

Safe Disposal of Different Solid Waste Streams and Energy recovery using Thermal Plasma Technology

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Waste Generation Data of India:

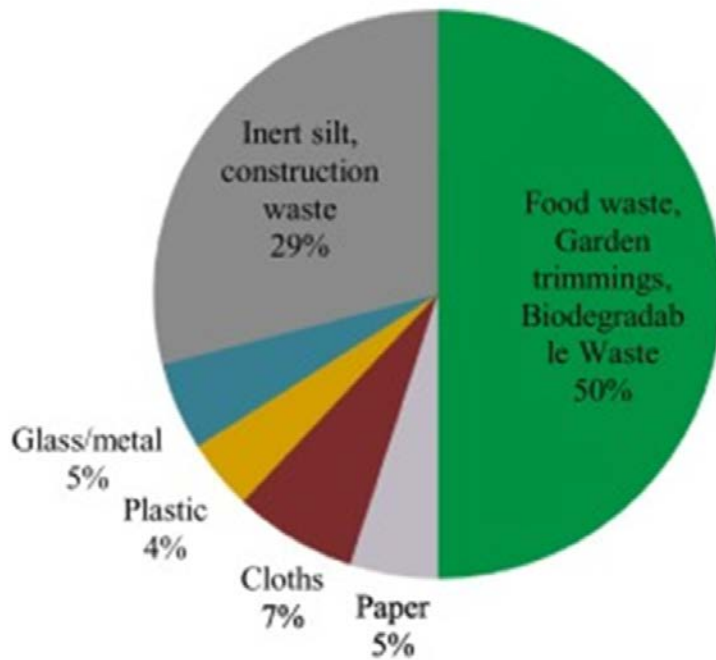
- In India nearly 1.5 Lakh tons MSW is generated every day (data from Swatchh Bharat Mission Report).

- Millions of Tons of tyre waste are piling up
- 20 Lakh Tons/year E-waste is generated
- Medical waste : Around 60000 tons per day biomedical waste is generated In India. **few 10's of tons/day** in each major cities in India.

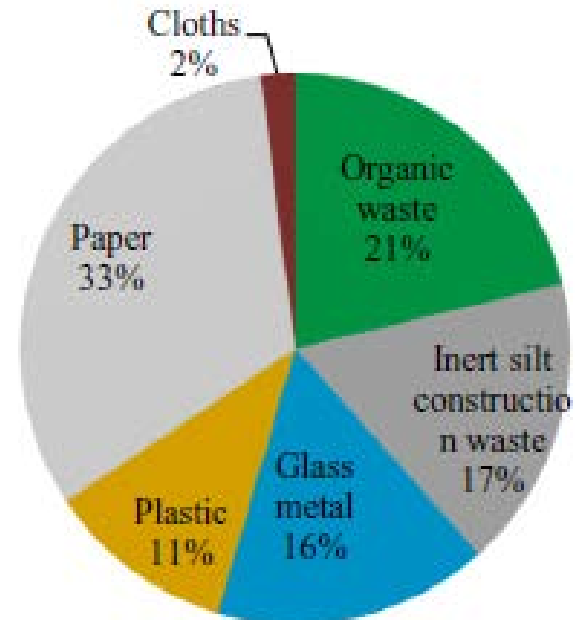


A typical waste composition

Indian Cities



Cities in Developed Countries



Akhilesh kumar et. al. "Recent trend in solid waste management and potential for the future Indian Industries", A review paper in current research in environment sustainability, ELSEVIER

Conventional Approach: Incineration

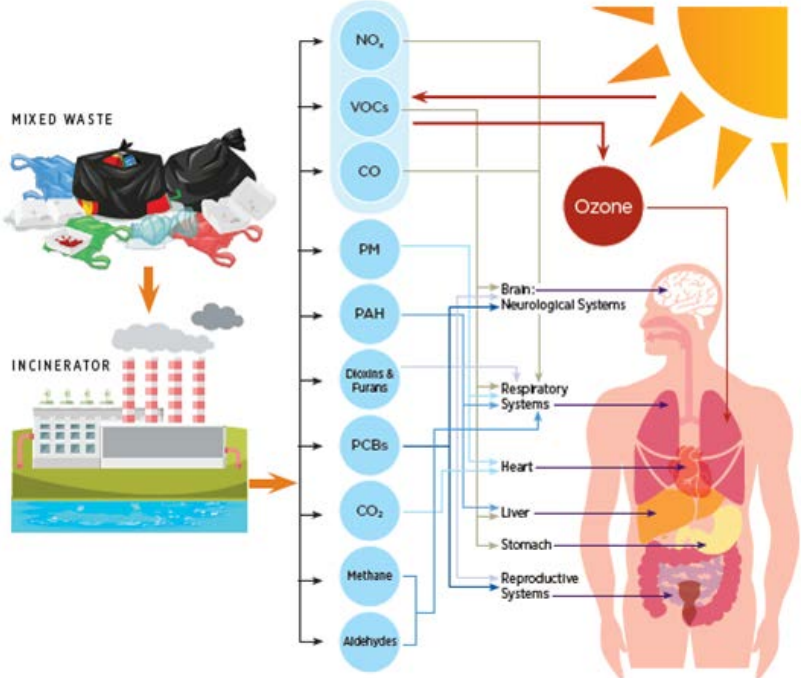


Incineration – Burning of waste in Primary In excess of air (Cold pockets)



Dioxin-TCDD

Toxic Exposure from Incineration



- Direct Burning of Waste
- Large quantity of Air
- Produce PAH, Dioxins, Furans, PM, NOx
- Environment Polluting

Necessity of a Safe Technology – Environment Friendly solution !!!

Plasma Pyrolysis – An Ideal Technology for Safe Disposal of waste

- High temperature is generated using plasma torch that break down the Hazardous & toxic compounds into harmless elemental constituents – **NO DIOXINS & FURANS**
- Inorganic materials are converted into vitrified mass (**highly resistant to leaching**)
- organic mass(**>99% volumetric reduction**)
 - Converted to fuel gases – **Energy recovery**
syn gas (H_2 , CO) and CH_4 mainly.

Plasma Torch : The Work Horse in Pyrolysis/Gasification Technology



Water cooled Plasma Torch



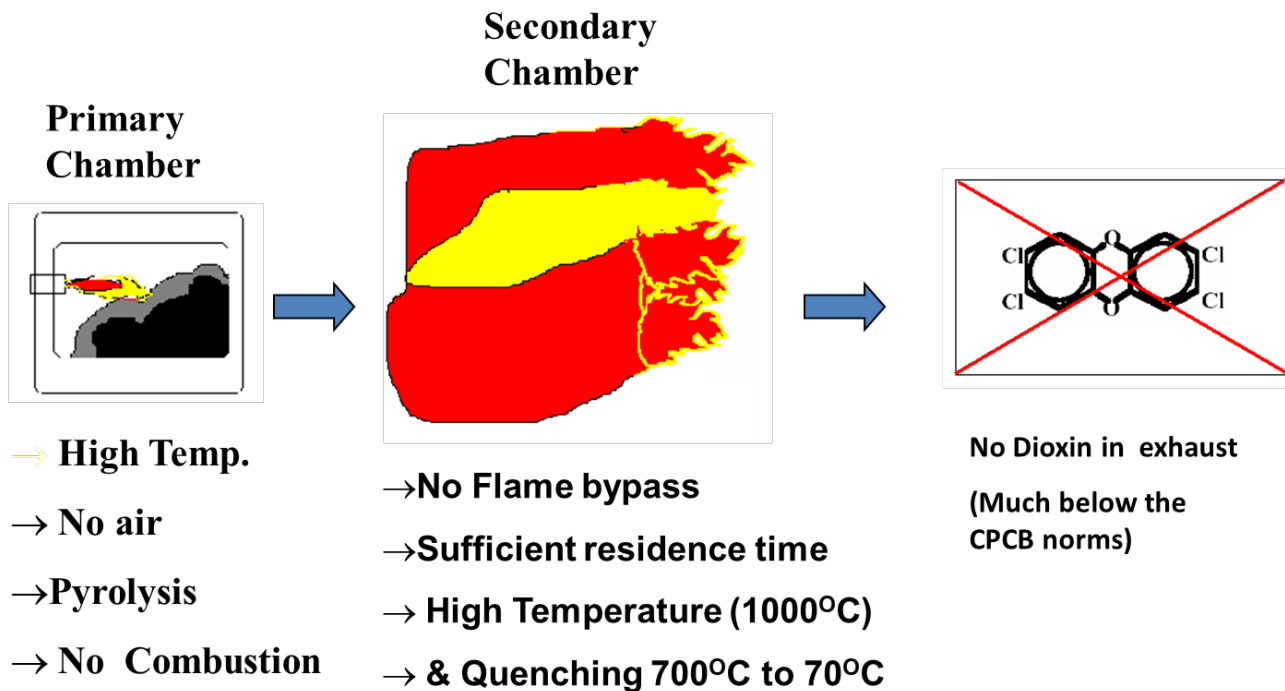
Plasma torch provides

1. Extremely high temperature
2. High directed energy flux
3. Fast heating: due to $\sim 5000K$ core temperature
4. High processing rates

Graphite based
plasma torch
with no water
cooling



How does Plasma Pyrolysis System destroy toxic molecules?



Pollutants	CPCB India standards	Emissions from Plasma Pyrolysis System
CO	≤ 100 mg / Nm ³	40-85 mg / Nm ³
NOx	≤ 400 mg / Nm ³	7-25 mg / Nm ³
PM	≤ 50 mg / Nm ³	31-52 mg / Nm ³
Dioxins & Furans	≤ 0.1 ng / Nm ³ TEQ	0.01 – 0.05 ng / Nm ³ TEQ



“Plasma Pyrolysis Technology Recognized by MoEF/CPCB for safe disposal of Biomedical Waste”

[Published in the Gazette of India, Extraordinary, Part II, Section 3, Sub-section (i)]
GOVERNMENT OF INDIA MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE
(MoEF & CC) NOTIFICATION New Delhi, the **28th March, 2016**

<http://www.moef.gov.in/sites/default/files/BMW%20Rules,%202016.pdf>

Plasma Pyrolysis/Gasification Technology Transferred to Industries

A non-exclusive technology transfer :

- For Organic Waste (paper, plastics etc.) disposal :

- M/s B.L. Engineering, Ahmedabad
- M/s Bhakti Energy, Rajkot
- M/s G.P. Green Energy System Ltd., Kolkata
- M/s Excel Industries Limited, Mumbai

- For Biomedical Waste Disposal:

- M/s Bhagwati Pyrotec Pvt. Ltd (Limited exclusivity- now over)
- M/s Ankur Scientific Pvt. Ltd., Vadodara (Non-exclusive)
- M/s Bhakti Energy, Rajkot (2023)

Global Status of the Plasma Pyrolysis/Gasification Technology

1. The PLASCON process, developed by CSIRO and SRL Plasma Ltd in Australia in the 1990s, uses a dc plasma torch with a tungsten cathode, PCB destruction & removal efficiency 99.999%.
2. Alter NRG in Japan using Westinghouse torch for Plasma Gasification of MSW and other organic waste to produce Plasma Converted Gas for multiple applications.
3. PEAT International's plasma-arc 60 kg/hr system working at Shanghai, China for medical waste and oil refinery sludge.
4. More than 10 plants are currently operational in Australia, Japan, USA and Mexico, South Korea, India destroying halons and CFCs, hydrofluorocarbons (HFCs), PCBs, insecticides, MSW and the waste liquid from herbicide manufacture.
5. More thermal plasma systems operational in the world however it is not possible to cover all due to limited time.

Comparison of 10 and 100 TPD thermal plasma plants for MSW

Items	10 TPD scale	100 TPD scale
Thermal plasma consumption	0.817 MWh/ton	0.447 MWh/ton
Heat loss from effluent gases of stack	16%	10%
Heat loss through system walls	14%	7%
Energy recovery	Not used	Used through steam turbine

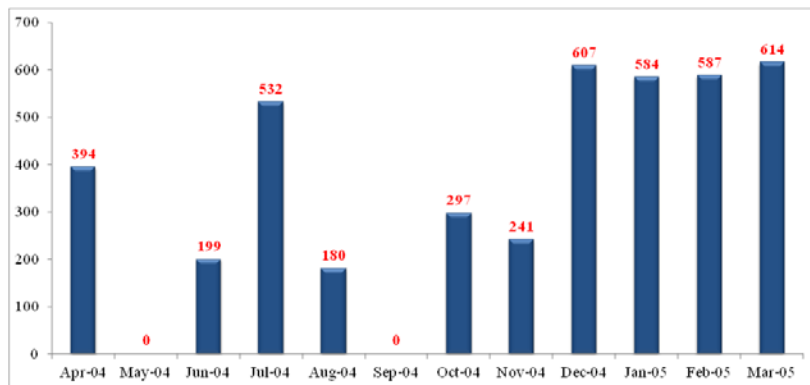
Courtesy from a book chapter on "Thermal Plasma Gasification of MSW" *Book Edited by : Y. Yun, ISBN 978-953-51-0818-4*

Plasma System's Developed for Waste Disposal at Institute for Plasma Research:

15kg/hr Plasma Pyrolysis Demo System commissioned at Goa Medical College, Bambolim, Goa in 2004 through Dept. of Sci. & Technology (DST), Govt. of India funding



Kg of waste



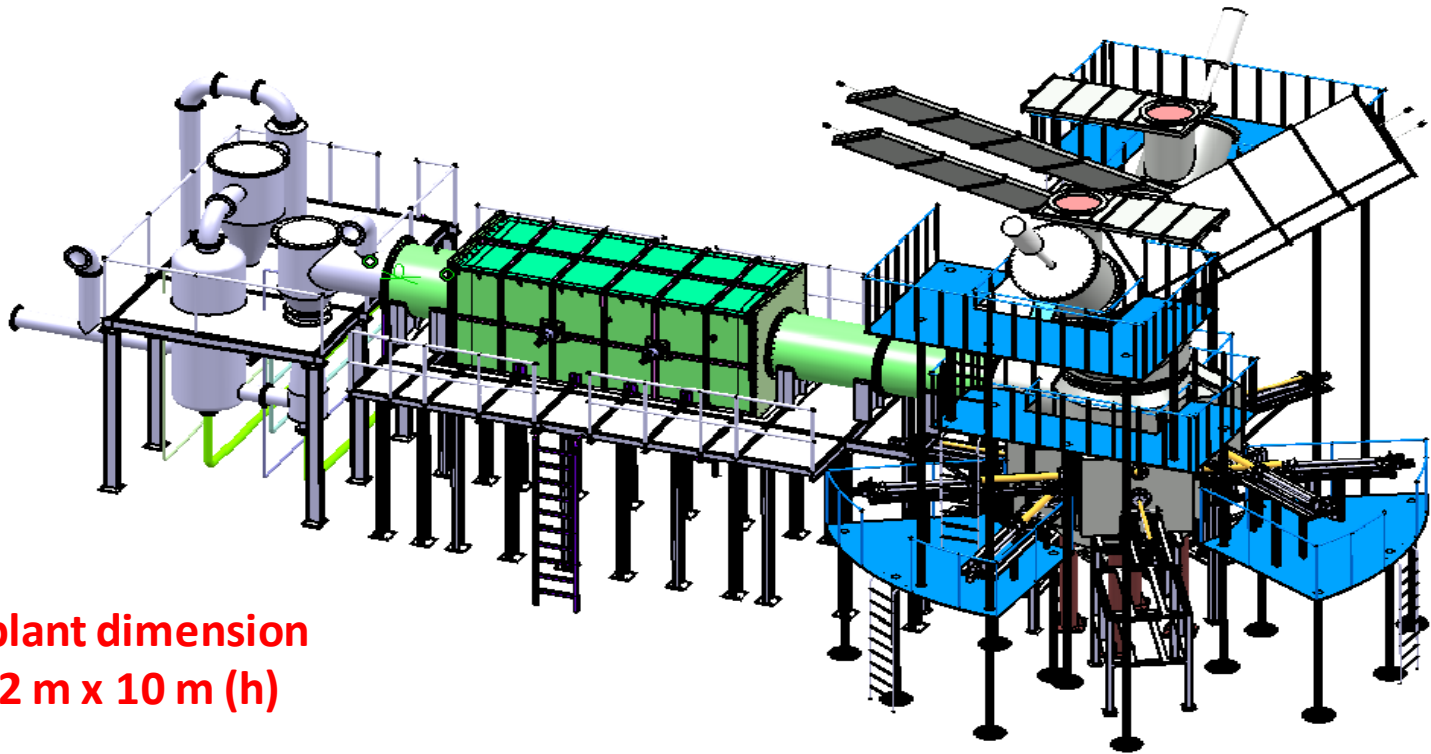
Per month biomedical waste disposed in kgs in Goa system, more than 3.5 tons of waste disposed in 1 year duration



1 ton/day (TPD) Plasma Waste Disposal System Developed at FCIPT Project was funded by DST

IPR is developing 5 TPD plasma system that will be commissioned at Homi Bhabha Cancer Hospital Site, Varanasi, India (DAE Funding)

It will serve the waste disposal need of 10,000 bed hospital.



**Overall plant dimension
35 m x 12 m x 10 m (h)**

5TPD Plasma System : Power source 3 nos. (100 kW each), Waste feeder chamber and primary chamber assembly , secondary chamber and gas cleaning system including conceptual support structure and service platform (will be tested at IPR by Jan 2024)

Wealth from Disposal & Treatment of Biomedical Waste Proposed Business Model (Waste from 10000 beds)

- i. Typically 200 gm infectious hospital waste is produced per bed. (Yellow bag)
- ii. Plastics (IV fluid bottles etc) 200 gm (Red bag)
- iii. Disposal Cost + Maintenance by Thermal Plasma Rs 30/- per kg (Yellow bags)
- iv. Sterilization and Shredding Cost of Plastics (Red bag) Rs 2.00 per kg

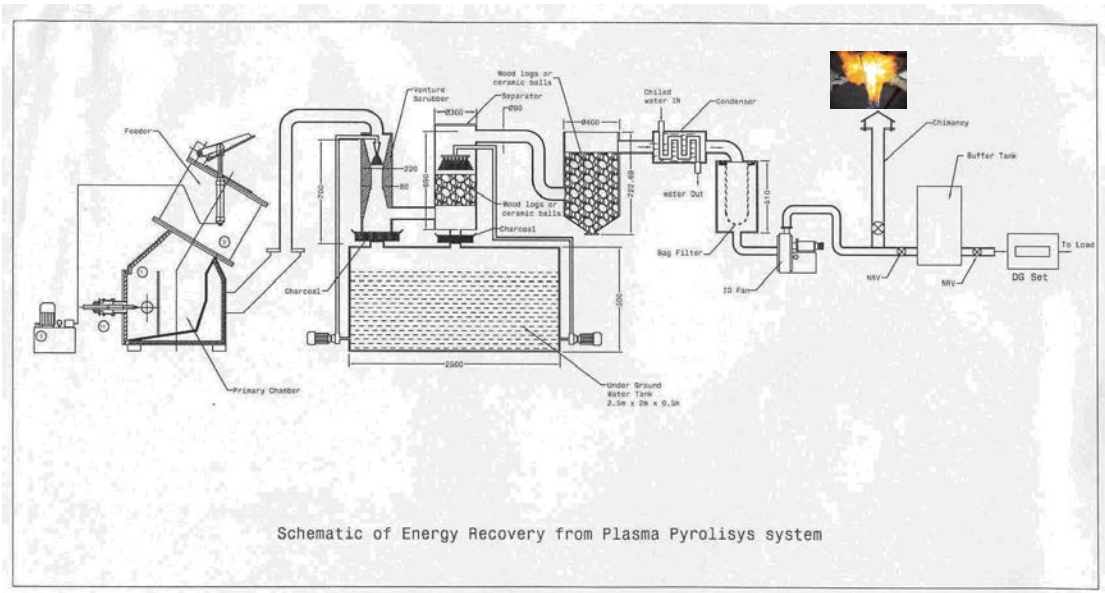
- (i) 10000 beds you will get 2000 kg infectious waste (Yellow Bags)
- (ii) 10000 beds you will get 2000 kg plastic waste (Red Bags)
- (iii) Hospitals have to pay Rs 10/- per bed per day for safe disposal of their waste.
- (iv) Plastic waste sterilized & shredded are sold @ Rs25/- per kg

- Disposal Cost Yellow Bag:
 $\text{Rs } 30.0 \times 2000 = \text{Rs } 60000/-$
 - Disposal Cost Red Bag:
 $\text{Rs } 2.0 \times 2000 = \text{Rs } 4000/-$
 - Collection & Transportation of waste per day
 $= \text{Rs } 10000/-$
- Total Cost = Rs 74,000.00 Per Day**

Per day Amount Collection:

- Hospitals pay : $\text{Rs } 10 \times 10000 = 1.0 \text{ L}$
- Earning from Plastics $\text{Rs } 25 \times 2000 = \text{Rs } 50000/-$
- **Net Profit = Rs 76,000/- per day (\$27400 per month)**
- **Payback period 3.5 years in India**

Demonstration of Energy Recovery from Waste using Plasma Pyrolysis Technology



1. Pyrolysis Chamber
2. Gas Cleaning System
3. Generator set

Cleaned Pyrolysis Gases are entered into IC engine & Combusted. This in turn produce electrical Energy (From 15 kg/hr (70% cotton + 30 % PE) waste 15 kVA electrical energy output was demonstrated in 2007) .

Waste:

- **Plastics**
- **Petroleum Residue**
- **Biomass etc.**



Quality of pyrolysis gas was checked by intensity of flame in chimney

**Gases formed in Plasma Pyrolysis of
100% Polyethylene waste in 15kg/hr system**

Gases	Volume
Hydrogen	28-48 %
Carbon monoxide	20-35 %
Methane	15 -20 %
Higher Hydrocarbon*	4 – 7%
Carbon dioxide	4 – 5%
Nitrogen	3 - 7%

Soot particles also formed which are gasified in process chamber.

Syngas Generation from Plasma Gasification of Petroleum Industry Waste



Pet Coke



Sludge from Petroleum Refinery



Vacuum Residue

Composition of various FEED materials

Feed Material	Composition					
	C %	H %	O %	N %	Sulphur %	CV Kcal/Kg
Vacuum Residue	86.12	11.81	<1	-	1.95	11200
Pet Coke	86.3	3.6	<1	-	4.0	6800
Tank Sludge	51.45	2.22	45.9	0.12	0.21	3610

**Petroleum waste FEED conversion into Syn gas at fixed
power of 30kW**

FEED	Parameters	Steam Flow rate	Mixture of Oxygen and steam	Oxygen Flow rate
Vacuum Residue (8kg/hr)	Flow rate	166 LPM	Steam: 166 LPM Oxygen: 80 LPM	90 LPM
	Syn Gas % (H₂ + CO)	67.63%	73.8%	<u>85.4%</u>
Tank Sludge (9 kg/hr)	Flow rate	125 LPM	Steam: 125 LPM Oxygen: 40 LPM	30 LPM
	Syn Gas % (H₂ + CO)	71.8%	66.4%	70.5%
Pet coke (6Kg/hr)	Flow rate	185 LPM	Steam: 185 LPM Oxygen: 100 LPM	70 LPM
	Syn Gas % (H₂ + CO)	68.5%	70.81%	<u>77.5%</u>

Limitations in Conventional Gasification of MSW

- Low calorific value of MSW i.e. max 1800 kCal per kg in India. It has more than 50% of inorganic debris.
- Require very large systems (~ 100 TPD or more) to reach to break even point
- Conventional Gasifier generates pollutant tar (polycyclic aromatic compounds)
- Tar may lead to blockage of downstream (gas cleaning systems)
- Elimination of tar is essential to use the producer gas for electricity generation.

Advantages in using Plasma Assisted Gasifier

- Plasma Assisted Gasification is environment friendly.
- Tar free and higher calorific value producer gas is generated.
- Simple downstream processing is required as there is no tar formation.
- Water effluent free from tar and hence, no special water treatment is required.

* A Review on Biomass Tar Formation and Catalytic Cracking, Ronghua Zeng and et al.,

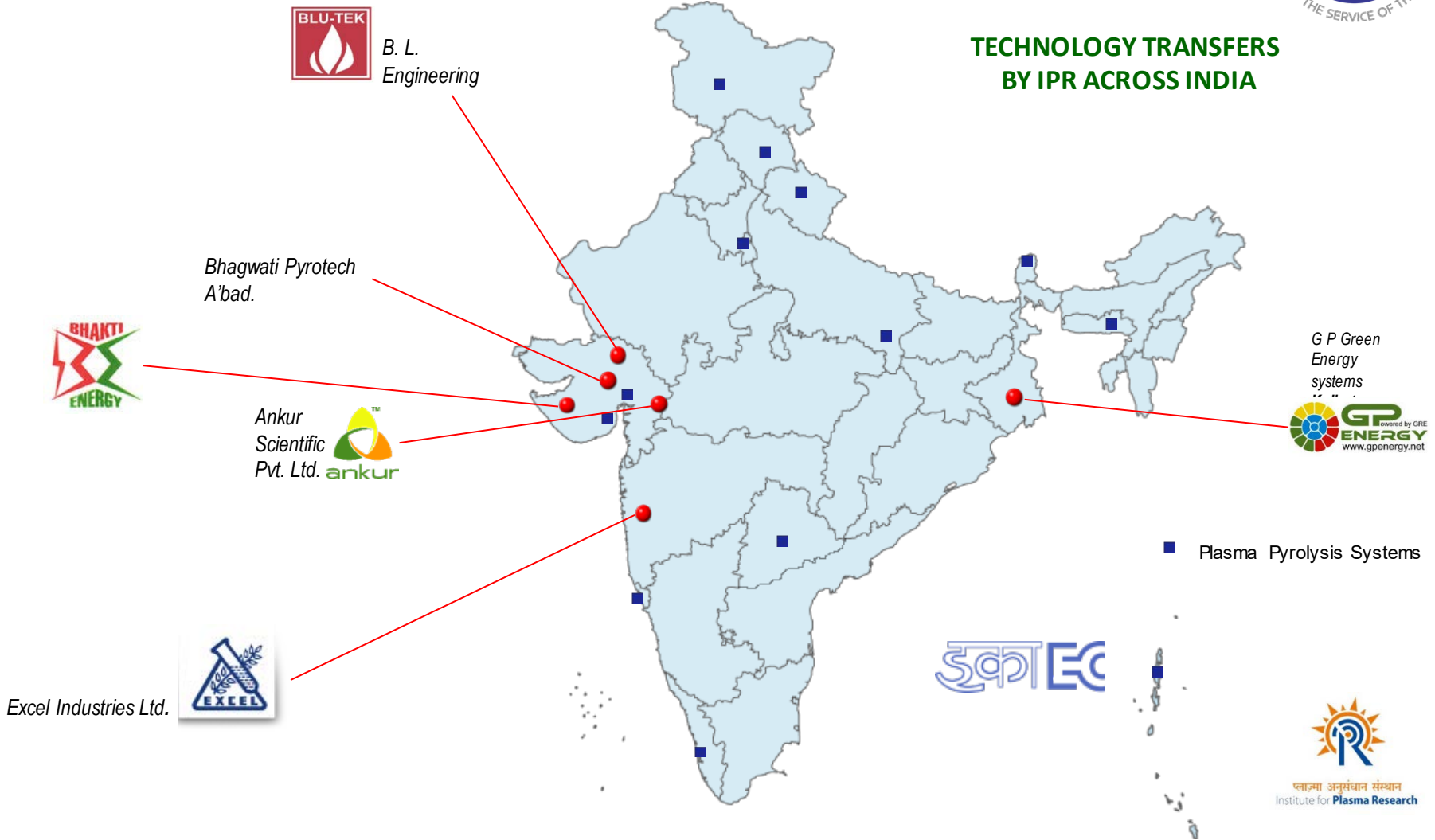
Summary

1. Thermal plasma technology has enormous potential for –
 - (i) E-waste disposal and **precious metal recovery and energy recovery**
 - (ii) Safe disposal of Hazardous waste (**PCBs, coolants-CFCs**, incinerator ash, asbestos, etc.),
 - (iii) **infectious biomedical waste** can be disposed safely & disposal is economically viable.
2. Plasma gasification is suitable for High calorific value industrial and plastic waste disposal and energy recovery from it. **MSW would require tipping fee as well as segregation of waste at source.**
3. The plasma gasification technology is **environmentally responsible** and if norms followed properly, then the plasma based technology has great potential to sustain in the market.

IPR's Societal Plasma Technologies- PAN India



TECHNOLOGY TRANSFERS BY IPR ACROSS INDIA



Thank you for your kind Attention !!

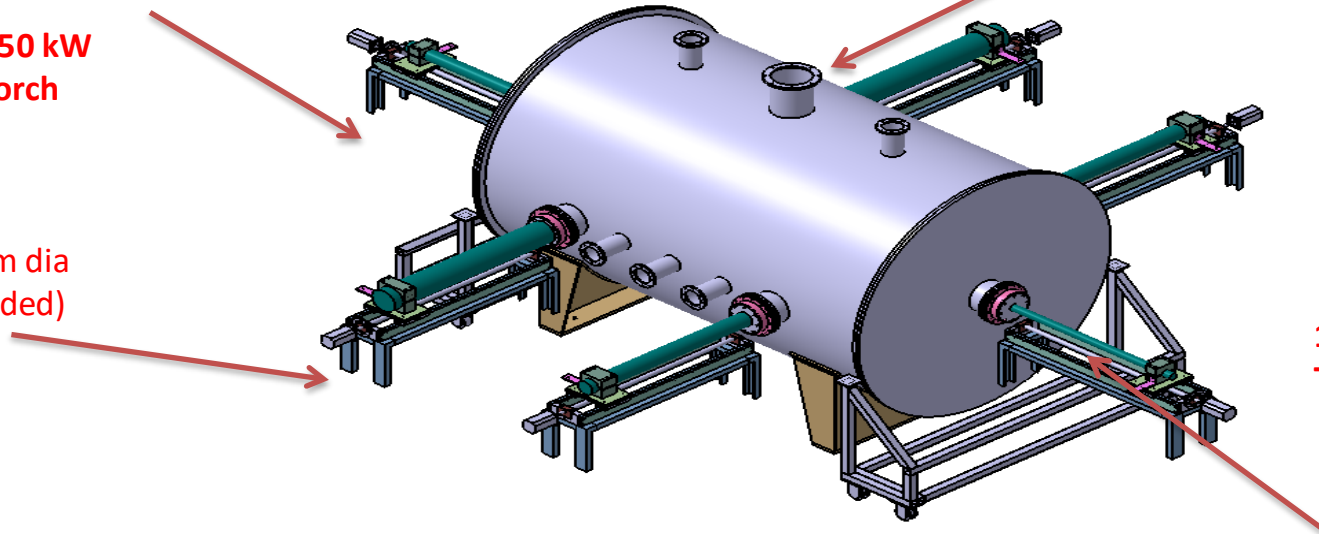
High Power Plasma Arc System

Cathode
(75mm dia)

250 kW
Torch

Anode
150 mm dia
(Grounded)

Gas Output port
Connected to Gas
cleaning system and ID
fan



100 kW
Torch

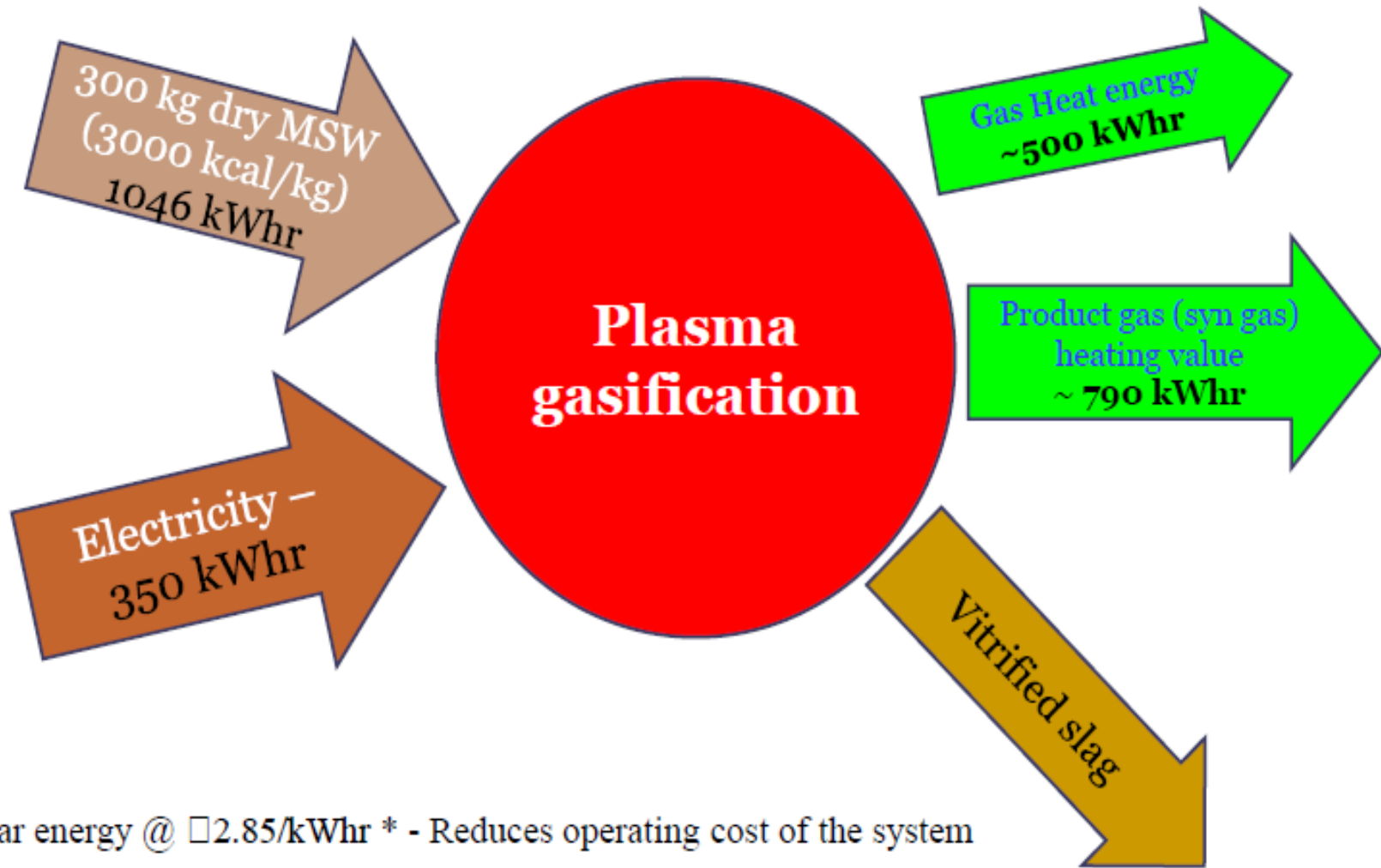


60 cm long plasma plume

- 100 kW tested for 120 hrs continuously
- 250 kW arc will be tested shortly once power supply is delivered.
- A patent filed on “An apparatus to generate large plasma arc plume for waste disposal and thermal processing applications” Indian Paten Appln no. 202121039223

300 kg/hr Plasma Arc system

- Segregation of MSW is important
- High calorific value waste 3000 kcal/kg



Solar energy @ \square 2.85/kWhr * - Reduces operating cost of the system

<http://www.thehindubusinessline.com/info-tech/infosys-produces-solar-power-at-285kwhr-plans-expansion/article9398901.ece>

Output Electrical energy = $1290 \times 0.3 = 387$ kWh
Self Sustaining Model