Introduction to Waste to Energy / Fuels

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What is Waste to Energy?

Any process, transformation of a wasted resource into usable forms or energy.

We will cover in each part of this presentation:

A. Biogas, with Biogas CHP plant at a Cassava Starch Factory in Cambodia
B. Thermal Technologies, with Biomass Power plant using Palm Biomass in Indonesia
C. Municipal Waste Treatment, with Biogas and Refuse Derived Fuel Approach
D. Some Innovative Ideas

Key Theme – Energy Transition – Distributed and Renewable
Energy Transition
The Waste Supply Chain and Competing Use

Solid – Briquettes, Pellets, Biochar
Liquid – Bioethanol, Biodiesel, DME, FAME, LPG, LNG
Gas – NG, CNG, BioCNG, Hydrogen, Syngas

Fuel

Energy

Chemicals

Waste

Fertiliser

Food

Solid – Rice Husk, Food Scraps, EFB, Fiber, MSW, Offal, Spent Grain, Ash
Liquid – POME, Process Waste, Sewerage, Sludge

Crops - Corn, Cassava, Palm, Sweet Sorghum, Sugar, Wheat, Rice, Edible Oils, Fruits, Algae, Grasses, Trees etc.
Livestock – Chicken, Beef Cattle, Diary, Duck, Sheep, Deer, Fish, Seafood et al

Thermal, Electrical, Stored, Transportable, Distributed/Microgrid Centralised Grid Emerging DC / Nano

NPK, UREA, Silica Phosphate Soil conditioners

Biochemical Industry

C5, C6, C7… upwards
Bags, plates cutlery

Biochar, Ash
Part A - Biogas - Methane (CH4)

Input Waste Water
A watery slurry of about 8-10% solids from various sources:
- Food waste
- Cassava Starch Effluent,
- Brewery Effluent
- Palm Oil Mill Effluent,
- Ethanol Factory Effluent,
- Sewerage Plant Sludges

Biogas
Mix of methane, CO₂, H₂S and trace gases.

Hydrogen Sulphide varies from 1% to 3% (must be removed). Remainder is CO₂.

Sludge/Biosolid

<table>
<thead>
<tr>
<th>Carbohydrates</th>
<th>Sugar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fats</td>
<td>Fatty acids</td>
</tr>
<tr>
<td>Proteins</td>
<td>Amino Acids</td>
</tr>
</tbody>
</table>

Hydrolysis

Acidogenesis

Acetogenesis

Methanogenesis

Hydrogen Acetic acid Carbon dioxide

Methane Carbon dioxide
Methane Sources

Animal feces

Food waste

Sewerage

Landfills

Biogas 30-65% Methane (CH4)

Anything Putrescible With High Carbon measured in COD – Chemical Oxygen Demand – mg/l or Kg/day

Factory waste water (palm, cassava, ethanol, brewery, food processing)

Images courtesy of W2E Pte Ltd
Types of Bacteria and Reactions

- **Hydrophilic** – performance related to volume, works well in tropical climates with constant ambient temperatures. Cheap & Easy.

- **Mesophilic** – takes place between 35°C and 50°C. Depending on location heating will be required. Not so Cheap.

- **Thermophilic** – takes place above 50°C. Requires heating for tanks and insulation to ensure constant temperature. Expensive.

- **Exotics** – saline tolerant and temperature tolerant methanogens. These have not been widely used. Very Expensive.
Project – Cassava Starch Factory, Cambodia

Kampong Cham

Image courtesy of W2E Pte Ltd
## Simplified Impacts on Cassava Factory

<table>
<thead>
<tr>
<th>YEARLY</th>
<th>Cassava Factory (operating at 90T/hr -55% capacity)</th>
<th>Cassava Factory with Biogas Plant</th>
<th>Cassava Factory with Biogas Plant with increase production and root price</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unit Cost $</td>
<td>Σ $</td>
<td>Unit Cost $</td>
</tr>
<tr>
<td>Inputs</td>
<td>Operating (Days)</td>
<td>260</td>
<td>$ 900</td>
</tr>
<tr>
<td></td>
<td>Roots (T)</td>
<td>77,220</td>
<td>$ 32</td>
</tr>
<tr>
<td></td>
<td>Raw Water (M3)</td>
<td>2,162,160</td>
<td>$ 0.15</td>
</tr>
<tr>
<td></td>
<td>Grid Power (Kwhrs)</td>
<td>5,000,000</td>
<td>$ 0.163</td>
</tr>
<tr>
<td></td>
<td>Heavy Fuel Oil (L)</td>
<td>936,000</td>
<td>$ 0.50</td>
</tr>
<tr>
<td></td>
<td>Biogas Power (Kwhrs)</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Biogas Heat (Nm3)</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Output</td>
<td>Waste Water (M3)</td>
<td>1,945,944</td>
<td>$ 0.05</td>
</tr>
<tr>
<td></td>
<td>Emissions (TCO2e)</td>
<td>0</td>
<td>-</td>
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<tr>
<td></td>
<td>Cassava Starch (T)</td>
<td>23,400</td>
<td>$ 190</td>
</tr>
<tr>
<td></td>
<td>Biosolids (T)</td>
<td>11,583</td>
<td>$ 5.00</td>
</tr>
<tr>
<td>Factory Operating Profit</td>
<td>$ 288,848</td>
<td>$ 1,105,251</td>
<td>$ 1,617,015</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>Nil</td>
<td>$ 3,100,000</td>
<td>$ 3,100,000</td>
</tr>
</tbody>
</table>

¹ Pricing from 2008 Project. No longer subject to confidentiality.
Agricultural Biogas Project Virtuous Cycle

Project driven by power quality issues. Existing supply was degraded. This caused equipment damage to motors and pumps.

Subsequent benefits became clear. With secure and good quality power, Capacity could be reached and Farmers encouraged to grow more Cassava roots.

Innovation step – use starch to make compostable bags and cutlery in totally renewable environment.
Part B - Thermal Technologies

- Mass Burn (Incineration - Thermal Oxidation)
- Pyrolysis
- Torrefaction
- Gasification
- Plasma Arc Gasification
Mass Burn – Incineration

- Proven technology for volume reduction
- Cogeneration potential
- Disposal of created ashes (10% to 25% of input)
- Bottom Ash – MSW contains metal slags with limited reuse options other than landfill
- Fly Ash - toxic ash – can be used in cement production
- Dioxins and Furans – family of toxic substances with similar chemical structure, crystalline “Agent Orange”. Produce between 450°C to 850°C – Form in cooling
Overview of Single-Stage Mass Burn Incinerator Plant
Video on Mass Burn - Incineration

https://www.bing.com/videos/search?q=Municipal+Waste+to+Energy+Plants&&view=detail&mid=48C98D32A44B5D4CACD48C98D32A44B5D4CACD&rvsmid=03BD81A5EE2D9DF14C5603BD81A5EE2D9DF14C56&FORM=VDQVAP
Types of Boilers Used in WTE Plant

Here is a list of some of the commonly used technologies:

- GF - Grate-firing/fired – 140 year old technology
- MG – Moving grate – Used to limit caking of burnt materials
- VGF – Vibrating grate – Common in Palm Oil Boilers
- FB - Fluidized bed
- FBC - Fluidized bed combustor
- FBI - Fluidized bed incineration
- BFB - Bubbling Fluidized Bed
- CFB - Circulating Fluidized Bed
- RFB - Rotating Fluidized Bed

Differing waste residency times, operating temperature and combustion dynamics.
Moving Grate

Material placed on a grate which moves and has air injected to keep burning pile at residence temperature.

Grate fired boilers have a slopping grate so that the brunt solids (Ash) can slide to collector.

Ash materials cool, slag forms and can be recovered.
Bubbling Fluidised Bed

Materials are delivered onto a bed with air blowing from underneath to create a bubbling effect. Allows for more efficient air access to combustible materials.

Heat is transferred to boiler tubes filled with water to run steam turbine. These are shown in the top of the illustration.
Circulating Fluidised Bed

A more efficient combustion design allows for higher efficiencies, more complete combustion and emissions benefits.

Circulation of materials reduces operating temperature and generally provides for Lower Nox emissions.

IMPORTANT TO NOTE:
Emission and Energy are directly related to the feedstock used, its handling into the boiler, the process controls and emissions reduction equipment used.

Flue gas cleaning using Bag filters, ESPs (Electrostatic Precipitators) and a range of filtering solutions need to be integrated to meet best practice for emissions.
Key Terms Used in WTE Plant

Here is a list of some of the commonly used terms with simplified explanation:

- \( MJ \) Mega joule is a measure of energy
- Higher heating value \( HHV \) \( MJ/kg \) or Cal/lb
- Lower heating value \( LHV \) \( MJ/kg \) or Cal/lb
- Nitrogen oxide(s) \( NOx \) \( kg \)
- Sulphur Oxides \( SOx \) \( kg \)
- CHONS – Relative proportions of Carbon, Hydrogen, Oxygen, Nitrogen and Sulphur
- Heavy Metals - cadmium, mercury, lead, arsenic, manganese, chromium, cobalt, nickel, copper, zinc, selenium, silver, antimony and thallium
- Dioxin – family of Chlorinated Compounds formed in oxygen combustion between 250°C and 900°C. Dioxin and Furans are tetrotoxic carcinogens
- Sensible Heat – the energy needed to change material phase for instance Solid to Liquid
- Fouling – damage to the interior of the boiler from caked combustion products. Reduces efficiency/energy output and increase maintenance cost
- Acid gas – gases formed which can damage internal components.
Pyrolysis

- **Pyrolysis**: the thermal decomposition of carbon-based materials in absence of oxygen/air to produce a synthetic gas (syngas)

- Depending on type of starting materials, yield of bio oil may be up to 70% by mass of the feedstock and is usually used a heating fuel rather than a transport fuel.

- The syngas may be used to generate energy more efficiently, if a gas engine is used, whilst incineration can only generate energy less efficiently using steam turbo generators.

- The calorific value of this syngas will depend upon the composition of the input waste to the gasifier.
Torrefaction > Pyrolysis > Gasification Processes

- Temperatures, Torrefaction (350–400°C), Pyrolysis (350–500°C) and Gasifier (500–900°C)
- Main Product Torrefier (Biochar), Pyrolyser (BioOil / BioChar) and Gasifier (Syngas – CO/H2)
- All process dependent on moisture content of feedstock
- Preferred moisture content - approx. 10% to 20% dependent on technologies
- Operating and maintenance issues with tars and particulate matter in gaseous emissions
- Limited production of Dioxins makes gas clean up easier. (Note Dioxins form in cooling phase also)
- Disposal of char / tars residue issues if not salable
Plasma Arc Gasification

Plasma, the fourth state of matter - an ionized gas with temperatures 2,000°C to 5,000°C. Hot ionized gases created by an electrical discharge. The gas is typically air, oxygen, nitrogen, hydrogen, argon or a combination of these gases.

A plasma torch is powered by an electric arc ionizes gas and catalyse organic matter into synthetic gas and slag solid waste.

A key product is the conversion of solid waste into syngas, mainly carbon monoxide and hydrogen which can be converted to energy (steam and/or electricity), other gases, fuels and/or chemicals.

Images courtesy of Westinghouse Inc.
Biomass Power – Indonesia

Empty Fruit Bunch (EFB)

Palm Kernel Shell (PKS)

Images courtesy of W2E Pte Ltd
# Commercial Scale Financing

<table>
<thead>
<tr>
<th>YEARLY</th>
<th>3 Mills - EFB Sold</th>
<th>10 Mwe EFB Powered Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unit</td>
<td>Cost $</td>
</tr>
<tr>
<td><strong>Inputs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating (hrs/yr)</td>
<td>$</td>
<td>-</td>
</tr>
<tr>
<td>Empty Fruit Bunch (T)</td>
<td>80,592</td>
<td>$ (12)</td>
</tr>
<tr>
<td>Raw Water (M3)</td>
<td>24,178</td>
<td>$ 3.00</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical Power (Kwhrs)</td>
<td>82,000,000</td>
<td>$ 0.11</td>
</tr>
<tr>
<td>Emissions (TCO2e)</td>
<td>73,000</td>
<td>$ 14.00¹</td>
</tr>
<tr>
<td>Ash (T)</td>
<td>3,224</td>
<td>$ 15.00</td>
</tr>
<tr>
<td><strong>Operating Profit</strong></td>
<td>$ 967,104</td>
<td></td>
</tr>
<tr>
<td><strong>Capital Cost</strong></td>
<td>Nil</td>
<td></td>
</tr>
</tbody>
</table>

1 Pricing from 2008 Project. No longer subject to confidentiality.
Risks/Safeguards


Social safeguards in supply chain should be well researched to avoid or transform areas utilizing exploitative practice on vulnerable or exploited persons. Seek collaboration with POWI programs.
Important – Fuel Preparation

• Mass Burn WTE plants can take a wide range of materials – wet garbage, oils, tars, sludges. Moisture contents of 50% can be incinerated however energy is lost in boiling of the waste. The drier the better.

• Pyrolysis and Gasification Plants require a much more controlled moisture content 15% with +/- 5% margin

• Fuel preparation, storage and handling is highly important.

• Refuse Derived Fuels (RDF) is the plastics, textiles, timber, rubber and other combustible materials shredded and compressed into a fuel pellet. This pellet can be combusted (with oxygen) or gasified (without oxygen)
Part C - Municipal Solid Waste
MSW Simplified Biogas Approach

- Weigh Bridge
- Bunker
- Shredder

Or Manual Process depending on site conditions:
- Magnetic Separation
- Pulper
- Inerts
- Grit Removal

Recyclables:
- Plastic
- Glass
- Metals
- Paper

- Mixing Tank
- Biogas

- Covered In-Ground Anaerobic Reactor (CIGAR™)

- Condensate
- H2S Scrubber

- Co-generation
- CBG Storage

- Biogas

- Post Treatment
- Effluent Weir
- Drying
- Floculation
- Dewatering
- Fertilizer

Heat
- Power

Image courtesy of W2E Pte Ltd
MSW – Agreement Structures – Biogas and RDF

Predevelopment Issues
- Legal Review
- CDM PIN & PC
- Prelim Design
- Waste testing
- Agmt for land use

Recycling Activities
- Glass
- Rubber/ textiles as RDF
- Timber as RDF
- Paper as RDF
- Plastics as RDF
- Metals
- Tyres

Other Issues
- Accra
- Residences
- Factories
- Restaurants
- Sludges
- Municipal

Collection
- Sorting
- Hard Non Recyclables
- Agmt for receiving unmined materials
- Supply Agmt Sulphuric

Possibly future: New Gasifier to handle 50T of Wood waste per day to produce 2.4 MWe

Connection to Power Grid
- Power Purchase Agreement
- Power out
- Effluent Discharge licence
- Sale Agmt
- Sale Agmt
- Revenue
- Process Water
- Onsite Usage only
- Water In
- Bio-Methanation Digester & Turbine
- Agmt for water supply & use
- Reuse STP effluent
- Water In
- Low Dose Urea
- Ammonia Fertiliser
- Sale Agmt
- Ammonia Fertiliser
- Sale Agmt
- Ammonia Fertiliser
- Sale Agmt

Other Issues
- City Support - MOU
- Authority Approvals
- Site Usage Agmt and Licence
- Exempt Import Duty Exemptions
- Income Tax exemptions
- Green Loan amounts offset
- Project Equity Contributions
- New Co. Shareholders Agmt
- Loan Agmt for Project Finance
- Framework on recyclers

Possible to make refuse derived fuel from plastics, textiles and paper for sale to Ghacem or set up recycling trading operation with third party.

Electrical Grid step up from 415 Volts 3Φ to factory and export balance to Grid

Image courtesy of W2E Pte Ltd
Cheaper & Cleaner than Incineration Only

<table>
<thead>
<tr>
<th>YEARLY</th>
<th>18 Mwe MSW Biogas Powered Plant (selling Refuse Derived Solid Fuel)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unit</td>
</tr>
<tr>
<td>Inputs Costs</td>
<td>$ 3,609,496</td>
</tr>
<tr>
<td>Operating (hrs/yr)</td>
<td>8,059</td>
</tr>
<tr>
<td>Raw Water (M3)</td>
<td>5,470,000</td>
</tr>
<tr>
<td>Output</td>
<td></td>
</tr>
<tr>
<td>Tipping Fee</td>
<td>547,000</td>
</tr>
<tr>
<td>Electrical Power (Kwhrs)</td>
<td>118,200,000</td>
</tr>
<tr>
<td>Heat Energy (Kwt)</td>
<td>135,930,000</td>
</tr>
<tr>
<td>Emissions (TCO2e)</td>
<td>107,000</td>
</tr>
<tr>
<td>Biosolid (T)</td>
<td>24,700</td>
</tr>
<tr>
<td>Recyclables</td>
<td>10,000</td>
</tr>
<tr>
<td>RDF</td>
<td>27,800</td>
</tr>
<tr>
<td>Operating Profit</td>
<td>$ 14,863,404</td>
</tr>
<tr>
<td>Capital Cost</td>
<td>$ 56,000,000</td>
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</tbody>
</table>

- Refuse Derived Fuels or Solid Recovered Fuels are high calorific fuels made to substitute coal.
- RDF/SRF used in cement production where high lime content limits dioxin formation. Buyer secured.
- Exportable power is about 14MWe due to parasitic plant load.
- Note equipment was priced directly from suppliers – name main contractor not included (add 18% if required)
- Land cost of US$ 100,000 included in Capital cost.

1 Pricing from 2008 Project. No longer subject to confidentiality.
Landfill Mining – Trommel and Shred

https://www.youtube.com/watch?v=m8P2LOcNOWc
**Phnom Penh Waste Story**

**Population**

2015 – 2.6M pp → 2,300 Mt/day MSW

2025 – 4.4M pp → 5,000 Mt/day MSW

**Infrastructure for Waste**

A – Steung Meancheay Landfill (Closed)

B - Dang Kau Landfill (EOL 2020)

**New Infrastructure**

C – Riverside MRF & Biogas Plant (600T/d)

D – **Snaor Biogas & Incinerator (2,000T/d)**

A+ - Mine RDF/MRF/Biogas at Steung Meancheay

B+ - Biogas/RDF at Dang Kau (1,200T/d)

E - Riverside North MRF & Biogas Plant (600T/d)
# Technology Portfolio & Terms

<table>
<thead>
<tr>
<th>Code</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>INCINERATOR</td>
<td>Municipal Incinerator</td>
</tr>
<tr>
<td>GASIFIER</td>
<td>Municipal Gasifier</td>
</tr>
<tr>
<td>PLASMA</td>
<td>Municipal Plasma Gasifier</td>
</tr>
<tr>
<td>PYROLYSIS</td>
<td>Municipal Pyrolysis Plant</td>
</tr>
<tr>
<td>OFMSW</td>
<td>Organic Fraction of Municipal Solid Waste to Biogas + Power</td>
</tr>
<tr>
<td>DRY OFMSW</td>
<td>Municipal Dry Fermenter + Power</td>
</tr>
<tr>
<td>OFMSW + RDF/SRF</td>
<td>OFMSW + Refuse Derived Fuel/Solid Recovered Fuel)</td>
</tr>
<tr>
<td>RDF/SRF</td>
<td>Municipal RDF/SRF + Gasifier</td>
</tr>
<tr>
<td>Torrefaction</td>
<td>Torrefaction - BioCoal</td>
</tr>
<tr>
<td>TDP</td>
<td>Thermal Depolymerization</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Code</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEWergas</td>
<td>Biogas Sewerage + Power</td>
</tr>
<tr>
<td>BIOGAS</td>
<td>Biogas Cassava Waste Water + Power</td>
</tr>
<tr>
<td>HICOD</td>
<td>Biogas Ethanol Waste Water + Power</td>
</tr>
<tr>
<td>POME</td>
<td>Biogas Palm Oil Mill Effluent + Power</td>
</tr>
<tr>
<td>FARMGAS</td>
<td>Biogas Cattle/Piggeries + Power</td>
</tr>
<tr>
<td>DRYFARMGAS</td>
<td>Cattle/Piggeries Dry Fermenter + Power</td>
</tr>
<tr>
<td>CHICKEN</td>
<td>Biogas Chicken Farm + Power</td>
</tr>
<tr>
<td>LFG</td>
<td>Landfill Gas</td>
</tr>
<tr>
<td>FARM</td>
<td>Household/Farm Biogas</td>
</tr>
<tr>
<td>BRIQUETTE</td>
<td>Briquettes - Char</td>
</tr>
<tr>
<td>PELLETS</td>
<td>Fuel Pelletisation from biomass</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Code</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>FORESTRY</td>
<td>Biomass Forestry Waste</td>
</tr>
<tr>
<td>BAGASSE</td>
<td>Biomass Sugar Bagasse</td>
</tr>
<tr>
<td>EFB</td>
<td>Biomass EFB Waste</td>
</tr>
<tr>
<td>MIXED FUEL</td>
<td>Biomass Mix Fuel Agriculture</td>
</tr>
<tr>
<td>MICROGASIFIER</td>
<td>Biomass Small Scale Waste</td>
</tr>
<tr>
<td>TORREIFIER</td>
<td>Torrefied biosolids</td>
</tr>
<tr>
<td>ZeoChar</td>
<td>Modified Gasification of sludge &amp; Silica</td>
</tr>
<tr>
<td>SLUDGE</td>
<td>Soil Conditioner from Biogas Process</td>
</tr>
<tr>
<td>BIOCHAR</td>
<td>Biochar</td>
</tr>
<tr>
<td>COMPOST</td>
<td>Windrow, anaerobic, biodry or other</td>
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</table>

**Biogas**

- Municipal Solid Waste (MSW)
- Agriculture

**Soil Fuels**

- Soil Fuels
# Technology Portfolio & Terms

<table>
<thead>
<tr>
<th>Waste Heat Recovery</th>
<th>Code</th>
<th>Technology</th>
<th>Biofuels</th>
<th>Code</th>
<th>Technology</th>
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<tbody>
<tr>
<td></td>
<td><strong>CCGTup</strong></td>
<td>GT to CCGT (Gas Turbine - Combined Cycle Gas Turbine)</td>
<td><strong>DME</strong></td>
<td>Dimethyl Ether</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>ORC</strong></td>
<td>Organic Rankine Cycle (ORC) System (Reverse Absorption Chiller)</td>
<td><strong>BioDME</strong></td>
<td>DME made from Biological feedstock</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>PREHEAT</strong></td>
<td>Preheating with waste heat</td>
<td><strong>FAME / Biobutanol</strong></td>
<td>Fatty Acid Methyl Ether / Gasohol</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>DRYING</strong></td>
<td>Waste heat used for drying</td>
<td><strong>BIOFAME</strong></td>
<td>FAME using Enzymes</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>PROCESS</strong></td>
<td>Waste heat used to heat fuel oil</td>
<td><strong>CATALYTIC FAME</strong></td>
<td>FAME using Catalysts</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>HEAT PUMP</strong></td>
<td>Heat pumps are used for district heating and energy transfer (hot water)</td>
<td><strong>BioCNG</strong></td>
<td>Compressed Natural Gas made from waste</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Nano Antennae</strong></td>
<td>Nano Antennae harvesting radiant heat/radiation around the 300 nanometer spectrum.</td>
<td><strong>BioLNG</strong></td>
<td>Liquified Natural Gas made from waste</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>BIOPLASTIC</strong></td>
<td>Bioplastics - Bags/Cutlery</td>
<td><strong>BioEthanol</strong></td>
<td>Ethanol using Enzymes</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>MSW&gt;C5,6,7</strong></td>
<td>MSW to Chemicals - Ethylene</td>
<td><strong>SYNMETH</strong></td>
<td>SYNGAS to Methanol (Gasifier)</td>
<td></td>
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<td></td>
<td><strong>BIOMETHANOL</strong></td>
<td>Methane to methanol using catalysts</td>
<td><strong>CATALYTICS</strong></td>
<td>Syngas to methanol using catalysts</td>
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<td><strong>MSW&gt;</strong></td>
<td>MSW to Chemicals - Ethylene</td>
<td><strong>BIOMETHANOL</strong></td>
<td>Methane to methanol using catalysts</td>
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Bio Energy kiosk in rural areas selling biofuels, BioCNG and other fuel substitutes directly to consumers at roadside kiosk close to source.
Innovation in Action – Enerkem Rotterdam

1. Non-recyclable waste is supplied as a source of carbon
2. AkzoNobel and Air Liquide provide hydrogen and oxygen as reactants
3. The Port of Rotterdam provides the infrastructure
4. Methanol is produced using Enerkem's proprietary technology
5. AkzoNobel produces essential raw materials and specialized chemicals to make green products

Partners:
- Air Liquide
- AkzoNobel
- Enerkem
- Port of Rotterdam

ADB
Distributed bioenergy facilities in neighborhood MRFs (Material Recovery Facilities). Empowers local communities to derive financial social and environmental benefits from their waste resources (local renewable energy, local jobs, less truck impact on roads, local center for circular economy and general increase in local cohesion.)
Thank you!