

# **Evaluating Conversion Technology for Municipal Waste Management**

Presented to  
CIWMB  
Sacramento, California

October 27, 2008

Alternative Resources, Inc.

9000-2

# Introduction:

## Alternative Resources, Inc.

- Independent consulting firm, Concord, MA
- 25 years of service to public clients nationwide
- Provide management, engineering, environmental, economic/financial services
- Feasibility, planning, procurement, implementation solid waste projects
- Focus company: beneficial use of waste, since application of waste-to-energy (early 1980's) as innovative technology
- Current CT projects
  - County of Los Angeles
  - City & County of Santa Barbara
  - City of San Diego
  - SMUD
  - NYC
  - CRRA
  - DSWA
  - Taunton, MA

# Technology Options for Post-Recycled MSW Management

- Conventional
  - MRF
  - Composting
  - Waste-to-Energy
  - Landfill
  - Transfer
- Conversion Technologies
  - Thermal
  - Digestion
  - Hydrolysis
  - Chemical Processing
  - Mechanical Processing

# Conversion Technologies

- Thermal
  - Use or produce heat to change the composition of MSW
  - Products include synthesis gas or fuel gas, fuels, vitrified residue or char, and recovered metals
  - Descriptors: gasification, pyrolysis and plasma
- Digestion (Aerobic and Anaerobic)
  - Decomposes organic fraction of MSW using microbes
  - Anaerobic digestion produces biogas and compost
  - Aerobic digestion produces compost
- Hydrolysis
  - Chemical reaction in which water (typically with acid) reacts with another substance to form new substances
  - Extracts cellulose from MSW to form products or sugar which is fermented to ethanol
  - Some products include ethanol, levulinic acid
- Chemical Processing
  - Example: depolymerization – converts organic fraction into energy, oil, specialty chemicals, carbon solids
- Mechanical Processing
  - To create a fuel or other reusable products

# Examples of Conversion Technology Providers

- **Thermal**

- AdaptiveARC
- Alter NRG/Westinghouse
- Bioengineering Resources, Inc.
- Ebara Corporation
- Entech Solutions
- GEM America
- International Environmental Solutions
- Interstate Waste Technologies/Thermoselect
- Plasco Energy Group
- Primenergy, LLC
- Rigel Resources Recovery and Conversion Co./Westinghouse
- Solena Group
- Startech Environmental
- World Waste Technologies
- Ze-Gen

- **Biological**

- ArrowBio
- Canada Composting
- Ecocorp
- Organic Waste Systems/DRANCO
- Orgaworld
- Waste Recovery Systems, Inc./Valorga

- **Chemical**

- Changing World Technologies

- **Hydrolysis**

- Arkenol/Blue Fire Ethanol
- Biofine
- Genahol
- Masada OxyNol

- **Other**

- Herhof GmbH

# Why Consider Conversion Technologies?

- Environmental benefits, including reduction in greenhouse gas and other emissions
- Enhanced beneficial use of waste; less waste requiring transfer and landfilling
- Production of needed “renewable” products with strong, year-round markets
  - Electricity
  - Gas
  - Fuels – CNG, LNG, ethanol, hydrogen, biodiesel

# Experience of Conversion Technology Companies and Reference Facilities October 2008

Experience of Sponsors	Technology							
	Anaerobic Digestion		Gasification		Pyrolysis		Plasma Arc	
	US	Outside US	US	Outside US	US	Outside US	US	Outside US
• Permitting		✓		✓	✓	✓		✓
• Design		✓		✓	✓	✓		✓
• Construction		✓		✓	✓	✓		✓
• Operation		✓		✓	✓	✓		✓
• Product Marketing		✓		✓	✓	✓		✓
• Financing		✓		✓	✓	✓		✓
• Example MSW Reference Facilities	<b><u>ArrowBio</u></b> Tel Aviv, Israel 50,000 tpy (1 @ 150 tpd) 2003; Sydney, Australia 100,000tpy (2@150 tpd) 2008 <b><u>Ecocorp</u></b> Barcelona, Spain 330,000 tpy (900 tpd) 2001 <b><u>OWS</u></b> Vitoria, Spain 120,000 tpy (330 tpd) 2006 <b><u>WRSI/Valorga</u></b> Barcelona, Spain 264,552 tpy (725 tpd) 2004		<b><u>Ebara</u></b> Kawaguchi City, Japan 153,300 tpy (3 @ 140 tpd) 2002 <b><u>Entech</u></b> Genting, Malaysia 24,500 tpy (67 tpd) 1998 <b><u>IWT</u></b> Kurashiki, Japan 223,400 tpy (3 @ 204 tpd) 2005		<b><u>GEM America</u></b> South Wales, U.K. 14,600 tpy (1 @ 40 tpd) 2000-2001 <b><u>IES</u></b> Romoland, CA 18,250 tpy (1 @ 50 tpd) 2004		<b><u>AdaptiveARC</u></b> Monterey, Mexico 36,500 tpy (1 @ 100 tpd) 2005 <b><u>AlterNRG</u></b> Utashinai, Japan 109,500 tpy (300 tpd) 2003 <b><u>Plasco</u></b> Ottawa, Canada 40,150 tpy (1 @ 110 tpd) 2007	

# Landfill Diversion

(By weight)

<b>Thermal</b>	
<b>Gasification</b>	94-100%
<b>Pyrolysis</b>	72-95%
<b>Plasma Arc</b>	95-100%
<b>Anaerobic Digestion</b>	68-85%

# Net Energy Production

	<b>Net Electric / Fuel Output</b>	<b>1,000 TPD 100% Availability</b>
<b>Thermal</b>		
<b>Gasification</b>	400-650 kWh/Ton	16-27 MWe
<b>Pyrolysis</b>	450-530 kWh/Ton	19-22 MWe
<b>Plasma Arc</b>	400-1250* kWh/Ton	16-52* MWe
<b>Anaerobic Digestion</b>	125-250 kWh/Ton	5-10 MWe
<b>Acid Hydrolysis</b>	31 Gal Ethanol/Ton	11 Million Gal/Year

\* 1250 assumes prepared fuel, including tires, which results in higher HHV than MSW

# Comparison of Air Emissions

	<b>Conversion Technology as Compared to Incinerators in Massachusetts*</b>
Dioxin	up to >100 times less
Mercury	up to 10 times less
Nitrogen Oxides (Precursor to Ozone)	Approximately 10 times less

\* Data from 2006 Source Registration Reports and 2004 TURA Reports

# Status of U.S. Public Initiatives Conversion

## Technology

### October 2008

U.S. Public Initiatives	Status	Technology			
		Anaerobic Digestion	Gasification	Pyrolysis	Plasma Arc
• LA County, California	Request for Offers Issued to Qualified Technology Suppliers; five Responses received 8/08, being evaluated	✓	✓	✓	
• City of Los Angeles, California	Proposals received and under review	✓	✓	✓	✓
• City and County of Santa Barbara, California	Established shortlist of Qualified Technology Suppliers; RFP in preparation	✓	✓	✓	✓
• City of Sacramento, California	Negotiating Letter of Intent				✓
• San Jose, California	Request for Information was in progress; current status uncertain				
• Salinas Valley, California	Nine Proposals received; five shortlisted, being evaluated	✓	✓		✓
• Santa Cruz County, California	County considering offer for Demonstration Facility; decision expected 11/08				✓
• City of San Diego, California	Study underway	✓	✓	✓	✓
• Orange County, California	Procurement underway for consultant to do CT Evaluation	✓	✓	✓	✓

# Status of U.S. Public Initiatives

## Conversion Technology

### October 2008 (continued)

U.S. Public Initiatives	Status	Technology			
		Anaerobic Digestion	Gasification	Pyrolysis	Plasma Arc
• NYC, New York	Studies completed; siting underway	✓	✓	✓	✓
• St. Lucie County, Florida	Permitting				✓
• Taunton, Massachusetts	RFP released 6/08; Prequalifications received 9/08 – 16 companies; Proposals due 2/09	✓	✓	✓	✓
• Connecticut Resources Recovery Authority	Second Study underway	✓	✓	✓	✓
• Delaware Solid Waste Management Authority	Study completed	✓	✓	✓	✓
• NYC, New York	Studies completed; siting underway	✓	✓	✓	✓

# The Promise

- Next generation of technology
- Not perfect, but better than existing alternatives
- Lower emissions
- Reduction in amount waste landfilled
- Enhances recycling and conversion of waste for beneficial use
- Provides source of renewable energy

# Hurdles

- Lack of commercial demonstration in US
- Lack of development/acceptance for certain product markets in US or regulatory hurdles for product use
- Applicability of regulations for environmental permitting is unclear, non-existent, or inadvertently problematic
- Qualification for renewable energy credits for power sale is not consistent
- Need for public education

# NYC Phase 1 Summary of Findings (September 2004)

## Development Status of Conversion Technologies by Category

Technology Category	Commercial Use Outside U.S. for MSW	Pilot Testing with MSW
Anaerobic Digestion	✓	✓
Thermal Processing	✓	✓
Hydrolysis		✓

# NYC Phase 1 Summary of Findings (September 2004)

## Comparison of Commercially Advanced Conversion Technologies (Anaerobic Digestion and Thermal Processing) to Modern Waste-to-Energy

Criteria	Advantageous	Comparable	Disadvantageous
Emissions	✓		
Public Acceptability	✓		
Residuals Requiring Disposal	✓		
Beneficial Use of Waste	✓	✓	
Cost		✓	
Ownership Preferences		✓	
Risk Allocation		✓	
Utility Needs		✓	
Facility Size and Flexibility		✓	✓
Acreage Required		✓	✓
Experience of Sponsors		✓	✓
Readiness and Reliability			✓

# Technologies Included in NYC Phase 2 Study

## Anaerobic Digestion

**Arrow Ecology & Engineering** (Wet anaerobic Digestion;  
Upflow Anaerobic Sludge Blanket)

**Waste Recovery Systems** (Dry Anaerobic Digestion;  
Valorga Process)

## Thermal Processing

**Ebara** (Fluid Bed Gasification with Ash Vitrification)

**GEM America** (Thermal Cracking Gasification Process)

**Interstate Waste Technologies** (High Temperature  
Gasification Process)

**Rigel Resource Recovery and Conversion**  
(Westinghouse Plasma Gasification Process.)

## Hydrolysis

**Masada OxyNol** (Waste-to-Ethanol Process)

# NYC Phase 2: Summary of Economic/ Financial Evaluation (March 2007)

- Planning level economic analyses indicate that anaerobic digestion and thermal processing technologies, on a commercial scale, are comparable to or less costly than costs for current export practices
- Projected cost for export practices (2014) = \$124/ton
- Projected tipping fee for private ownership and financing (2014):
  - Anaerobic digestion (sale of compost) = \$56-\$80/ton
  - Anaerobic digestion (compost disposed) = \$72-\$108/ton
  - Thermal processing = \$103-\$165/ton
- Projected tipping fee for public ownership and financing (2014):
  - Anaerobic digestion = \$43-\$65/ton
  - Thermal processing = \$76-\$129/ton
- Corporate teaming experience in the U.S. continuing to develop for the technology suppliers

# NYC Project Status

- Siting Evaluation – underway
- Procurement for Demonstration Facility – 2009-2010  
(300-1000 TPD)
- Permitting/Financing/Design/  
Construction – 2011-2015

# LA County

## Technology Evaluation and Procurement Process

- Phase I: 2004-2005; Preliminary Screening to Shortlist Technologies and Sites for CT Demonstration Project
  - Request for Information (RFI)
  - Evaluation of Responses
  - Report (August 2005), Preliminary Shortlist of Technologies/Sites
- Phase II: 2006-2008; Facilitate Demonstration Project, Select Technology(ies) and Site(s), Negotiate Contract Terms
  - Supplemental RFI (October 2006)
  - Evaluation of Responses (December 2006-October 2007)
  - Interviews, Reference Facility Visits (January-April 2007)
  - Report (October 2007), Final Shortlisting of Technologies/Sites
  - Request for Competitive Offers (RFO) (January 2008)
  - Offers Submitted (August 2008)
  - Offers Evaluated (August-October 2008)
  - Demonstration Project(s) Selected, Contract(s) Negotiated (November 2008-February 2009)

# Technology Suppliers Considered for Participation in Phase II

<b>Technology Suppliers Recommended (Shortlisted) in Phase I Report</b>	<b>"New" Technology Suppliers not Evaluated in the Phase I Report <sup>(1)</sup></b>
Interstate Waste Technologies Primenergy NTech Environmental GEM America Changing World Technologies BRI Energy	Allan Environmental* Arkenol/BlueFire Ethanol* Choren BTL/ANRTL, LLC Cleansave Waste Corporation* Eco Waste Solutions EnerTech Environmental, Inc.* EnviroArc Technologies/Nordic American* Enviro-Tech Enterprises, Inc. Global Alternative Green Energy (GAGE)* Global Recycling Group, LLC*
<b>Technology Suppliers Passing the Phase I Screening Criteria but not Recommended in the Phase I Report</b>	Harold Craig Herhof GmbH* Integrated Environmental Technologies* Prime Environmental International Recycled Refuse International* Wastes Conversion Company World Waste Technologies, Inc. Zero Waste Energy Systems*
Arrow Ecology and Engineering Canada Composting Ebara Corporation Geoplasma LLC Green Energy Corporation International Environmental Solutions Organic Waste Systems Waste Recovery Systems	

(1) The 18 technology suppliers identified as "new" were sent a questionnaire in September 2006, soliciting information on their technologies. The 11 identified with an asterisk (\*) responded to the County's questionnaire.

# LA County Phase II: Project Concepts by Technology Supplier (October 2007)

Technology Supplier	Proposed Facility Size	Site Size	Estimated Tipping Fee
ArrowBio (Anaerobic Digestion)	300 TPD	4 acres	\$50/ton <sup>(1)</sup>
	1050 TPD	12 acres	\$50/ton <sup>(1)</sup>
CWT (Chemical)	220 TPD	3 acres	\$60/ton
	1000 TPD	5.8 acres	not provided
IES (Gasification)	125 TPD (prepared) 242 TPD (as received)	1 acre	\$56/ton <sup>(1), (2)</sup>
IWT (Gasification)	312 TPD	3.5 acres	\$131/ton
	623 TPD	5 acres	\$70/ton
	935 TPD	8 acres	\$59/ton
Ntech (Gasification)	413 TPD	3.5 acres	\$55/ton <sup>(1)</sup>

(1) Integrated pricing with MRF, considers use of existing scales, roads and site infrastructure at MRF.

(2) Assumes waste feedstock is preprocessed by MRF to 2" in size, glass, metal removed.

# LA County Technologies Shortlisted (Listed Alphabetically)

<b>Technology Supplier</b>	<b>Technology Type</b>
Arrow Ecology and Engineering (Arrow)	Anaerobic Digestion
International Environmental Solutions (IES)	Pyrolysis
Interstate Waste Technologies (IWT)	Pyrolysis / High Temperature Gasification
NTech Environmental (NTech)	Low Temperature Gasification

# LA County Sites/ Site Operators Shortlisted

(Listed Alphabetically)

<b>MRF/TS Facility</b>	<b>Location</b>
Del Norte Regional Recycling and Transfer Station	Ventura County (Oxnard)
Perris MRF/Transfer Station (CR&R)	Riverside County (Perris)
Rainbow Disposal Company, Inc. MRF	Orange County (Huntington Beach)
Robert A. Nelson Transfer Station and MRF (Burrtec)	Riverside County (Unincorporated)

# Rationale for Technology/ Site Shortlisting (Evaluation Criteria)

- Technology Supplier Qualifications
  - Technical Resources
  - Financial Resources
  - Financing Approaches
  - Financial Security
  - Risk Posture
- Economics
  - Project Costs
- Technology Performance
  - Readiness and Reliability of Technology
  - Development of a Complete Process
  - Processing Capability (Unit Size, Annual Throughput, Scaling)
  - Material and Energy Balance
  - Diversion Potential
  - Generation of Marketable Products
  - Environmentally Sound
  - Space/Utility Requirements and Site Integration

# REQUEST FOR OFFERS FOR LOS ANGELES COUNTY CONVERSION TECHNOLOGY DEMONSTRATION FACILITY

Issued by:

The County of Los Angeles  
Department of Public Works  
and  
Los Angeles County Solid Waste Management  
Committee/  
Integrated Waste Management Task Force's  
Alternative Technology Advisory Subcommittee

January 17, 2008



•Prepared by:



•Alternative Resources, Inc.



# LA County Current Status

- RFO on Street – January 2008
- Pre-Submittal Information Meeting – February 2008
- Addenda to RFO – Being Prepared as Needed
- Offers Being Prepared – Due August 2008
- Expect Four, Possibly Five Offers
- Selection/Negotiations – by February 2009
- Permitting, Design, Construction, Operations – by 2011-2012

# City & County of Santa Barbara

## Role, Objectives and Goals

- Role of City and County: Sponsor Project Development, Provide Site and Waste; Public-Private Partnership of Public Sponsor and Private Technology Supplier
- Objectives: Sponsor Development of Conversion Technology (CT) to Reduce Landfilling at Tajiguas Landfill
- Goals:
  - Increase Diversion of Post-Recycled MSW for Affected Jurisdictions
  - Reduce Environmental Impacts of Landfilling MSW
  - Provide Financial Feasibility and Sustainability
  - Produce Green Energy and Other Marketable Products
  - Provide a Humane Work Environment
  - Result in a Long-Term Waste Disposal Plan (20-year Minimum)
- Potential Benefits
  - Increased Materials Recovery, Beneficial Use of Waste
  - Source of Renewable Energy
  - Reduced Landfilling, Prolong Life of Tajiguas Landfill
  - Reduced Transportation Requirements and Associated Impacts
  - Reduced Environmental Impacts

# City & County of Santa Barbara Technology Evaluation and Procurement Process

- Previous Evaluation by MJSWTG (2002-2003)
- Adopted Project Goals and Evaluation Criteria (January 2008)
- Identified Conversion Technology Suppliers (February 2008)
- Prepared and Issued Request for Information (RFI) (February 2008)
- Received and Evaluated RFI responses (March 2008)
- Prepared Report (April 2008) – Shortlisted Technology Suppliers
- City and County Consideration of Report (May 2008)
- Prepare RFP (June 2008-January 2009)
- Release RFP (January 2009)
- Evaluate Proposals (2009)
- Negotiate Contract (2009-2010)

# Santa Barbara Conversion Technology Companies Identified for Consideration to Receive RFI

Anaerobic Digestion	Thermal Processing
CA Renewable Technologies (Arrow)*	AdaptiveARC
Canada Composting (BTA Process)	AlterNRG/Westinghouse
Ecocorp*	Bioengineering Resources, Inc.
Orgaworld	Entech Solutions
Organic Waste Systems (DRANCO)	Ebara Corporation
Waste Recovery Systems (Valorga)*	GEM America
Hydrolysis	International Environmental Solutions
Arkenol/Blue Fire Ethanol	Interstate Waste Technologies
Biofine (Biometrics)	Plasco Energy Group
Genahol*	Primenergy*
Masada	Solena Group
Other Processing	Startech Environmental Corporation
Herhof California*	World Waste Technologies
Waste-to-Energy, Inc.	

\* Conversion technology company included on the MJSWTG 2003 short-list.

# City & County of Santa Barbara RFI Process: Compliance with Evaluation Criteria (April 2008)

Project Developer and/or Technology Supplier  (Listed Alphabetically by Type of Technology)	1 – Processing Capacity	2 – Operating Term	3 – Compatibility with Solid Waste Programs	4 – Diversion from Landfill Disposal	5 – Projected Tipping Fee	6 – End Products	7 – Environmental Performance	8 – Demonstration of Technology	9 – Project Team Experience	10 – Financial Resources	11 – Not Debarred from Contracting	ARE ALL CRITERIA MET?
<b><u>ANAEROBIC DIGESTION</u></b>												
CA Renewable Technologies	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Yes
Ecocorp	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Yes
Organic Waste Systems	✗	✓	✓	✓	✗	✓	✓	✓	✗	✗	✓	No
<b><u>THERMAL PROCESSING</u></b>												
AdaptiveNRG (Plasma Gasification)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Yes
International Environmental Solutions (Pyrolysis)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Yes
Interstate Waste Technologies (Gasification)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Yes
Plasco Energy Group (Plasma Gasification)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Yes
Primenergy LLC (Gasification)	✗	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	No
Tajiguas Partners (Gasification)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Yes
World Waste Technologies (Gasification)	✗	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	No
<b><u>OTHER TECHNOLOGY</u></b>												
Herhof California (Other – Biological Drying/ Mechanical Separation/ Combustion Off-Site)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	Yes



# City & County of Santa Barbara

## Shortlist for RFP

(Unranked-Listed Alphabetically by Type of Technology)

### ANAEROBIC DIGESTION

CA Renewable Technologies - CR&R/Arrow

Ecocorp

### THERMAL PROCESSING

AdaptiveNRG (Plasma Gasification)

International Environmental Solutions (Pyrolysis)

Interstate Waste Technologies (Gasification)

Plasco Energy Group (Plasma Gasification)

Tajiguas Partners - WTE/Entech (Gasification)

### OTHER TECHNOLOGY

Herhof (Biological Drying/Mechanical Separation/Combustion Off-site)

# City & County of Santa Barbara Rationale for Technology Shortlisting (Evaluation Criteria)

- Processing Capacity (100,000-220,000 TPY, 6 acres)
- Operating Term (20 years)
- Compatibility with Solid Waste Programs
- Diversion from Landfill Disposal (>60%)
- Projected Tipping Fee (<10% impact on ratepayers)
- End Products (marketable)
- Environmental Performance
- Demonstration of Technology (50 tpd, 6 months)
- Project Team Experience
- Financial Resources
- Contracting Status (not debarred in CA)

# Next Steps

## City & County of Santa Barbara

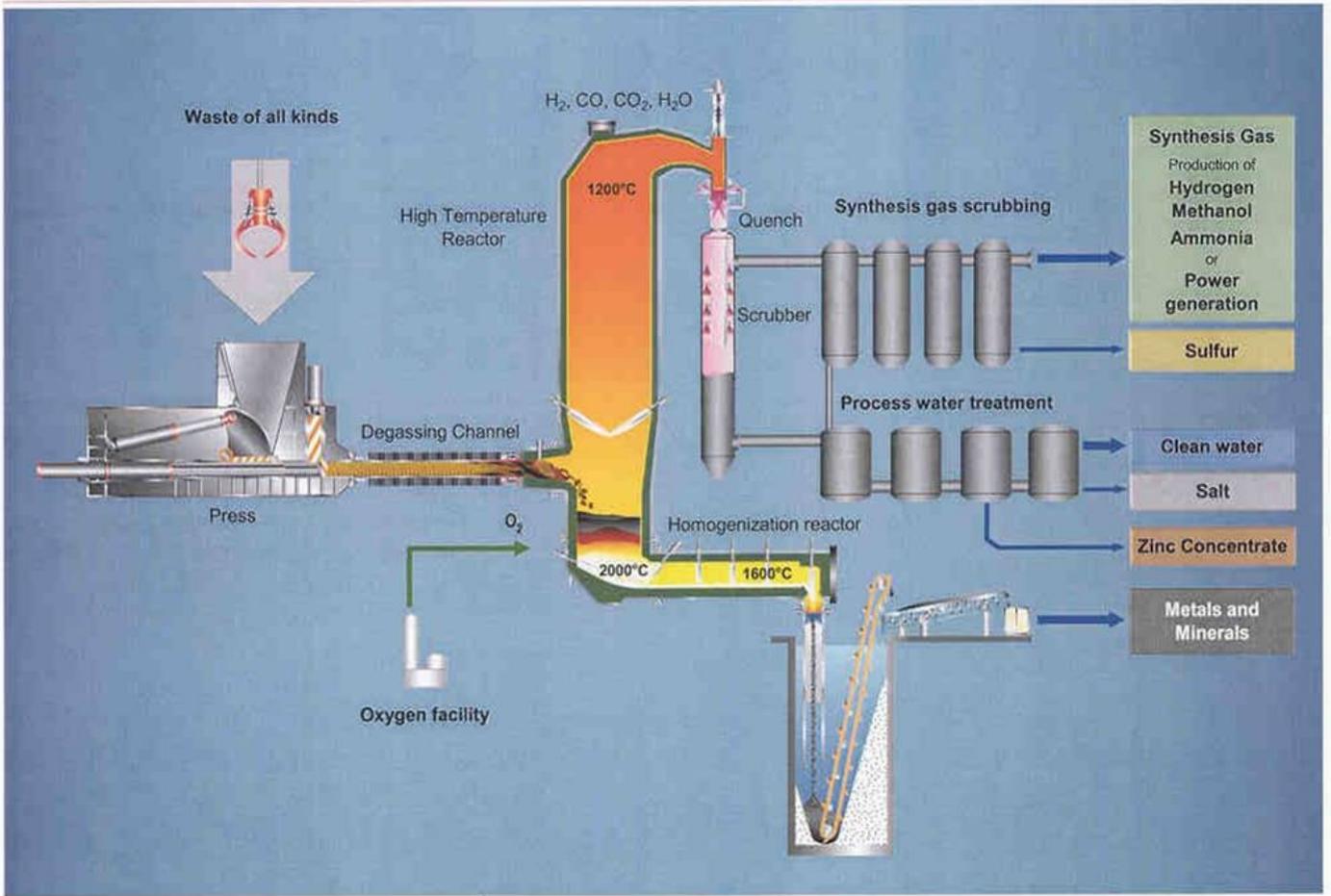
- Prepare RFP – June 2008-January 2009
- Release RFP – January 2009
- Evaluate Proposals - 2009
- Negotiate with Selected Proposer – 2009-2010
- Permit, Design, Construct, Startup Facility
- Operations

# Example

## Illustrations/Schematics of Conversion Technologies



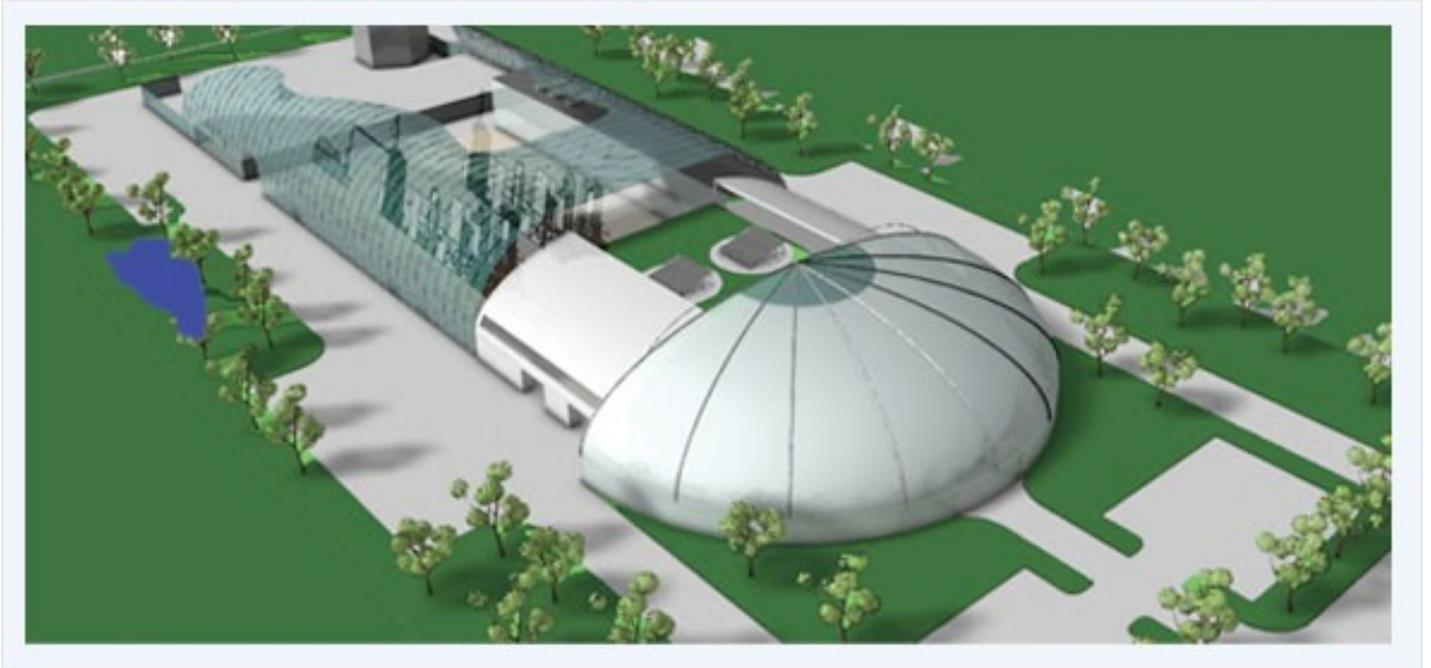
IWT – Chiba, Japan  
330 TPD  
(Operating since 1999)



IWT – Thermoselect Schematic Diagram



Westinghouse Plasma Gasification System  
Utashinai, Japan  
165 TPD for Auto Shredder Residue (ASR)  
or 300 TPD for MSW  
Date of Commercial Operation: 2003



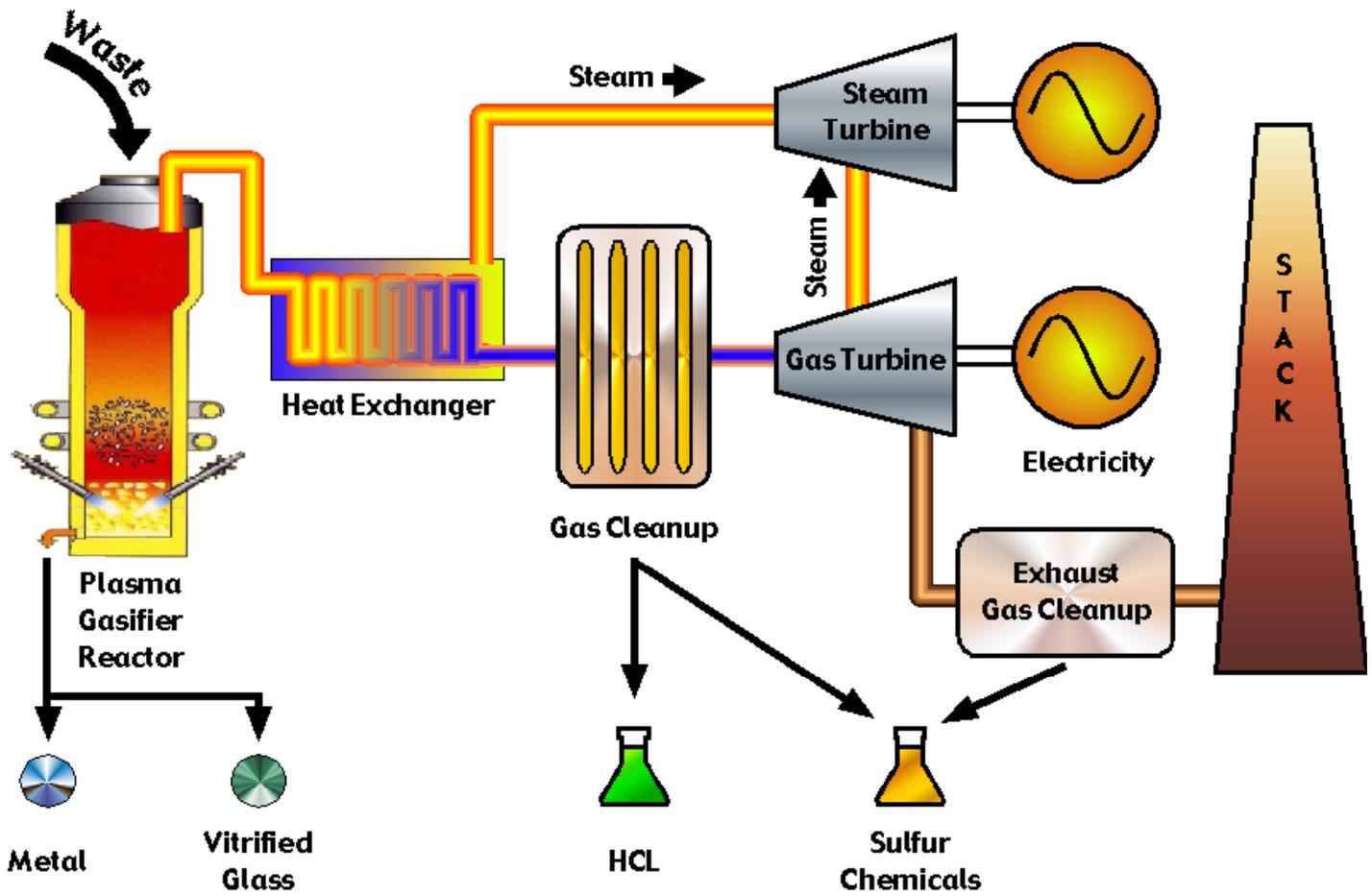
Plasco Energy Group – Plasma Gasification Facility  
Artist Rendering for Facility Proposed for  
City of Los Angeles  
200 TPD



Plasco Energy Demonstration Facility  
Ottawa, Canada

100 TPD (Permitted for 85 TPD,  
Generates 4 MW electricity)

Date of Initial Waste Processing: July 19, 2007

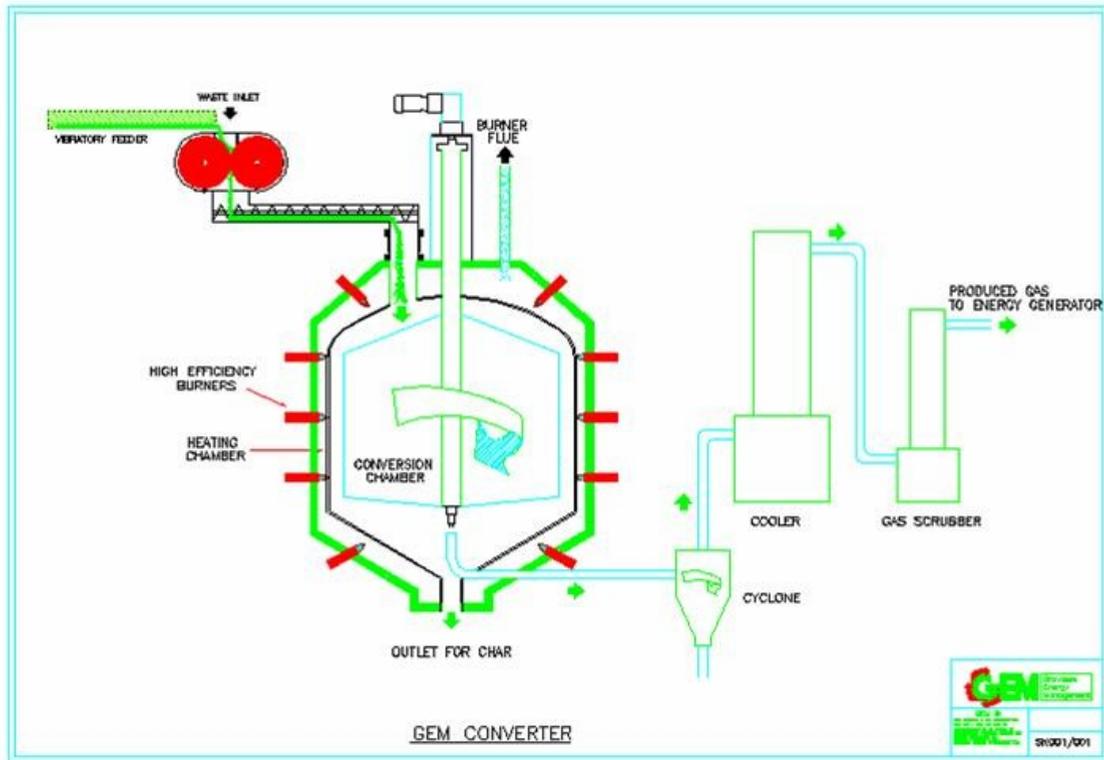


## Rigel Waste Conversion System: Westinghouse Plasma System

(Operating since 2004, Utashinai, Japan)



GEM America – Pilot Converter, South Wales  
40 TPD  
(Operated in 2001-2002)

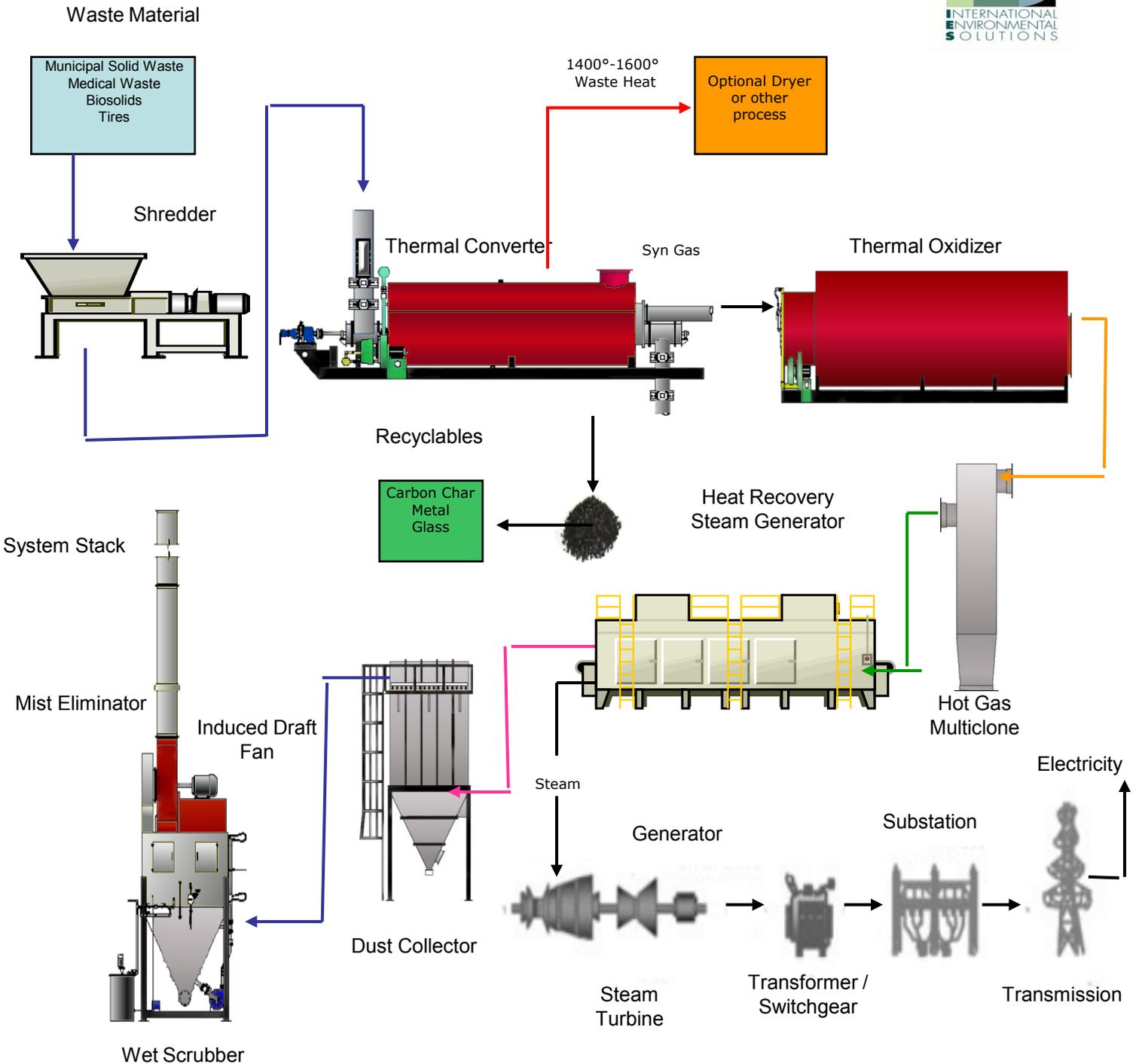


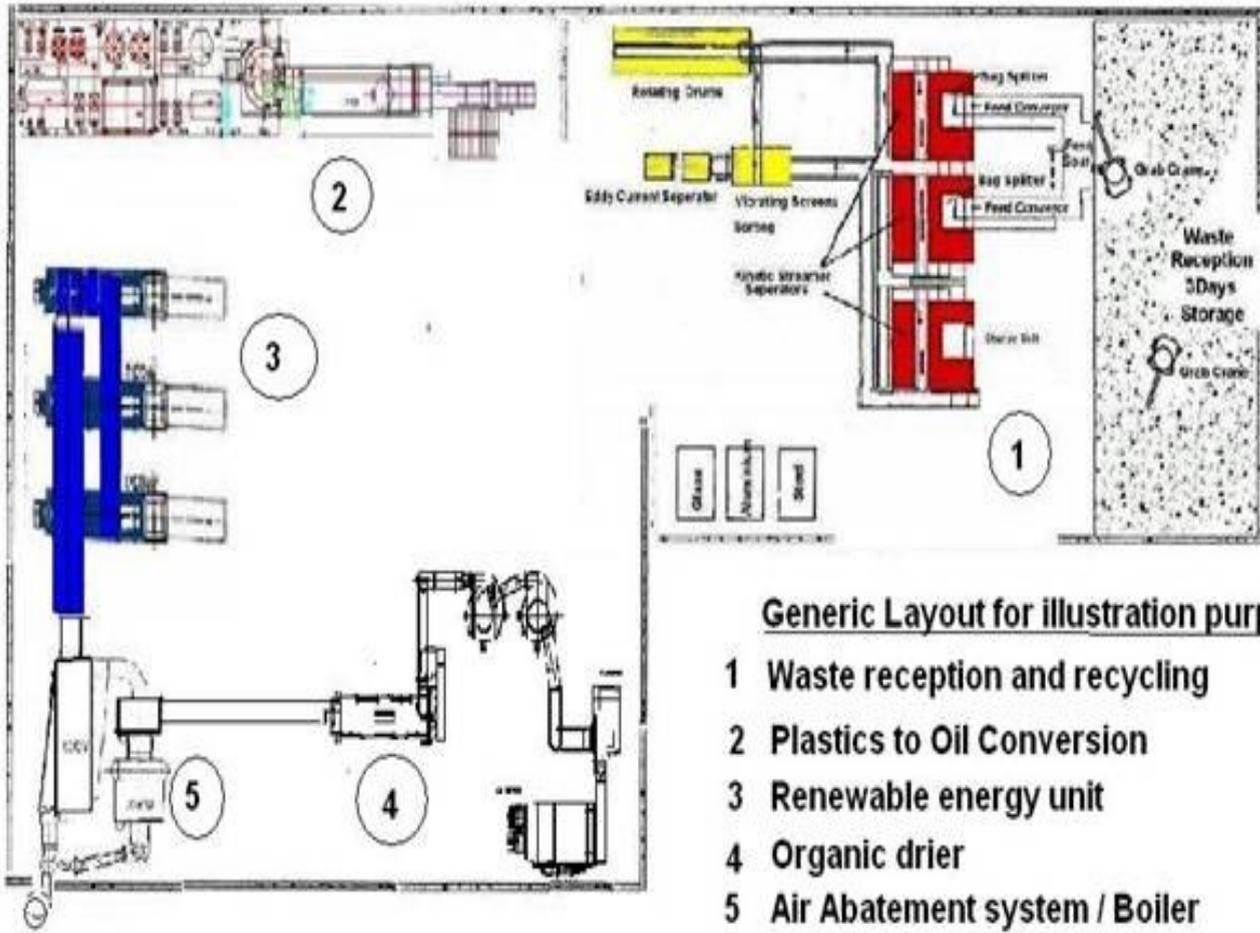
GEM America – Schematic Diagram



IES – Romoland, CA  
50 TPD  
(Operating since March 2005)

# PROCESS FLOW DIAGRAM





Entech Integrated Process Layout



Kinetic Streamer  
Wastec Facility, York UK  
(Operating since January 2005)



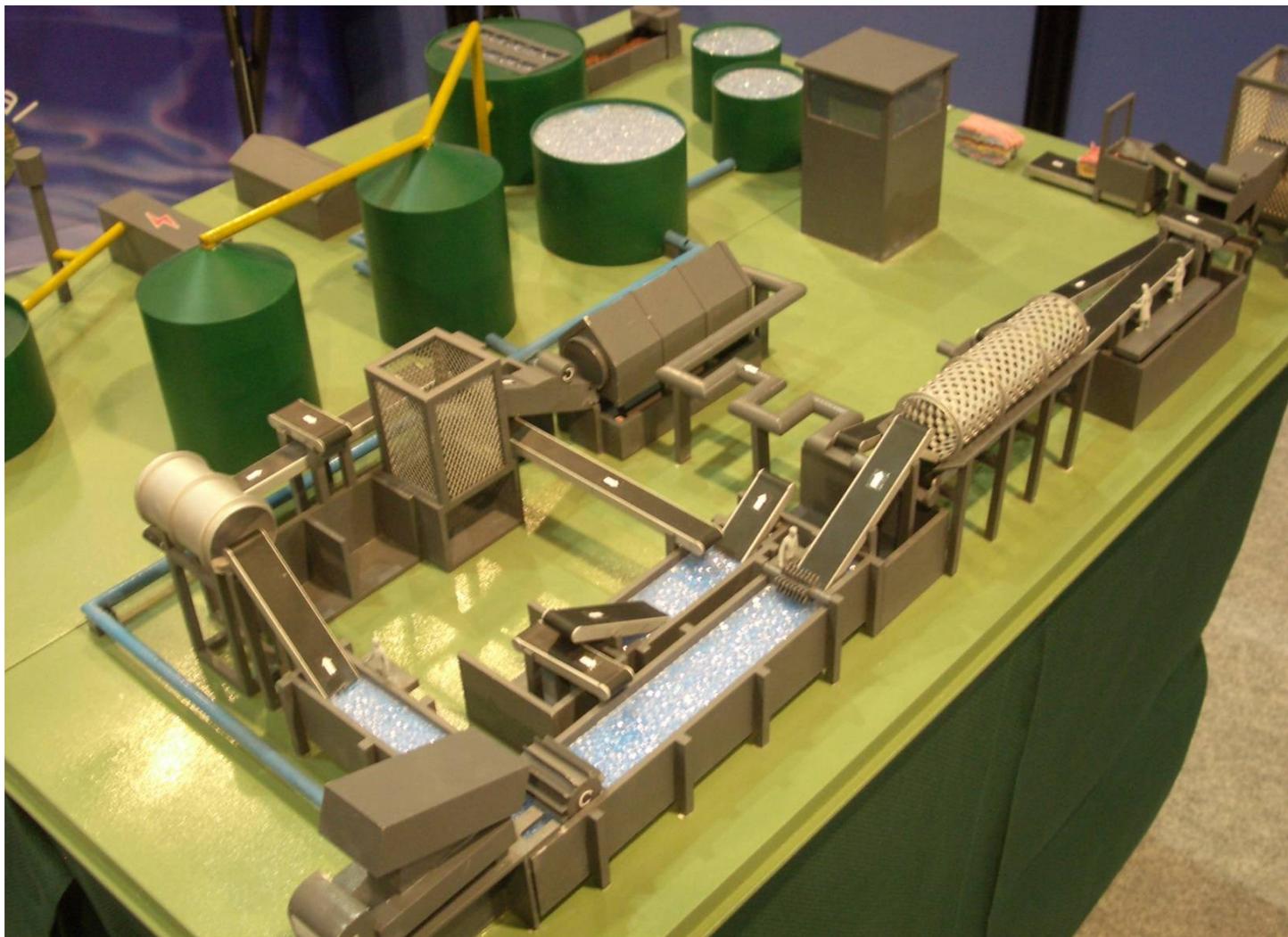
Royco (in Partnership with Entech)  
Plastic-to-Oil  
(Pyrolytic cracking using infra-red heating)  
North Korea  
3 TPD, Operation reported in 2007 to be  
“several years”



Gasifier and Thermal Oxidizer  
Entech Facility, Bydgoszcz, Poland  
25 TPD – Hospital Waste  
(Operating since February 2003)



NTech – Malaysia  
67 TPD



ArrowBio – Anaerobic Digestion  
System  
Tel Aviv  
110 TPD  
(Operating since 2003)



Separation/Processing

ArrowBio, Tel Aviv



Tipping to Process  
ArrowBio, Tel Aviv



Primary Flotation  
ArrowBio, Tel Aviv



Digestion Tanks  
ArrowBio, Tel Aviv



## Soil Amendment Results

ArrowBio, Tel Aviv



Reciprocating Engine/Gen Set

ArrowBio, Tel Aviv



ArrowBio – Artist Rendering for  
Sydney, Australia  
300 TPD



ArrowBio  
Jacks Gully  
Sydney, Australia  
May 2007



ArrowBio  
Jacks Gully  
Sydney, Australia  
November 2007



Plant View – Site Construction  
ArrowBio – Jacks Gully  
Sydney, Australia  
300 TPD  
April 2008



Plant View – Site Construction  
ArrowBio – Jacks Gully  
Sydney, Australia  
300 TPD  
July 2008



Plant View  
ArrowBio – Jacks Gully  
Sydney Australia  
300 TPD  
September 2008



Plant View  
ArrowBio – Jacks Gully  
Sydney Australia  
300 TPD  
September 2008



Plant View – Back Side  
ArrowBio – Jacks Gully  
Sydney Australia  
300 TPD  
September 2008



Primary Vats, Receiving Trommels  
Arrow Bio  
Jacks Gully  
Sydney, Australia  
300 TPD  
April 2008



Primary Vat  
ArrowBio – Jacks Gully  
Sydney, Australia  
300 TPD  
April 2008



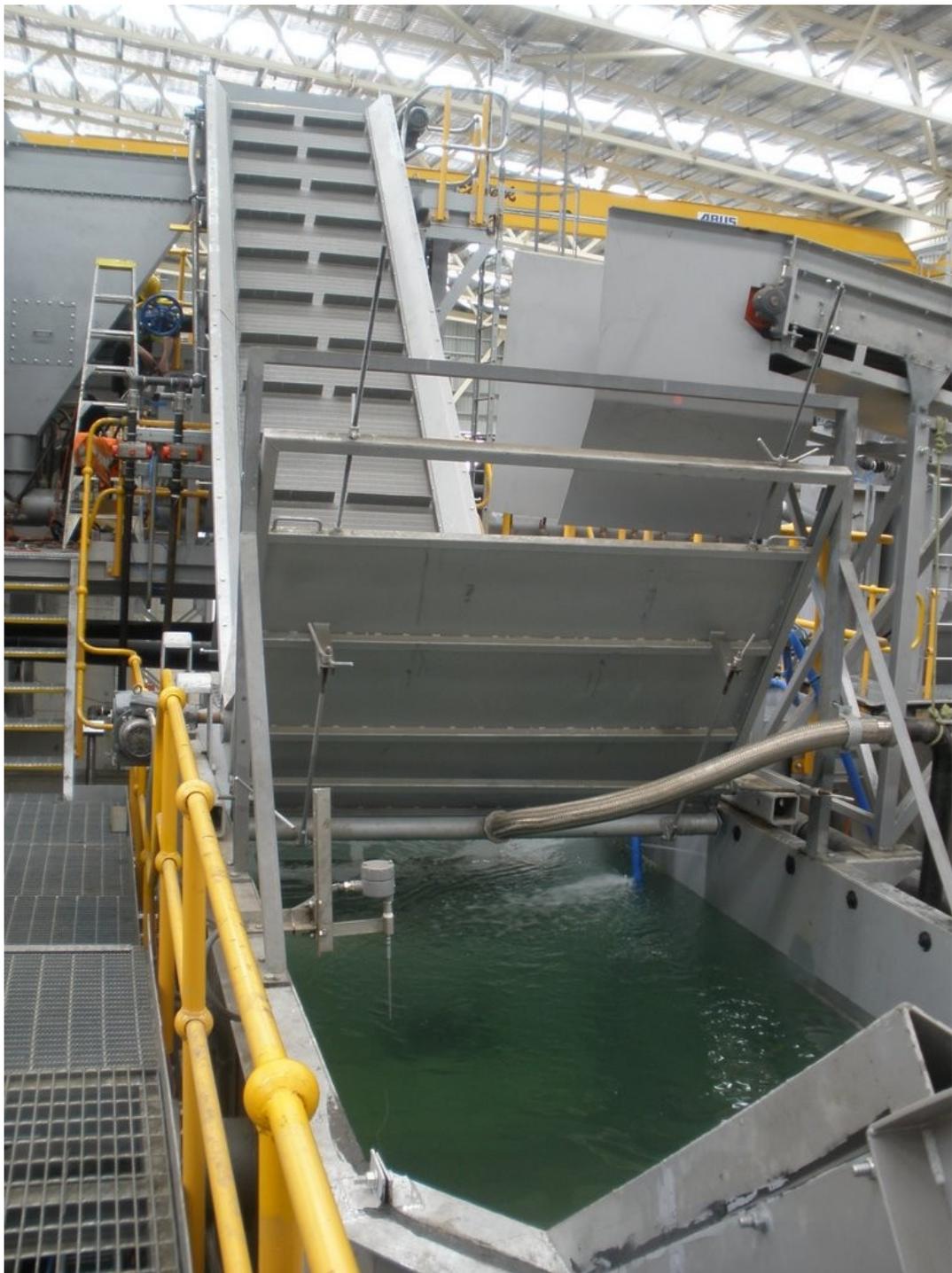
Receiving Trommel  
ArrowBio – Jacks Gully  
Sydney, Australia  
300 TPD  
April 2008



Strain Press  
ArrowBio – Jacks Gully  
Sydney Australia  
300 TPD  
April 2008



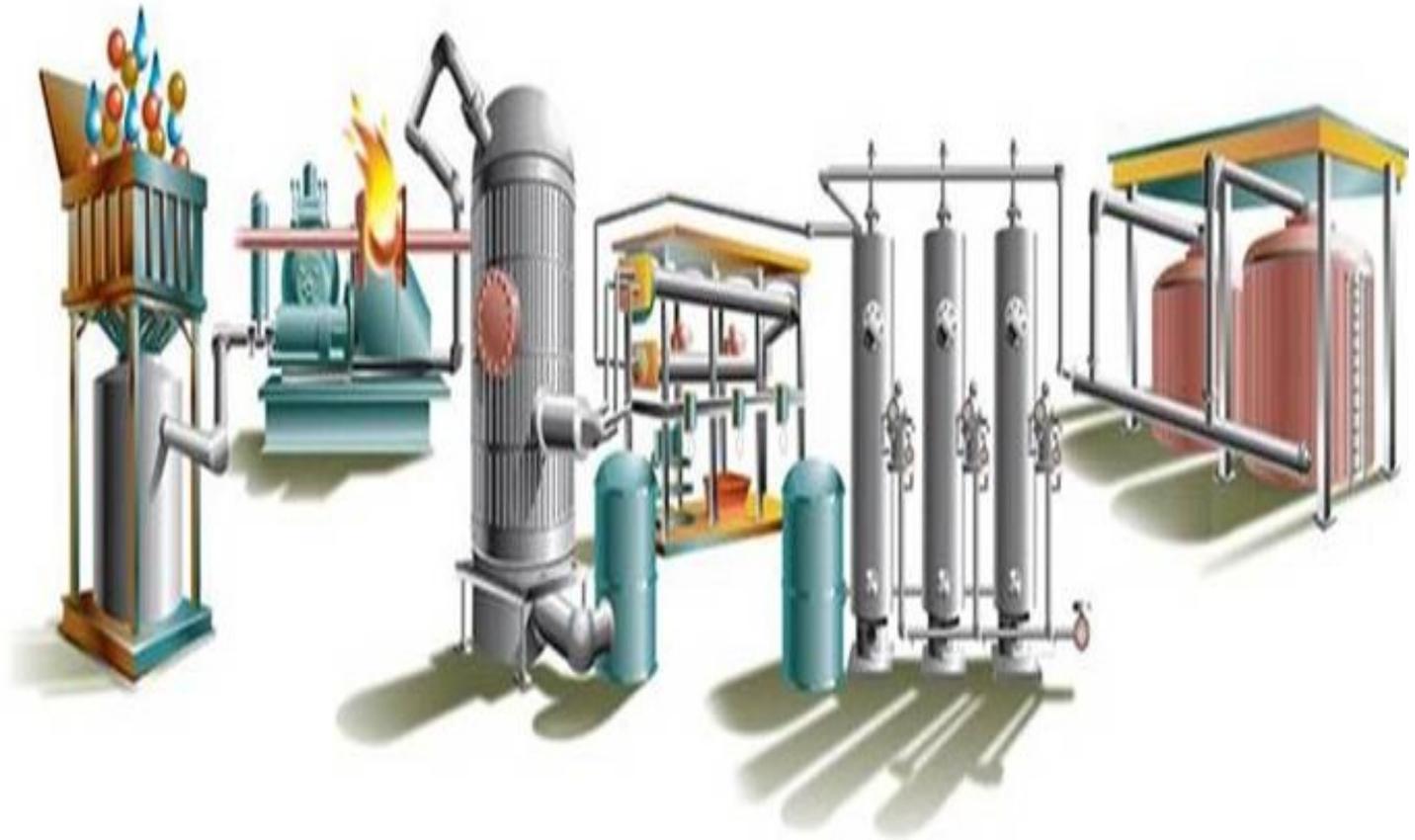
Vats and Trommels  
ArrowBio – Jacks Gully  
Sydney Australia  
300 TPD  
September 2008



Secondary Vat  
ArrowBio – Jacks Gully  
Sydney Australia  
300 TPD  
September 2008



CWT – Process Equipment  
Carthage, MO  
250 TPD  
(Operating since February 2005)



## Changing World Technologies – Process Steps



CWT – Oil Products