STARTECH ENVIRONMENTAL CORP.

Presents:

Thermal Conversion of Wastes to Hydrogen for Fuel Cell Applications

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Introductions

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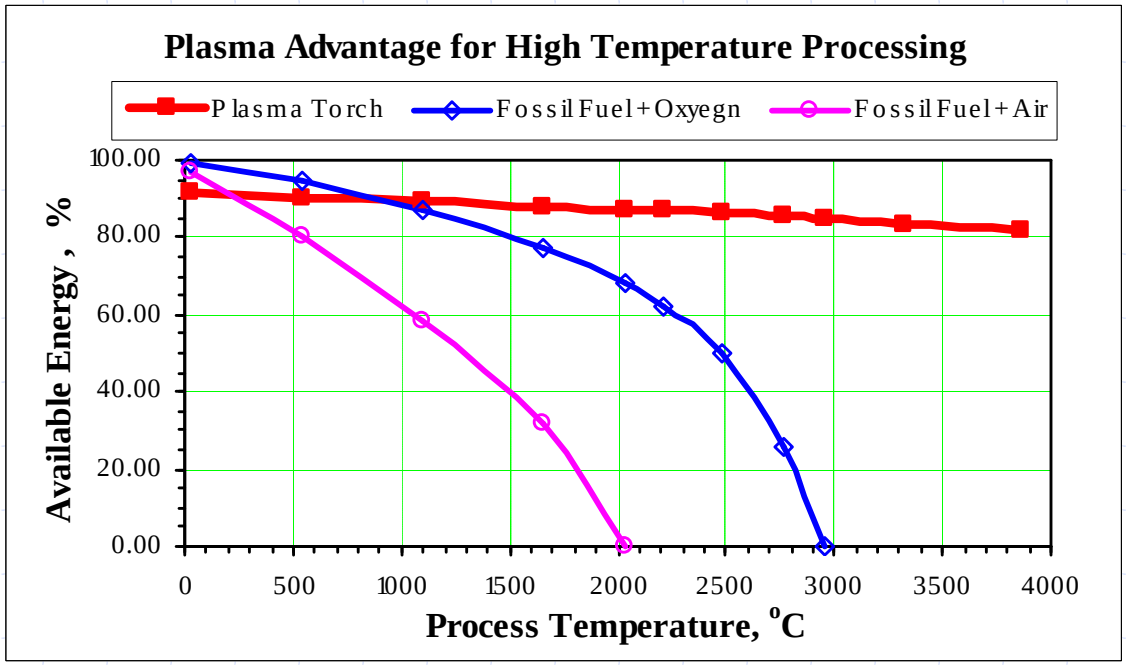
What are the Energy Needs? Now and in the Future.

- Energy from calorific waste streams.
- Distributed energy production.
- Distributed hydrogen production.
- Reduce dependence on fossil fuels.

The Startech Plasma Converter System and StarCell™ Hydrogen Separation System Can Satisfy These Needs.

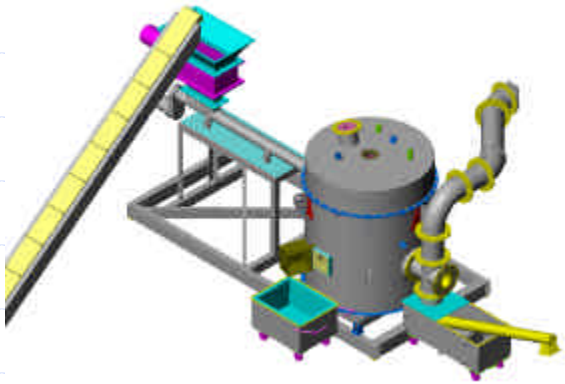
Advantages of Thermal Plasma

- **Superior Environmental Performance**
- **"Massless Heat"**
- **High Temperatures**
- **Recover Valuable Commodities: Hydrogen**
- **Low Gas Volumes**



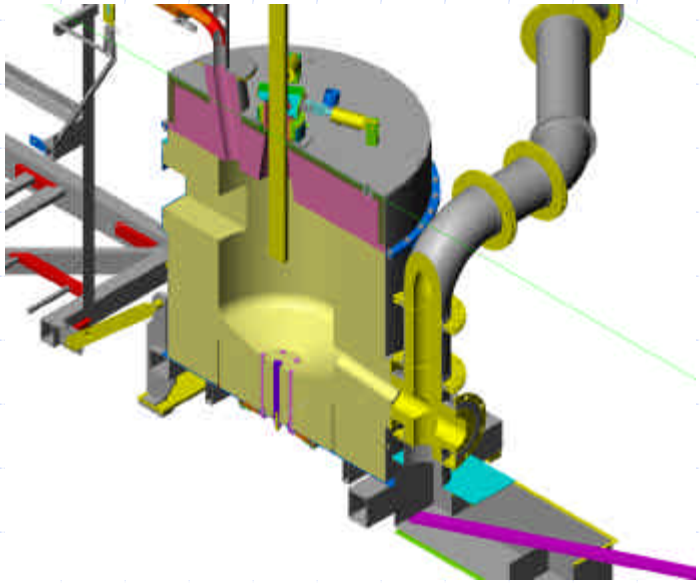
The Startech PCS

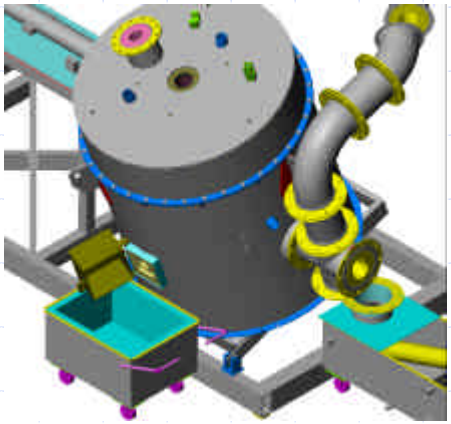
Feed Systems

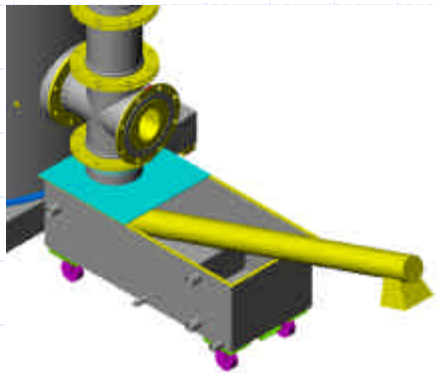


- **Loss-in-Weight Liquid Feed**
  - Feed from drums or tank
  - Peristaltic pump with dedicated transfer hose
  - Metered steam blend and injection into vessel
- **Multiple automatic solid feed configurations available based on feed materials:**
  - Ram Feed
  - Shredder
  - Conveyor
  - Auger
  - Rotary Valve

Plasma Vessel

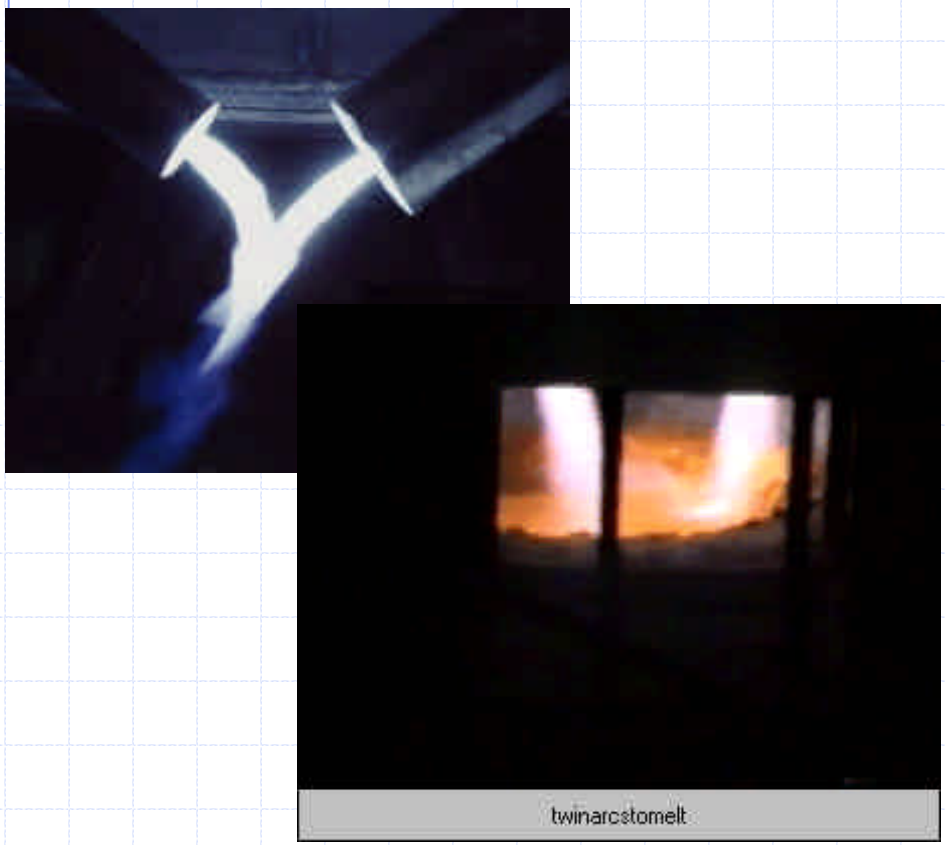




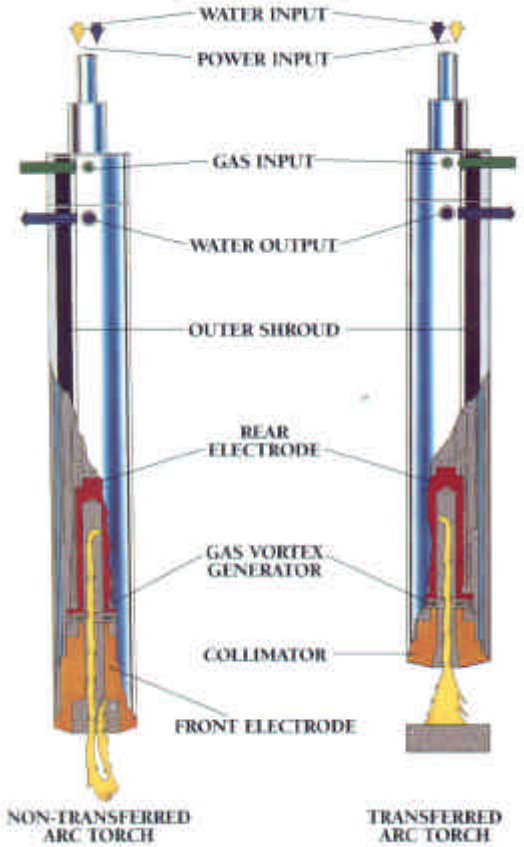


- Vessel
  - Two segment design
    - Main Vessel
    - Vessel Lid
  - Refractory lined walls
  - Sealed, negative pressure operation
  - Single PCG and melt exit port
- Melt Removal
  - Melt/Quench Cart
    - Continuous melt removal into water-cooled cart
    - Auger screw design
  - Tilt removal to side

Types of Plasma Torches



Twin Torch – Non-Transferred and Transferred Operation



Single Torch – Non-Transferred and Transferred Operation

Gas Polishing System

- **Removes solids at three stages:**
  - **>10 microns, >1 micron, and >0.3 microns.**
- **Cools PCG™ in two stages:**
  - **~1,400°C to 900°C, and 900°C to 40°C (10^4°C/second).**
- **Neutralizes and removes:**
  - **acid gases, nitrogen oxides, heavy metals, organic compounds.**
- **Removes entrained water and heats PCG™.**
- **Maintains negative pressure to pull PCG™ through system.**

Cooling Water System

Plasma Skid

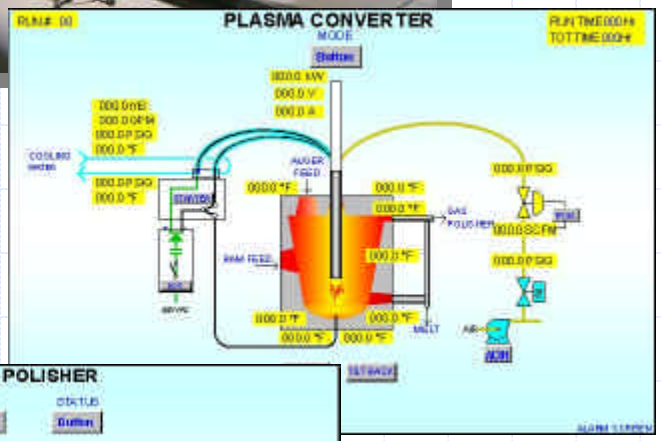
Gas Polisher

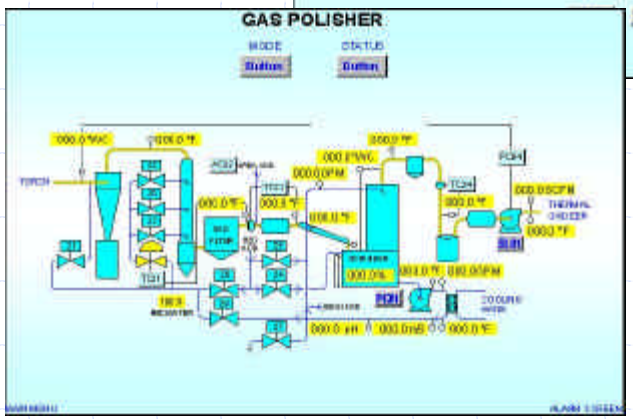
Chiller

DI CW System

Control System

- PLC Based control system
- Skid Mounted Control Panels with Remote I/O
- Centralized Operator Station
- PC Based Human Machine Interface
- Real-Time Video and Process Monitoring

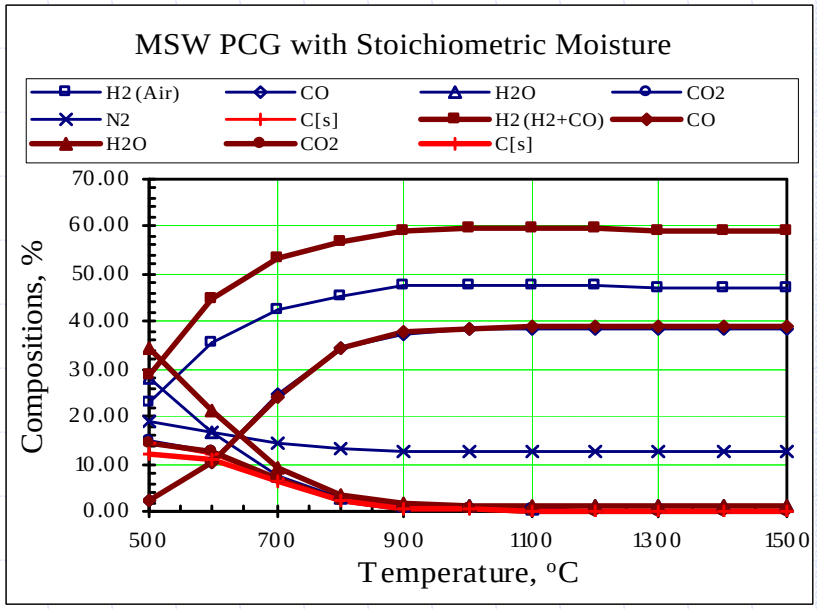


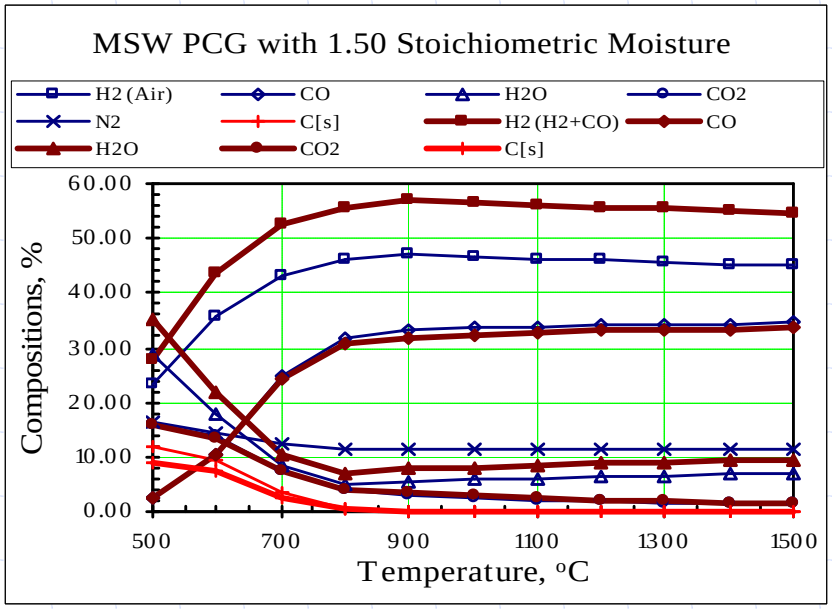


The Startech PCS: Advantages

- Non-Combustion Reducing Vessel Atmosphere:
  - Dioxins/furans (<0.05ng TEQ/Nm^3)
  - NOx (<50ppm)
  - 1/10^{th} the gas flow of an oxidizing system, allowing much higher efficiency gas cleaning.
- Low Operating Cost:
  - Energy efficient
  - Highly automated
  - Low maintenance
  - Potential for sale of valuable products - ***HYDROGEN***
- Low Capital Cost:
  - No secondary combustion chamber (as in oxidizing systems).
  - Smaller equipment to handle lower gas flow volumes
  - Standardized designs/components allow shorter delivery schedule
  - Skid-mounted modular equipment for lower installation cost
  - Standard commercial off-the-shelf (COTS) components

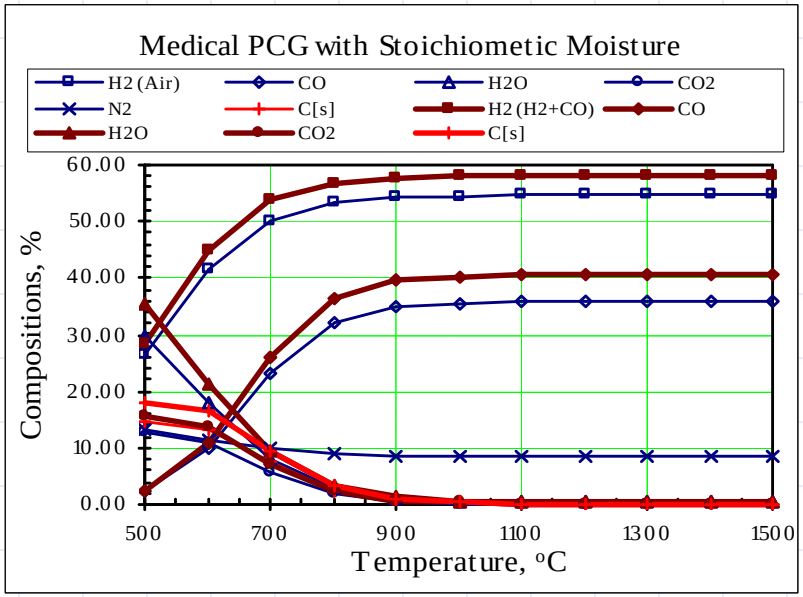
Plasma Processing of MSW - Thermodynamics

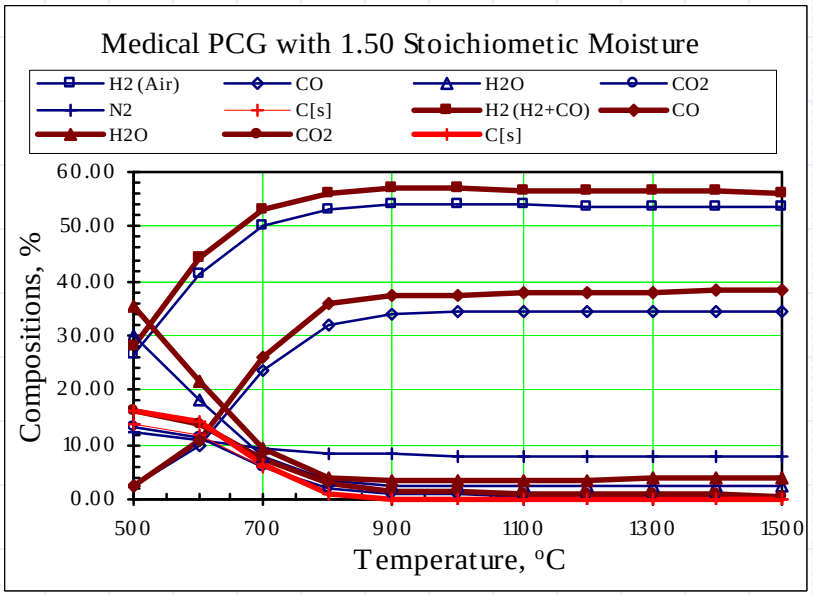




- Thermodynamic analyses with air and CO/H2 as plasma media.
- Steam used to convert C to CO, also bolsters H2 content.
- Excess moisture (up to 1.5 times stoichiometric) minimizes particulate carbon formation.
- Hydrogen concentration 47% to 57% by volume.
- Approximately 1.8 to 2.0 Nm^3 PCG/kg waste.

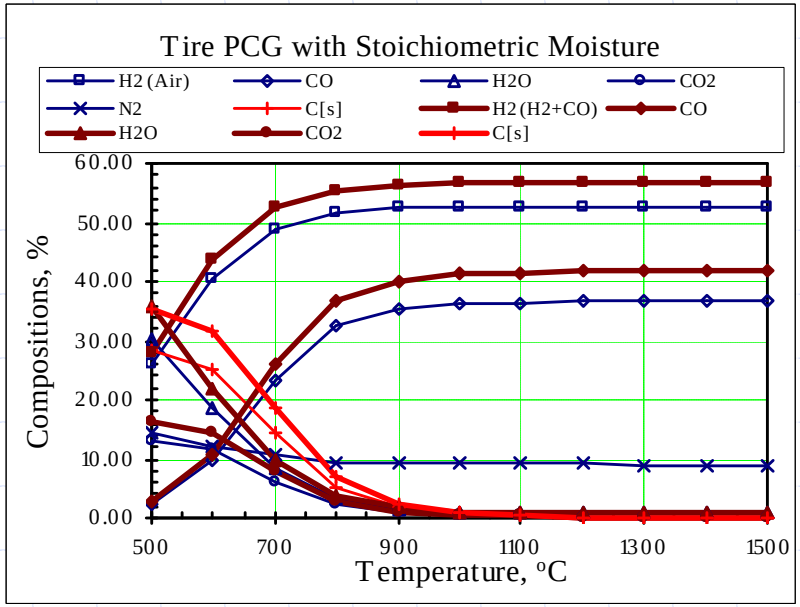
Plasma Processing of Medical Waste - Thermodynamics

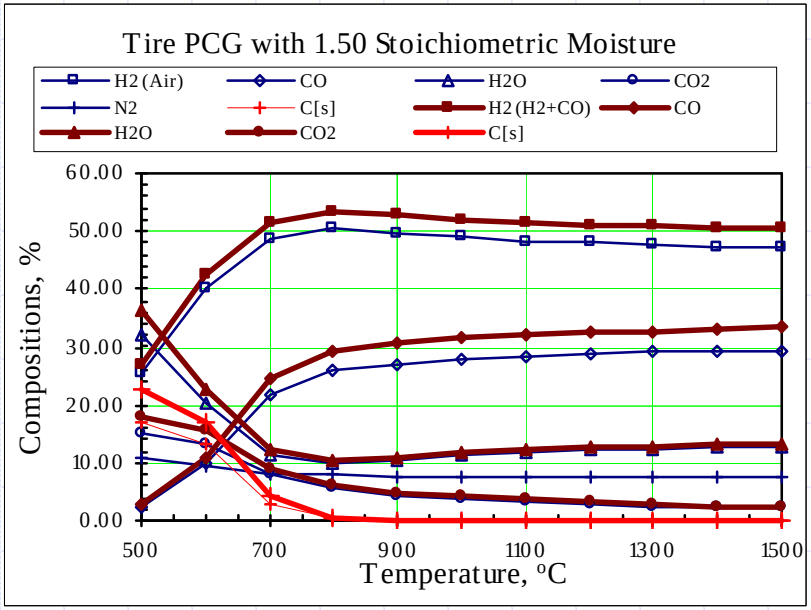




- Thermodynamic analyses with air and CO/H2 as plasma media.
- Steam used to convert C to CO, also bolsters H2 content.
- Excess moisture (up to 1.5 times stoichiometric) minimizes particulate carbon formation.
- Hydrogen concentration 54% to 57% by volume.
- Approximately 2.3 to 2.6 Nm^3 PCG/kg waste.

Plasma Processing of Used Tires - Thermodynamics

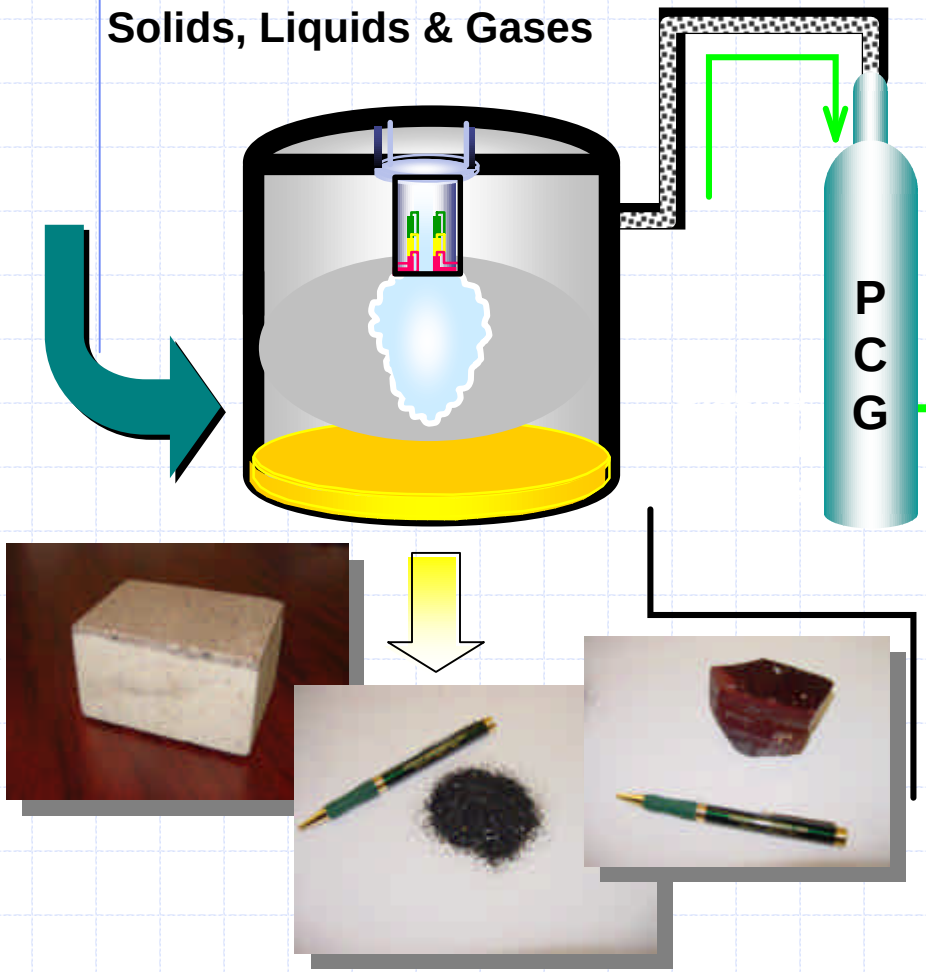




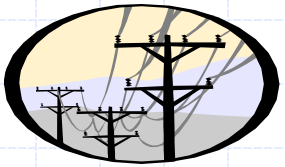
- Thermodynamic analyses with air and CO/H2 as plasma media.
- Steam used to convert C to CO, also bolsters H2 content.
- Excess moisture (up to 1.5 times stoichiometric) minimizes particulate carbon formation.
- Hydrogen concentration 50% to 53% by volume.
- Approximately 4.5 to 5.5 Nm^3 PCG/kg waste.

PCS Products Produced

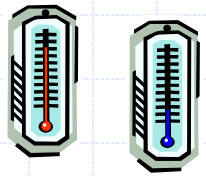
Material Fed In:
Hazardous & Nonhazardous,
Solids, Liquids & Gases



ELECTRIC GENERATION



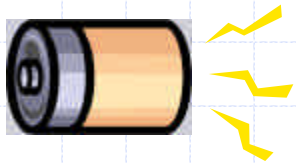
PLANT and PROCESS HEATING & COOLING



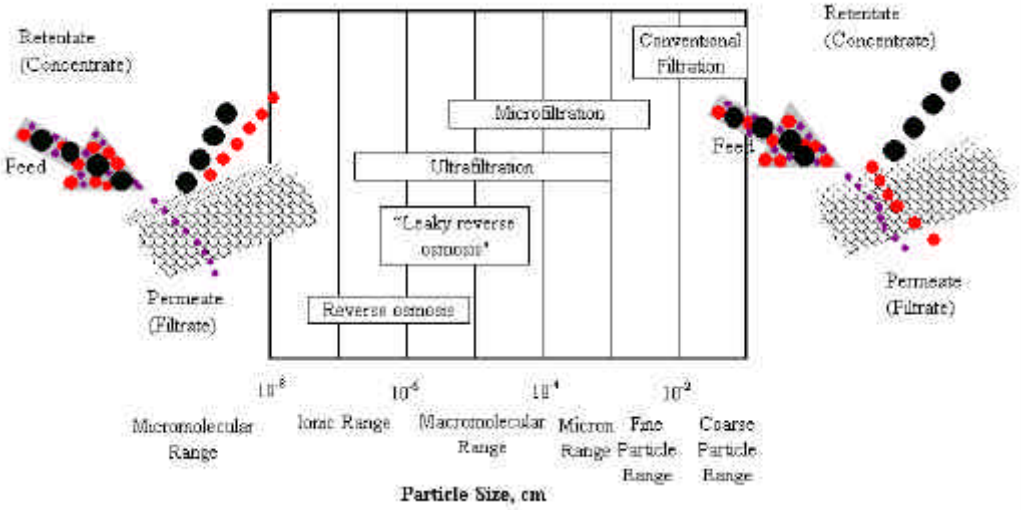
CHEMICALS

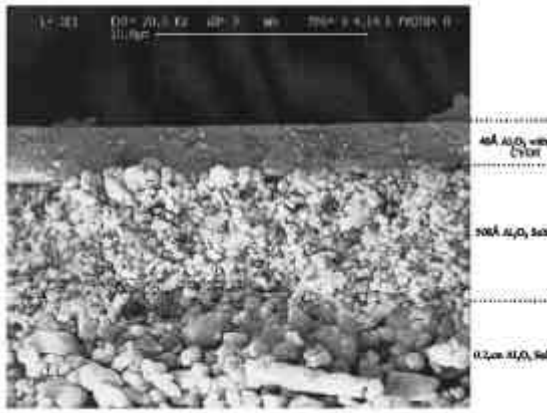
PRODUCE FRESH WATER

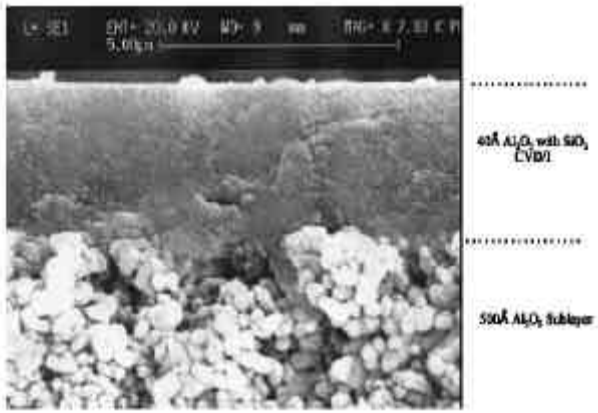
FUEL CELL ELECTRICITY



StarCell™ Hydrogen Separation and Purification Membrane

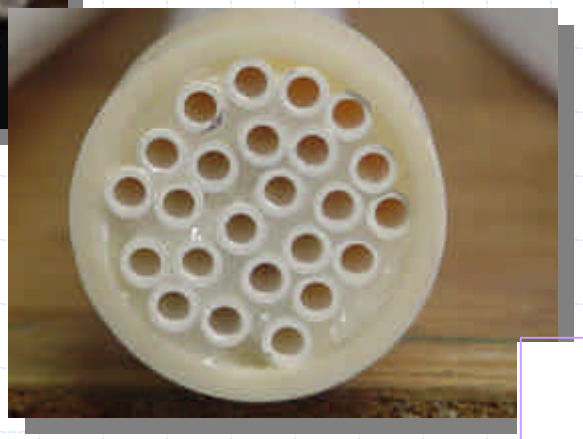






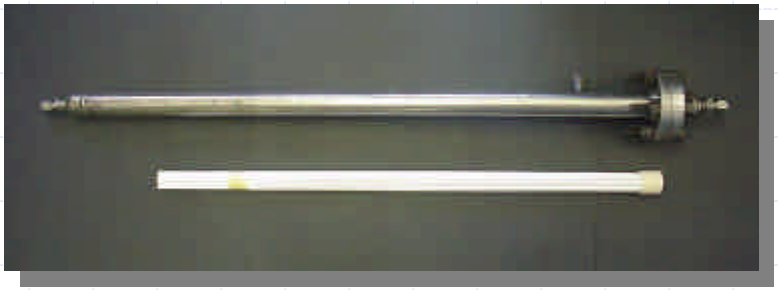
- Robust ceramic metal oxide membrane.
- Excellent material, chemical and thermal stability.
- Highly selective for H_2.
- Reasonable P&T operation.
- Patented product.
- Entering final development/ commercialization phase.

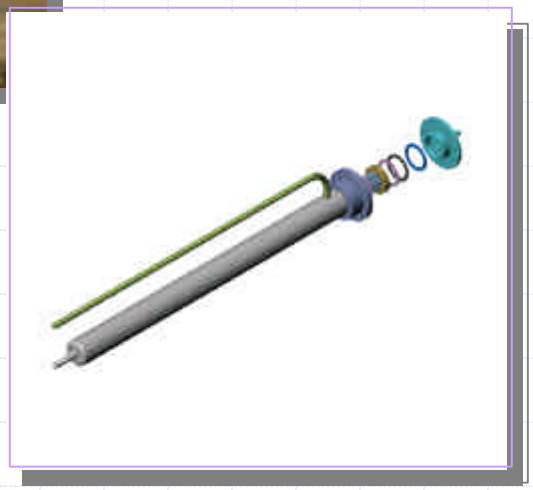
StarCell™ Hydrogen Separation and Purification Module



- Individual membrane tubes are produced by the proprietary Thin Film Chemical Vapor Infiltration process.
- Tubes are potted together into a bundle.

- Each bundle is installed into into a housing module.



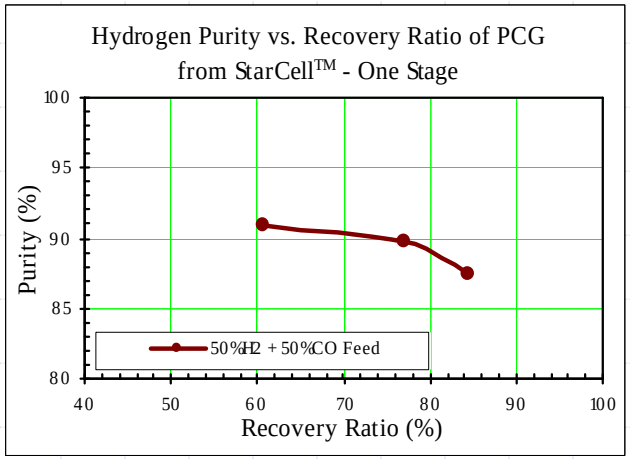


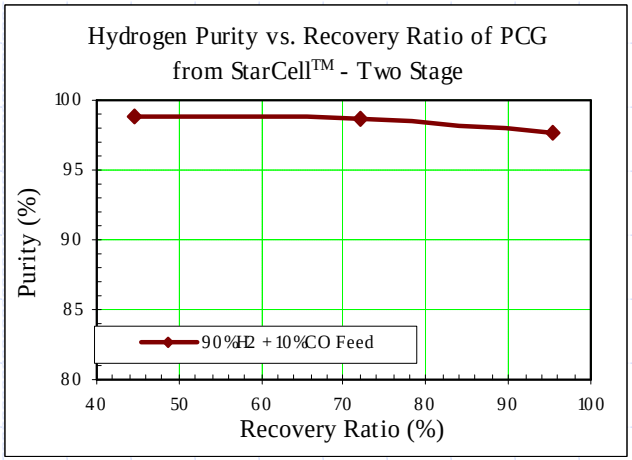
StarCell™ Hydrogen Separation and Purification System

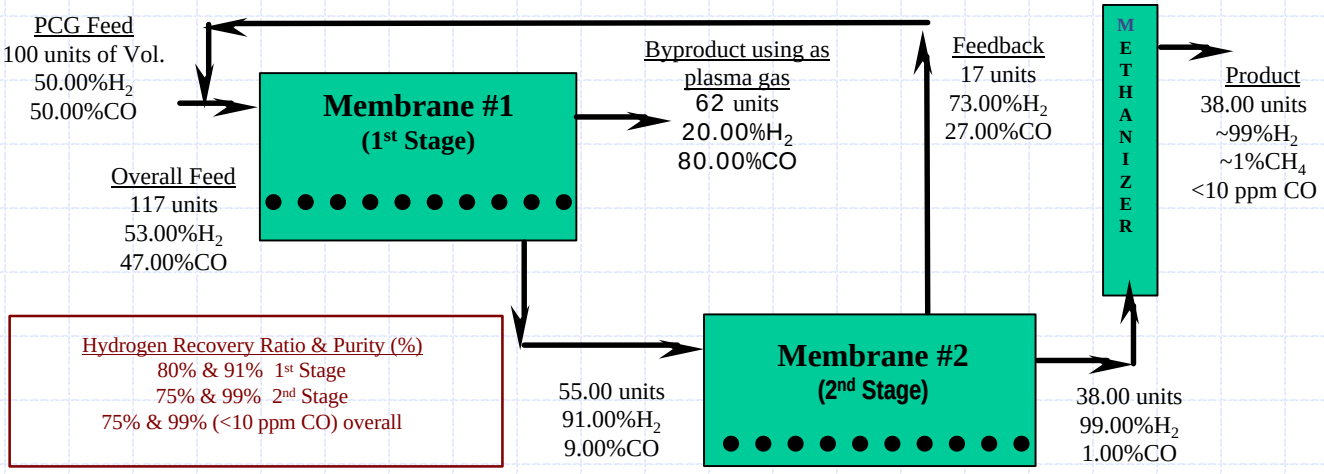
- Modules are connected together with three manifolds:
  - PCG In
  - H_2 Out
  - PCG Out
- A PCG heating section is integrated into the module chamber.

- StarCell™ equipment is installed in a standard cabinet enclosure.
- Instrumentation includes monitoring of the pressure and temperature of the three gas streams.

StarCell™ Performance







StarCell™ Commercialization

- Preliminary economics indicate that distributed H_2 can be produced at a price very competitive with world-class steam/methane reforming plants.
- Depending on waste processed, H_2 cost is projected to be ½ to 1 times the current production cost.
- Next step is a development/commercialization program:
  - Public sector cost sharing
  - Optimize StarCell™
  - Produce H_2 from actual PCG from waste materials
  - Fabricate industrial prototype
  - Beta site testing
- Startech expects commercial product in approximately 12 months.

In Summary

- PCS processes a wide range of feedstocks to produce PCG.
- Safer than environmental standards.
- StarCell™ separates out the Hydrogen from the PCG and similar mixtures.
- Undergoing final commercial development in the next 12 months.
- Revenue potential on front and back-ends.

Back-Up Slides

Plasma vs. Incineration and Landfill

- Startech PCS
  - >1,400ºC
  - Produces Products
  - Ultra Low Emissions
  - Endothermic Process
  - Rapid
  - 40% to 50% O.T.E.
  - High Public Acceptability
- Incinerator
  - <1,250ºC
  - Produces Wastes
  - Higher Emissions
  - Exothermic Process
  - Rapid
  - 15% to 25% O.T.E.
  - Very Low Public Acceptability
- Landfill
  - Uncontrolled
  - Produces Wastes
  - Very High Emissions
  - Exothermic Process
  - Very Slow
  - Efficiency Not Measurable
  - Very Low Public Acceptability

Wastes as Resources

MSW (3,100 kWh/ton)	wt%	Medical Waste (4,800 kWh/ton)	wt%	Used Tire (8,900 kWh/ton)	wt%
Paper	25.97	Cellulose	18.40	Carbon black	30.50
Yard	8.25	Glass	11.04	Rubber	46.00
Food	7.43	Polypropylene	11.04	Sulfur	2.50
Plastics	7.16	Polyethylene	11.04	Nitrogen	1.00
Metals	5.32	Polystyrene	7.36	Steel	15.00
Rubber, leather, textile	4.50	Organic tissue	3.50	Ash	5.00
Glass	3.75	Stainless steel	3.68		
Wood	3.61	PVC	3.68		
Others	2.18				
Moisture	31.84	Moisture	30.25		
Total	100.00		100.00		100.00

- **Current practices lead to harmful emissions and wasting of resources.**
- **With the Startech process:**

  "Where there are people there is waste. Where there is waste, there is hydrogen. We can distribute hydrogen where it is needed."

Specific Energy Required

- The energy required to process a given waste stream depends on the properties of the specific waste.
- Empirical data for various wastes is as follows:

Materials	kWhr/tonne		10^3 BTU/ton	
	[min.]	[max.]	[min.]	[max.]
Steel scrap melting	584	584	1810	1810
Pyrolysis of hospital waste	595	1101	1844	3415
Pyrolysis of PCB oil	441	1212	1366	3756
Pyrolysis of MSW	771	1542	2390	4780
Pyrolysis of auto tires	1872	1872	5805	5805
Pyrolysis of pathological wastes	1968	1968	6100	6100
EAF dust treatment	1487	1927	4610	5976
Niobium recovery	2203	3194	6829	9902
PGM recovery from auto catalyst	3029	4405	9390	13658
Ceramic production	2533	15022	7854	46575