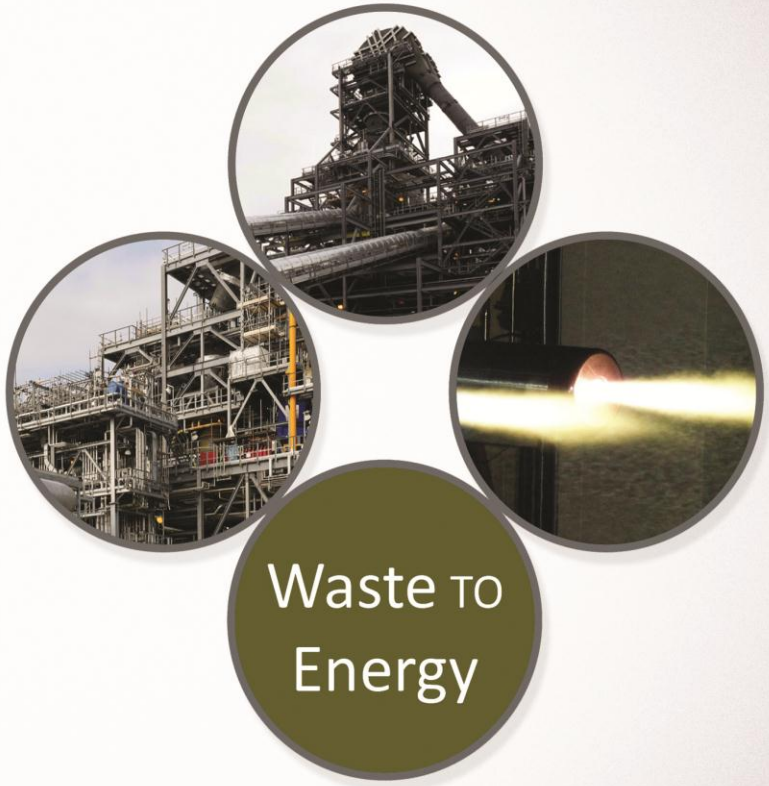
Treating Waste as a Renewable Source of Energy

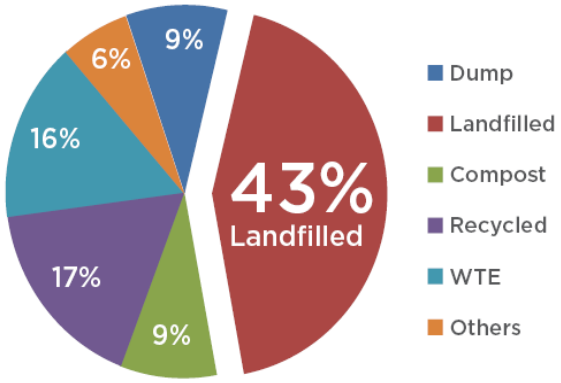


Advanced Thermal Technologies for the conversion of Waste-to-Energy

WRETC - 7th World Renewable Energy Technology Congress & Expo, August 21-23, 2016
Delhi, India

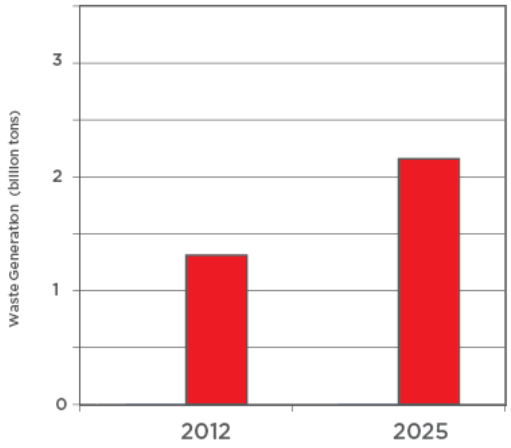
We Have A Global Waste & Population Growth Challenges

Most of the world's MSW is landfilled



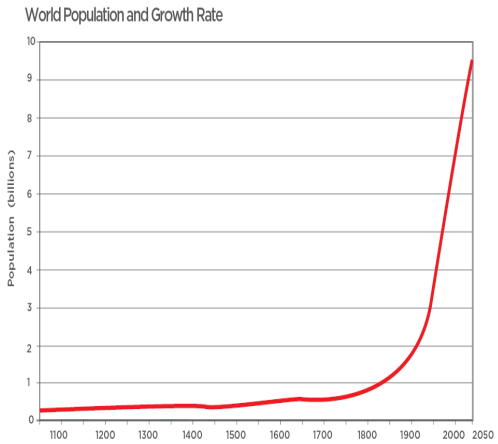
(Source: World Bank, 2012)

MSW generation (billion tpy):



(Source: World Bank, 2012)

World population growth (estimates in billions):



(Source: UN Population, 2014)

Facts are that landfills cause:

- Greenhouse gas emissions, both CO_2 and methane
- Unnecessary land occupation
- Water contamination through leaching
- Emissions that contain hazardous air pollutants that can be dangerous
- Clean up issues for future generations

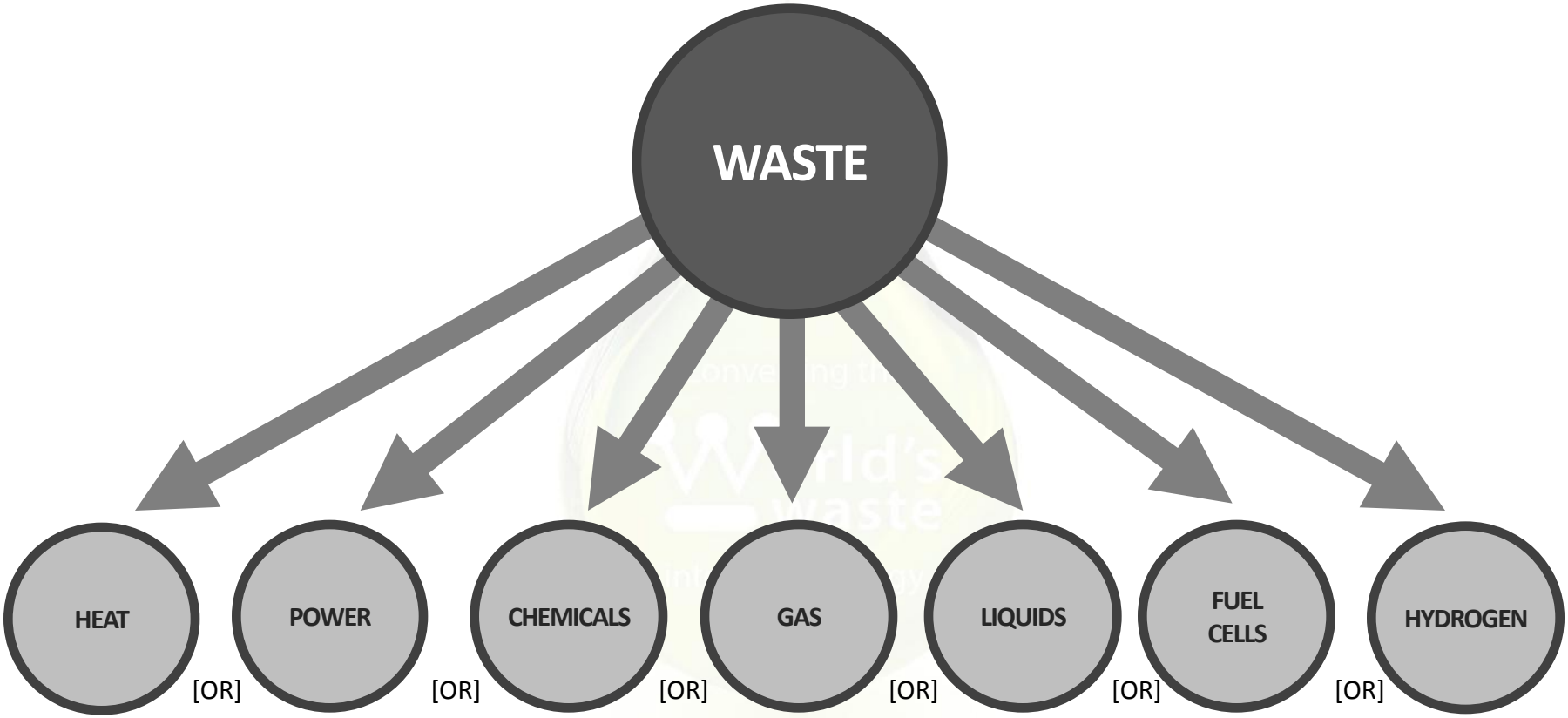
World population growth impacts waste generation:

- World population is projected to reach 9 Billion by 2050
- Urbanization will account for 86% in developed countries; 64% in developing countries
- Increase in urban population and consumption has a direct impact on the increase of waste generation

"Waste generation levels are expected to grow by 69% by 2025." *(World Bank Study, 2012)*

WASTE-TO-ENERGY: DEFINITION

Conversion of waste materials into useable energy.



Global Waste Management
(Practice & Challenges)

GLOBAL WASTE MANAGEMENT: PRACTICE & CHALLENGES

Waste Management & Evolution	Tier 1 (E.g. Western Europe, Japan)	Tier 2 (E.g. USA, Canada, Australia)	Tier 3 (E.g. Middle East, S. America, E. Europe)	Tier 4 (E.g. Asia/India, Developing Countries)
Waste segregation at source (E.g. 3R's)	HIGH	HIGH	MEDIUM	LOW
Advanced landfilling	HIGH	HIGH	LOW	LOW
Thermal Treatment	**HIGH**	**LOW**	**LOW**	**N/A**
Environment pollution (E.g. methane gas, CO_2, gas flaring, open dumping, health hazard, etc.)	LOW	MEDIUM	HIGH	HIGH

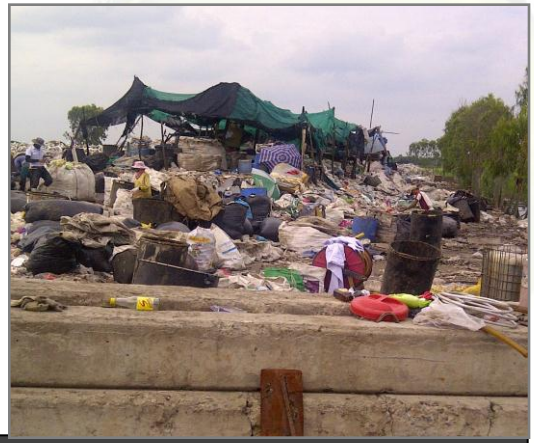
Tier 1 – Current State of the Art

Urban - Denmark

Urban - Denmark

Rural - UK

Tier 4 – Not state of the Art



Human habitation near a landfill

Crop cultivation besides a landfill

Waste Management
(Challenges & Opportunities)

Asia/India Perspective

Challenges:

- Asia is a highly populated region of ~4 Billion people (India - 1.3 Billion); with highly populated urban centres
- Lack of adequate waste management/recycling facilities
- Waste material consists of high moisture content/wet organics
- Country risk, including political, social, changing renewable policies, difficult to obtain long-term energy price
- Scarcity of development capital and scarcity of credible project developer/owners

Opportunities:

- Waste volumes are growing and majority of waste is largely landfilled
- Acute energy demand for power generation and economic growth
- Limited availability of land for landfilling vs. human habitation
- International pressure for cleaner/sustainable waste practices and GHG reduction

ASIA/INDIA VERSUS NA/EU

	North America / Europe	Asia
Waste	• RDF widely used with low moisture/organic content • Low in glass/metals content • High calorific value and energy output	• High moisture/organic content • High in glass/metals content • Lower energy output • Low calorific value
Long-term Contracts	• Mostly open markets • Allowance to negotiate long-term waste and energy contracts	• Mostly closed markets • Obtaining secure, low-risk contracts is much more difficult
Revenues	• Revenues are higher due to medium/high tipping fees	• Revenues are lower due to low tipping fees
Capital Cost	• Medium/high labor and material costs • Higher capital costs to build a facility	• Low labor and material costs • Lower capital costs to build a facility
Political Risk	• Stable governments • Long-term policy with predictable business environment	• Less favorable conditions
Permitting	• Permitting is a lengthy process due to many stakeholders and stringent permit/license processes	• Permitting often easier due to fewer NGOs and simpler permit/license processes

GLOBAL DEVELOPMENT CHALLENGES

- NGO pressure – anything short of 100% recycling is not acceptable
- Changing or uncertain renewable energy policies
  - Unfavourable mandates or lack of incentives
  - Unavailable/uncertain long-term waste supply agreements/PPAs
  - Waste-to-energy not addressed or not considered renewable
  - Incentives come and go with political change
- Limited access/unavailability to large project development capital/funding
- Less than factual media coverage, speculation and misunderstandings about advanced thermal technologies (e.g. plasma gasification)
- Risk aversion to newer technologies

Government Initiatives & Incentives for Waste Conversion

Government Initiatives & Incentives

Country	Landfill Tax	Renewable Energy Mandate	Legislations	First Legislations Enacted
India	✗	✓	✓	1986
China	✗	✓	✓	1989
Australia	✓	✓	✓	2009
EU (27)	✓	✓	✓	2008
USA	✗	✓	✓	1976

Source: MEP China; COAG Australia; EC.Europa; EPA/RCRA USA

Role of Governments and Private Enterprise

ENGAGING ALL STAKEHOLDERS IN THE WASTE VALUE CHAIN

- Waste management is a challenging task for government and other stakeholders
- The costs for waste management will grow from ~$205 billion to ~$375 billion by 2025
- An on-going need to improve waste management plans
- Resource-efficient waste hierarchy is a long-term approach to integrated waste management - including recycle, reuse and recovery
- Large-scale investment in advanced thermal technologies would be the lock-in options in the future
- Waste management is an opportunity (for both public and private sector) to recover resources for a sustainable future, to realize environmental, economic and social benefits

Source: The World Bank, UNEP

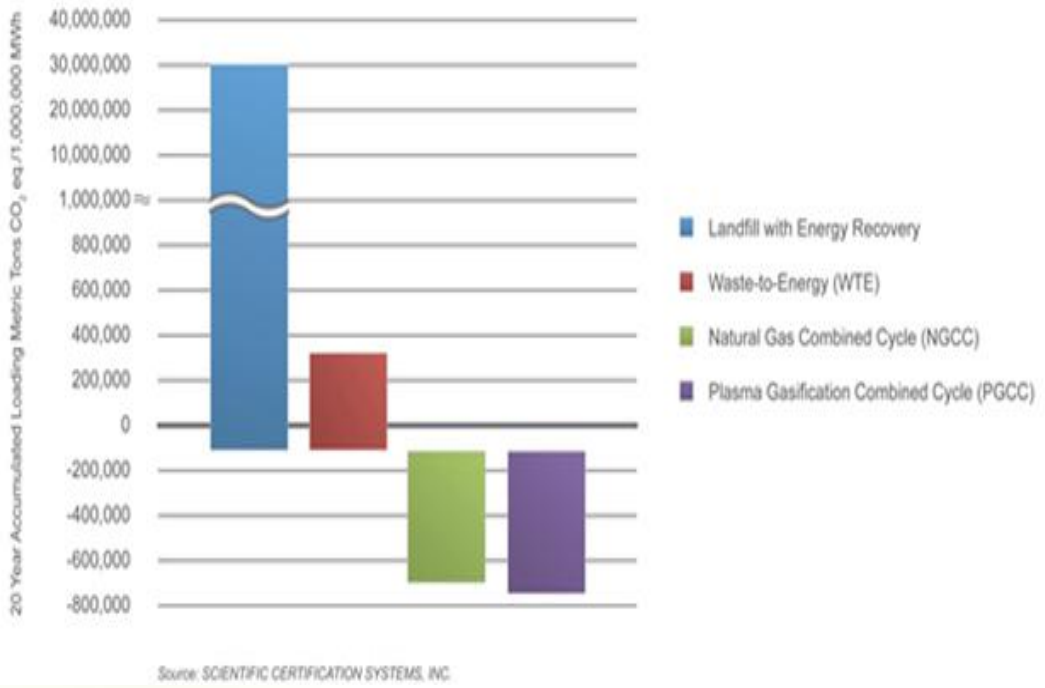
CO_2 Emissions
(Landfill vs. Thermal Treatment)

GHG Emissions Comparison

- Plasma gasification reduces greenhouse gas emissions (GHG) by over 50% on a lifecycle basis compared to conventional landfilling
- Emission levels from a combined cycle power plant using plasma gasification are similar to those from a natural gas fired power plant

- The use of waste as a feedstock in a plasma gasification power plant eliminates the GHG produced by otherwise landfilled waste and therefore the technology is expected to be RPS and REC eligible

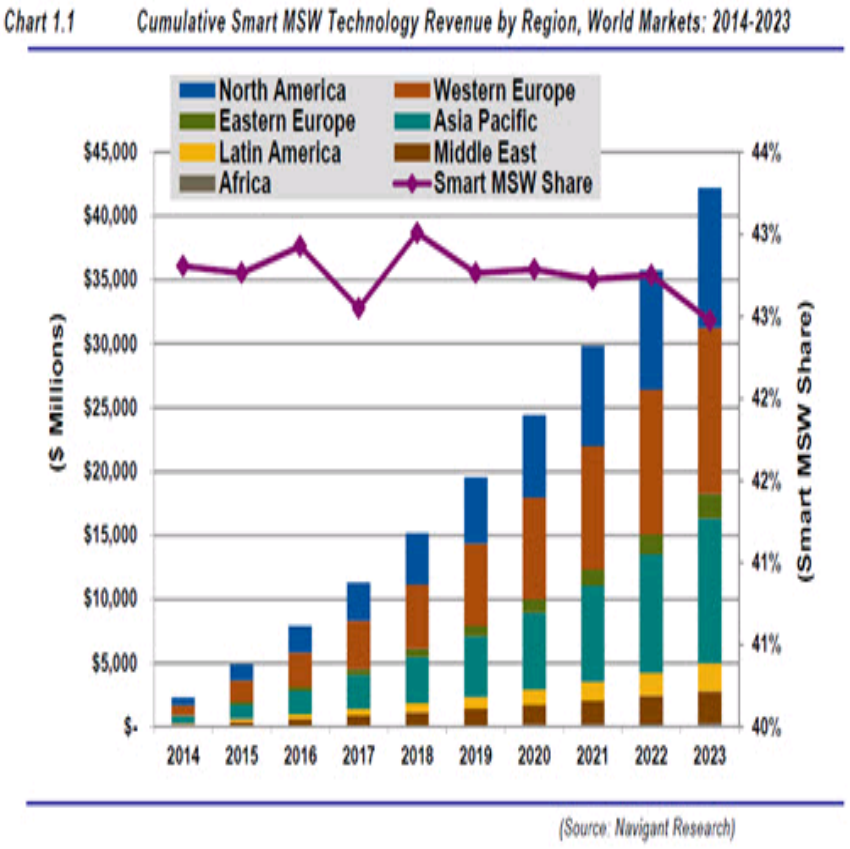
A 2010 report by Scientific Certification Systems comparing Landfill, Waste to Energy (incineration) and Plasma Gasification Combined Cycle configurations, concluded that a "Plasma Gasification Combined Cycle (PGCC) system provides the lowest greenhouse gas emissions of the evaluated systems for waste disposal."



Global Economic Impact
(Revenues & Employment)

MSW as an Opportunity

- Waste-to-energy (WTE) technologies are combustion, gasification and anaerobic digestion
- $42.2 billion in cumulative revenue; annual revenue from smart MSW technology (e.g. WTE) is expected to experience a 12.2% compound annual growth rate, significantly more than the anticipated 4% revenue growth from conventional MSW technology
- The market for WTE technologies is projected to reach $29.2 billion by 2022, up from $6.2 billion in 2012
- WTE plants will treat a minimum of 261 million tonnes of waste annually by 2022



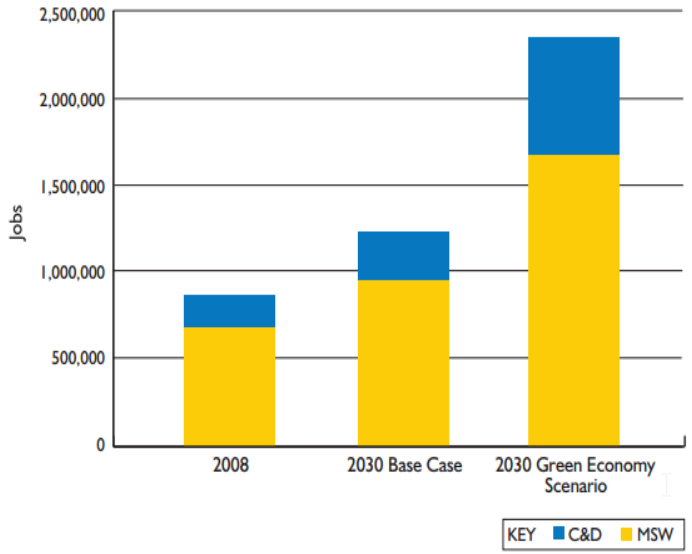
Source: Navigant Research

WASTE AS AN OPPORTUNITY

Job Creation

- The Green Economy Scenario with a 75% diversion rate generates 2.3 million total direct jobs — over 1.1 million more jobs than in the base case, and nearly 1.5 million more jobs than in 2008.

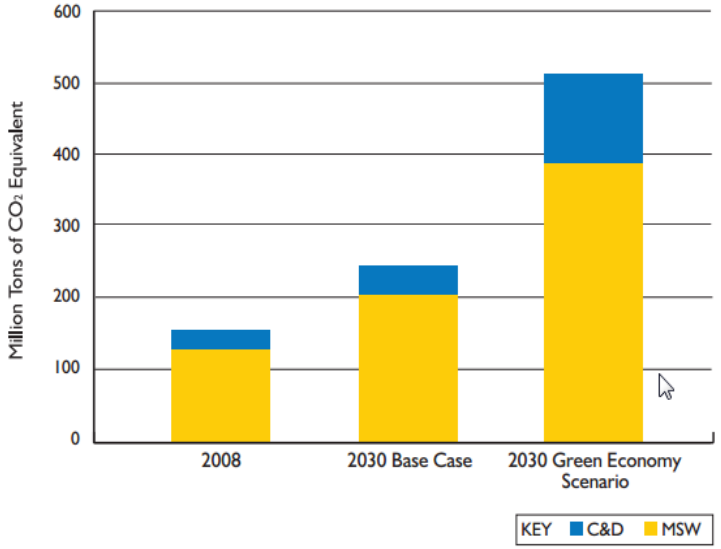
Figure ES-3
Total MSW and C&D Job Impacts



Emissions Reduction

- The combined additional GHG reductions achieved in 2030 in the Green Economy Scenario relative to the Base Case total 276 $MMTCO_2E$ (185 million tonnes from MSW and 91 million tonnes from C&D), equivalent to shutting down about 72 coal-fired power plants or taking 50 million cars off the road.

Figure ES-4
Climate Change Emissions Reductions from Diversion



Source: NRDC, BlueGreen Alliance

Technology Readiness for Waste Management

ALTERNATIVES FOR WASTE TREATMENT

BURY
Landfilling waste:

200 kWh (net) recovered per tonne of waste

RESULTS:
Passes the problem to future generations

BURN
Incinerating waste:

500-650 kWh (net) recovered per tonne of waste

RESULTS:
Creates ash requiring secondary processing or landfilling

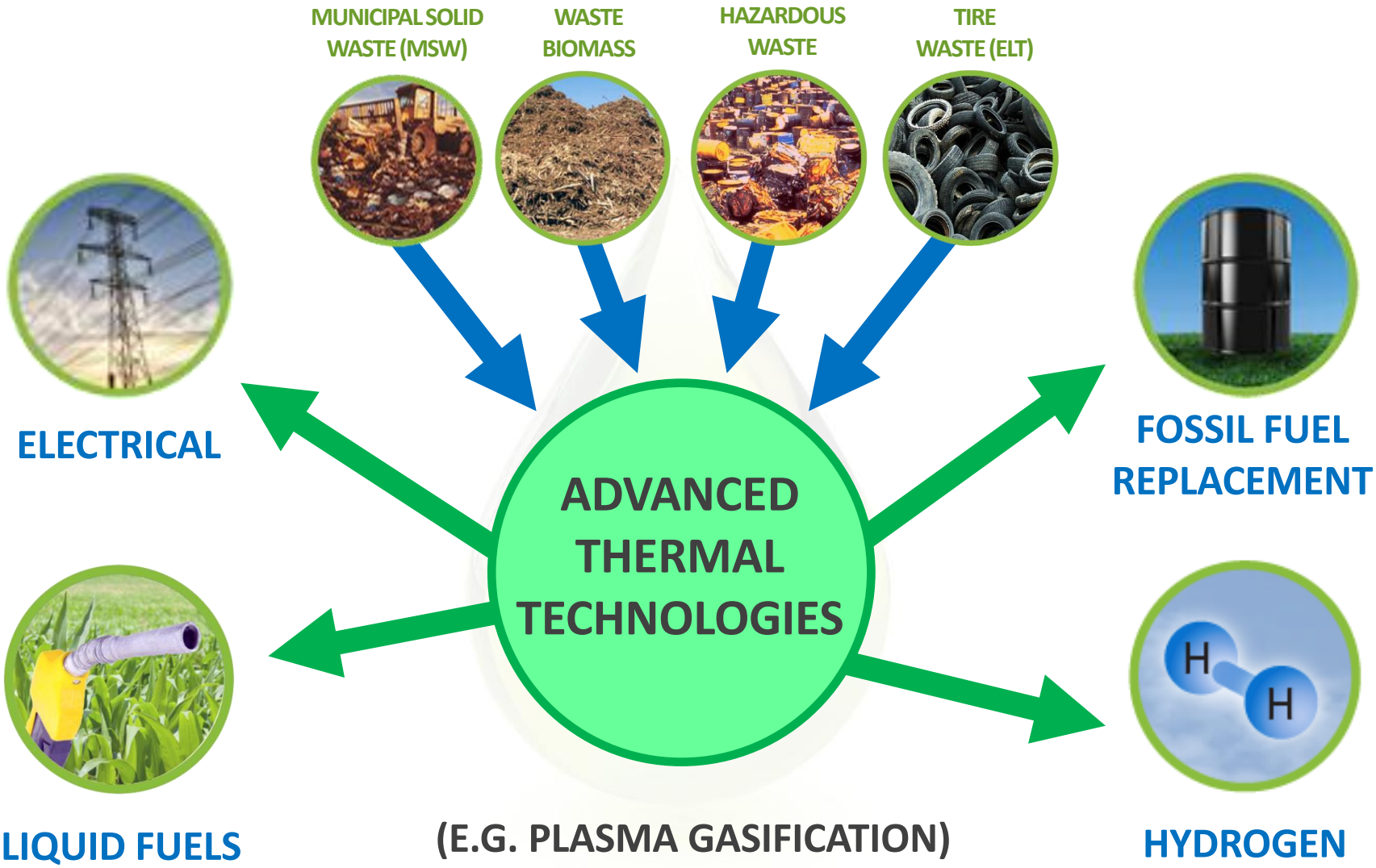
CONVERT
Advanced Thermal Treatment

In addition to electricity the plasma gasification process can also create: ethanol gasoline, diesel fuel or oil replacement

RESULTS:
Life without landfills

EVOLUTION OF THE WASTE CONVERSION PROCESS

WASTE TREATMENT USING ADVANCED THERMAL TECHNOLOGIES



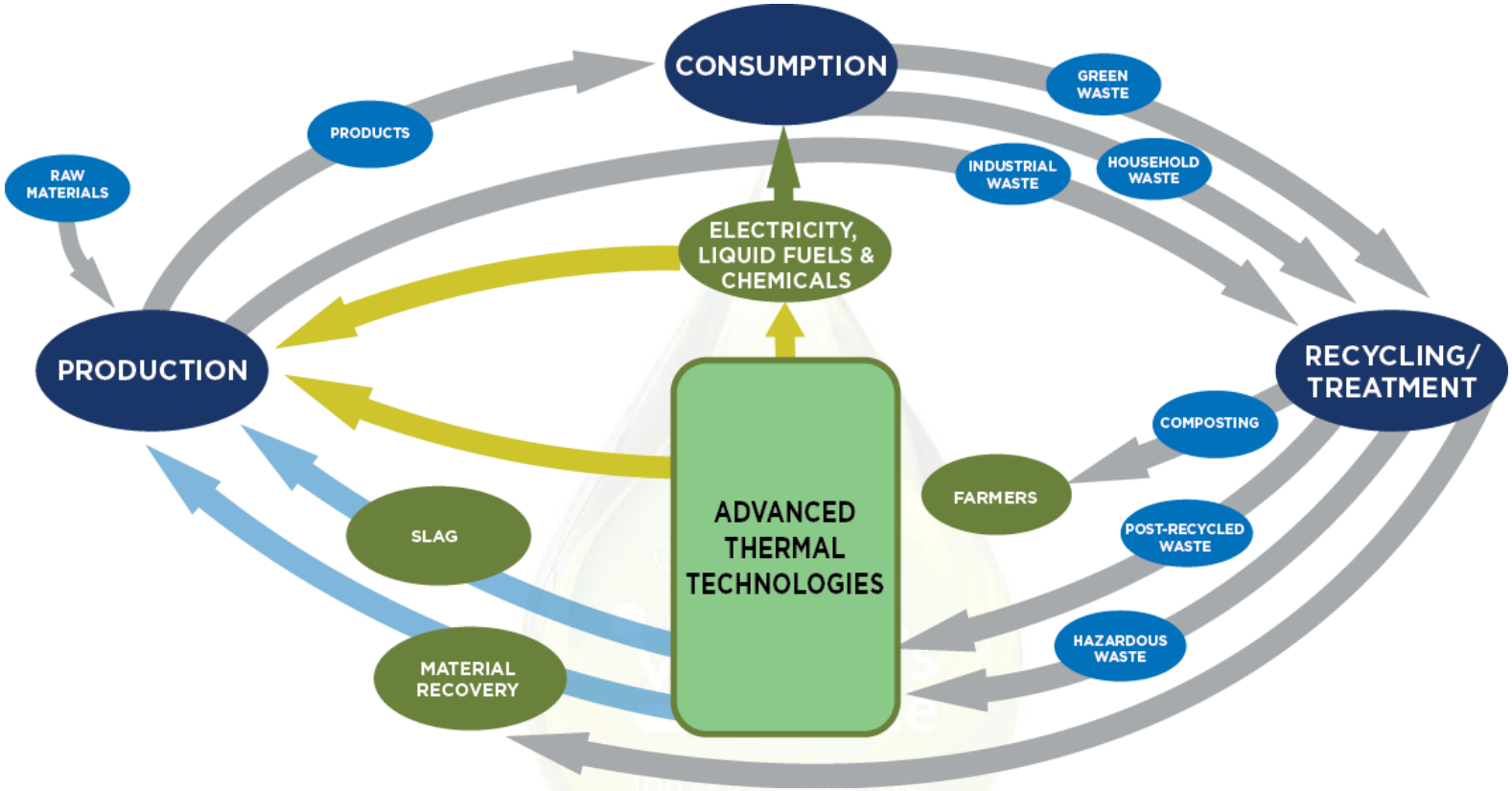
Waste Diversion Rate by Treatment Method

(E.g. 1000 tpd waste handling/treatment)

	Recycling/MRF	Incineration	Advanced Thermal Technologies
Waste Diversion	~20%	~70%	**~98%**
Waste for Treatment or Landfilling	~80%	~30%	**~2%**

- Recycling/MRF alone cannot eliminate majority of waste
- Incineration creates significant amount of residual waste that still require landfilling/disposal
- Advanced thermal technologies creates minimal residual waste for landfilling/disposal

ADVANCED THERMAL TECHNOLOGIES ARE PART OF THE 'CIRCULAR ECONOMY'



- Advanced thermal technologies are part of the 'circular economy' and product life-cycle
- E.g. Plasma Gasification is suitable for processing post-recycled waste/RDF or waste that cannot be recycled and require appropriate disposal (e.g. hazardous waste)

Waste-to-Energy in India:
(Proposed Tariffs, Policy Measures & Incentives)

Waste-to-Energy in India: Proposed Tariffs, Policy Measures & Incentives

Proposed tariffs:

- Bio-Power (biomass/gasification and bagasse cogeneration) - US ¢ 11.5 – 13.5
- Waste-to-Power (RDF route) - US ¢ 12

Policy measures:

- Interest subsidy to reduce the rate of interest to 7.5%
- Financial assistance of up to 50% of capital cost per MW for demonstration size projects (limited to Rs. 3 crores/US$ 448,800)
- Financial incentives for power generation per MWe (Rs. 15 lakh/US$ 22,440) ; cost-free waste feedstock supply to site; land on a long-term lease (30+ years)

Power generation incentives:

- MSW/RDF route (Rs. 15 million/US$ 224,400); MSW on gasification/pyrolysis /plasma arc (Rs. 39 million/US$ 583,440); Bio-methanation technology and processes
- Others: per project development assistance and capacity building initiatives

Waste Management - as a renewable source of energy

GLOBAL WASTE HAS SIGNIFICANT ENERGY DEVELOPMENT OPPORTUNITIES

ESTIMATED MUNICIPAL SOLID WASTE

MSW WASTE
~3.6 Million Tonnes/day

SYNGAS
37 Million Btu/day

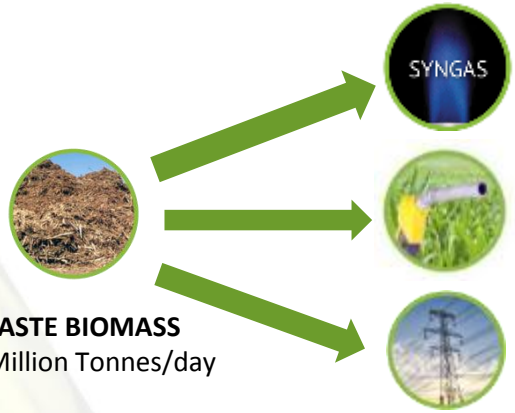
(OR)

LIQUID FUELS
3 Million Bbls/day

(OR)

ELECTRICAL
178 GW Capacity

ESTIMATED WASTE BIOMASS



WASTE BIOMASS
~14 Million Tonnes/day

SYNGAS
120 Million Btu/day

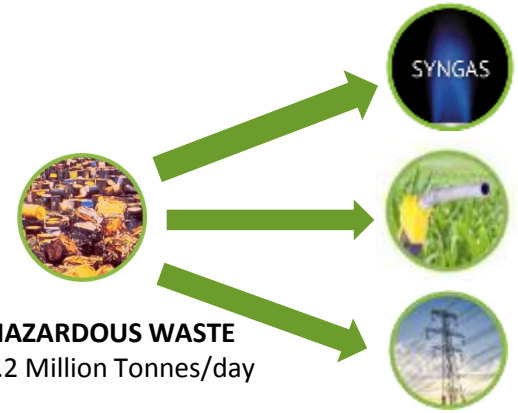
(OR)

LIQUID FUELS
12 Million Bbls/day

(OR)

ELECTRICAL
685 GW Capacity

ESTIMATED HAZARDOUS WASTE



HAZARDOUS WASTE
~1.2 Million Tonnes/day

SYNGAS
17 Million Btu/day

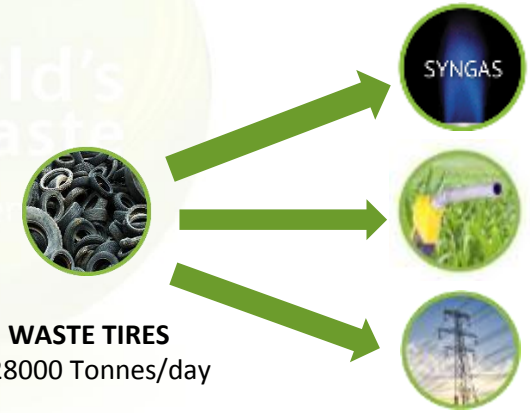
(OR)

LIQUID FUELS
874,000 Bbls/day

(OR)

ELECTRICAL
43 GW Capacity

ESTIMATED WASTE TIRES



WASTE TIRES
~ 28000 Tonnes/day

SYNGAS
520,000 Btu/day

(OR)

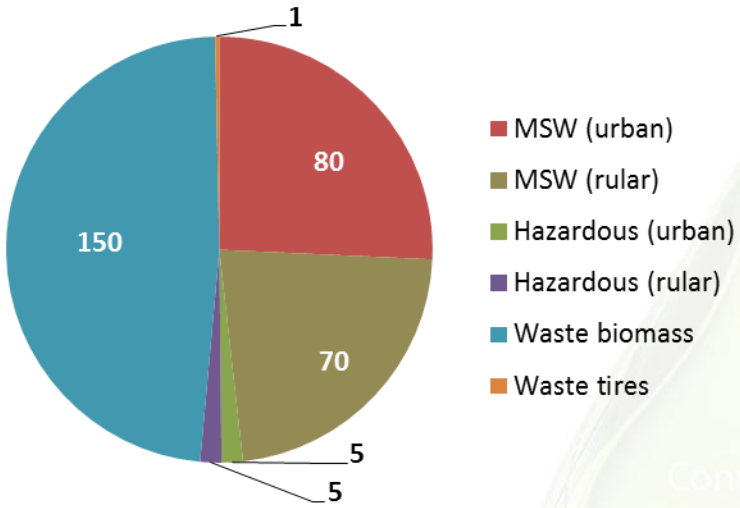
LIQUID FUELS
24,000 Bbls/day

(OR)

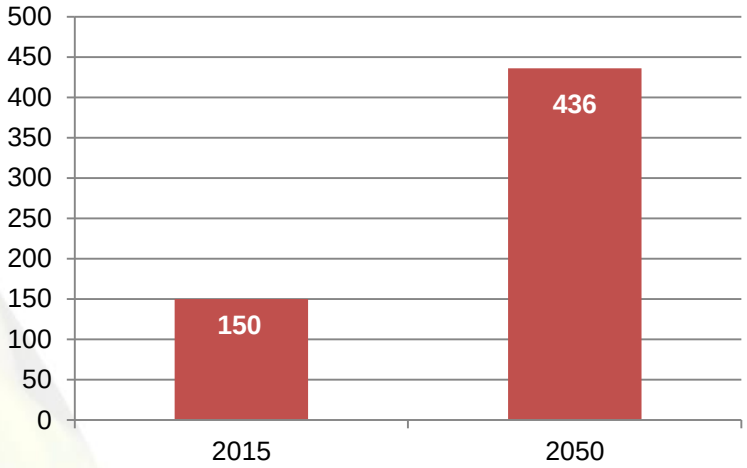
ELECTRICAL
1.4 GW Capacity

India's Waste Challenges

~80% of MSW is landfilled (approximate, million tpy):



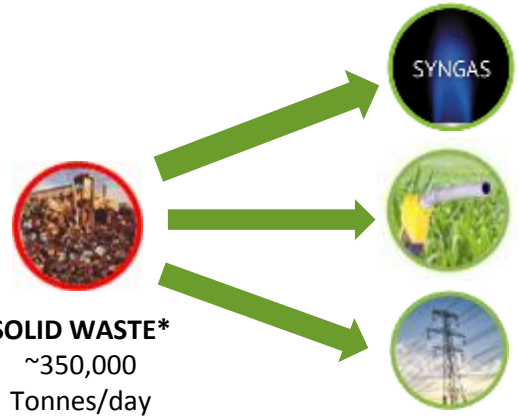
MSW generation (approximate, million tpy):



- Growing population, urbanization increases waste volumes and environmental concern
- On a cumulative basis, current 'urban' MSW generation is **~80** Million Tonnes/year; (estimated to reach **~436** Million Tonnes/year by 2050)
  - It is estimated, that an additional **70-80** MM TPY of 'rural' MSW would be generated but unaccounted (per capital basis)
  - **~80%** of MSW is landfilled and **~20%** is treated/recycled
- Additional waste streams are: hazardous/medical (**~5** MM TPY); surplus waste biomass (**~150** MM TPY; waste tires (**~1** MM TPY) are generated
  - It is estimated, that an additional **1-3** MM TPY of 'rural' hazardous waste would be generated but unaccounted

MONETIZING WASTE IN INDIA: A RENEWABLE SOURCE OF ENERGY

ESTIMATED SOLID WASTE



SOLID WASTE*
~350,000
Tonnes/day

SYNGAS
3.6 Million Btu/day

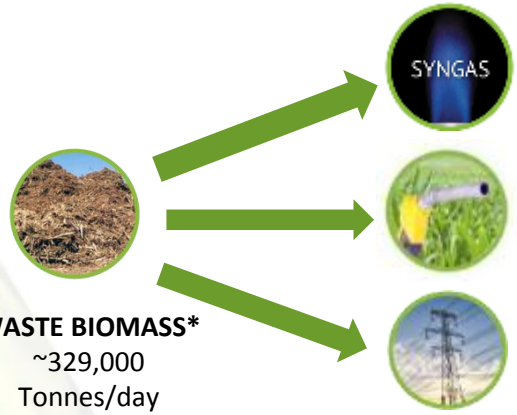
(OR)

LIQUID FUELS
300,000 Bbls/day

(OR)

ELECTRICAL
17.5 GW Capacity

ESTIMATED WASTE BIOMASS



WASTE BIOMASS*
~329,000
Tonnes/day

SYNGAS
3.4 Million Btu/day

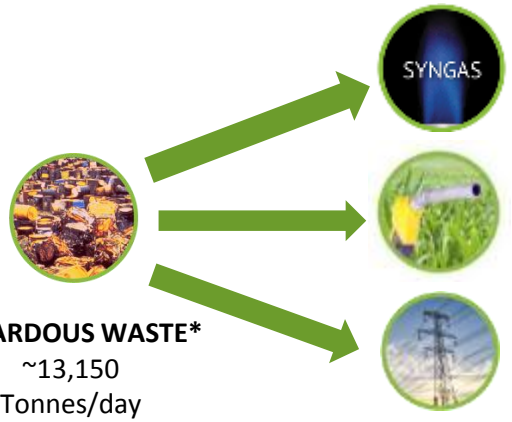
(OR)

LIQUID FUELS
283,000 Bbls/day

(OR)

ELECTRICAL
16 GW Capacity

ESTIMATED HAZARDOUS WASTE



HAZARDOUS WASTE*
~13,150
Tonnes/day

SYNGAS
137,000 Btu/day

(OR)

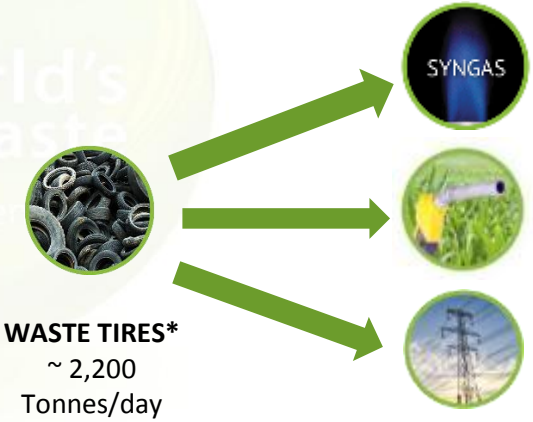
LIQUID FUELS
11,000 Bbls/day

(OR)

ELECTRICAL
650 MW Capacity

*~80% of urban/rural waste volumes)

ESTIMATED WASTE TIRES



WASTE TIRES*
~ 2,200
Tonnes/day

SYNGAS
23,000 Btu/day

(OR)

LIQUID FUELS
1,900 Bbls/day

(OR)

ELECTRICAL
110 MW Capacity

THE WRAP UP

- Growing population/urbanization increases waste volumes and environmental concern
- Waste management is a global challenge but presents multiple opportunities
- Converting waste into renewable energy for the growing economies
- Waste management has global economic benefit on revenue growth and employment opportunities
- Some governments are providing meaningful regulations, policy framework and incentives to accelerate the development of the waste-to-energy sector
- Advanced thermal technologies (e.g. Plasma Gasification) provide clean, reliable and flexible waste-to-energy solutions
  - Diverting multiple waste streams from landfills (~98%), while creating power, liquid fuels or as a fossil fuel replacement
  - Enable governments/municipalities to implement their mandates on waste reduction, reuse, recycling (3Rs), while fostering the 'circular economy' plan.

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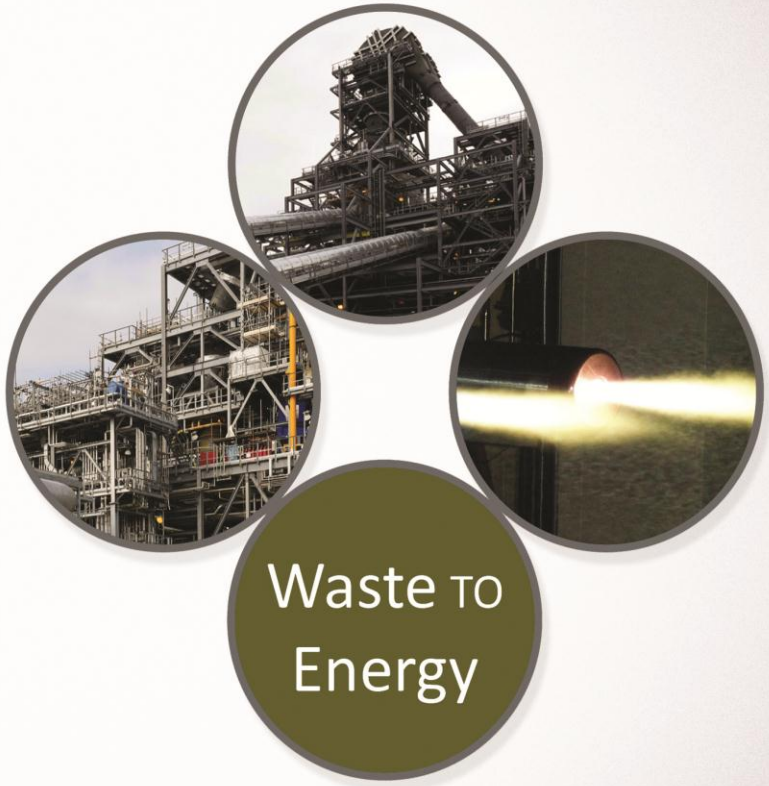

THANK YOU