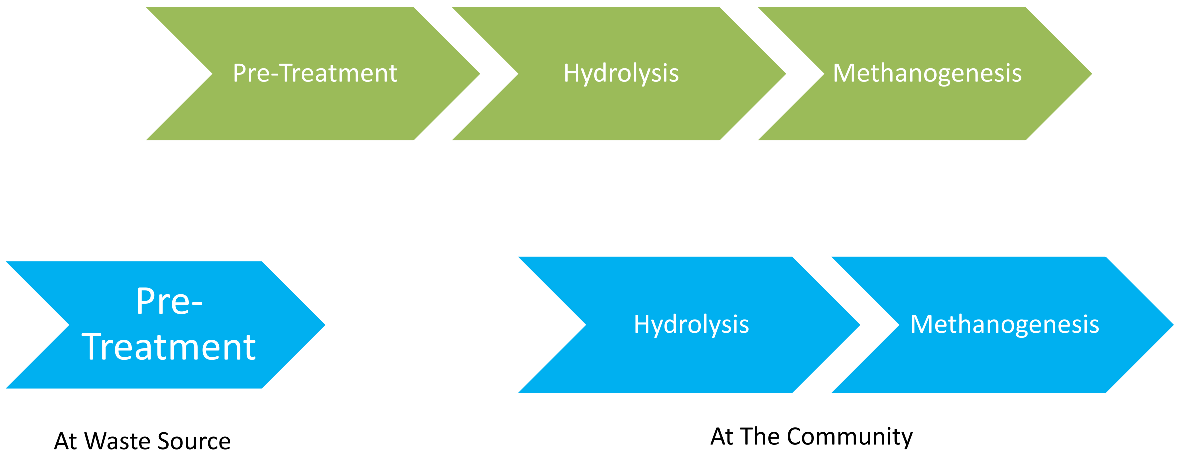
# Satellite Food Waste Management

# Consideration for Satellite Food Waste Treatment



## Satellite Approach for Decentralized Waste to Energy

- Splitting the conventional Centralized Anaerobic Digestion process

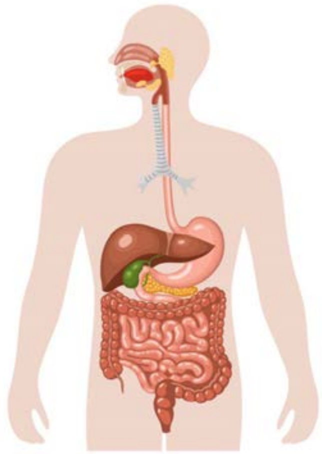



## Containerized Two Stage Anaerobic Digestion

An all-in-one 2-stage Anaerobic Digestion (AD) system that converts food waste into Energy

- Compact / Small Food Print
- Zero Discharge
- Fully Automated – Unman operation with IoT
- Exterior Design to match the surrounding environment

## Two Stage Anerobic Digestion Process



Mimic Human Digestion

**Pre- Treatment**
- Mouth – Chew and Grinding to breakdown Food

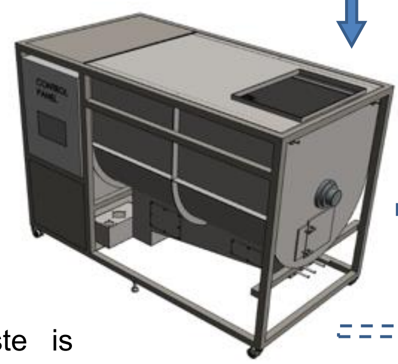
**Hydrolysis / Acidification**
- Stomach - Using Acid to breakdown food

**Methanogenesis**
- Using bacteria to covet food into biogas

## Patented Food Waste Pretreatment System

Food waste (100%)

Feeding food waste



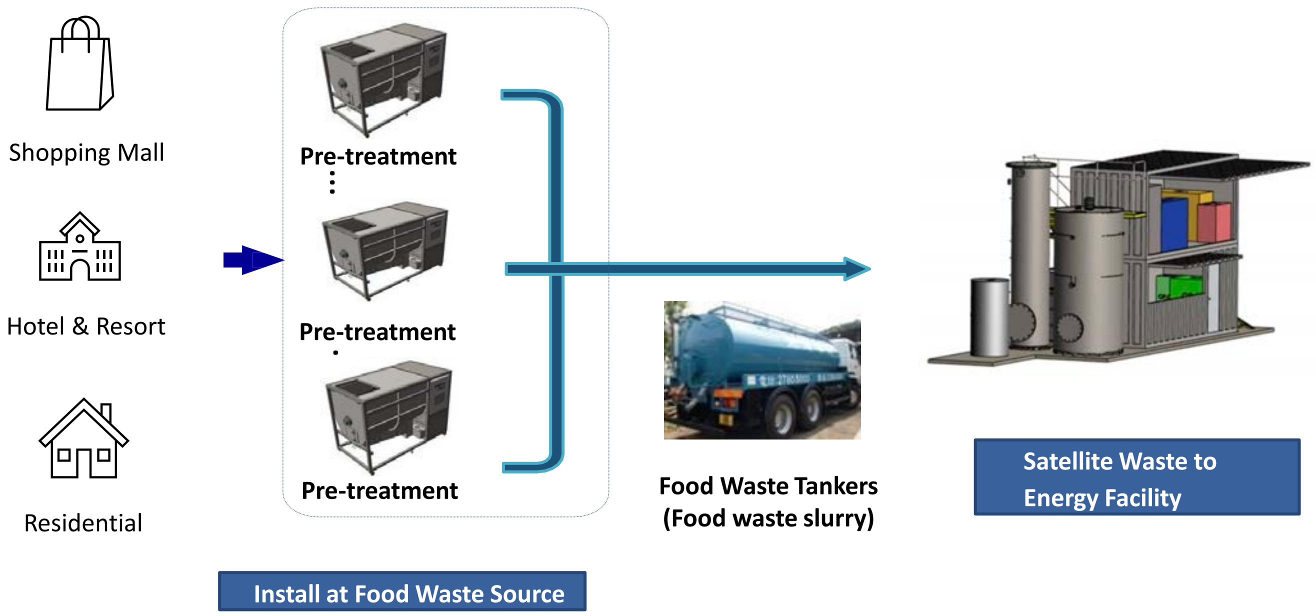
Food Waste Slurry (97%)

Garbage (3%)

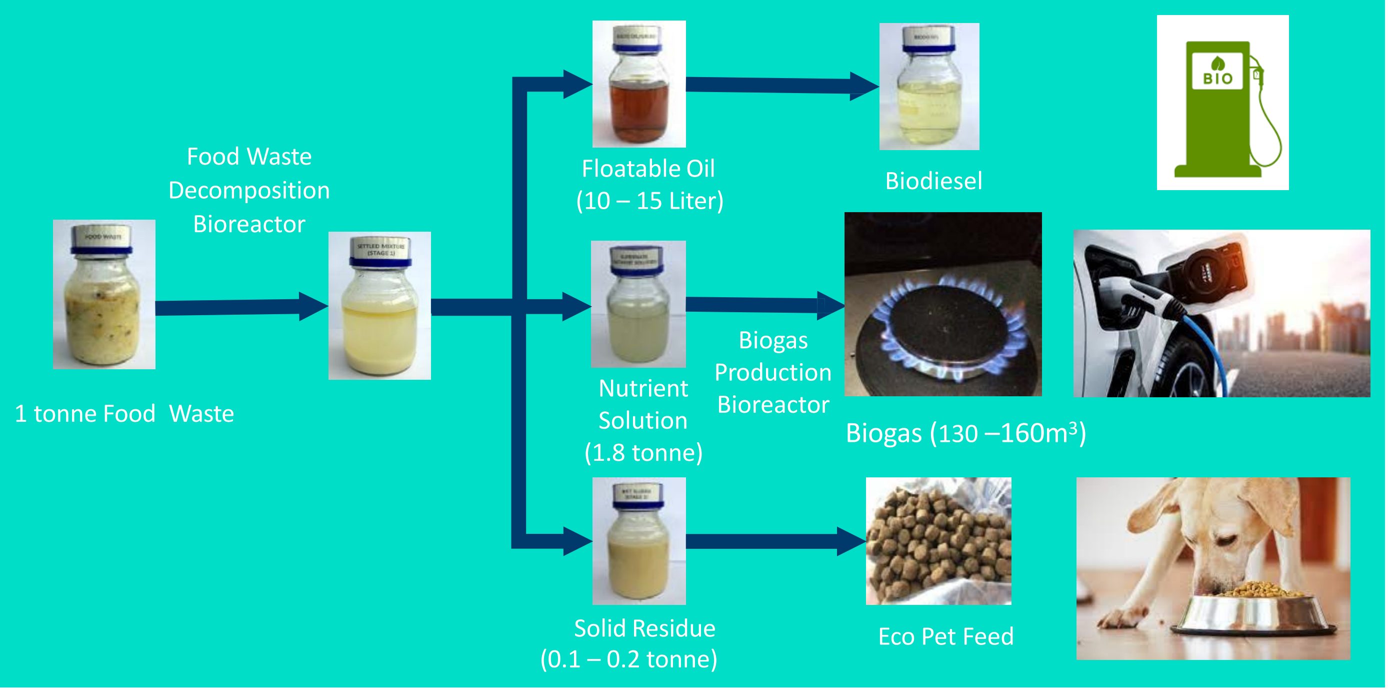
- ~97% of the food waste is converted into slurry, leaving ~3% garbage for disposal.

19

## Satellite Food Waste Management




## Recycling of Food Waste to Valuable Resources



# Awards – Hong Kong



18th October 2022

"Food TranSmarter", the food waste conversion system developed by the Hong Kong Productivity Council (HKPC), scooped two grand awards at the first-ever City I&T Grand Challenge. It was crowned the Champion of the Open Group (Environmental Sustainability) category and won the Most Favoured Award by receiving the most public votes from the audience of the award presentation ceremony on-site.

# Awards – International

•IChemE Global Awards 2018 - Highly Commended for the Energy and Sustainability Award

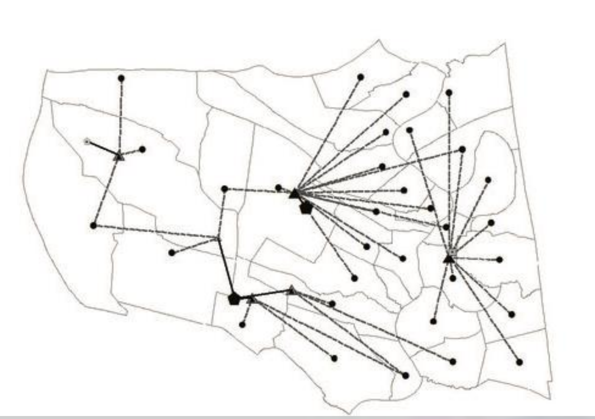
•45th International Exhibition of Inventions of Geneva, 2017 - Gold medals

Gold Medal– "Total Food Waste Recycling System" - High Market Value Products and No Wastage


•IET Innovation Award 2017 - Winner of the IET Innovation Award for Power and Highly commended in the for Sustainability

The "Food Waste Total Recycling System", developed by HKPC, was granted the winner of the "Power" category and a "Certificate of Highly Commended" in the "Sustainability" category at the prestigious "IET Innovation Awards" in London, the UK

## Summary



- Reduce Transport Cost and Frequency
- Reduce Carbon Emission
- Improvement Sanitation
- Fully Automated with IoT Control
- Provide Green Renewable Energy
- High-value Animal/Pet Feed
- Provide an Education tool in the community

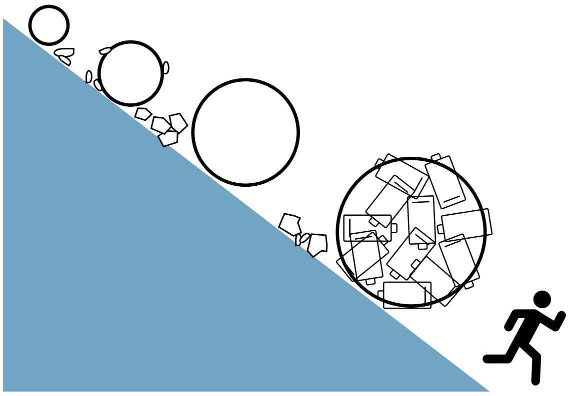
# Thank You!

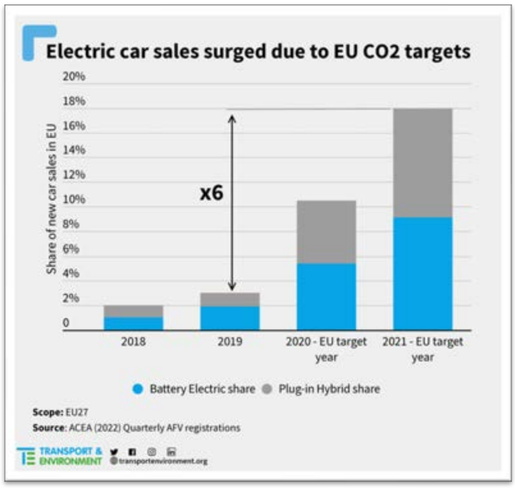
Please come to visit our Booth B13

| 二十一 |
| --- |
| 電動汽車鎳錳鈷**(NMC)**電池回收的全面性的永續評估<br>**(Full Sustainability Assessment of an Electric Car NMC Battery Recycling)** |
| 歐盟提議從2035年開始禁止銷售新的汽油和柴油汽車。據估計，2021年將產生240噸廢棄電動汽車電池，這種龐大的電動汽車電池廢棄物料將需要經過報廢管理的程序，並考慮所有相關的永續性指標。 |

# E-MOBILITY AND THE WASTE SNOWBALL

- Electric vehicle sales grew 9% in 2021
- ban on the sale of new petrol and diesel cars from 2035
- 240 ktonnes of waste EV batteries (2021)



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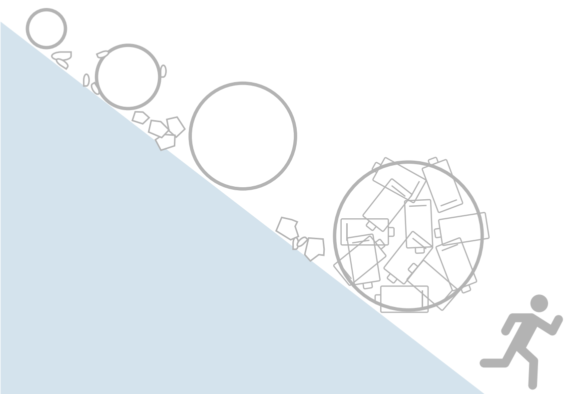

**Recycling**

- Solves waste treatment
- Provides critical raw materials
- Secondary materials can be produced locally
- BUT -> there are limitations

## PROJECT TRIPLELINK

**Project goal:**
Create an integrated software solution to help design, assess and optimize the footprint of products and technologies.

**Target audience:**
Process and manufacturing industry

**Assessment methods:**
- LCA
- Material Criticality
- Circularity
- Thermo-economic information

**Funding**

eit RawMaterials — Connecting matters

Funded by the European Union

TNO innovation for life

## CASE STUDY

### CASE STUDY DESIGN

Test the assessment framework with different indicators

Test the software solution developped

Generate knowledge on the challenges and limits for recyclability of energy storage technology
- (choice: electric vehicle NMC 111 batteries)

TNO innovation for life

## RESEARCH QUESTIONS

How does pre-treatment influence the recycling of EV batteries?

Image credits: Images from HSC chemistry software

## RESEARCH QUESTIONS

How does pre-treatment influence the recycling of EV batteries?

Can we use thermodynamic principles to tackle battery recyclability limits and assess circularity at once?

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How does pre-treatment influence the recycling of EV batteries?

Can we use thermodynamic principles to tackle battery recyclability limits and assess circularity at once?

How does recycling affect the environment and battery material criticality?

## CASE STUDY

### NMC 111 BATTERY

- weight: 360 kg
- Composition from GREET model*

- <u>Functional unit</u>
- Pyrometallurgical recycling of 1 kg of NMC 111 battery

- <u>Assessment</u>
- Environmental impacts [ReCiPe 2016 (h)]
- Thermodynamic circularity [CExD and exergy loss]
- Criticality [GeoPolRisk]

| Battery Part | Material | % weight |
|---|---|---|
| Battery casing (34%) | Steel | 5.7% |
| | Electronics | 2.7% |
| | Aluminum | 17.9% |
| | Plastics | 5.7% |
| | Cables | 2.3% |
| Module (10%) | Aluminum | 5.3% |
| | Plastics | 1.5% |
| | Steel | 3.3% |
| Cathode (20%) | Al foil | 5.5% |
| | Li | 1.0% |
| | Ni | 3.0% |
| | Co | 3.0% |
| | Mn | 2.7% |
| | O2 | 4.6% |
| Anode (17%) | Cu foil | 9.2% |
| | Graphite | 7.8% |
| Cell Housing | Aluminum | 5.8% |
| Electrolyte | Volatiles | 8.3% |
| Separator | Plastics | 3.8% |
| Binder | Difluoroethylene | 1.1% |

*Source: Dai, Q., Kelly, J. C., Dunn, J., & Benavides, P. T. (2018). Update of bill-of-materials and cathode materials production for lithium-ion batteries in the GREET model. Argonne National Laboratory.

# CASE STUDY

## NMC 111 BATTERY

Foreground system:

- Discharge and disassembly
- Thermal and mechanical treatment for material separation

Pre-treatment

- Pyrometallurgical recycling
- Hydrometallurgical processing of the slag
- Material recovery (avoided products)

- Background system (EcoInvent 3.8):
- Further sorting and recycling of waste streams
- Waste treatment and landfilling of mixed residual waste
- Transport

| Battery Part | Material | % weight |
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# CASE STUDY

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Foreground system:

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HSC chemistry simulation

- Material recovery (avoided products)

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## CASE STUDY

### NMC 111 BATTERY

Foreground system:

- Discharge and disassembly
- Thermal and mechanical treatment for material separation
- Pyrometallurgical recycling
- Hydrometallurgical processing of the slag
- Material recovery (avoided products)

LCA model

- Background system (EcoInvent 3.8):
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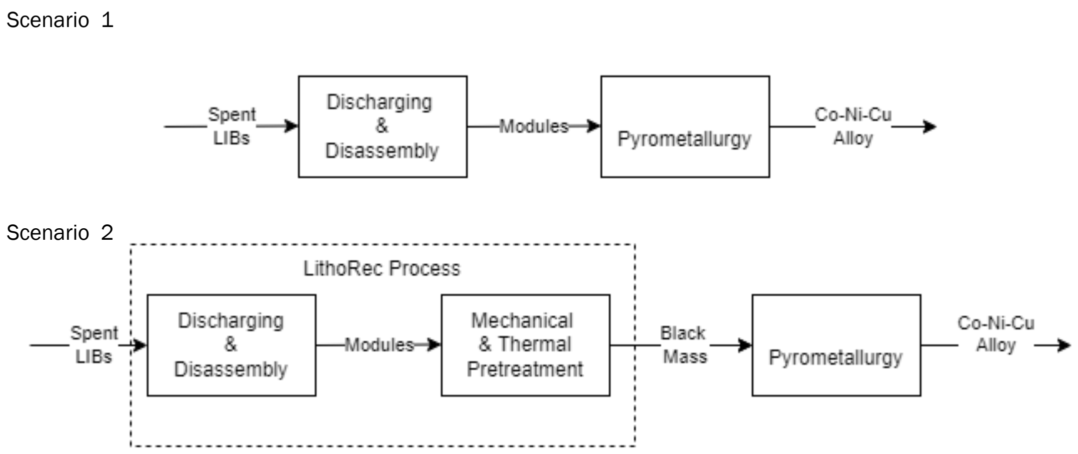
## SYSTEM BOUNDARIES



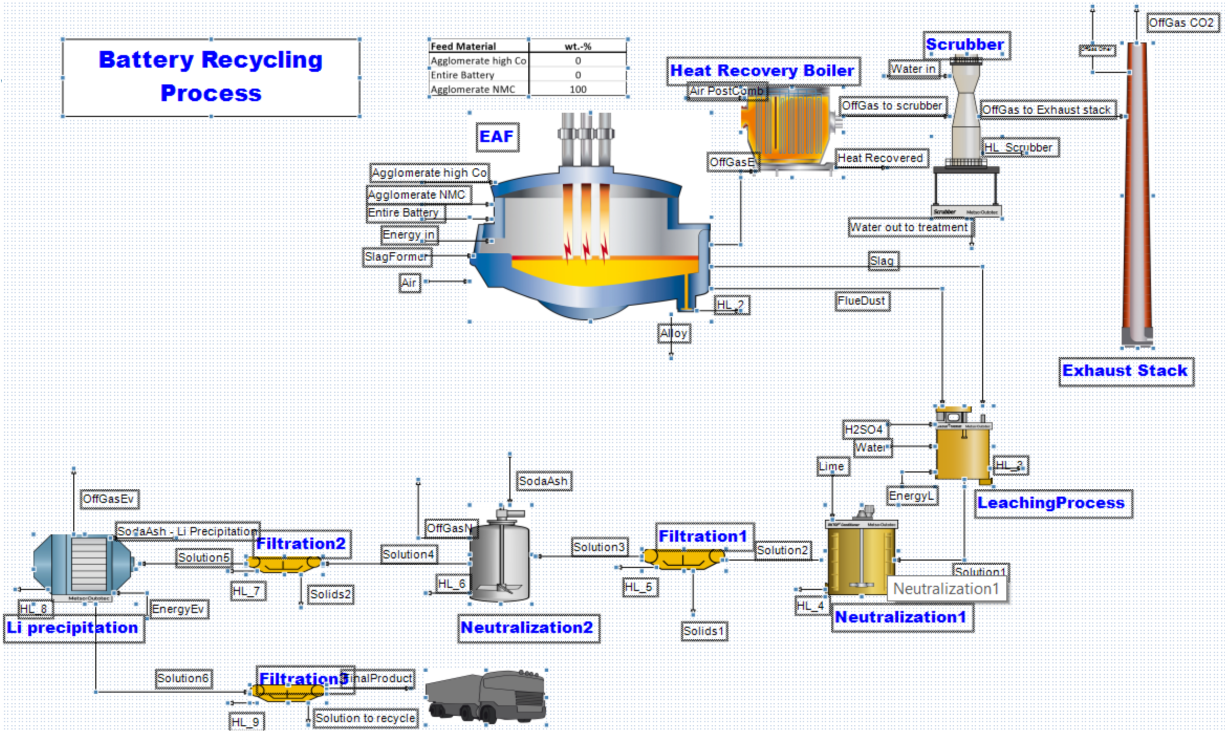



Image credits: Images from HSC chemistry software

# PRE-TREATMENT PROCESS

75% efficiency assumed

up to 98% possible

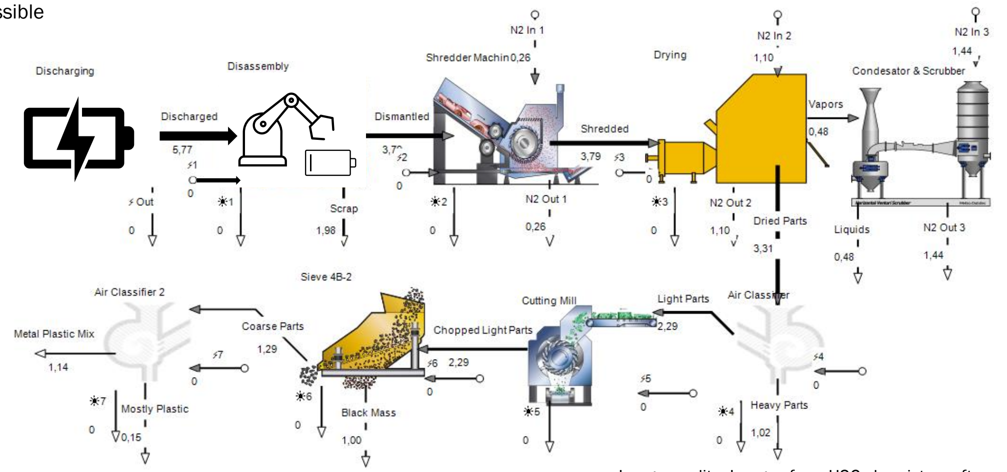
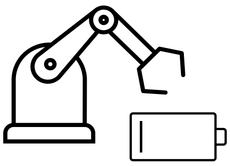


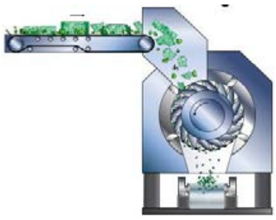

Image credits: Images from HSC chemistry software

Sources for pre-treatment process:
Diekmann, J., Hanisch, C., Loellhoeffel, T., Schälicke, G., & Kwade, A. (2016b). Ecologically friendly recycling of lithium-ion batteries-the lithorec process. ECS Transactions, 73(1), 1.
Diekmann, J., Rothermel, S., Nowak, S., & Kwade, A. (2018). The LithoRec Process. In Recycling of Lithium-Ion Batteries (pp. 33-38). Springer, Cham.
Kwade, A., & Diekmann, J. (2018). Recycling of lithium-ion batteries. The LithoRec Way, Switzerland: Springer International Publishing AG.
Kwade, A., Diekmann, J., Hanisch, C., Spengler, T., Thies, C., Herrmann, C., ... & Scholl, S. (2016). Recycling von lithium-ionen-batterien—lithoRec II Abschlussberichte der beteiligten Verbundpartner. Verbundprojekt im Rahmen des Förderprogramms, Erneuerbar Mobil "des Bundesministeriums für Umwelt, Naturschutz, Bau und Reaktorsicherheit, 2017-01.

## RESEARCH QUESTIONS

How does pre-treatment influence the recycling of EV batteries?





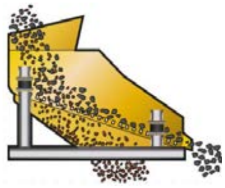


Image credits: Images from HSC chemistry software

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## RESULTS

### HOW DOES PRE-TREATMENT INFLUENCE THE RECYCLING OF EV BATTERIES?

- 2x more energy consumption (due to less aluminium and graphite in black mass)
- 25% - 2% cathode material loss in mixed waste streams
- 94,1% of the resulting alloy is Cobalt and Nickel
- Copper impurities reduced from 55% to 5,5%

| Scenario 1 (no pre-treatment) | |
|---|---|
| Alloy component | Content in %mass |
| Mn | 0,1% |
| Co | 18,1% |
| Ni | 19,2% |
| Cu | 55,1% |
| Al | 0,0% |
| Fe | 7,5% |
| Li | 0,0% |

| Scenario 2 | |
|---|---|
| Alloy component | Content in %mass |
| Mn | 0,2% |
| Co | 44,7% |
| Ni | 49,4% |
| Cu | 5,5% |
| Al | 0,0% |
| Fe | 0,2% |
| Li | 0,0% |

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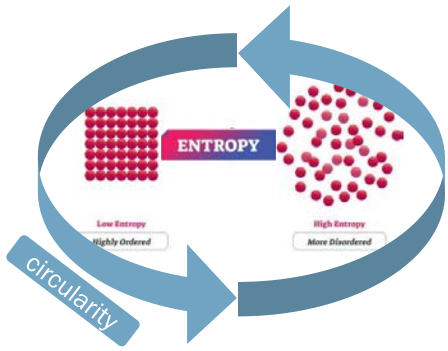
## RESEARCH QUESTIONS

Can we use thermodynamic principles to tackle battery recyclability limits and assess circularity at once?

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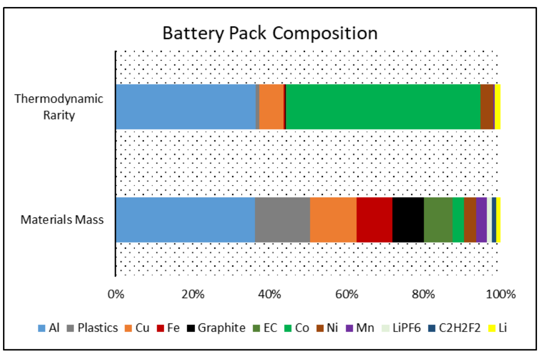
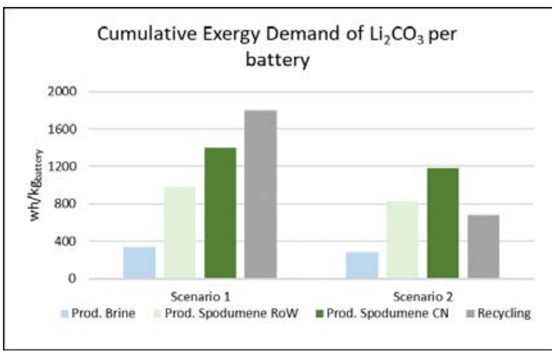
## RESULTS – CIRCULARITY (THERMOECONOMICS)

- Mass circularity: recycling Al and Co = 39%
- Thermodynamic circularity:
  - recycling Al and Co = 87%




- 62% of the Exergy lost due to Lithium recovery
- Higher for recycling than for primary production
- Exergy conservation/Circularity: - 81% scenario 1, -58% Scenario 2

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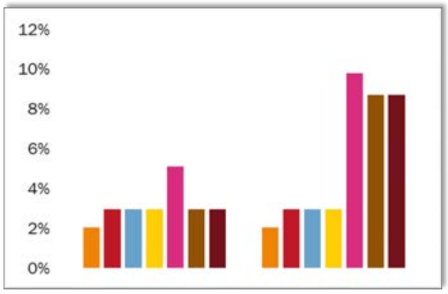
## RESEARCH QUESTIONS

How does recycling affect the environment and battery material criticality?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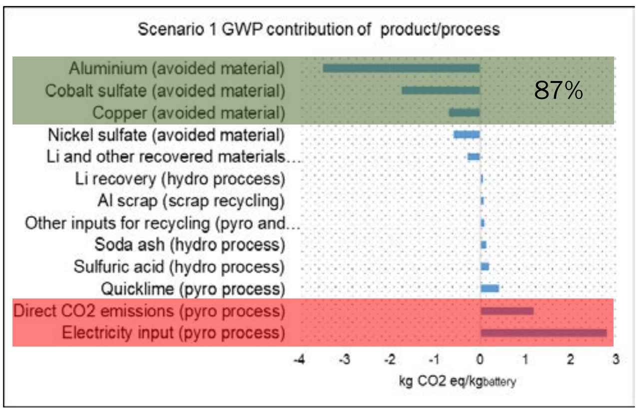
## RESULTS – LCA (GWP)

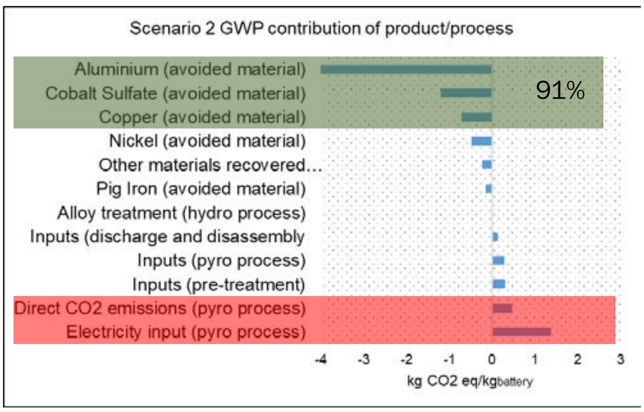
**Without pre-treatment**

- $CO_2$ emissions avoided = 1.75 kg $CO_2$
- 80% emissions of $CO_2$ eq. from Heat demand, combustion of graphite, plastics etc

**With pre-treatment**

- $CO_2$ emissions avoided = 6.79 kg $CO_2$ (4x better)
- 80% emissions of $CO_2$ eq. from Heat demand and direct $CO_2$ emissions

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# RESULTS – LCA

- Scenarios 1 and 2
  - impact reduction in 16 out of 18 impact categories with pre-treatment
- Scenario 2 performs better than scenario 1 in all categories except for
  - Mineral resource scarcity
  - Terrestrial ecotoxicity
  - Water consumption
  - Stratospheric ozone depletion

| Impact Category | Scenario 1 | Scenario 2 | Unit | |
|---|---|---|---|---|
| Fine particulate matter formation | -0.01 | -0.02 | kg PM2.5 eq | 43% |
| Fossil resource scarcity | -0.74 | -1.75 | kg oil eq | 57% |
| Freshwater ecotoxicity | -10.84 | -11.20 | kg 1,4-DCB | 3% |
| Freshwater eutrophication | -0.01 | -0.01 | kg P eq | 19% |
| Global warming | -1.75 | -6.79 | kg CO2 eq | 74% |
| Human carcinogenic toxicity | -0.91 | -2.35 | kg 1,4-DCB | 61% |
| Human non-carcinogenic toxicity | -106.54 | -110.69 | kg 1,4-DCB | 4% |
| Ionizing radiation | 0.81 | 0.25 | kBq Co-60 eq | 70% |
| Land use | 0.05 | 0.01 | m2a crop eq | 87% |
| Marine ecotoxicity | -13.48 | -13.92 | kg 1,4-DCB | 3% |
| Marine eutrophication | -4.30E-04 | -4.70E-04 | kg N eq | -9% |
| Mineral resource scarcity | -1.09 | -0.89 | kg Cu eq | -23% |
| Ozone formation, Human health | -0.02 | -0.03 | kg NOx eq | 25% |
| Ozone formation, Terrestrial ecosystems | -0.02 | -0.03 | kg NOx eq | 25% |
| Stratospheric ozone depletion | -2.79E-06 | -3.75E-06 | kg CFC11 eq | -34% |
| Terrestrial acidification | -0.03 | -0.05 | kg SO2 eq | 42% |
| Terrestrial ecotoxicity | -125.25 | -85.36 | kg 1,4-DCB | -47% |
| Water consumption | -0.37 | -0.31 | m3 | -21% |

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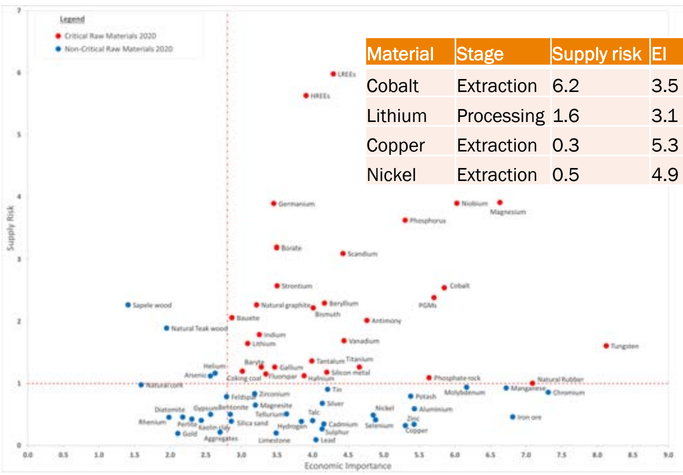
# RESULTS – MATERIAL CRITICALITY

**GEOPOLRISK ($)**

- criticality is calculated taking material prices into account
- 10% material recycling = - 5% up to -17% (cobalt)

| Recycling rate | Scenario | Cobalt | Lithium | Copper | Nickel |
|---|---|---|---|---|---|
| 0% | - | 26,56 | 1,60 | 7,91 | 2,76 |
| 5% | best case | 24,01 | 1,51 | 7,26 | 2,55 |
| 5% | worst case | 25,88 | 1,52 | 7,71 | 2,67 |
| 10% | best case | 21,99 | 1,43 | 6,76 | 2,33 |
| 10% | worst case | 25,20 | 1,44 | 7,48 | 2,56 |

**EU Material Criticality method**



| Material | Stage | Supply risk | EI |
|---|---|---|---|
| Cobalt | Extraction | 6.2 | 3.5 |
| Lithium | Processing | 1.6 | 3.1 |
| Copper | Extraction | 0.3 | 5.3 |
| Nickel | Extraction | 0.5 | 4.9 |

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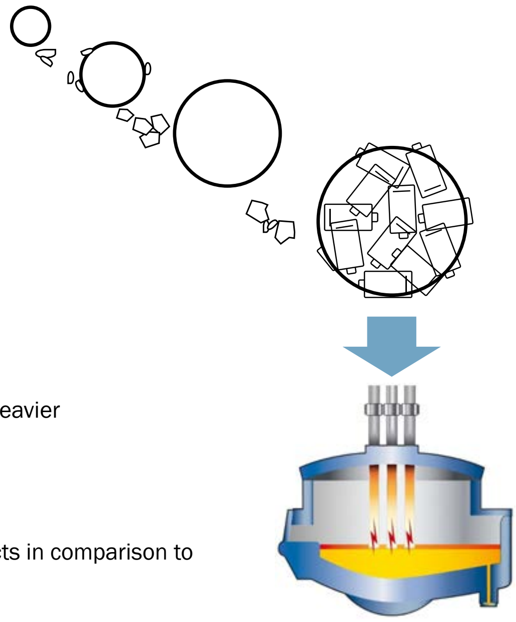
## CONCLUSIONS



- Pre-treatment -> big and positive impact
  - environmental impacts in general
  - Circularity (more materials and high quality)
- Battery discharge -> 20% to 80% of the energy demand of pre-treatment
  - (only 0,2% of total GWP)
- Indicate circularity with CExD -> possible but... energy flows weigh much heavier

### SENSITIVITIES AND BOUNDARY CONDITIONS

- Pyrometallurgical recycling can result in reduction of environmental impacts in comparison to primary production
- Results are sensitive to the geographic location
- Highest reduction -> aluminium and cobalt recovery

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## THANK YOU FOR YOUR ATTENTION

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DIANA.GODOIBIZARRO@TNO.NL

TNO innovation for life

TRIPLELINK

Partners

université de BORDEAUX, GreenDelta, HZDR Helmholtz Zentrum Dresden Rossendorf, eramet, Metso:Outotec, University of Waterloo, TNO innovation for life, Bordeaux INP Aquitaine

Funding

eit RawMaterials Connecting matters

Funded by the European Union

| 二十二 |
| --- |
| 用氣化技術實現零廢棄物世界<br><br>**(Realizing A World of Zero Waste with Gasification Technology)** |
| 儘管全世界都對永續發展充滿熱情，但在全球每年產生的 20.1億噸城市固體廢棄物中，只有13.5%得到回收利用。 Green Desert以將廢棄物轉化為有價值的資源為願景，已在越南以商業的規模成功開發和部署氣化技術，即一種閉鎖且環境永續方式的廢棄物處理技術。該解決方案可以將所有城市和工業固體廢棄物轉化和重新利用為有用的最終產品，從廢棄物中創造出有價值的產品及通過廢棄物氣化技術實現循環經濟的實踐經驗。 |

## TABLE OF CONTENTS



## 1. ABOUT US

**Green Desert Company Limited (*)** is the only company dedicated to the R&D and commercialization of its in-house patented gasification technology for **Solid Waste** treatment in Vietnam.

We have successfully commissioned our first Solid Waste (Municipal and Industrial) Gasification Plant passing all the strictest tests by the Environmental Authority of Vietnam, recognized by both the MONRE *(Ministry of Natural Resources and Environment)* and the MOST *(Ministry of Science and Technology)* to have successfully achieved **3 goals :**

- **Least Impact** on the environment
- **Negative Carbon Emission**
- **Waste Recovery & Complete Circular Economies** by converting all solid waste into **commercially useful end products.**

# Our vision

### A WORLD FREE OF TRASH

- **Mindset change:**

  Waste is no longer a problem to be solved, but rather a renewable source of energy and resource.

- **Set new standards for waste management:**
  - All domestic & industrial solid waste will be **transformed or repurposed** into **useful** and **environmental-friendly** end-products, creating **complete circular economies.**
  - Our ultimate goal is not just to achieve zero carbon emissions but rather achieve **net negative carbon emissions** from the process of solid waste treatment to effectively combat climate change.

# Our mission

### TO CREATE SUSTAINABLE WASTE TREATMENT SOLUTIONS

**NO MORE heavily polluted solid waste landfills or incineration waste to power plants** resulting in serious environmental degradation on water, land and air that poses serious health risks to the general public

**Develop complete circular economies** by transforming solid waste (Municipal and Industrial alike) into two main products: **Syngas and Biochar**

# 2. Complete circular economy - Output products


**All of the trash, domestic and industrial alike**, after segregation for recycling such as paper, plastics, and metal, are repurposed and/or transformed into:

- ✓ **Syngas** - a **CLEAN** renewable source of energy
- ✓ **Biochar** - enriched/enhanced soil, made of organics and biochar, excellent for anti-erosion, degradation of soil and great for organic farming.

Our technology has one of **the LOWEST** emissions **IMPACT** on the environment when compared to other commercial solid waste treatment solutions.

# Complete Circular Economy is here

All solid waste that ends up in our plant will be processed, recycled, or repurposed into useful end-products such as the very unique products below.
**This is the complete circular economy we have been striving for**

## SYNGAS

Syngas is a green renewable energy produced from gasifying MSW which contains plastic and biomass. Syngas can be used for steam boilers, municipal heating systems, generation of **CLEAN Electricity,** and production of petrochemicals such as ethanol and methanol.

## BIOCHAR

"Biochar, also known as "black soil" or “chernozem”, has been used in agriculture in developed countries such as Germany to improve and breathe new life into nutrient-depleted lands.

## UNBURNT BRICK BLOCKS

Only 1-2% of the inorganic materials normally found in the incoming trash is turned into clean non-burnt bricks for construction projects.

# APPLICATIONS OF SYNGAS

Syngas is burnt to produce heat for drying waste before transferring them into the gasification reactors.

Lighting system at the Dong Van I Industrial Park run by Syngas-powered internal combustion engine generator from waste gasification for 7 consecutive days

# Advantages of Biochar in improving organic and circular agriculture

VINACERT-CONTROL

KẾT QUẢ THỬ NGHIỆM
TEST REPORT

Test result of VINACERT-CONTROL
(August 2020)
No: VICB12012841/YNKVICB1.2313

The test results show that our organic carbon **does not contain** 4 heavy metals (Cd, As, Pb, Hg) and 2 bacteria (E.coli & Salmonella)

**10. Kết quả/** *Results:*

| STT *No.* | Chỉ tiêu *Parameter* | Đơn vị *Unit* | Kết quả *Results* | Phương pháp thử *Testing method* | Ghi chú *Note* |
|---|---|---|---|---|---|
| 1 | pH $H_2O$ | - | 7,95 | Ref.TCVN 5979: 2007(**)(C) | |
| 2 | Nitơ tổng số | % | 0,71 | TCVN 8557:2010(**)(C) | |
| 3 | $P_2O_5$ hữu hiệu | % | 1,22 | TCVN 8559:2010(**)(C) | |
| 4 | $K_2O$ hữu hiệu | % | 1,74 | TCVN 8560:2018(C) | |
| 5 | Cadimi (Cd) | mg/kg | KPH | TCVN 9291:2018(C) | LOD = 0,1 mg/kg |
| 6 | Asen (As) | mg/kg | KPH | TCVN 11403:2016 | LOD = 2,5 mg/kg |
| 7 | Chì (Pb) | mg/kg | KPH | TCVN 9290:2018(**)(C) | LOD = 0,5 mg/kg |
| 8 | Thủy ngân (Hg) | mg/kg | KPH | TCVN 10676:2015(C) | LOD = 0,25 mg/kg |
| 9 | Cacbon hữu cơ tổng số | % | 8,54 | TCVN 9294:2012(**)(C) | |
| 10 | *E. coli* | /g | KPH | TCVN 6846:2007 (ISO 7251:2005) (**)(C) | |
| 11 | *Salmonella* spp. | /25g | KPH | TCVN 10780-1:2017(**)(C) | |

**11. Tài liệu kèm theo/** *Enclosed documents (nếu có/If any):*

**12. Nhận xét khác/** *Comments (nếu có/If any):*

*Hà Nội, ngày/date 19 tháng/month 08 năm/year 2020*

**TUQ. TỔNG GIÁM ĐỐC**
**TRƯỞNG PHÒNG THỬ NGHIỆM**
Head of Lab

CÔNG TY CỔ PHẦN CHỨNG NHẬN VÀ GIÁM ĐỊNH VINACERT
Q. HOÀNG MAI

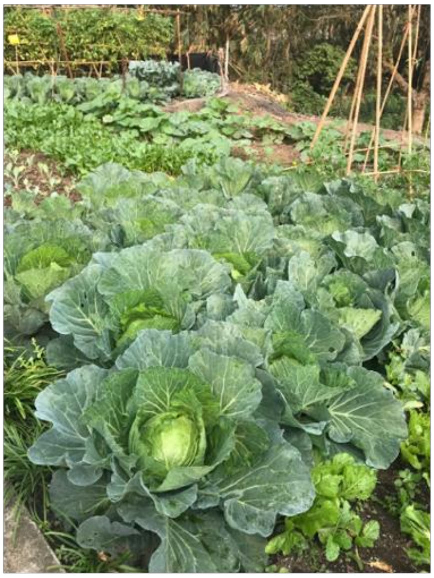
**Đỗ Thị Thu Hà**

# Advantages of Biochar in improving organic and circular agriculture


Beans after 5 weeks planted on soil without biochar (left) and with biochar (right)
***Source:*** *Tedx Talks*

Roots grow deep into the soil with GD's biochar. Well-developed roots help absorb more nutrients for plant growth.

# Organic plants and vegetables grown with our nutrient rich soil at GD's Gasification plant



## Organic plants and vegetables grown with our nutrient rich soil at people's home

## BIOCHAR HAS BECOME A TREND IN ORGANIC & CIRCULAR AGRICULTURE

***"Black Gold" of Ukraine***

According to the World Reference Base (WRB), the United Nations Food and Agriculture Organization's (FAO) soil classification system, Chenozem is the name of a soil in Ukraine that has an at least 25-cm black top layer and is rich in decomposed plant material.

Chernozem contains a lot of humus and carbon. This type of soil has a very good structure, supporting roots to easily develop and providing enough oxygen for organisms in the soil. Chernozem contains a wide range of organisms and they work at greater depths than other soils, thus helping to further improve soil structure. Black soil also composes a lot of calcium so it is not easily acidic. All these properties allows Chernozem to produce high crop yields without additional fertilizers or soil conditioners.

***"Good black soil, like Ukraine's Chernozem, is the black gold of the future."***

*Source: Dantri*

# LEAST CARBON EMISSIONS
# - Combat global warming and climate change

## The Innovation of our Technology - Negative Carbon Output

- Our waste processing technology releases only a small amount of $CO_2$ into the air. The carbon in the waste **is mostly sequestered** in our biochar during the gasification process.
- When trapped in a solid-state as biochar, the carbon is not released back into the atmosphere and can be stored for thousands of years in the soil, helping to **slow climate change and improve agriculture output.**

**Source:** *University of New South Wales*

**1** Ton of biochar could retain

**3** Tons of $CO_2$, preventing carbon dioxide from being released into the atmosphere

***Source:*** *Carbon Gold*

# BIOCHAR HAS BECOME A TREND TO HELP REDUCE OUR CARBON FOOTPRINT IN THE WORLD

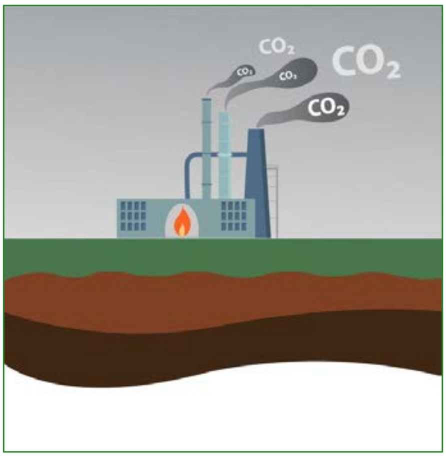
***Stockholm Biochar Project - Low Carbon City***

*"With the help of the city residents and local authorities, garden and park waste are collected and stored in different waste management centers located across Stockholm. Once gathered in the plant, this waste is turned into biochar through a carbonization process. The by-product of the biochar production, pyrolysis gas, generates energy for the city's district heating system.*

*When delivering garden waste to the management centers, the residents can pick up biochar to use in their gardens. The product is also sold to other local authorities to be used to grow plants and trees in parks and public spaces of the city."*

**Source**: https://nordregio.org/sustainable_cities/stockholm-biochar-project/

## OUR TECHNOLOGY ACHIEVES NET NEGATIVE CARBON EMISSIONS THROUGH CARBON SEQUESTRATION





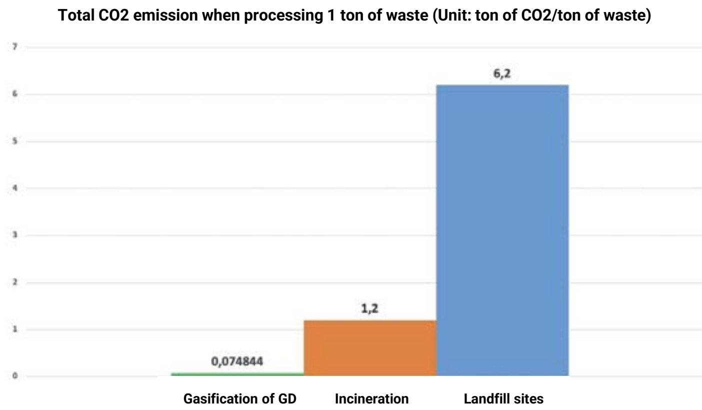
**Normal CO2 emissions**

**GD's Gasification Plant: Carbon sequestration**

Through carbon sequestration, we will be able to meet the carbon neutral target set forth by the UN's Climate Change Resolution.

## Comparing CO2 emissions

- **Incineration method**: Releases about **0.7 to 1.7** tons of CO2/ton of waste.[1]
- **Landfilling method:** Releases about **6.2** tons of CO2/ton of waste.[2]
- **GD's Gasification method**: Releases about **0.074844** ton of CO2/ton of waste.[3]

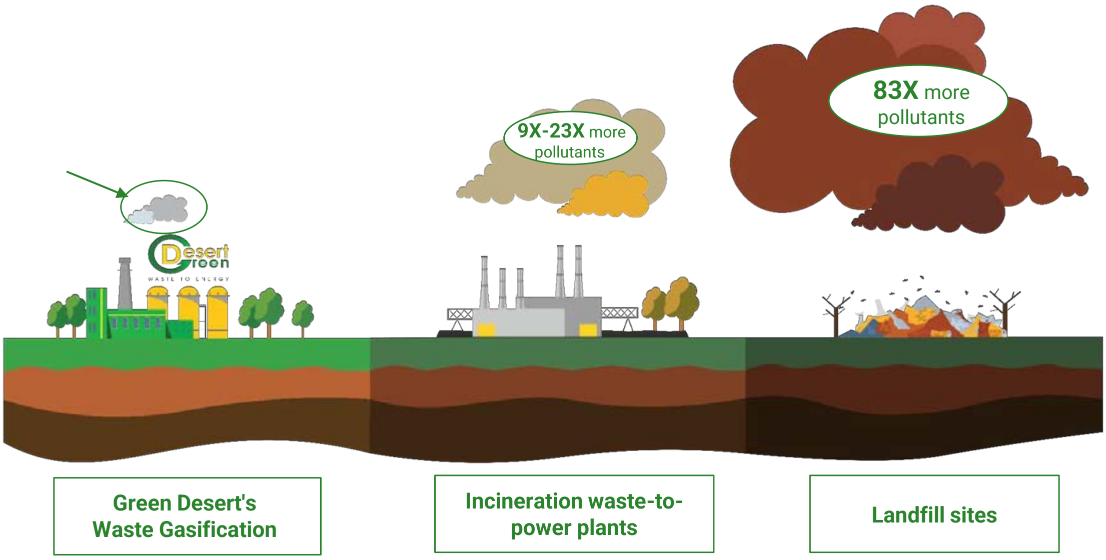



1 Waste Incineration getting away with CO2 emissions unscathed, Zero Waste Europe, 2019

2 How Gasification Turns Waste Into Energy, CNBC, 2020

3 Test result of Green Desert

## CO2 emission of GD's gasification plant in comparison with those of I-WTE plants and landfill sites




The amount of CO2 emission when processing 1 ton of solid waste by Incineration (waste-to-power plants) is 9-23 times higher than that by Waste Gasification.

The amount of CO2 emission when processing 1 ton of solid waste by Landfills is 83 times higher than that by Waste Gasification.

# 3. HOW DOES IT WORK?

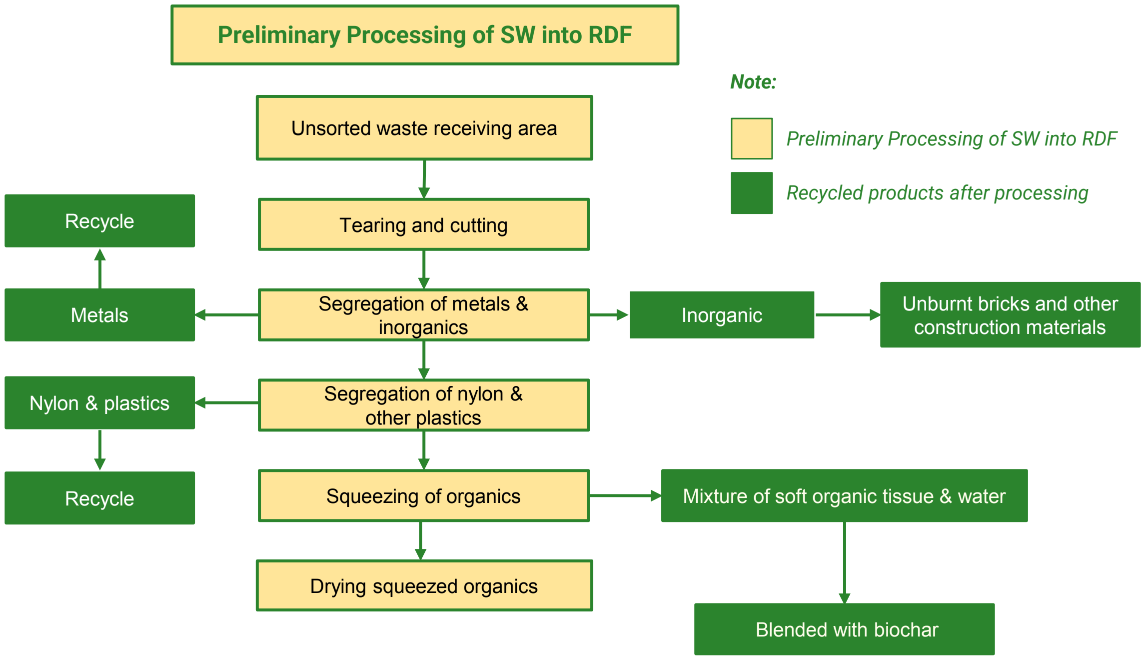
The plant consists of 2 sections:

**Section 1: Preliminary Processing of Solid Waste into RDF (*)**

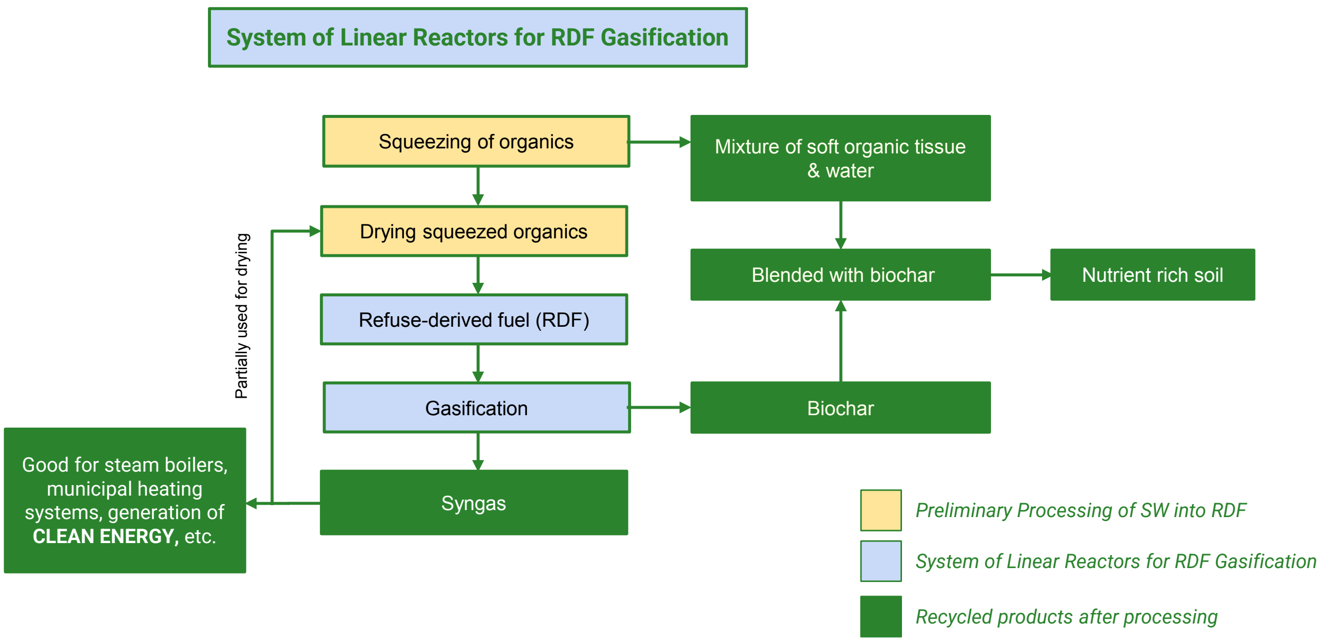
**Section 2: RDF Gasification System of Linear Reactors**

*(*) RDF: Refuse Derived Fuel*

# Section 1: Preliminary Processing of SW into RDF




# Section 2: System of Linear Reactors for RDF Gasification



## THE PROCESS OF GASIFICATION TECHNOLOGY


*Tearing and cutting machine*


*Segregation of metals & inorganics*


## THE PROCESS OF GASIFICATION TECHNOLOGY


*Segregation of nylon & other plastics*

*Squeezing of organics*

*Drying system*

# THE PROCESS OF GASIFICATION TECHNOLOGY

*Gasification System*

*Syngas purification and separation*

# THE PROCESS OF GASIFICATION TECHNOLOGY

*Emission treatment system*

# THE PROCESS OF GASIFICATION TECHNOLOGY


*Mixing biochar with organics*

# 4. BENEFITS OF GREEN DESERT's GASIFICATION

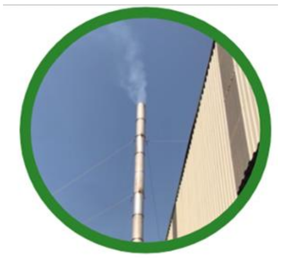
## 4.1. Reducing Our Environmental Footprint

**ABSOLUTELY NO WASTE WATER**

discharged and free of leachate, which is normally a headache found in all landfills and incineration-based waste-to-energy plants.

**NO SOLID WASTE**

is dumped into the environment such as fly ash, which is contaminated with toxic dioxin and furan, typically found in incineration-based W2E plant (I-W2E plants)

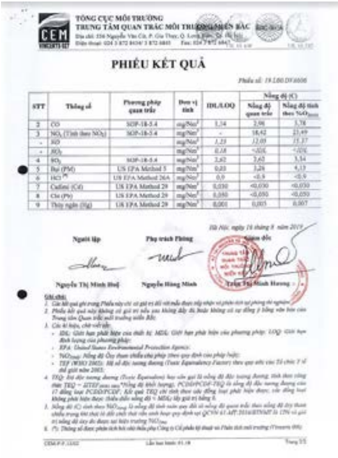


**LEAST AIR EMISSIONS**

in terms of **toxicity levels**, where we are lower than the limits mandated by the EU, Japan and S.Korea

and in terms of **total volume**, which is dozens of times less than other conventional technologies.

# GD's Test results of air emissions


PHIẾU KẾT QUẢ

Test result of Northern Center for Environmental Monitoring (CEM) - Vietnam Environment Administration (MONRE)
(August 2019)
No: 19.L60.DVA606


PHIẾU KẾT QUẢ

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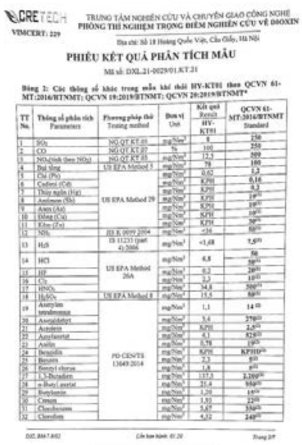
# GD's Test results of air emissions




PHIẾU KẾT QUẢ PHÂN TÍCH MẪU

Test result of Center for Research and Technology Transfer (CRETECH)
(January 2021)
NO: DXL.21-0029/01.KT.21


PHIẾU KẾT QUẢ PHÂN TÍCH MẪU

Test result of Center for Research and Technology Transfer (CRETECH)
(March 2021)
NO: DXL.21-0081/03.KT.13

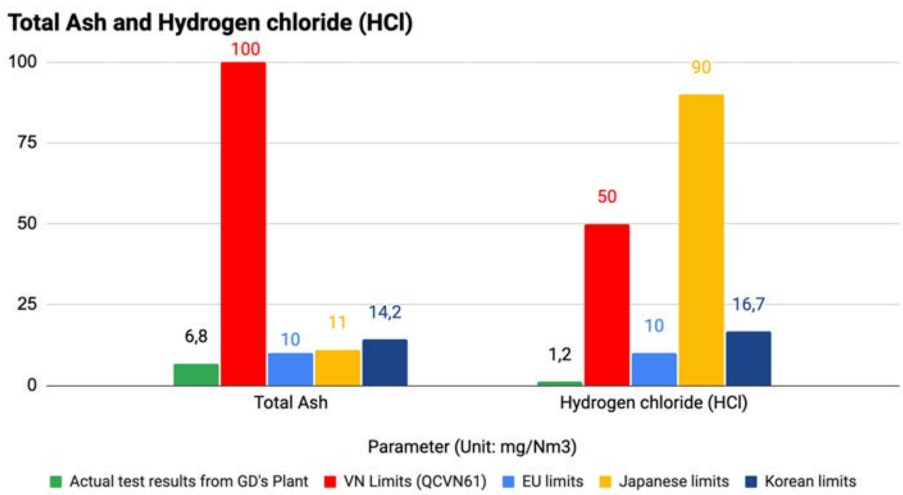
# Air emission monitoring and sampling at the plant

*Emission monitoring and sampling over 4 consecutive days from 5th to 8th February 2021 conducted by Northern Center for Environmental Monitoring (CEM) - Vietnam Environment Administration (MONRE)*

*Under the supervision of Hung Yen's Department of Natural Resources and Environment and the observation of residents near the plant.*

## TOXICITY LEVELS - EXTREMELY LOW

## Comparison of air emissions from GD's plant with the current regulation limits




*(*)"Gasification of Municipal Solid Waste" by Yong-Chil Seo, Md Tanvir Alam, and Won-Seok Yang (https://www.intechopen.com/chapters/59269)*
(**) Based on actual test results from GD's plant, measured by State agencies

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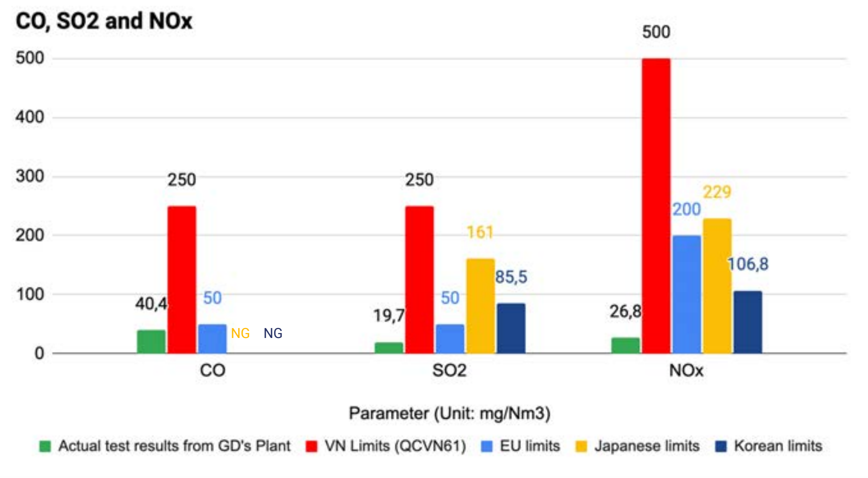


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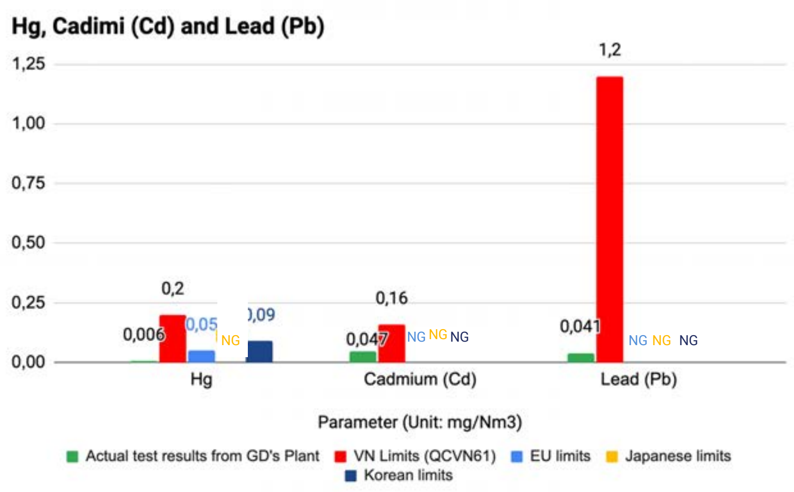


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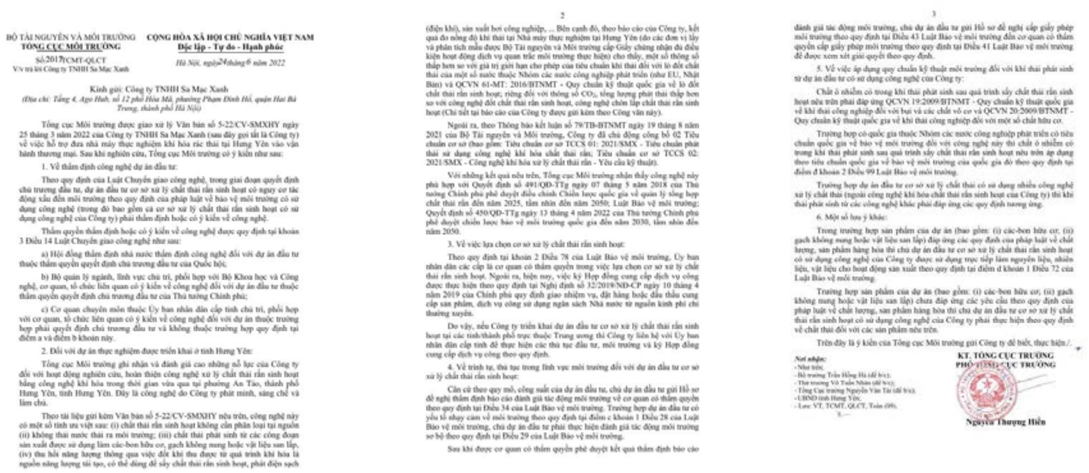
# Which would you choose?

Waste incineration plant

Green Dessert's Plant

Source: Green Dessert

## Opinion of Vietnam Environment Administration on Gasification Technology of Green Desert



BỘ TÀI NGUYÊN VÀ MÔI TRƯỜNG
TỔNG CỤC MÔI TRƯỜNG

Số: 2017/TCMT-QLCT
V/v trả lời Công ty TNHH Sa Mạc Xanh

CỘNG HÒA XÃ HỘI CHỦ NGHĨA VIỆT NAM
Độc lập - Tự do - Hạnh phúc

*Hà Nội, ngày 24 tháng 6 năm 2022*

Kính gửi: Công ty TNHH Sa Mạc Xanh
*(Địa chỉ: Tầng 4, Ago Hub, số 12 phố Hòa Mã, phường Phạm Đình Hổ, quận Hai Bà Trưng, thành phố Hà Nội)*

Tổng cục Môi trường được giao xử lý Văn bản số 5-22/CV-SMXHY ngày 25 tháng 3 năm 2022 của Công ty TNHH Sa Mạc Xanh (sau đây gọi tắt là Công ty) về việc hỗ trợ đưa nhà máy thực nghiệm khí hóa rác thải tại Hưng Yên vào vận hành thương mại. Sau khi nghiên cứu, Tổng cục Môi trường có ý kiến như sau:

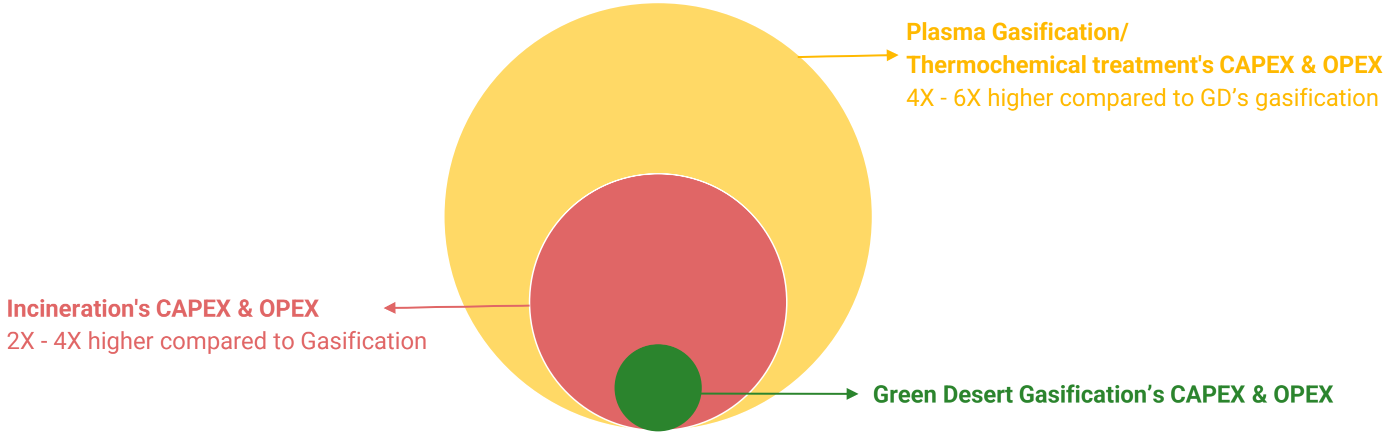
1. Về thẩm định công nghệ dự án đầu tư:

Theo quy định của Luật Chuyển giao công nghệ, trong giai đoạn quyết định chủ trương đầu tư, dự án đầu tư cơ sở xử lý chất thải rắn sinh hoạt có nguy cơ tác động xấu đến môi trường theo quy định của pháp luật về bảo vệ môi trường có sử dụng công nghệ (trong đó bao gồm cả cơ sở xử lý chất thải rắn sinh hoạt có sử dụng công nghệ của Công ty) phải thẩm định hoặc có ý kiến về công nghệ.

"The results of emission concentrations measured at the plant in Hung Yen (sampled and analyzed by units granted the certificate of eligibility for operation of environmental observation services by the Ministry of Natural Resources and Environment) show that **some parameters are lower than the emission standards of some developed countries** (such as EU, Japan) and **QCVN 61-MT: 2016/BTNMT** - National technical regulation on solid waste incinerators."

# D. BENEFITS OF GREEN DESERT's GASIFICATION

## 4.2. Lowest CAPEX and OPEX compared to existing solutions




***Sources:***
*https://en.vietnamplus.vn/first-energyfromwaste-incinerator-built-in-can-tho/114158.vnp*
*https://www.researchgate.net/publication/232924683_thermal_plasma_gasification_of_municipal_solid_waste#pf21*
*https://www.biofuelsdigest.com/bdigest/2013/01/17/enerkem-raises-37-5m-for-landmark-waste-to-biofuels-plant-in-edmonton/#:~:text=And%20in%20December%202011%2C%20Waste,week%20by%20WM%20and%20EB*


# D. BENEFITS OF GREEN DESERT's GASIFICATION


## 4.3. Minimal consumption of input resources

**LAND**
No landfill required for toxic fly ash.

**WATER**
Minimal water usage as the cooling water is circulated in a closed-loop system.

**LESS OXYGEN CONSUMED**
Gasification operates in an oxygen-controlled chamber, therefore very little concentrations of oxygen is required when compared with incineration.

**POWER**
Minimal outside power required as electricity produced from the plant can fully sustain its operations.

**CHEMICALS AND ADDITIVES**
Our air emission contains mainly steam from dehumidification of garbage, therefore it requires less chemicals and additives to clean, as is the case with waste incineration where the concentration of dust and other particulates is high within the emissions.

**Green Desert Company Limited**

**Address:** 4th floor, Ago Hub, 12 Hoa Ma Street, Pham Dinh Ho Ward, Hai Ba Trung District, Ha Noi, Viet Nam

**Website:** greendesertwte.com

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## 二十三

### 管理醫療廢棄物及該如何減輕它們的危害和風險

**(Hazards & Risks Association with Managing Healthcare Waste and How to Mitigate Them)**

在COVID-19肆虐期間，醫療廢棄物的管理已引起公眾的注意，許多穿戴式的個人防護設備(PPE)出現被過度分類為醫療廢棄物的狀況。大規模疫苗接種計劃產生的疫苗針頭以及治療其他疾病製造出的傳染性廢棄物可能比照護COVID-19患者產生的廢棄物構成更大的風險，這主要是攸關於病原體的傳播方式所導致的，因此講者建議妥適地分類處理和良好的廢棄物處理訓練是必要的，以設法降低危害。

# Introduction

- Why
- Risks to Public Health
- Pandemic waste
- Classification of waste
- Sharps
- Handling
- Summary

# Why?

- It is important that everyone is kept safe and the management and movement of waste does not cause harm to people or the environment.

- 4-5% of global greenhouse gas emissions come from the delivery of healthcare
- Good healthcare waste management is key to reducing this
- Open burning and dumping of healthcare waste still a global issue

iswa.org

# Ebola 2014

Open burning

Waste pit

Sharps on the ground

Smoke from short incinerator stack

Eventually autoclaves supplied but later in the outbreak

All images from WHO WASH report, Emmanuel et al, 2015

# What is Healthcare Waste?

- Sharps
- Infectious waste
- Pathological waste including anatomical
- Blood
- Chemicals
- Pharmaceuticals, non hazardous and cytotoxic/cytostatic
- Medical Devices
- Radioactive Materials

- Must all be segregated to ensure correct treatment
- Note: Not just from humans also from animals including farming

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# Quantities of healthcare waste

- Of the waste generated in the delivery of healthcare waste around 15% of it is considered hazardous
- It may be a small waste stream typically less than 0.15% of a nations waste arising but can have massive health effects when managed incorrectly.
- High income countries up to 0.5kg hazardous per day, 2.5 kg including non hazardous – non pandemic
- In some economies the cost of wasted pharmaceuticals is up to 30% of that prescribed
- Wastes must be correctly segregated to ensure correct disposal

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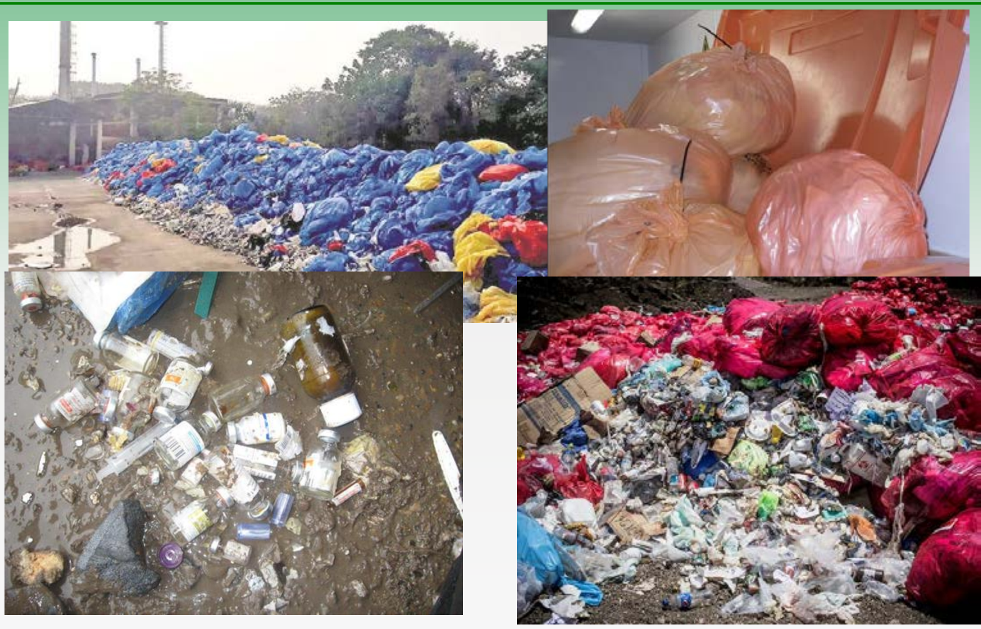
# Risks to public health

- Sharps injuries – needles from drug users, discarded in recycling
- Exposure to infectious material, toxic pharmaceuticals, chemicals and radioactive material
- Injuries associated with heat treatment, chemical treatment and manual handling



# For the pandemic

- Global availability of PPE was the primary goal.
- Global portal for the supply of PPE set up involving 7 major UN partners, 87,000 tonnes supplied between March 2020 and November 2021.
- Many healthcare systems under stress prior to the pandemic.
- The environment and climate crisis did not stop just because a pandemic was occurring.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# Classification

- Many countries classified all healthcare waste as hazardous rather than the 10-15% that it would normally be
- SARS-CoV-2 is an enveloped virus which means that is inactivated relatively quickly when exposed to environmental factors such as heat and light
- Research shows that transmission is from person to person rather than from viral particles on surfaces
- WHO has indicated that the normal procedures for classifying wastes as infectious or non infectious are sufficient
- All that waste, yet only 5 million biohazard bags suppliedcapable of taking 61,000 tonnes of waste.
- 87,000 tonnes of PPE (plus other wastes generated) what happened to the other 26,000 tonnes?

unep.org

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# Sharps

Items that could cut or puncture:

- Needles
- Syringes with needles
- Broken glass ampoules
- Scalpels & other blades
- Infusion set (sharps part thereof)

# Public Health – focus on wellness

- 16 billion injections administered each year, mostly to prevent disease, not all safely delivered
- Open burning can cause health issues as can open dumping, however well managed incineration with energy recovery may be an option
- Need to be aware of drug resistant microorganisms and ensure that they are not unintentionally released into the environment
- In 2015 WHO/UNICEF found only 58% of sampled facilities from 24 countries had safe disposal for healthcare waste

# Not just healthcare workers

- Can also affect those who have to handle waste and do not expect to find healthcare wastes e.g in recycling and domestic waste streams

# Vaccination waste

- Over 11 billion doses of vaccination have been administered covering over 56.6% of the world population, this was 35% in December 2021
- Over 80 million sharp boxes will have been used
- Creating 150,000 tonnes of additional waste
  - 90,000 tonnes of glass vials
  - 50,000 tonnes of syringes and needles
  - 10,000 tonnes of sharps boxes
- No requirement to wear gloves when vaccinating, but people do, why?

## Manual Handling

- Specific training for lifting and moving heavy items
- There is an expectation that if it fits in the receptacle it can be lifted
  - Not always so!



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## Handling Golden Rules

- Wear protective clothing when handling waste.
- NEVER transfer waste from sack to sack/bag to bag or press down to make more room.
- Don't carry bags against the body but hold them away
- Don't grab bags in the middle, always carry by the top where the tag is.
- Hand hygiene is important even after wearing gloves

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## Support in a crisis

- World Health Organisation has materials to help planning
- Red Cross
- Doctors without Borders Médecins Sans Frontières
- Oxfam
- ISWA Healthcare Waste Working Group
  - International experts and suppliers of equipment
  - Experience of migrant crises, Ebola, flooding, tsunami, economic collapse, global COVID-19 pandemic
  - Might not be able to physically attend but can offer advice from afar
  - Consultants may be prepared to be contracted to assist

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## Summary

- The principles of good health and safety practice applies to everyone
- Good training will reduce risks of manual handing and needlestick injuries throughout the waste chain
- An emergency plan is crucial, you don't want to be planning whilst managing a crisis

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# Quotes

Dr Michael Ryan, Executive Director, WHO Health Emergencies, WHO.

"It is absolutely vital to provide health workers with the right PPE. But it is also vital to ensure that is can be used safely without impacting on the surrounding environment."

Dr Mandeep Dhaliwal, Director HIV Health and Development, UNDP.

"Waste management is an integral part of the supply chain, as a result of the use and expiry of health products. Inadequate and inappropriate handling of healthcare waste can have serious public health and environmental consequences and can significantly impact on the health of people and planet."

Ruth Stringer, Science and Policy Coordinator, Healthcare Without Harm.

"In the face of COVID-19, sustainable healthcare waste management is more important than ever to protect communities, health workers , and the planet and prevent pollution."

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ISWA

# Thank you

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| 二十四 |
| --- |
| 在健康層面疫情對醫療廢棄物的產生和管理的效用<br>**(Effects of the Pandemic on Waste Generation and Management in Healthcare)** |
| COVID-19不僅對人們的健康和全球經濟造成嚴重破壞，甚而挑戰各國迅速應對現代生活方方面面（包括廢棄物管理）的能力。廢棄物量的遽增成為現今嚴重的問題。因此，講者建議應制定一套有彈性的醫療廢棄物管理計畫、審查和修訂醫療廢棄物的相關政策及指南、研究及開發綠色採購計畫、邀請回收商成為廢棄物管理的夥伴，並提高醫院員工的廢棄物監測、廢棄物審計等的廢棄物管理需求，增強醫療廢棄物的管理效用。 |

# Effects of the Pandemic on Waste Generation and Management in Healthcare

**Health Care Without Harm Southeast Asia**

noharm-asia.org

ISWA World Congress 2022

Singapore

Leaders' Forum on Long-term Resilient Healthcare Waste Management Planning

# Introduction


| Facility Name | Waste/Day (kg) | Plastics/Day (kg) | % Plastic |
|---|---|---|---|
| Alabang Medical Clinic | 70 | 15.1 | 21% |
| Mary Johnston Hospital | 1239 | 674.3 | 54% |
| St. Paul Hospital Cavite | 219 | 157.5 | 72% |
| Syamsudin Hospital | 1398 | 689.3 | 49% |
| UGM Hospital | 568 | 292.3 | 52% |

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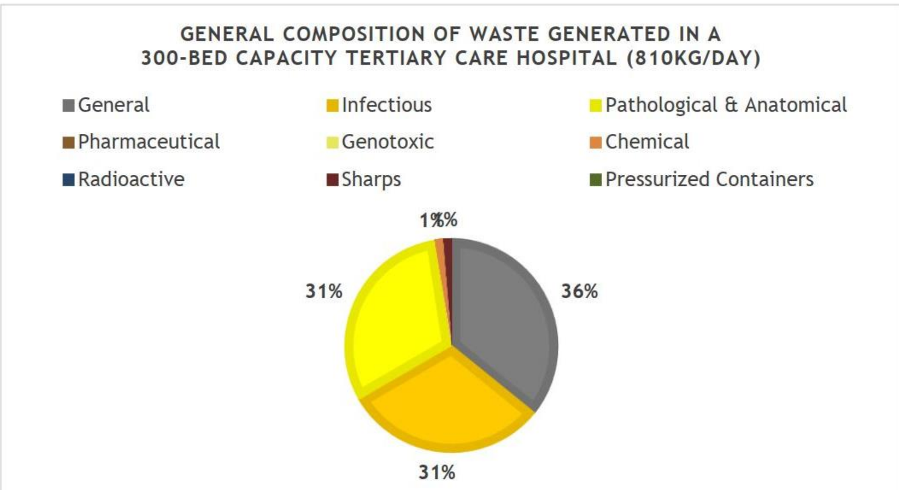


Source: Survey on health care waste generation and management (LCI, 2019)

**Before the pandemic struck, healthcare facilities* in the capital region had been estimated to produce only 47 metric tons of medical waste daily, with 56%—around 26 tons—of this considered potentially infectious.**

https://www.philstar.com/headlines/2020/08/15/2034986/earth-not-healing-medical-waste-piles-covid-19-cases-rise

*** At 216 hosps in 2019, it means the average waste generation of hosps was 217 kgs of waste per hosp daily.**

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**Dr. Gerardo D. Legaspi, MD, director of the University of the Philippines (UP)-Philippine General Hospital (PGH) in Manila, explains that as a tertiary hospital, their facility accumulates around 1.2 to 1.5 tons of garbage daily. Disposing waste can cost 1.2 to 1.3 million pesos a month, and this amount continues to rise with the increasing number of patients.**

https://news.abs-cbn.com/ancx/culture/spotlight/05/14/20/how-hospitals-are-managing-the-covid-19-threat-of-overflowing-medical-waste

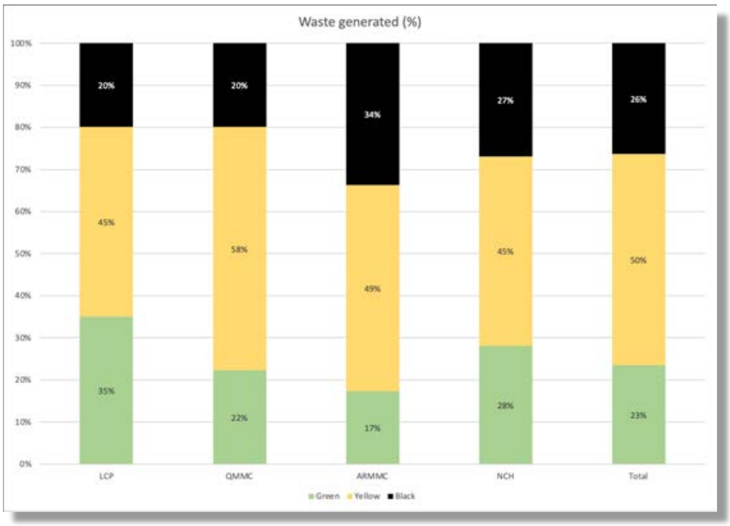



**DOH and HCWH conducted plastic waste audit during the 2nd half of 2020.**

Half of the waste produced by 4 surveyed areas* in five hospitals are infectious

- **50%** of total waste across all hospitals are **infectious**
- **226 kgs** - Average weight of waste produced by 4 surveyed areas* in 5 hospitals per day.

**Dietary, ER, ICU, Medical Ward*

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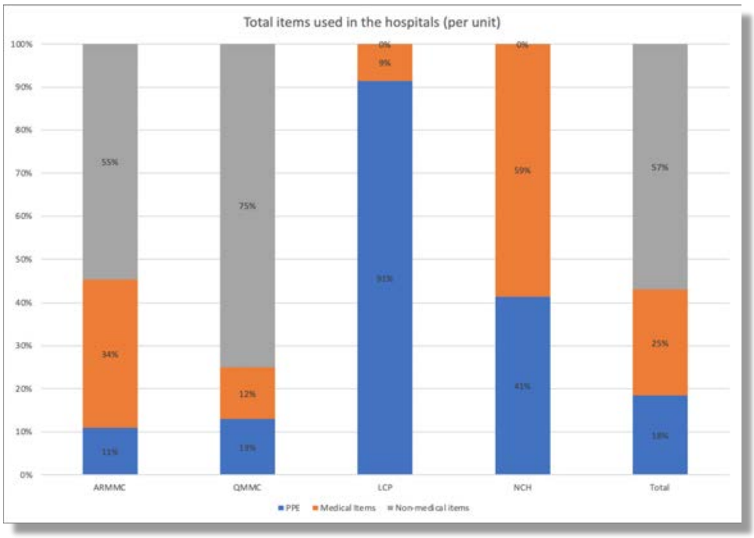
## Breakdown of waste materials

- **57%** of total plastic wastes are **non-essential**, ie. food preparation, food storage, utensils
- **25%** of total plastic wastes are **essential**
- **18%** of total plastic wastes are **PPE**

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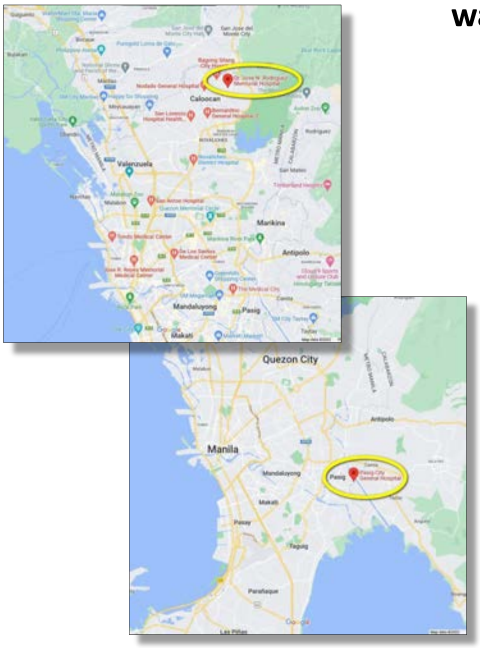
## DOH and HCWH through the support of UNDP conducted waste audit early this year [2022]




- **Pasig City General Hospital** and **Jose N. Rodriguez Memorial Hospital**
- Trainings on Health Care Waste Management were conducted in April 2022
- Followed up by a health care waste audit training in May 2022
- Waste and Supplies audit were conducted for seven (7) days
- For the Emergency Room (ER), Intensive Care Unit (ICU), Medical Ward and Dietary areas.
- All three shifts of waste collection were part of the audit
- Data collation was conducted using the Health Care Without Harms Baseline Assessment Tool.

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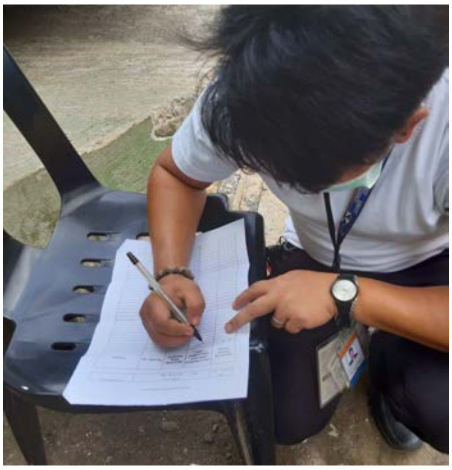
Waste Audit and E-Registry Training


## Pasig City General Hospital




# Dr. Jose N. Rodriguez Memorial Hospital

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Healthcare Waste Management Planning

## Pasig City General Hospital

### Total waste per day (kg)

| | Total Waste per day (kg) | ER | ICU | Medical | Dietary |
|---|---|---|---|---|---|
| Yellow bag | 68 | 33 | 19 | 18 | 0 |
| Black Bag | 61 | 9 | 10 | 30 | 12 |
| Green Bag | 40 | 2 | 2 | 18 | 18 |
| | | | | | |
| Total | 169 | 44 | 31 | 66 | 30 |
| | | | | | |

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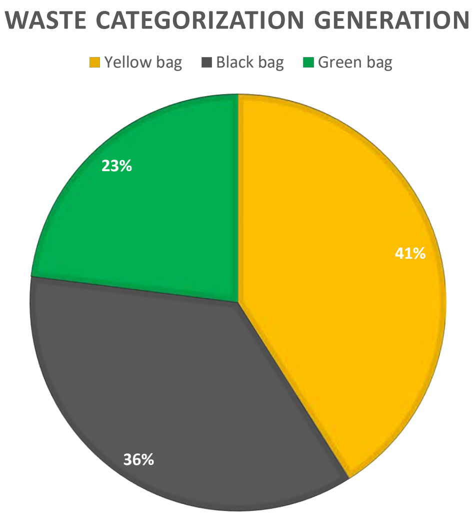
Healthcare Waste Management Planning

# Pasig City General Hospital

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# Dr. Jose N. Rodriguez Memorial Hospital

## Total waste per day (kg)

| | Total Waste per day (kg) | ER | ICU | Medical | Dietary |
|---|---|---|---|---|---|
| Yellow bag | 414 | 98 | 154 | 162 | 0 |
| Black Bag | 180 | 126 | 20 | 22 | 12 |
| Green Bag | 71 | 18 | 12 | 33 | 9 |
| Others | 14 | 6 | 6 | 2 | 0 |
| | | | | | |
| Total | 679 | 248 | 192 | 217 | 21 |
| | | | | | |

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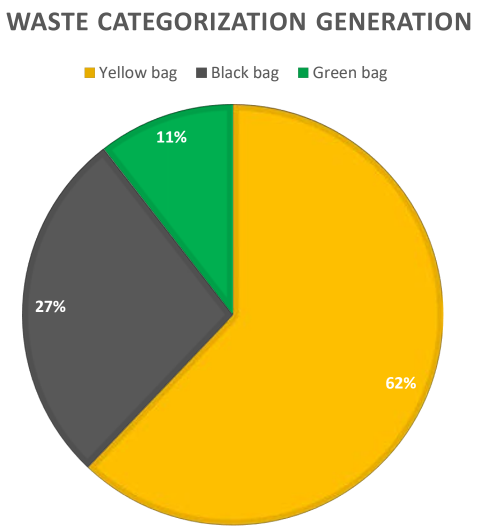
# Dr. Jose N. Rodriguez Memorial Hospital






# Waste Summary

| | PCGH | DJNRMH |
|---|---|---|
| Number of Beds audited | 129 | 143 |
| Total waste per day (kg) | 169 | 679 |
| Total waste/occupied bed/day (kg) | 1.32 | 4.75 |
| | | |

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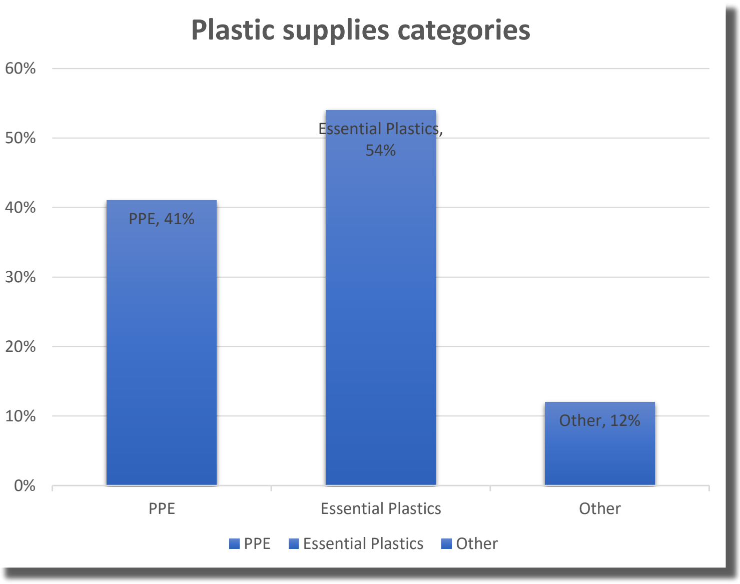
# Plastic supplies categories

- **PPEs**
  - Materials that are used as protective covering of the hospital personnel from infectious agents
  - i.e. gloves, isolation gowns, bunny suit, facemasks, face shields
- **Essential plastics**
  - Plastics that are involved in direct patient safety and treatment including medical paraphernalia
  - i.e. Syringes, IV bottles, IV lines, IV cannula, respiration tubes (ET tubes, O2 cannula), O2 masks, and other medical plastics not specified
- **Non-essential plastics**
  - Plastic materials that are not directly involved in the treatment of the patient but is still used in the hospital
  - i.e plastic food containers, (sachet, bottle for condiments, wrappers), bottled water, plastic food ware (plastic bento boxes, plastic cups), and plastic utensils



# Pasig City General Hospital

- **54%** of total plastic wastes are **essential plastics**
- **41%** of total plastic wastes are **PPE**
- **12%** of total wastes are **Others** (gauze)

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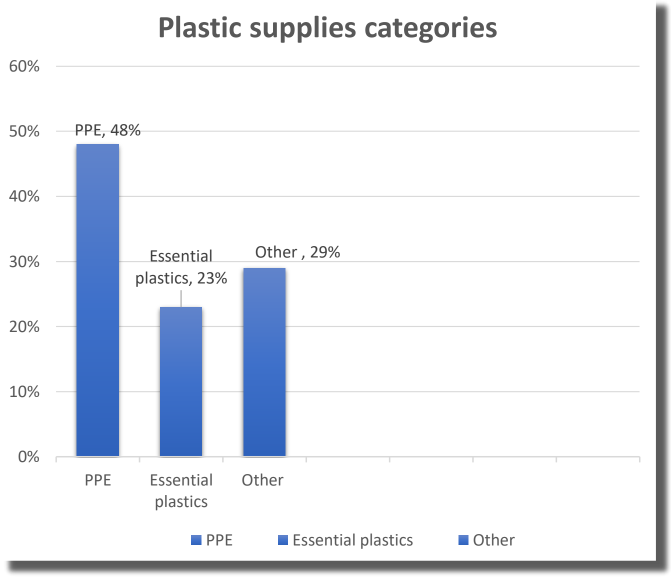
# Dr. Jose N. Rodriguez Memorial Hospital

- **23%** of total plastic wastes are **essential plastics**
- **48%** of total plastic wastes are **PPE**
- **29%** of total wastes are **Others** (gauze and cottons balls)

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# Conclusions

Based on the results of the audit:

- Some medical wards have very high percentages of infectious waste [unsegregated]
- **HCFs should improve segregation especially in non-covid areas in order to reduce the amount of waste requiring expensive treatment**
- Annually, hospitals generate tonnes of food waste, which can attract disease vectors and generate methane, a green house gas, as it rots
- **When possible, HCFs should compost or biodigest food waste to retain some of its value and reduce the carbon footprint**
- There are some gaps in the data
- **Implement continuous waste monitoring via the waste data registry**

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## Recommendations

To Department of Health and the Department of Environment and Natural Resources:

1. Develop a resilient Health Care Waste Management Plan with the participation of facility staff including housekeeping personnel who handle waste
2. Continuously build the capacity of the hospital staff on waste monitoring, waste audit, and other waste management needs
3. Bring in recyclers as partners in waste management
4. Review and revise the JAO 2005-02 (Policies and Guidelines on adequate and proper handling, collection, transport, treatment, storage, and disposal of health care wastes)
5. Study, understand, and develop ways to leverage green procurement initiatives.

Leaders' Forum on Long-term Resilient Healthcare Waste Management Planning

## Thank you!

## Health Care Without Harm
## Southeast Asia
## noharm-asia.org

**HCWH SEA Team**
Paeng Lopez, Faye Ferrer, Ruth Stringer, Pats Oliva,
Ramon San Pascual, Kris Evangelista
infoasia@hcwh.org

Leaders' Forum on Long-term Resilient Healthcare Waste Management Planning

| 二十五 |
| --- |
| 改善固體廢棄物收集和處理的工人安全<br><br>**(Improving Worker Safety in Solid Waste Collection and Disposal)** |
| 無論在已開發國家和發展中國家，收集和管理固體廢棄物和可回收的廢棄物是一項風險性極高的工作。在美國，廢棄物收集是第六大危險職業，每年在道路上和廢棄物處置設施處發生數千起的傷害和碰撞事故。北美固體廢棄物協會 (SWANA)制定一項安全計劃，為美國和加拿大的固體廢棄物僱主和僱員提供有用的安全資源和訊息，藉此來增加安全性，並呼籲僱主有義務提供僱員安全訓練，協助減少事故和傷害。 |

# Improving Worker Safety in Solid Waste Collection and Disposal

DAVID BIDERMAN, SWANA EXECUTIVE DIRECTOR
DBIDERMAN@SWANA.ORG

ISWA 2022
WORLD CONGRESS
21 - 23 SEPTEMBER, SINGAPORE

# Background on SWANA

The Solid Waste Association of North America is the largest waste association in the U.S. and Canada – we are celebrating our 60th anniversary this year!

SWANA has 11,000+ members in the public and private sector solid waste sector

47 chapters in states/provinces and 7 Technical Divisions

A very strong commitment to improving safety in the waste industry

ISWA 2022
WORLD CONGRESS

# SWANA Safety Program and Resources

Safety Ambassadors in all 47 chapters

Annual Safety Summit/Safety Awards at WASTECON

*Safety Matters* – weekly safety newsletter – available in English/Spanish/French

*Five to Stay Alive* worksheets – available in English/Spanish

Frequent chapter summits & training sessions

OSHA Alliances – National and Regional Partner with federal safety agency in US

Slow Down to Get Around

Safety Pledge

Hauler Safety Outreach

www.swana.org/safety

SLOW DOWN TO GET AROUND

ISWA 2022
WORLD CONGRESS

# Why Safety?

Improving safety in the solid waste industry is a universal need
- Large/small companies
- Cities/counties
- Collection/processing/recycling/disposal

Reducing fatalities, accidents, and injuries is the right thing to do

Reducing fatalities, accidents, and injuries makes the industry more attractive to work in

SWANA has made safety a core part of its new Strategic Plan



# Collecting Waste is a Dangerous Job

In the US, waste collection workers have the 6th highest workplace fatality rate in the country – higher than police officers or firefighters. <u>This is an improvement over past years.</u>

There are thousands of crashes and injuries every year

1 worker is killed each week, and 2 deaths per week involving collisions with industry trucks

- Drivers

- Pedestrians

- Bicyclists/Motorcycles

# This Problem is not Just in America

A recent article in an Indian newspaper reported 16 fatalities involving a single municipal waste collection system over the past 7 years!

**DEATH BY CITY CORPORATION'S GARBAGE TRUCKS**

| YEAR | NUMBER OF DEATHS |
|---|---|
| 2022 | 4 |
| 2021 | 6 |
| 2019 | 2 |
| 2017 | 2 |
| 2016 | 2 |

SOURCE: MEDIA REPORTS

**NUMBER OF VEHICLES AND DRIVERS**

| CITY CORP | VEHICLES | REGISTERED DRIVERS |
|---|---|---|
| DSCC | 337 | 135 |
| DNCC | 145 | 113 |

ISWA 2022 WORLD CONGRESS

# This Problem is not only in America

**India** | BBMP garbage truck kills bank official; 3rd death in 1 month (April 2022); Two killed as Pune Municipal Corporation garbage truck hits motorcycle (August 2022)

**Australia** | Garbage truck driver dies two days after Mount Wallace crash in early morning fog (April 2022)

**Japan** | Garbage truck driver arrested over fatal hit-and-run in Kamakura (Jan 2022)

**Canada** | Vancouver council mandates side guards for city-owned heavy trucks after cyclist's death (June 2022)

**Guyana** | Woman crushed to death by garbage truck (May 2022)

**Nigeria** | Waste Truck Crushes 2 Soldiers To Death In Kaduna (July 2022)

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# Principal Safety Hazards - Collection

There are a wide variety of safety hazards facing waste collection workers on a daily basis

1. The truck
2. The garbage
3. Distractions
4. Weather
5. Pedestrians
6. Other drivers
7. The disposal site




# Principal Safety Hazards – Collection

A helper should not ride on the riding step unless the truck is going forward 10 mph or less and is going less than 1000 feet (300 meters) or is backing (ANSI ASC 245.1)

Driver and helper should always wear safety belts

Driver should always follow traffic laws and driver/helper should not be on phone or texting

All collection employees should wear personal protective equipment (hi viz, gloves, footwear)

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# Principal Safety Hazards - Disposal

Every collection crew brings waste or recyclables to a disposal site. It is important to remind collection employees to follow the site's safety rules

- Traffic direction/speed limits
- Truck separation at the landfill
- Do not walk under an open tailgate
- Slips trips and falls
- No cell phone use
- PPE – hi viz, shoes, gloves

# Principal Safety Hazards - Disposal

Landfill, WTE, recycling and other disposal facilities can be dangerous and employees need to receive training on applicable safety hazards.  They differ by type of site, but there are some common hazards:

- Heavy equipment/trucks need to stay separate
- Spotters at landfills need to be highly visible
- Lockout tagout of equipment – balers/compactors/repairs
- Confined space
- Slips trips and falls
- No cell phone use
- Always wear PPE – hi viz, shoes, gloves, safety glasses



# Education and Training on Safety

SWANA recommends frequent and consistent communications, using lots of pictures, and making safety personal for the employees as the best way to reduce accidents and injuries.

Safety Communication – meetings/posters/signage

“A picture tells 1,000 words” – this is particularly true in safety.

# Use Pictures


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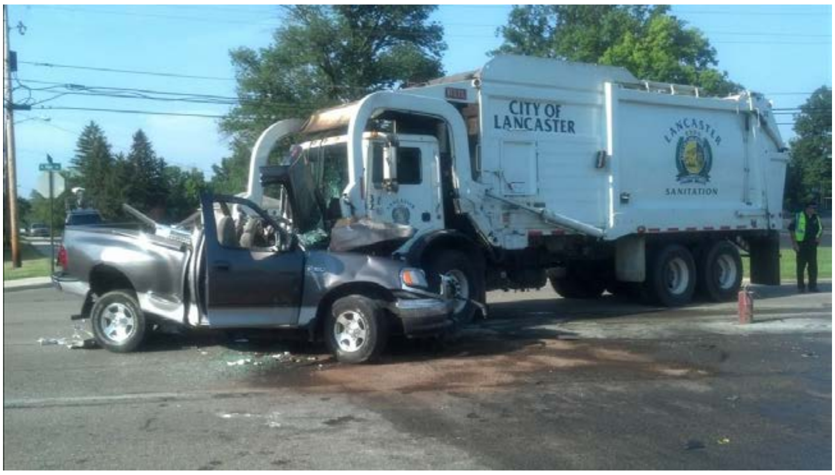
# Use Pictures

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# Make Safety Personal for the Workers

Many solid waste employees perform their job safely on a regular basis.

20% of workers have 75% of the accidents, injuries, and claims.

Explain why these workers should be safe:

1. They could lose their job
2. They could get injured or killed
3. They could kill someone else



# Concluding Thoughts

Solid waste collection and disposal is often dangerous work and employers have a responsibility to provide safety training and information to workers to help them reduce accidents and injuries

With garbage generation increasing and collection/recycling becoming more formalized, now is the right time to make worker and public safety a top priority

SWANA has developed a sophisticated safety program with resources that associations, companies, and government agencies can use to develop their own safety program

**SWANA will assist other ISWA members to develop better safety programs – and save lives.**

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# Thank you

## QUESTIONS?

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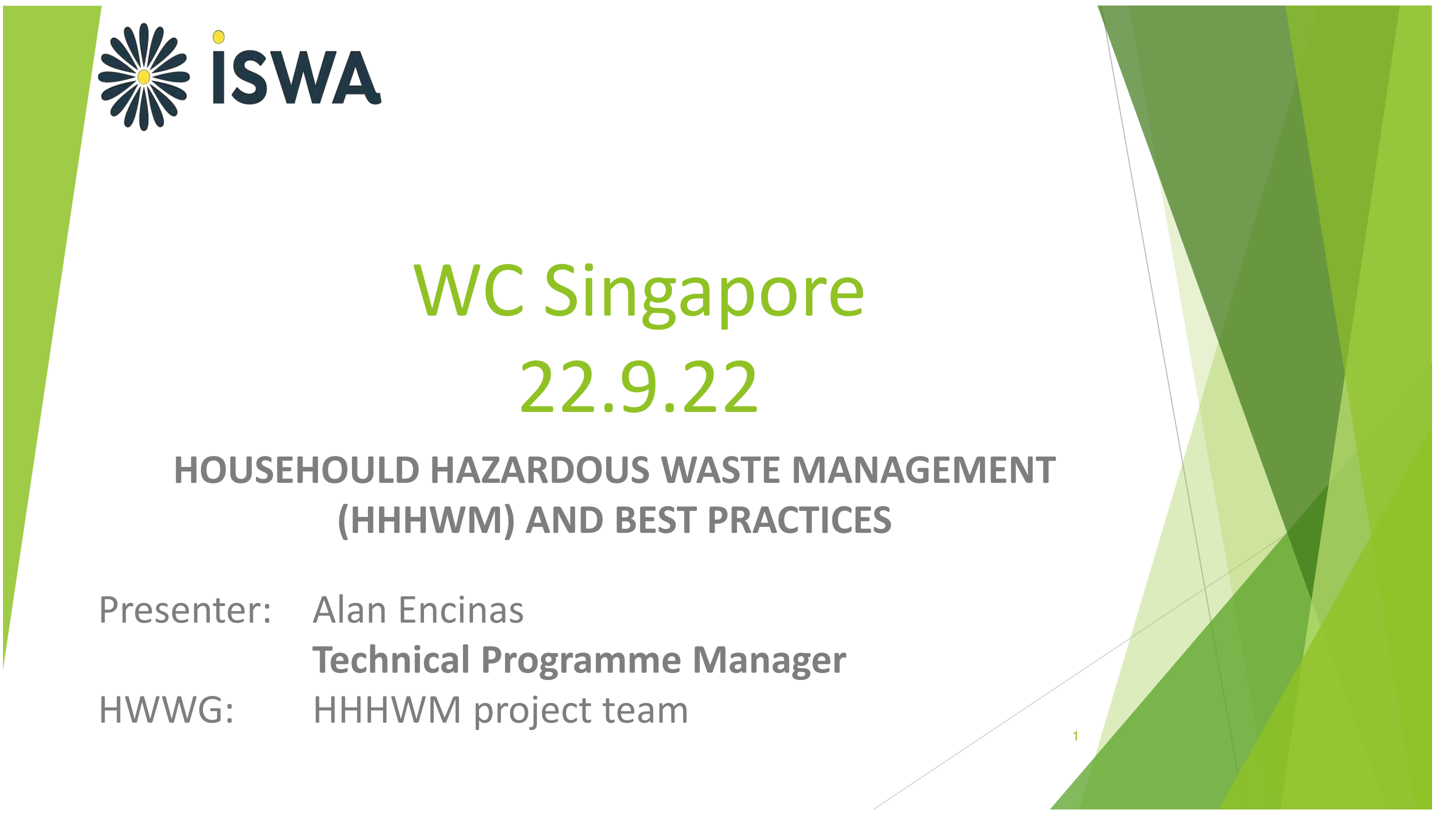
# 二十六

## 家戶有害廢棄物分類收集的良好做法

## (Good Practices to Separate Collection of Households Hazardous Wastes)

就有害廢棄物而言，首要任務是確保分開收集有害廢棄物與非有害廢棄物，而家戶有害廢棄物尤其如此，雖然這些廢棄物僅佔一小部分，但同時可能對健康和環境產生重大影響。不同國家有不同作法，因此ISWA的有害廢棄物工作小組旨在收集並提出最安全的解決方案，以適當地收集和處理家戶有害廢棄物，並同時預防風險保護健康和環境。



## Household hazardous waste management and best practices

- ✓ HHW Definition
- ✓ Types of HHW
- ✓ Segregation
- ✓ Collection
- ✓ Can re-use be an option?
- ✓ How can you reduce HHHW
- ✓ Examples of household HW Management
- ✓ When can HHWM management work?
- ✓ Next steps and recommendations

2

## Defining household hazardous waste

Household hazardous wastes (HHW) are materials found in residential wastes that would be regulated as hazardous wastes if they were generated outside of a household. These household wastes can be flammable, toxic, corrosive, or reactive and can be dangerous if handled improperly.

HHW = 1%-4% of MSW, risks though to health and environment are disproportionate





3

## Types of household hazardous waste

Aerosol sprays
Asbestos
Batteries
Cleaners and disinfectants
Fire extinguishers
Fluorescent bulbs
LED bulbs
Medication
Nail polish & remover
Perfumes
Sharps/needles
Shoe Polish
Toiletries

Fertilizers
Fungicides
Insecticides
Pesticides
Pool chemicals
Propane (5 gallon-cylinders and smaller)
Rodenticides
Weed killers

Antifreeze
Auto batteries
Automatic transmission fluid
Brake fluid
Engine cleaners
Flammable liquids & solids
Fuels (such as butane, diesel, gasoline, kerosene and lamp oil)
Solvents

4

## Segregation








5

## Collection

**Collection centers:** Locations where waste is delivered, weighed, segregated and stored until their final disposal in a licensed facility

**Collection at home:** Door2door collection on particular days

6

## Can re-use be an option?

Re-use is to use again for the same purpose for which they were conceived.

Some types of waste if not further needed can be reused:

- Waste paints
- Laboratory chemicals
- Fertilizers
- Cleaning products

Liability is an issue → Limit what and to who is given, have guidelines, and limit types of products




## How can you reduce household hazardous waste

**THINK AND ACT BEFORE YOU BUY!**

- Purchase non toxic products, read labels and choose. Try environment friendly products.
- Purchase what and as much as you need only, check what you already have, use it up.
- Does someone need what you no longer need?
- Make your own product: Vinegar, salt, baking soda, lemon juice make miracles!
- Store properly, keeping original labels for future use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## Examples of household hazardous waste recycling

According to 2001/83/EK for the medicines of human use the member states need to have the relevant infrastructure for their collection and final disposal.

- Non expired medicines can be collected from social pharmacies on each municipality. Donation location can be found at GIVEMED
- 12000 containers have been placed outside pharmacies in Greece for the collection of **expired medicines**.
- The institute of pharmaceutical research and technology (IFET) is responsible for the collection and storage of the medicines until a large amount has been collected. A tender is then issued for their safe final disposal following segregation and re-use of non expired medicines.
- The Greek Ministry of Health targets to create a Management Body for these medicines that will be supervised by the Ministry of Environment and Energy and all pharmaceutical companies and IFET will participate.(Public Private Partnership)

GIVMED Share medicine Share life

ΙΦΕΤ

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## Examples of household hazardous waste recycling

**Pesticide container** waste collection has taken place in various municipalities of Greece, however this has not been so successful so far.

The ministry of Environment is currently considering to create an Alternative Management System, where each pesticide container bought will be “charged” at the VAT number of each farmer and he needs to return it to designated location and only then will be “released” from his VAT number

It is important to segregate contaminated or not empty containers from those which are triple rinsed and contained a product with less than 1% active ingredient.

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## Examples of household hazardous waste recycling

Alternative management system for **household batteries** AFIS operating since 2004, is running very successfully in Greece. It managed to engage all cizitens and has placed a cylinder almost everywhere.
AFIS had placed 65000 cylinders up to now in public sector, private businesses, shops etc
There is no excuse, you will find somewhere the special cylindrical container!


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## When can HHWM management work?

- **Awareness:** when people understand the impact of illegal dumbing in the environment or mixing with the non hazardous solid waste stream
- **Training and education:** Classification of waste, safe storage
- **Disposal points:** in nearby locations <10km
- **Collect from home** scheme
- **Digital use:** Online platform/application (where/what/how)
- **Show them:** creating accessible info to see the impact but also the solution/ way to manage it.
- **Encourage**, make them part of it!
  - Provide special containers for the collection
  - organize campaigns and special recycling weeks


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## Who is paying?

Extended Producer responsibility

- **Paying as a citizen:** via the municipality tax
- **Paying as a consumer:** via the increase of cost in the product due to disposal
- **Pay as you throw:** fair, but what incentives does it give?


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## Next steps/ Recommendations

In the ambition of circular economy, citizens need to understand the importance of segregation. If we need to increase the resources from non hazardous waste, this can be achieved with uncontaminated waste streams.

Some input could be made to the existing technical guidelines on Basel Convection in order to clearly include household hazardous waste.

How much would you be willing to pay per year?
What is being done in your country?



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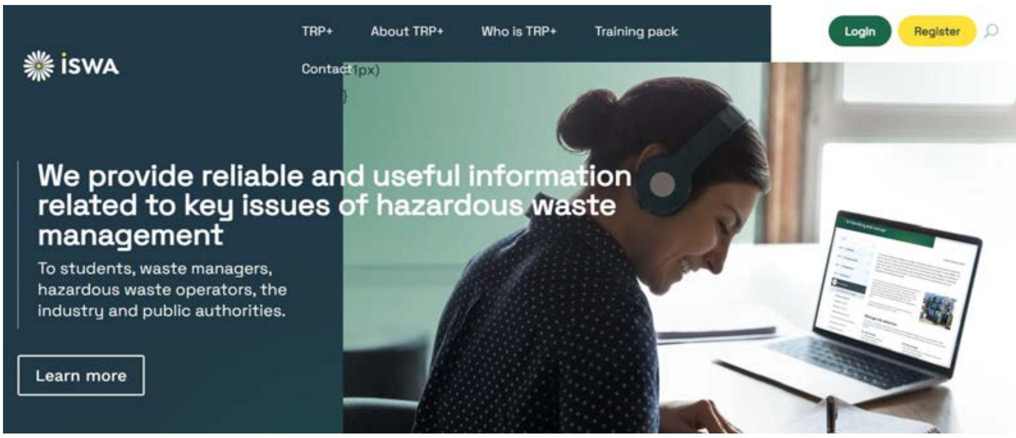
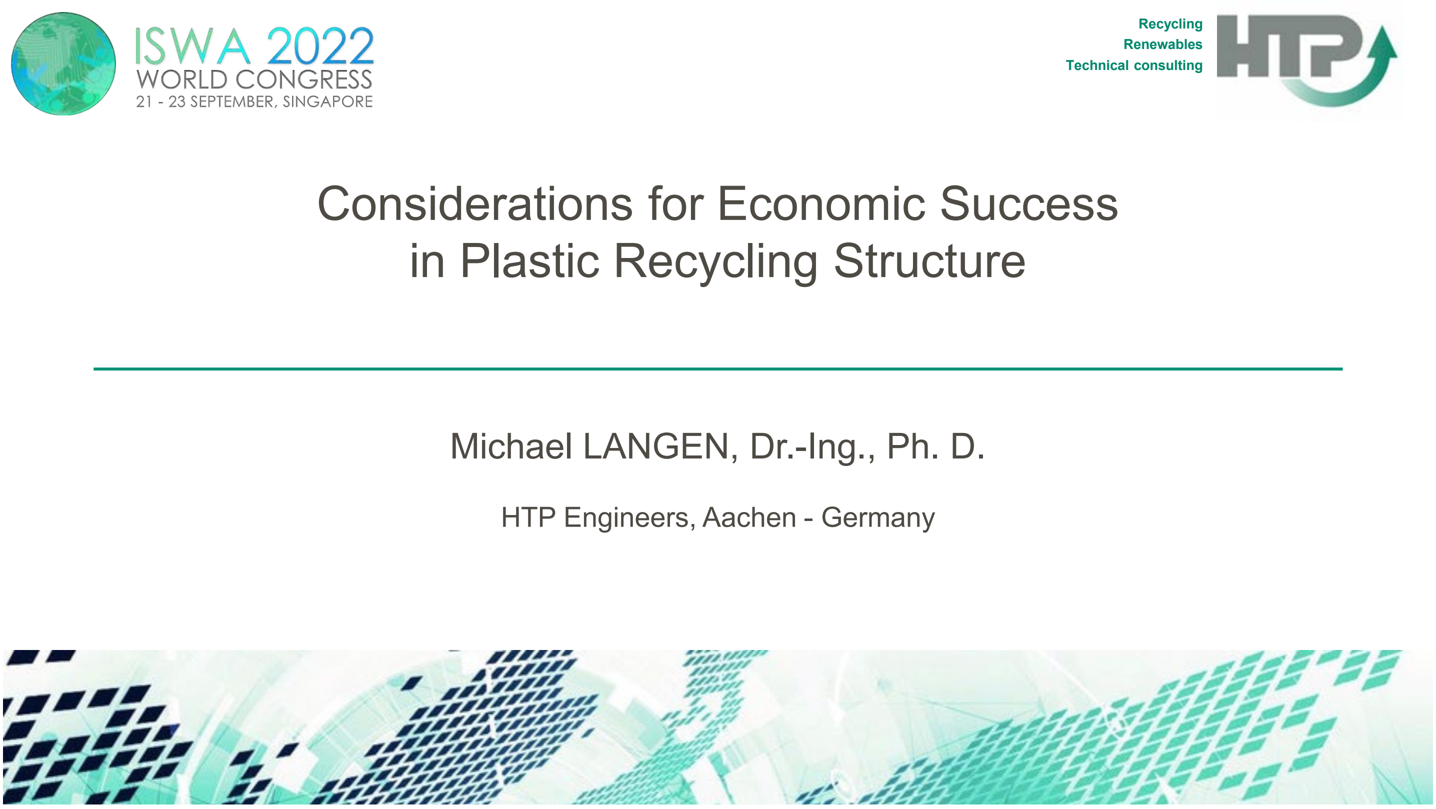
# TRP+ Officially Launched




https://trpplus.iswa.org/

15

| 二十七 |
| --- |
| 塑膠回收結構在經濟成就上的考量因素<br><br>**(Considerations for Economic Success in Plastic Recycling Structure)** |
| 通過了解從分類到回收的成本結構和技術，可以實現塑膠的循環經濟。了解基本事實和數據，例如清洗和再造粒的具體成本數據、根據技術盤點需要多少生產線，以及輸入和輸出的品質，然後它將能夠闡明實現經濟成功的關鍵數據，如產量費率、能源效率、廢棄物管理和工廠可用性以及計算總和，促使資訊更加透明化，帶動與石油市場脫鉤後的塑膠循環經濟能夠在經濟上取得成就。 |



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1. Structures in plastic recycling
2. Facts and figures for sorting and reprocessing
3. Cost analysis of value chains
4. Price analysis of virgin polymers
5. Drawing the sums
6. Key figures & Summary



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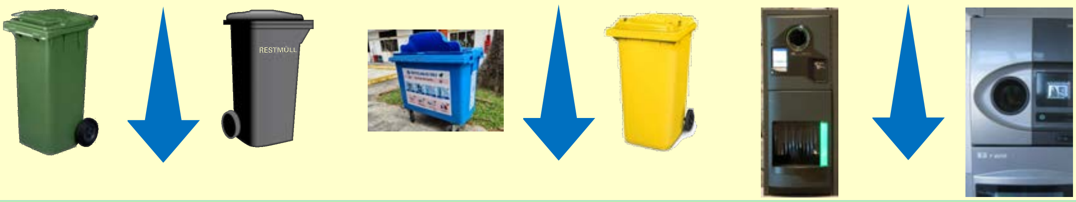
## 1. Structures in plastic recycling

**Plastic recycling has been good practice** since the early days of plastic industry. Post-industry waste is recycled and taken as feedstock to substitute virgin plastics. **The challenge is with post-commercial waste plastics**, which are mixtures of different polymers **and with post-consumer waste streams**, which contain any type of polymers along with other waste material.

| collection | Sorting | Reprocessing | | Feasibility | |
|---|---|---|---|---|---|
| | By type of polymer/material | washing | extrusion | technical | economical |
| post-industry | - | - | + | ✓✓ | ✓✓ |
| post-commercial | + | o | + | ✓ | ✓ |
| post-consumer | ++ | ++ | + | shall be looked at in the presentation | |

Legend: ✓ successful - not needed o little need + needed

## 1. Post consumer waste streams containing plastics

| | SOURCE | Post consumer waste streams containing plastics | | |
|---|---|---|---|---|
| COLLECTION | collection | residual waste | segregated recyclables | Deposit refund scheme (DRS) |
| | |  | | |
| SORTING | sorting | • single/split-line<br>• yield 5 – 20 % plastics (all Polyolefins, PET) | • single/split-line<br>• yield 50 – 80 % plastics (all Polyolefins, PET, PS) | • single-line<br>• yield 100% plastics (PET, HDPE) |
| REPROCESSING | washing | • min. 3-lines (LDPE-film, HDPE/PP, PET)<br>• yield 55 – 75 % | • min. 4-lines (LDPE-film, HDPE/PP, PET, PS)<br>• yield 65 – 85 % | • min. 3-lines (PET-clear, PET-colour, HDPE)<br>• yield 75 – 95 % |
| | extrusion | • min. 2-lines (Polymers, PET)<br>• yield 94 – 98 % | • min. 3-lines (Polyolefins, PET, PS)<br>• yield 94 – 98 % | • min. 3-lines (Polyolefins, PET)<br>• yield 96 – 99 % |

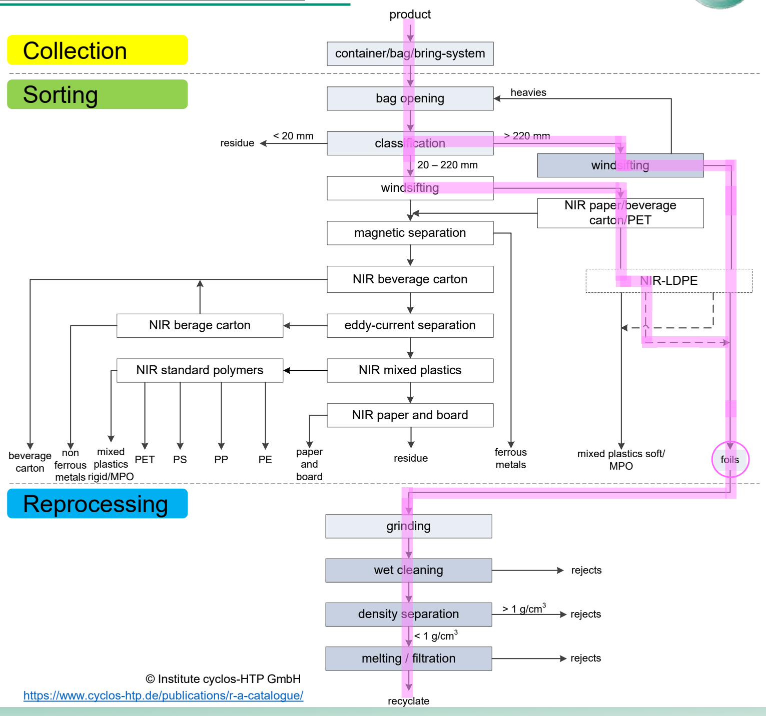


1. Structures in plastic recycling
2. **Facts and figures for sorting and reprocessing**
3. Cost analysis of value chains
4. Price analysis of virgin polymers
5. Drawing the sums
6. Key figures

## Modules in LDPE film sorting

| | residual | segregated | DRS |
|---|---|---|---|
| **capacity** | 35 t/h<br>240,000 t/y | 12 t/h<br>80,000 t/y | 4 t/h<br>20,000 t/y |
| **yield** | 8 % | 20 % | - |

| | residual | segregated | DRS |
|---|---|---|---|
| **capacity** | 19,200 t/y | 16,000 t/y | - |
| **yield** | 55 % | 65 % | - |
| **Output** | 10,560 t/y | 10,400 t/y | |

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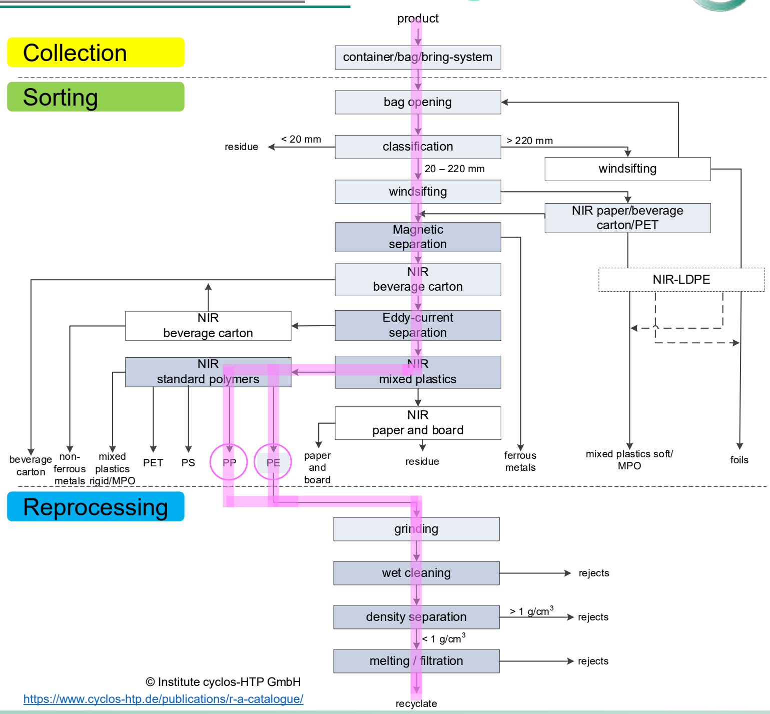
2. Facts and figures for sorting and reprocessing

## Modules in HDPE/PP sorting

| | residual | segregated | DRS |
|---|---|---|---|
| **capacity** | 35 t/h<br>240,000 t/y | 12 t/h<br>80,000 t/y | 4 t/h<br>20,000 t/y |
| **yield** | 4 % | 15 % | 20 % |

| | residual | segregated | DRS |
|---|---|---|---|
| **capacity** | 9,600 t/y | 12,000 t/y | 4,000 t/y |
| **yield** | 70 % | 80 % | 90 % |
| **Output** | 6,720 t/y | 9,600t/y | 3,600 t/y |

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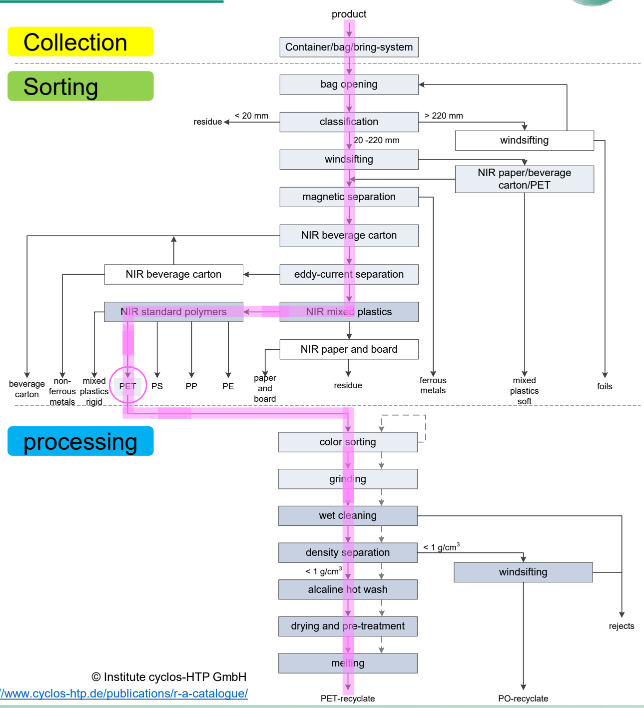
## 2. Facts and figures for sorting and reprocessing

### Modules in PET-bottle sorting

| | residual | segregated | DRS |
|---|---|---|---|
| **capacity** | 35 t/h<br>240,000 t/y | 12 t/h<br>80,000 t/y | 4 t/h<br>20,000 t/y |
| **yield** | 4 % | 30 % | 70 % |

| | residual | segregated | DRS |
|---|---|---|---|
| **capacity** | 9,600 t/y | 24,000 t/y | 14,000 t/y |
| **yield** | 70 % | 80 % | 90 % |
| **Output** | 6,720 t/y | 19,200 t/y | 12,600 t/y |

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## 3. Cost analysis of value chains

**Specific cost figures**

| | | LDPE/PP | HDPE/PP | PET |
|---|---|---|---|---|
| Sorting | residual | 120 €/t | | |
| | segregated | 180 €/t | | |
| | DRS | 80 €/t | | |
| washing | residual | 300 €/t | 220 €/t | 280 €/t |
| | segregated | 280 €/t | 250 €/t | 250 €/t |
| | DRS | - €/t | 200 €/t | -250€/t |
| extrusion | | 280 €/t | 250 €/t | 400 €/t |

**Value chain figures (processing cost)**

The specific cost figures are taken to calculate the value chain figures of processing the polymers by applying the information got so far e. g.

$LDPE_{residual}$ = $cost_{sorting}$ x volume + $cost_{washing}$ x volume + $cost_{extrusion}$ x volume = production cost



## 3. Cost analysis of value chains

**Value chain figures (total cost)**

| | | Production cost | | | |
|---|---|---|---|---|---|
| | | total processing | collection | disposal | per unit / per ton |
| LDPE | residual | 23,116,800 €/y | | 1,045,440 €/t | 2,288 €/t |
| | segregated | 11,506,286 €/y | 350 €/t | 4,197,600 €/t | 1,860 €/t |
| | DRS | | | | |
| HDPE, PP | residual | 10,992,000 €/y | | 290,400 €/t | 1,636 €/t |
| | segregated | 7,457,143 €/y | 350 €/t | 3,810,400 €/t | 1,524 €/t |
| | DRS | 2,055,556 €/y | 900 €/t | 48,400 €/t | 1,471 €/t |
| PET | residual | 12,576,000 €/y | | 580,800 €/t | 1,871 €/t |
| | segregated | 19,851,429 €/y | 350 €/t | 4,100,800 €/t | 1,384 €/t |
| | DRS | 9,784,444 €/y | 600 €/t | 169,400 €/t | 1,377 €/t |

Remark:

- Collection cost are to be allocated for source segregation and DRS schemes
- Disposal cost are to be allocated for residues of sorting and washing processes (110 €/t)

## Content of the presentation

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## 4. Price fluctuation virgin polymers (1/2)

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**LDPE-film grade**

**LOW**-level: 1.750 €/t

**HIGH**-level: 2.300 €/t

Fluctuation: +/- 31 %


**HDPE-injection moulding**

**LOW**-level: 1.550 €/t

**HIGH**-level: 2.100 €/t

Fluctuation: +/- 35 %

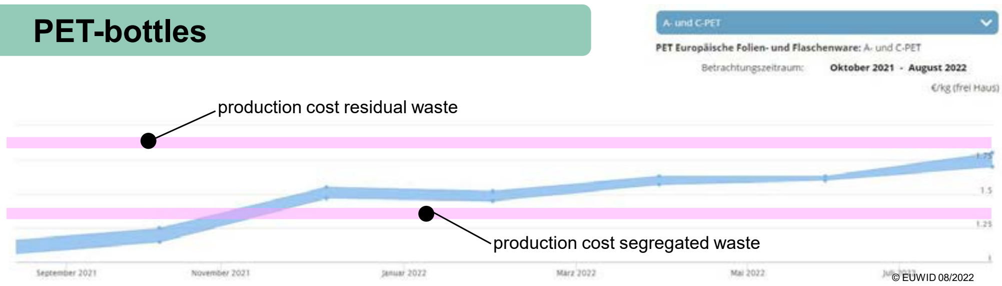
## 4. Price fluctuation virgin polymers (2/2)

**PET-bottles**

**LOW**-level: 1,050 €/t

**HIGH**-level: 1,750 €/t

Fluctuation: +/- 40 %






## 5. Drawing the sums

- The main recycling structures are residual waste collection/sorting, source segregated collection/sorting and deposit refund schemes (DRS).
- The total volumes to be processed to get the same volumes of recycled polymers are 3 to 5 times higher when processing residual waste streams against source segregation or DRS.
- The production costs when sourcing recycled polymers from residual waste are the highest compared to source segregation or DRS-schemes, even taking additional collection and disposal cost into consideration.
- Source segregation and DRS schemes do not deviate significantly in production cost; the main difference is the limited coverage of packaging types with DRS-schemes.
- The price of virgin polymers do not cover the production cost of recycled polymers from any of the recycling structures. Additional financing like licenses or premiums on virgin prices are needed.

## 6. Key figures-Summary

- The prices of virgin polymers over the period of the last 12 months varied between 1,500 €/t (LOW) and 2,300 €/t (HIGH) for Polyolefins and 1,100 €/t (LOW) and 1,800 €/t (HIGH) for PET-A bottle grade.
- The total cost to collect and process recycled polymers varied between, 1,550 €/t and 2,300 €/t for r-HDPE, r-PP and r-LDPE and between 1,400 €/t and 1,900 €/t for r-PET.
- Profitability of plastic recycling is being jeopardizes by fluctuation in virgin prices/oil prices (HIGH levels in spring 2022 mainly due to the Ukraine crisis). LOW levels cannot be weathered by small and medium sized companies of the recycling industry.
- Profitability is safeguarded only with a premium for recycled polymers on virgin prices or alternative financing e.g., Extended Producer Responsibility (EPR) licenses.
- Presently, r-PET is traded with a premium of ca. 30 % against virgin PET, that makes r-PET a profitable business.
- Prospectively, Polyolefin recycling would be profitable if traded with a premium against virgin as well. To achieve this, r-Polymer prices need to be decoupled from the oil market and a recycled content should be mandatory.



## Contact

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| 二十八 |
| --- |
| 向循環經濟轉型：世界銀行集團對城市固體廢棄物管理的支持評估<br>（**2010-2020**）<br>**(Transitioning to a Circular Economy: An Evaluation of WBG's Support for Municipal Solid Waste Management (2010-2020))** |
| 世界銀行集團領導的多邊開發銀行為城市固體廢棄物管理 提供融資和知識的開發。儘管世界銀行集團提倡廢棄物分級和循環經濟方法，但尚未將其納入許多國家的戰略和運營的主流。世界銀行集團須與發展夥伴和私營部門合作，在決策層面提高其形象，並為循環經濟制定未來的可行性。 |

## IEG's Unique Role in the World Bank Group (WBG)

- An independent unit within WBG
- Reports directly to the Board of Executive Directors
- With a mandate to
  - Foster WBG accountability
  - Contribute to learning by the WBG
  - Support Evaluation Capacity Development globally



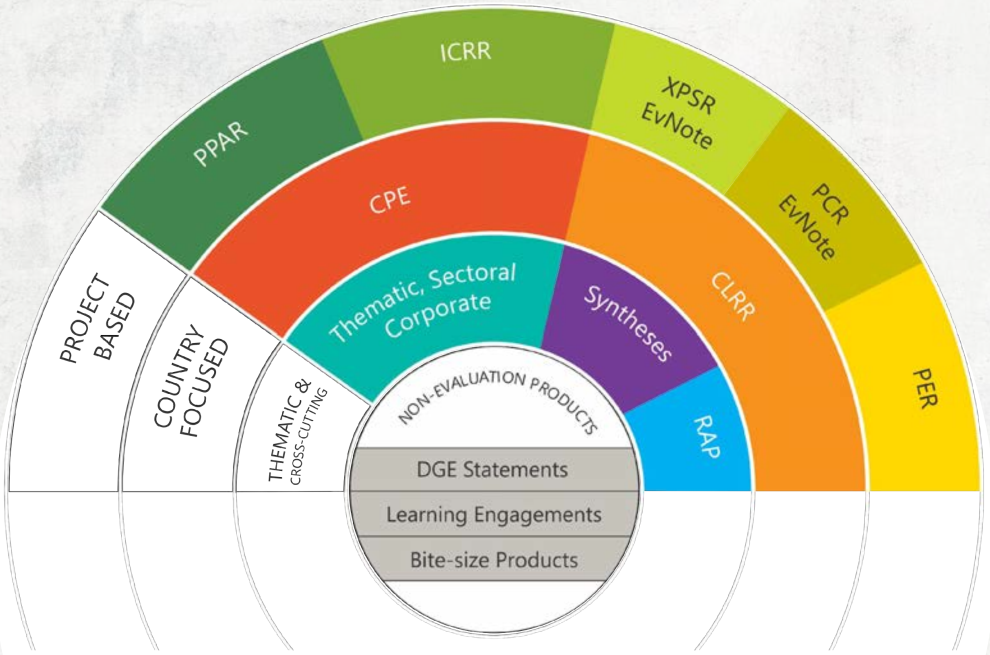

## World Bank Group Evaluation Principles

| Main Purposes of Evaluation | 3 Core Principles | Evaluation Modalities |
|---|---|---|
| • Promote accountability<br>• Promote learning<br>• Promote development effectiveness | • Utility<br>• Credibility<br>• Independence | • Independent evaluation<br>• Self-evaluation |

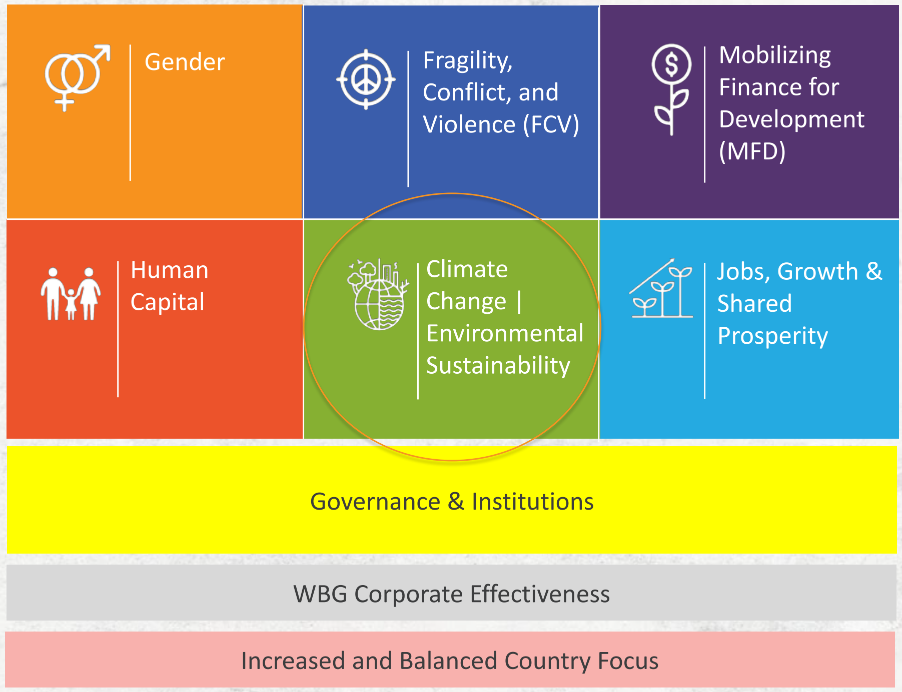
## Theory of Change

**IEG Implements the WBG Evaluation Principles** → **Stakeholders Use Evaluations** → **Evaluation Use Influences Change**

## IEG's Products



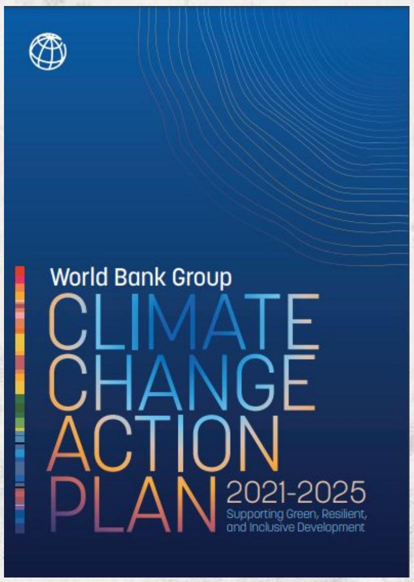
## Our strategic framework is aligned with WBG's priorities.






## MSWM and Climate Change

- **Poor MSWM contributes to climate change.** Landfills and open dumps contribute 4-5 percent of global greenhouse gas emissions.
- **Landfill gas is a natural byproduct of the decomposition of organic material in landfills** and is composed of roughly equal proportions of methane and CO2 together with a small quantity of non-methane organic compounds.
- **MSW can potentially be a resource and a net sink of greenhouse gases** through recycling and reuse.
- **The World Bank Group's Climate Change Action Plan (CCAP) sets out a goal of pursuing integrated waste management and circular economy approaches** to help countries and cities advance climate, development, and broader sustainability goals.



## IEG's evaluation: Transitioning to a Circular Economy

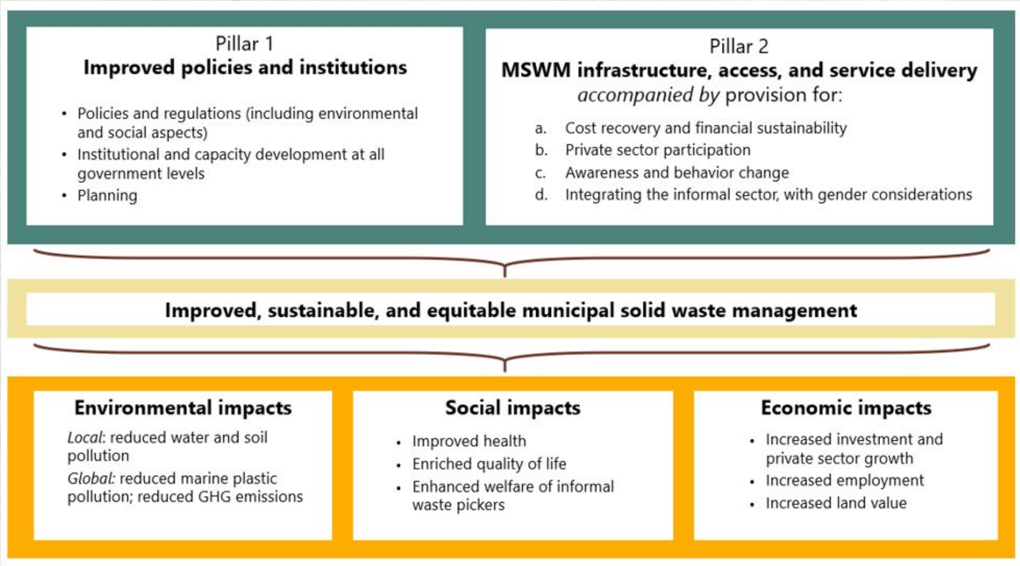
- This is **IEG's first thematic evaluation of the World Bank Group's** (WB, IFC and MIGA) **support for municipal solid waste management** (MSWM) covering fiscal years 2010-20.
- The evaluation adopts an **SDG context**:
  - ✔ **SDG 11** for sustainable cities
  - ✔ **SDG 12** for reducing waste generation through prevention, reduction, recycling, and reuse.
  - ✔ **Other SDGs** relevant to waste to energy, informal workers' welfare and employment, climate action, and marine plastic pollution.




## Transitioning to a Circular Economy – evaluation questions

1. How **relevant** is the Bank Group's approach and engagement in meeting client country needs, considering the latest evidence and thinking on MSWM practices and country context and readiness?
2. How **coherent** has the Bank Group engagement been in collaboration among the World Bank, the International Finance Corporation, and the Multilateral Investment Guarantee Agency (MIGA), and collaboration and partnerships with other actors to support better outcomes for client MSWM needs?
3. How **effective** have Bank Group engagements been in delivering improved MSWM for clients, and what factors explain such effectiveness?

## Transitioning to a Circular Economy – evaluation framework

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## Transitioning to a Circular Economy – findings (relevance and coherence)

•**WBG lends less for MSWM than for any other urban service,** but is the leader among multilateral development banks in providing finance and knowledge on solid waste management.

•**WBG has increasingly recognized and advocated for waste hierarchy and circular economy approaches for MSWM**, but these are adopted sporadically in the lending portfolio.

•**Low-income countries (LICs) received less than 2 percent of World Bank lending for MSWM and no investments from IFC**. In contrast, MSW is projected to triple in volume in low-income countries by 2030.

•**WBG is well positioned to convene other developmental institutions to raise MSWM's profile in client countries** given its lending portfolio, flagship publications [*'What a Waste' and 'Bridging the Gap'*], online MSWM courses, and leadership in the ProBlue initiative that addresses riverine and marine plastic pollution.

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## Transitioning to a Circular Economy – findings (effectiveness)

- **WBG support for basic MSW infrastructure and service delivery—the main WBG activity for MSW – has been generally effective.** These are necessary but not sufficient conditions for mainstreaming waste hierarchy measures and a circular economy approach.
- **Lack of financial unsustainability limits the effectiveness of infrastructure and services projects**. Only 56% of projects which supported cost recovery yielded positive results.
- **Very few projects tracked outcomes of MSWM activities**. Only 6 to 15 percent of projects in the portfolio capture environmental, health, social, or economic outcomes linked to MSWM activities making it difficult to make the case for greater attention o MSWM.

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## Transitioning to a Circular Economy – findings (factors supporting / inhibiting effectiveness )

- **Long-term, well-sequenced, and coherent engagement** across the evaluation pillars of the evaluation framework improves MSWM.
- **Lack of provincial and central government policymakers' attention** to updating policy and regulation attaining financial sustainability.
- **Local governments' lack of accountability** for providing adequate and sustainable MSWM services constraints effectiveness.
- **Constraints in ability to acquire land** for solid waste infrastructure is a systematic constraint across the portfolio.

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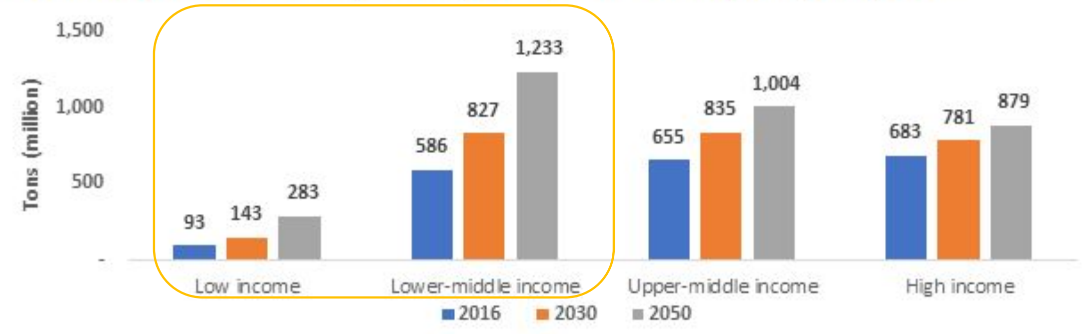
## Waste generation in low income and lower middle-income countries is growing at alarming rates

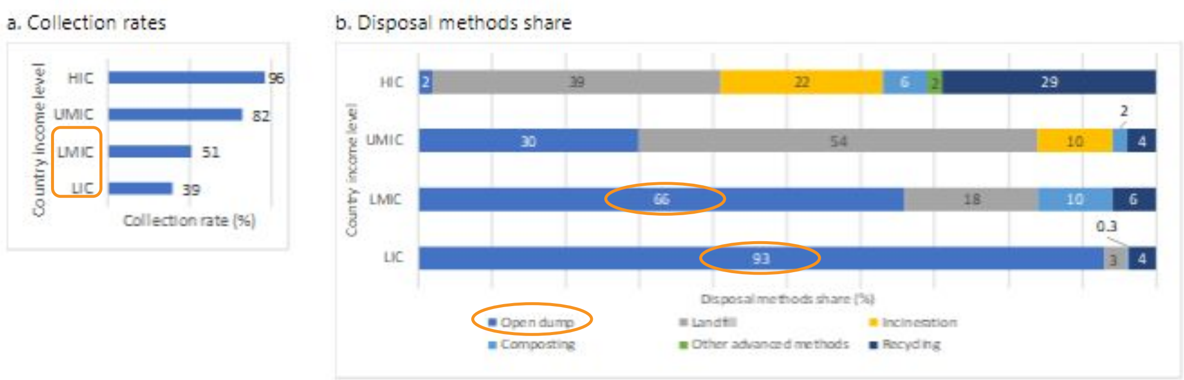
### Estimated Waste Generation by Country Income Classification, 2016, 2030, 2050






## 93% of waste in low-income countries and 66% in low-middle income countries is disposed of in open dumps

### Select Municipal Solid Waste Parameters by Country Income Category



## Transitioning to a Circular Economy (1)

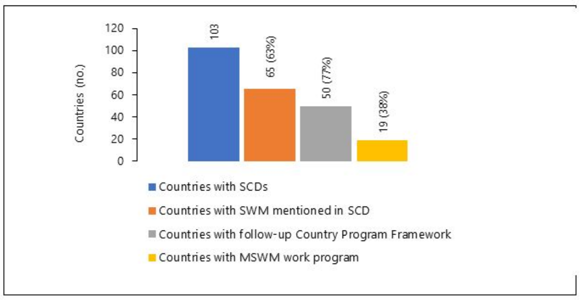
- **Waste hierarchy and circular economy principles are yet to be mainstreamed** into many country strategies and operations.

- Just over one-third of the 55 countries in which the World Bank has supported MSWM activities include **references to the waste hierarchy or circular economy** aims in their country diagnostic and partnership framework documents and only 20 percent included related activities.

a. Waste Hierarchy


b. Circular Economy


MSWM in Systematic Country Diagnostics (SCDs) and Country Program Frameworks (CPFs) 2010-20






## Transitioning to a Circular Economy (2)

- There has been **little intra World Bank Group collaboration** (WB, IFC, and MIGA) **in support of MSWM**.
- MSWM is **absent** from most **IFC** country strategies.
- MSWM has been a very **difficult sector** for **MIGA** to enter due to several constraints, mainly related to the lack of bankable projects.

World Bank Group MSWM Activities (Approved and Ongoing FY10–20)

| Activity Category | Countries (no.) | Projects (no.) | Commitments ($, millions) | Projects closed and evaluated (no.) |
|---|---|---|---|---|
| World Bank projects | 55 | 117 | 2,676 | 68 |
| World Bank ASA | 40 | 156 | 44 | n.a.[a] |
| IFC investments | 7 | 13 | 398 | 1 |
| IFC advisory services | 19 | 26 | 23 | 9 |
| MIGA guarantees | 1 | 1 | 106 | 0 |

## Transitioning to a Circular Economy (3)

- **Low-income countries**, where MSW is set to triple by 2050, get the **least attention.**

World Bank Group Municipal Solid Waste Management Operations by Country Income Group (Approved and Ongoing, 2010–20)

| Income Group | World Bank Lending | | | IFC Investment | | | IFC Advisory | | |
|---|---|---|---|---|---|---|---|---|---|
| | Countries | Commitments | | Countries | Commitments | | Countries | Commitments | |
| | (no.) | ($, millions) | (percent) | (no.) | ($, millions) | (percent) | (no.) | ($, millions) | (percent) |
| HIC | 1 | 22 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| UMIC | 11 | 616 | 34 | 4 | 382 | 96 | 11 | 11.3 | 50 |
| LMIC | 21 | 1,145 | 63 | 3 | 16 | 4 | 5 | 9.2 | 40 |
| LIC | 4 | 28 | 1.5 | 0 | 0 | 0 | 2 | 2.4 | 10 |
| Total | 37 | 1,811 | 100 | 7 | 398 | 100 | 17 | 22.9 | 100 |



## Transitioning to a Circular Economy (4)

- **IFC**'s investments are **low** compared to WB, and are **concentrated in a few upper-middle income (UMIC) countries**.

World Bank Group Municipal Solid Waste Management Operations by Country Income Group (Approved and Ongoing, 2010–20)

| Income Group | World Bank Lending | | | IFC Investment | | | IFC Advisory | | |
|---|---|---|---|---|---|---|---|---|---|
| | Countries | Commitments | | Countries | Commitments | | Countries | Commitments | |
| | (no.) | ($, millions) | (percent) | (no.) | ($, millions) | (percent) | (no.) | ($, millions) | (percent) |
| HIC | 1 | 22 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| UMIC | 11 | 616 | 34 | 4 | 382 | 96 | 11 | 11.3 | 50 |
| LMIC | 21 | 1,145 | 63 | 3 | 16 | 4 | 5 | 9.2 | 40 |
| LIC | 4 | 28 | 1.5 | 0 | 0 | 0 | 2 | 2.4 | 10 |
| Total | 37 | 1,811 | 100 | 7 | 398 | 100 | 17 | 22.9 | 100 |

## Transitioning to a Circular Economy (5)

- **Performance** in Policies, Institutions, Capacity Building, and Planning is mostly **favorable**.

- But **results are mostly outputs** (new polices, plans, training) but **follow up is poor**, and **impact on MSWM outcomes is unclear**.

Effectiveness of Pillar 1 Determinants: Policies, Institutions, Capacity Building, and Planning

| Determinants | Projects Addressing Determinant (of Total Portfolio of 117 Projects) (no.) | Share of portfolio (percent) | Projects closed and evaluated (no.) | Projects with Effective Performance[a] (no.) | Share (percent) |
|---|---|---|---|---|---|
| Policy and regulations | 17 | 15 | 10 | 7 | 70 |
| Institutional development | 19 | 16 | 13 | 9 | 69 |
| Capacity building | 35 | 30 | 21 | 17 | 81 |
| Planning | 28 | 24 | 14 | 10 | 71 |

- WB **support for basic municipal solid waste infrastructure and service delivery** has been generally **effective**.

- The **effectiveness** of infrastructure and services activities is **undermined** by challenges achieving financial sustainability.

Table 3.2. Effectiveness of Pillar 2 Determinants: Infrastructure, Access and Service Delivery

| Determinants | Projects Addressing Determinant (no.) | Share of portfolio (percent) | Projects closed and evaluated (no.) | Projects with Effective Performance[a] (no.) | Share (percent) |
|---|---|---|---|---|---|
| Infrastructure development | 65 | 56 | 40 | 33 | 83 |
| Access and service delivery | 44 | 38 | 26 | 24 | 92 |
| Solid waste management operations | 44 | 38 | 31 | 23 | 74 |
| Cost recovery/ financial sustainability | 37 | 32 | 25 | 14 | 56 |
| Private sector participation | 22 | 19 | 15 | 11 | 73 |
| Awareness and behavior change | 35 | 30 | 23 | 20 | 87 |
| Integration of informal waste pickers | 21 | 18 | 11 | 9 | 82 |
| Gender considerations | 12 | 10 | 5 | 5 | 100 |

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## Transitioning to a Circular Economy (6)

- Very **few projects tracked** the environmental, social, or economic **outcomes of improved MSWM activities**.

Environmental, Social, and Economic Impacts of Improved MSWM Activities

| Determinant | Projects Addressing Determinant (no.) | Share of portfolio (percent) | Projects closed and evaluated (no.) | Projects with Effective Performance (no.) | Share (percent) |
|---|---|---|---|---|---|
| Environment | 25 | 21 | 20 | 13 | 65 |
| Climate change | 12 | 10 | 7 | 5 | 71 |
| Social (focus on health) | 11 | 9 | 8 | 2 | 25 |
| Job creation | 17 | 15 | 12 | 7 | 58 |

Achievement of MSWM Outcomes in Dedicated MSWM Projects Versus Part-MSWM Projects

| Solid waste management content | All projects | World Bank commitment ($, millions) | Closed and evaluated projects (no.) | MS+ Outcome Rating[d,e] (no.) | (percent) |
|---|---|---|---|---|---|
| Dedicated MSWM projects[a] | 25 | 611 | 15 | 11 | 73 |
| 'Part-MSWM' projects[b] | 68 | 1,834 | 37 | 23 | 62 |
| Other[c] | 23 | 181 | 16 | 8 | 50 |
| Total | | 2,626 | 67 | 42 | 63 |

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## IEG's recommendations

### Give clear priority to the adoption and implementation of waste hierarchy practices

**Recommendation 1 ->** To achieve more sustainable and scalable outcomes in MSWM, WBG technical and financial support to clients should give **clear priority to the adoption and implementation of waste hierarchy practices**, in line with client needs and capabilities for municipal solid waste management. To achieve this, the World Bank Group's support should:

- Build on **WBG's own experience in addressing the entire waste value chain** (collection, transport, recycling, recovery, and disposal) in an integrated and incremental manner.
- Foster **greater collaboration** between the World Bank, IFC, and MIGA to support governments for financial sustainability and accountability in service provision
- Increase **awareness** and **behavioral change**
- Integrate **waste pickers** into MSWM processes.

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## IEG's recommendations

### Urgently support low-income countries (LICs) where municipal solid waste is growing most rapidly

**Recommendation 2 ->** To support the LICs where municipal solid waste is growing most rapidly, WBG should **identify constraints on demand and investments**, and **leverage external partnerships** to implement context-specific MSWM solutions.

In **LICS**, the World Bank Group's should:

- Increase its **advisory services and analytics**
- Leverage **external partnerships** to supplement lending limits and technology needs
- Find context-specific solutions for systematically closing illegal dumps, ensuring clear and predictable **regulatory framework**, and provide **incentives** to reduce growth of waste generation and increase recycling, with a view to leapfrogging to the extent possible.

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## IEG's recommendations

### Need for a Global convening mechanism to raise the profile of MSWM

**Recommendation 3 ->** To bring prominence to and spur action on the global MSW agenda, the World Bank Group should take up a **clear leadership position**, collaborating and convening with developmental partners.

In the absence of an international coordination mechanism for MSWM, leading sector experts see scope for a **global convening role for the World Bank Group on MSWM** by leveraging current partnerships to improve municipal solid waste practices in the context of the CCAP and in specific areas such as with PROBLUE for addressing riverine and marine plastic pollution.

One area for expanded action is of **current efforts on marine plastic pollution through PROBLUE** and advocacy for circular economy approaches for MSWM under the **Climate Change Action Plan**.



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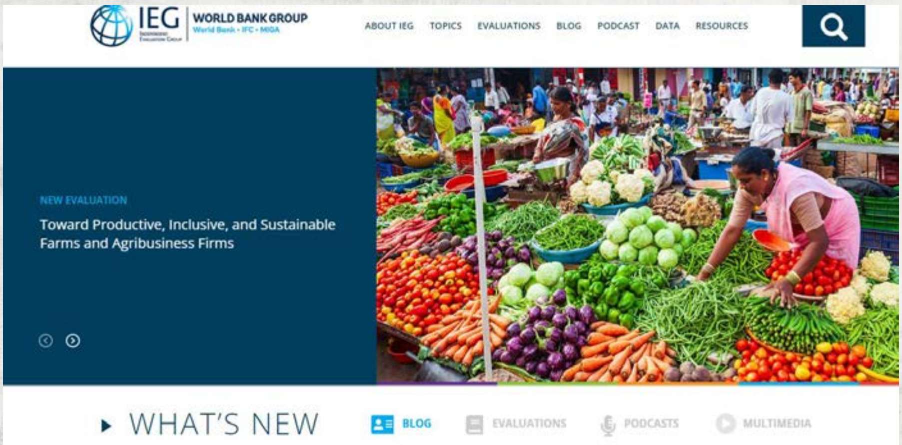


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