The role of Waste-to-energy in a circular economy society

August 24, 2017

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WTERT-US and the Global WTERT Council (GWC)

• WTERT-U.S. was founded by the Earth Engineering Center of Columbia University with the aid of the U.S. WTE industry in 2002

• At the end of 2011, GWC was incorporated as a non-profit organization under the laws of the state of New York and the U.S.A.
The mission of the Global WTERT Council (GWC):

- Identify the **best available technologies** for the recovery of materials and energy from all types of “wastes”

- Disseminate this information by means of publications, the multilingual WTERT web pages, and periodic meetings and national and international conferences.
Circular economy: The concept

Linear economy

EXTRACT -> PROCESS -> MANUFACTURER -> CONSUMER -> WASTE DISPOSAL

Mixed technical and biological materials

Circular economy

Technical nutrients  Biological nutrients
Importance of resource recovery for the sustainability of the planet:

23 million tons in 2015

11 million tons of copper consumed in 1995

Themelis’ lecture to Metallurgical Society of Finland (1996)
Some conclusions from the previous slide:

- 1996: Humanity used much more copper in the period of 1950-1995, than it had been used in 6,000 years before that.
- 2016: Consumption of copper has nearly doubled from 1995 to 2015.
- 2016: If it had not been for recycling of copper, the world would have run out of copper and copper would have become very expensive.
Global Waste Generation

Past and projected global waste generation

Waste generation (millions of tonnes per day)

Global waste generation predictions (Hoornweg, Bhada-Tata and Kennedy, 2013)
Methods of managing MSW

- Waste Reduction
- Reuse & Recycling
- Anaerobic Digestion
- Aerobic Composting
- Energy Recovery (WTE)
- Modern Landfill Recovering & Using CH₄
- Modern Landfill Recovering & Flaring CH₄
- Landfills without CH₄ Capture
- Unsanitary Landfills & Open Burning

“Recycling”

“Post-recycling”

Source Separated Materials
Mechanical Biological Treatment (MBT)

Mixed MSW

Recyclables and/or refused derived fuel (RDF)

Sorting (mechanical, optical) and pre-treatment

Biological treatment

Compost product

Residues to landfill or WTE

Biogas and energy (anaerobic digestion)
Necessary ingredients for successful recycling

• **Communities with separate collection** of recyclable materials (principally metals, paper/cardboard, green wastes)

• **Citizens who separate** recyclables at the source

• **Markets** that can use/make profit from the recyclable materials (e.g. metal smelters, secondary paper mills)
Increasing composting

• **Least costly** way for municipal government to increase composting: Provide a windrow composting center where municipality and citizens transport their park/yard wastes and get compost product to be used as soil conditioner.

• **Next and more costly means**: Anaerobic Digestion facility where source-separated food wastes from large generators (institutions, food processors) are treated to produce methane and a compost product.
Impact of source separation on Heavy metals concentration in MSW compost

Ref: Ranjith Annepu MS-Thesis, EEC-Columbia, Sustainable Solid Waste Management in India
Limitations to recycling and composting

• It is not possible to collect all recyclables or to process all wastes (E.g. disposable diapers) to marketable materials

• For example, after many efforts to increase recycling in California, less than 10% of the plastic wastes are being recycled

• Therefore, it has been necessary, universally, to develop means for disposing properly the post-recycling wastes
What to do with post-recycling wastes?

1) **Sanitary landfilling**

- protects ground and surface waters
- cuts down GHG emissions by about 0.5 ton GHG/ton MSW.
- costs $100-200 per annual ton of capacity
- uses $1 m^2$ of land for every 10 tons of MSW landfilled
Photo of sanitary landfill (Stevens County, WA)
Landfilling consumes land: For example Beijing is literally surrounded by hundreds of landfills

Source: Extraordinary film by Wang Juliang, shown at CU by EEC
The Global Landfilling picture (EEC, 2015)

- MSW to global landfills: 1 billion tons/y
- Landfill Gas (LFG) generation: 50 million tonnes CH₄
- LFG collected and used or flared*: 6 million tonnes CH₄
- LFG emitted globally: 44 million tonnes CH₄*

*Equivalent to 920 million tons of CO₂
(over 3% of global Greenhouse Gases (GHG))

*The US captures over 50% of the LFG captured globally
Estimated average ultimate use of land for proper (sanitary) landfilling of MSW: One square meter gone for ever, for every 10 tons of MSW landfilled

- Current global landfilling converts an estimated 100 square kilometers of greenfields to landfills
- If it were done at one landfill it would use up a land surface equal to that of metropolitan Paris
- At present rate of MSW generation, continued landfilling would use up 10,000 square kilometers in this century
Some nations are spending billions in missions in the hope of developing living space in Mars, etc.

How much would it cost to create 100 square kilometers of earth-like land on Mars?
What to do with post-recycling wastes? (Continued)

MSW Combustion

Waste to Energy

Bottom Ash
150-250 kg/ tonne MSW

Electricity and
district heating/cooling

Air Pollution Control Residues
25-35kg/ tonne MSW

Resources from Waste
<table>
<thead>
<tr>
<th><strong>Pyrolysis</strong></th>
<th><strong>Gasification</strong></th>
<th><strong>Full combustion</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Normally no air</td>
<td>Sub stoichiometric air</td>
<td>Excess air</td>
</tr>
<tr>
<td>Only heat (external or internal)</td>
<td>Lower total volumetric flow</td>
<td>Higher volumetric flowrate</td>
</tr>
<tr>
<td>Want liquid, Gases not desired</td>
<td>Lower fly ash carry over</td>
<td>Fly ash carry over</td>
</tr>
<tr>
<td>Pollutants in reduced form (H₂S, COS)</td>
<td>Pollutants in reduced form (H₂S, COS)</td>
<td>Pollutants in oxidized form (SOₓ, NOₓ, etc)</td>
</tr>
<tr>
<td>High Char</td>
<td>Char @ Low T</td>
<td>Bottom ash</td>
</tr>
<tr>
<td><strong>Scale:</strong> ~ 10 tons/day</td>
<td>Vitrified Slag @ high T</td>
<td><strong>Scale:</strong> ~ 1500 tons/day</td>
</tr>
</tbody>
</table>

- No additional Oxygen (only heat)
- Unconverted solid will remain!

- Some additional Oxygen (or air)
- Heat added or comes from reactions
- Much additional Oxygen (or air)
- Heat comes from reactions
The most efficient EfW facilities are co-generators of electricity (> 0.6 MWh per tonne of MSW) and district heating (> 0.5 MWh per tonne of MSW).
Waste-to-Energy (WTE) Facility

Reducing the Volume of Waste & Generating Energy

IN

100 cubic yards of waste

90% volume reduction

10 cubic yards of (inert) ash

OUT

Energy is mass times a constant

\[ E = M \times C^2 \]
Waste to Energy bottom ash recycling plant

Coarse fraction, 10-15%

MAGNETS, ECS

SCREEN

Medium fraction, 40-70%

Fine fraction, 15-45%
Managing post-recycling wastes

Only two options to manage post-recycling wastes:

• Waste to Energy (WTE)
• Sanitary landfills

WTE advantages over sanitary landfilling:

• Destruction of pathogens
• Conservation of land near cities (LF=1 m²/10 tons MSW)
• Electricity production: >0.5 MW over sanitary LF
• GHG emission reduction: 0.5 - 1 ton per ton MSW to WTE
• Metal recovery
In some countries, there is continuing opposition to WTE based on the early history of incineration.

For example, any new proposal for WTE is opposed by people who claim that a new WTE plant will emit dioxins harmful to public health.
Columbia detailed studies of four nations annual WTE dioxin emissions

<table>
<thead>
<tr>
<th>Country</th>
<th>Year of study</th>
<th>MSW processed (million tons)</th>
<th>Average Dioxin Emissions (ng TEQ/Nm³)</th>
<th>Total Dioxins Emitted (g TEQ/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>2012</td>
<td>25.9</td>
<td>0.027</td>
<td>2.90</td>
</tr>
<tr>
<td>France</td>
<td>2010</td>
<td>13.8</td>
<td>0.013</td>
<td>0.79</td>
</tr>
<tr>
<td>South Korea</td>
<td>2010</td>
<td>3.9</td>
<td>0.007</td>
<td>0.11</td>
</tr>
<tr>
<td>China</td>
<td>2015</td>
<td>61.8</td>
<td>0.1*</td>
<td>24.7</td>
</tr>
</tbody>
</table>

*Assumed average; Everbright average: 0.04 ng TEQ/Nm³
U.S. dioxin emissions from all industrial sources, forest and landfill fires, flaring of LFG, etc., in grams TEQ

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total industrial sources</td>
<td>13,833</td>
<td>2,634</td>
<td>998</td>
<td>511</td>
</tr>
<tr>
<td>Total industrial plus area sources</td>
<td>16,125</td>
<td>4,925</td>
<td>3,827</td>
<td>3,808</td>
</tr>
<tr>
<td>WTE dioxins as % of total U.S. dioxins</td>
<td>58.9%</td>
<td>24.4%</td>
<td>2.0%</td>
<td>0.08%</td>
</tr>
</tbody>
</table>

Dioxins from unintended landfill fires in the U.S. in 2012: 1,300 grams TEQ vs. 3.0 grams TEQ from WTE
Current GWC-Columbia study: Distance of global WTEs from center of city

Avg. distance: 5 km
People generally resist change, even when change is for the good.

The first central systems for potable water, for wastewater treatment, for management of solid wastes were resisted for lack of adequate information.

Some people acquire “fame” by leading movements against beneficial change.

It is therefore necessary for universities to lead the effort for sustainable development.
How universities can fulfill their role:

- Through educational programs
- Through academic research
- Through the dissemination of credible information (publications, the web, public meetings)

Universities need industry and government support!
The Global picture
Estimated global disposition of urban post-recycling MSW

- Thermal treatment (WTE): 230 mill. tons
- Sanitary landfill, partial CH4 recovery: 250 mill. tons
- Landfilled without CH4 recovery: >800 mill. tons

- MSW generation has tripled since 1950 and is expected to be six times greater by 2030
“Ladder” of sustainable waste management of nations

- Recycling
- WTE
- Landfilling

Chile
Sustainable waste management (SWM) index vs per capita GDP

GDP per capita of EU-28: $33,527 (PPP)
SWM index of EU-28: 66%

LOW GDP
HIGH SWMI

LOW GDP
LOW SWMI

HIGH GDP
HIGH SWMI

HIGH GDP
LOW SWMI

y = 0.6316x - 12.109
R² = 0.6015
Very high levels of recycling, composting and WTE, achieved in less than 20 years, by means of:

- Planning, policy, regulations, and public education at national level
- Implementation at municipal level
- Assistance by national/regional agencies to municipalities in implementing regulations
- Citizen compliance and participation

How S. Korea has done it?
Successful case in recycling and composting: UK through increase in landfill tax
Successful case in recycling and composting: UK through increase in landfill tax

Source: ETC/SCP, 2012 and Eurostat, 2012. Note: landfill tax is shown for active waste – for inactive waste it lies at GBP 2.50/tonne
UK campaign
UK campaign

When I stop spinning, I'm coming back as a helicopter!

When the spark's gone from your old electrical equipment don't bin them. Recycling centres, electrical shops, and local reuse groups can all help them live again.

Make a brighter future. Recycle.

Don't let Devon go to waste
0845 450 2477 | recycledevon.org

Your recycled plastic bottles can come back as footy shirts.

Lots of plastics from around your home can be recycled again and again into amazing things.

recycle for London
www.recycledforlondon.com
2017 Capacity: 230,000 tons/day
2017 number of WTEs: 254

Yating Yu, EEC/Columbia 2016
Reducing the initial capital investment in WTE plants has made them cost-competitive with sanitary landfills.

- China has demonstrated that it is possible to reduce the capital cost of WTE plants by means of:
  - Industrial and academic R&D
  - Mass production, instead of one plant at the time
- Incentives to WTE: Credit for renewable energy production ($30/MWh of electricity produced by WTE vs coal-fired power plants)
All types of WTE are much less costly in China.

Average of 25 other plants: $880/ton

Average of 21 Chinese plants: $230/ton
The Everbright Nanjing WTE
(4,000 tons/day; total investment: $270 million)
Everbright manufacturing plant of WTE equipment (Changzhou, China)
Control room of Nanjing WTE plant
Continuous public display of WTE plant emissions
2015 and 2016 dioxin emissions of Everbright plants (Columbia Univ. 2017 study, ng TEQ/Nm3 stack gas)

E.U. and U.S. standard for dioxin emissions

Plants we examined were well below the E.U. standard
China should be a good example to other countries

Developed nations took several decades to reach their present state of development and achievement in sustainable waste management

Developing nations can use Chinese knowhow and capital to accelerate the application of WTE technology and the phasing out of landfilling

Why all this talk about China becoming a world leader in WTE in about ten years?
MSW generation, recycling and landfilling in Chile

Fernanda Cabanas, EEC/Columbia 2017
<table>
<thead>
<tr>
<th>Management technique</th>
<th>S1: BAU</th>
<th>S2: ISWM + LF</th>
<th>S3: ISWM + WTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recycling</td>
<td>14%</td>
<td>25%</td>
<td>25%(^b)</td>
</tr>
<tr>
<td>Landfilling</td>
<td>86%(^a)</td>
<td>75%</td>
<td>55%(^c)</td>
</tr>
<tr>
<td>WTE</td>
<td>0%</td>
<td>0%</td>
<td>20%</td>
</tr>
</tbody>
</table>

\(^a\) It is assumed that 91% go to authorized landfills and 9% to illegal dumping.

\(^b\) It does include metal recovery from bottom ash.

\(^c\) It does include ashes from WTE.
Comparison of three scenarios for 2020

Greenhouse gases emissions
(Thousand tonnes of CO2eq)

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Recycling &amp; composting</th>
<th>Landfilling</th>
<th>WTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>-2,600</td>
<td>-1,600</td>
<td>-600</td>
</tr>
<tr>
<td>S2</td>
<td>-1,600</td>
<td>-1,400</td>
<td>400</td>
</tr>
<tr>
<td>S3</td>
<td>-1,400</td>
<td>-1,400</td>
<td>2,400</td>
</tr>
<tr>
<td></td>
<td>1,400</td>
<td>2,400</td>
<td>3,400</td>
</tr>
</tbody>
</table>

Fernanda Cabanas, EEC/Columbia 2017
Why it is the Perfect Time for Chile to join the modern age?

- A perfect opportunity for a PPP project
  - A nation blessed with world famous climate and land should not continue converting it to landfills
  - Technology is now available at an affordable capital cost
  - Outside investment is available and return on investment will be very high

- Required partner: Major Chilean company in construction and infrastructure

- The first and largest WTE in Santiago will lead to future smaller projects.
Taiwan WTE: Not your usual stack
Taiwan WTE Observation Deck on Stack
Leeds, UK (214,000 tons/year)
Worldwide examples: Copenhagen, Denmark
Worldwide examples: Spittelau, Vienna, Austria
To be built in Shenzen, China. The world’s largest (1.6 million tons)
GUIDEBOOK
FOR THE APPLICATION OF
WASTE TO ENERGY TECHNOLOGIES
IN LATIN AMERICA AND THE CARIBBEAN

NICKOLAS J. THEMELIS, MARIA ELENA DIAZ BARRIGA,
PAULA ESTEVEZ, AND MARIA GAVIOTA VELASCO

EARTH ENGINEERING CENTER
COLUMBIA UNIVERSITY

MARCH 2012

WTERT “wte guidebook”

• Already available
In English, Portuguese, Spanish.

• Chinese edition
underway
by WTERT-Asia
...for those of you interested in Sustainable Waste Management “google” W T E R T or look up www.sofos.org

Earth Engineering Center
Columbia University

Or look up Google for WTE Guidebook
Waste to Energy providing new material resources

Waste → Research → Resource opportunity

The best opportunities need research to make them happen……..

Thank you very much for your attention!
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