SIERRA ENERGY

Meeting Climate Change Goals with FastOx® Gasification

A&WMA West Coast Section Annual Conference 10/17/2019

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sierraenergy.com


IN 2025 THE WORLD WILL PRODUCE 2.2 BILLION TONS OF WASTE
Data from World Bank

Background – Problem Statement

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- U.S. generates 250 million tons of waste annually and 100 million tons are landfilled (U.S. EPA)
- California sends over 28 million metric tons of waste to landfills annually.
- 89% of transportation from fossil fuels still (2018, US eia).
- Methane is up to 84x more polluting than CO_2.

OVERVIEW

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- Background
- Technology
- Demonstration
- Results
- Next Steps

Sierra Energy team at Fort Hunter Liggett Site during commissioning

Background – Sierra Energy

About Sierra Energy

- Waste to clean energy company
- Proven technology developed and tested with the U.S. Army
- Profitable operations
- Global partners
- Series A funding for commercialization

Sierra Energy HQ in Davis CA

Background – Sierra Energy History

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2004
Sierra Energy is formed to find a way to make locomotive diesel fuel

2009
FastOx gasifier testing begins with UCD and DoD

2012
DoD invests $3M for project at Fort Hunter Liggett (FHL)

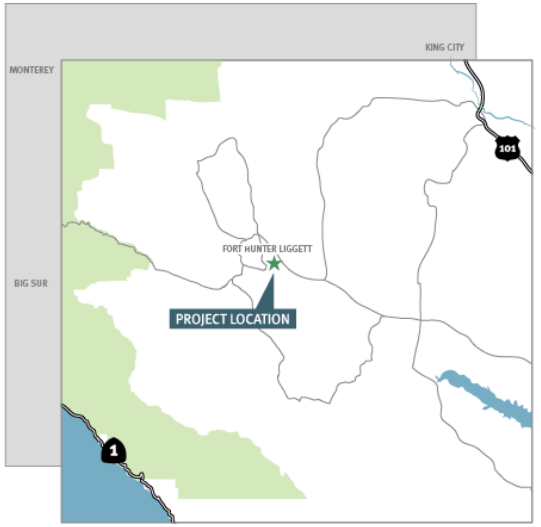
2013
CEC invests $5M in FHL project for fuel production

2016
Construction of first commercial facility begins at FHL

2017
Operations begin at FHL converting MSW to electricity and diesel

Background – Demonstration Project

Demonstration Site: U.S. Army Garrison Fort Hunter Liggett, Jolon, California



Objectives

- Design, develop, and demonstrate the effectiveness and economic feasibility of a commercial scale waste to renewable energy plant.
- Verify that this process is a beneficial way to achieve energy resiliency and security.

Project Funding

- $5M from CEC
- $3M from ESTCP
- Remainder of project funded by Sierra Energy

Technology - FastOx® gasification

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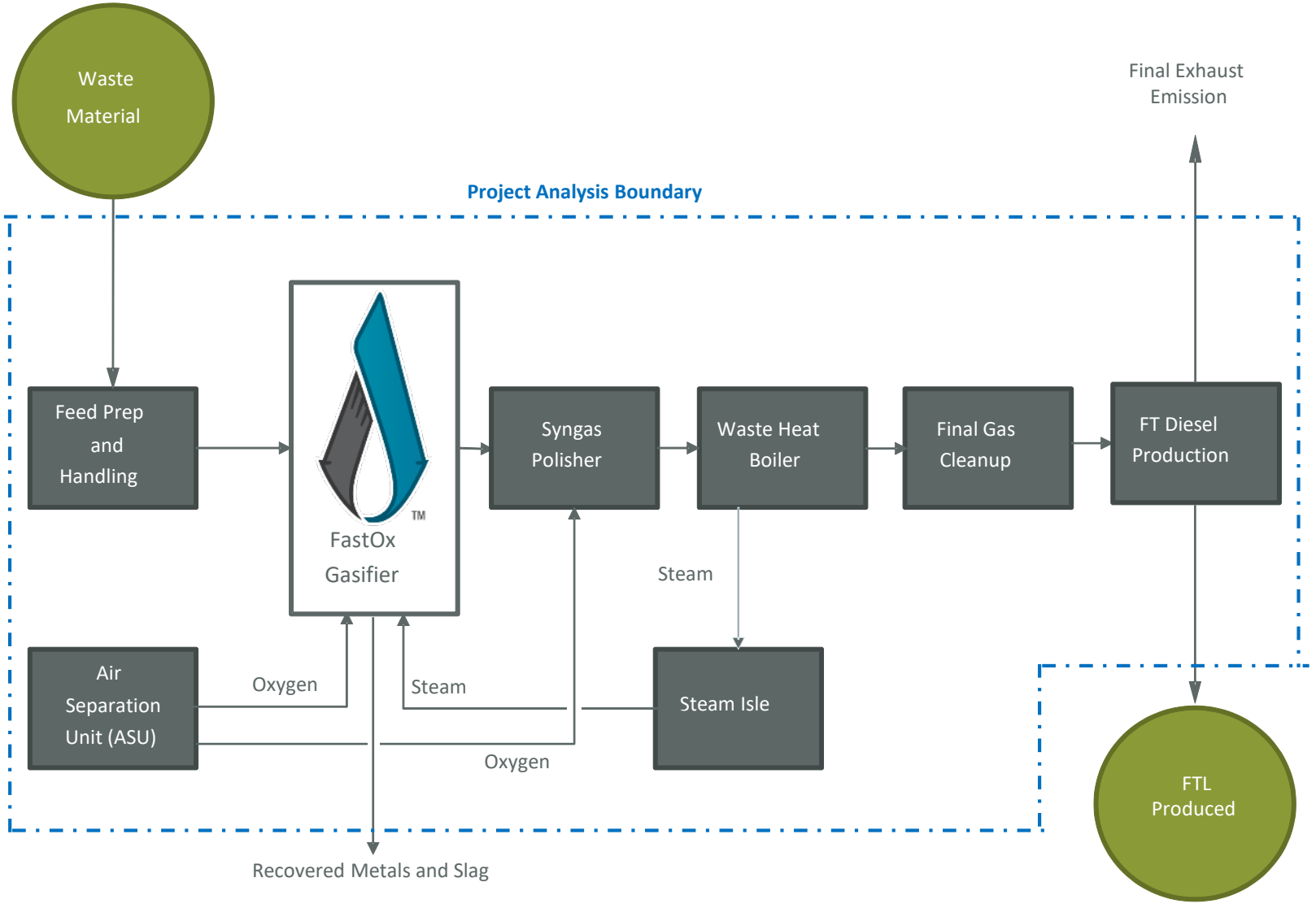

Technology – Prototype Testing

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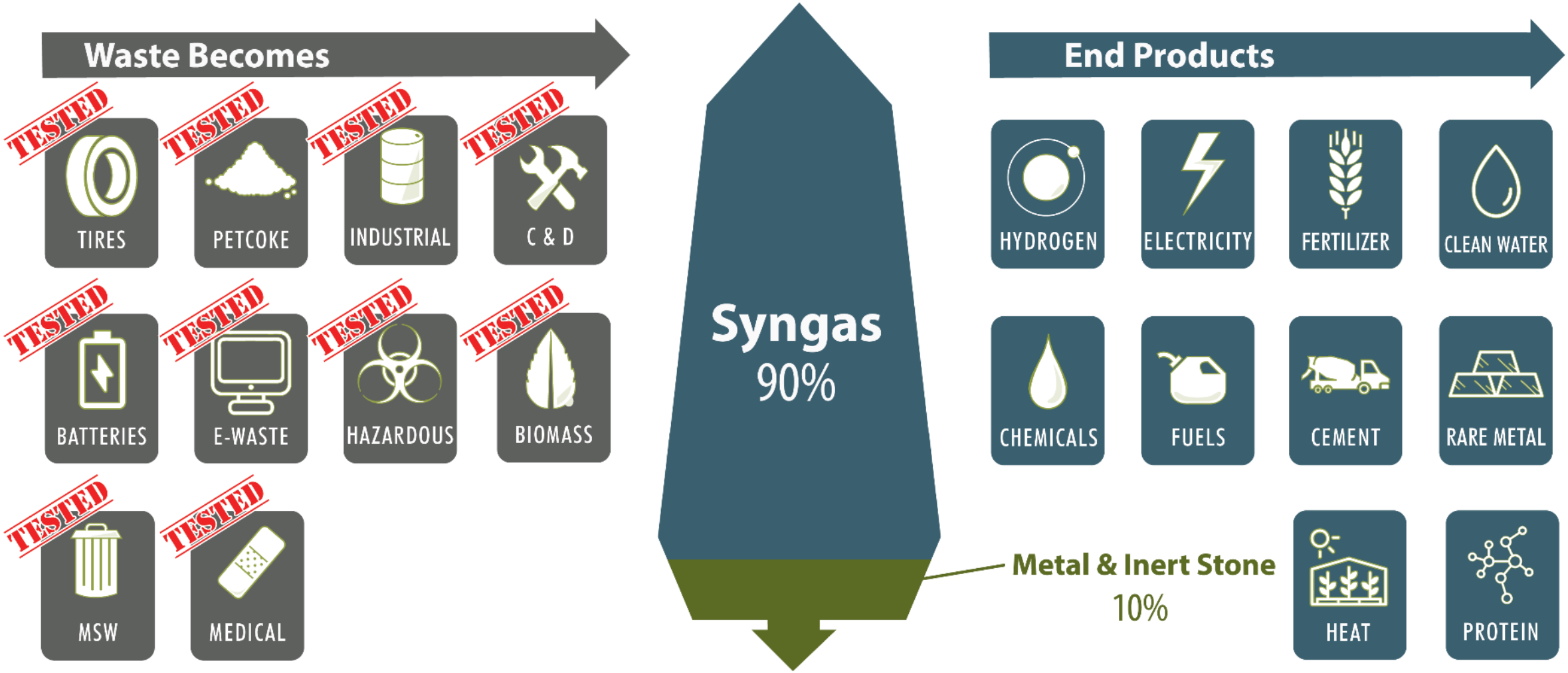

Technology – Full gasification plant

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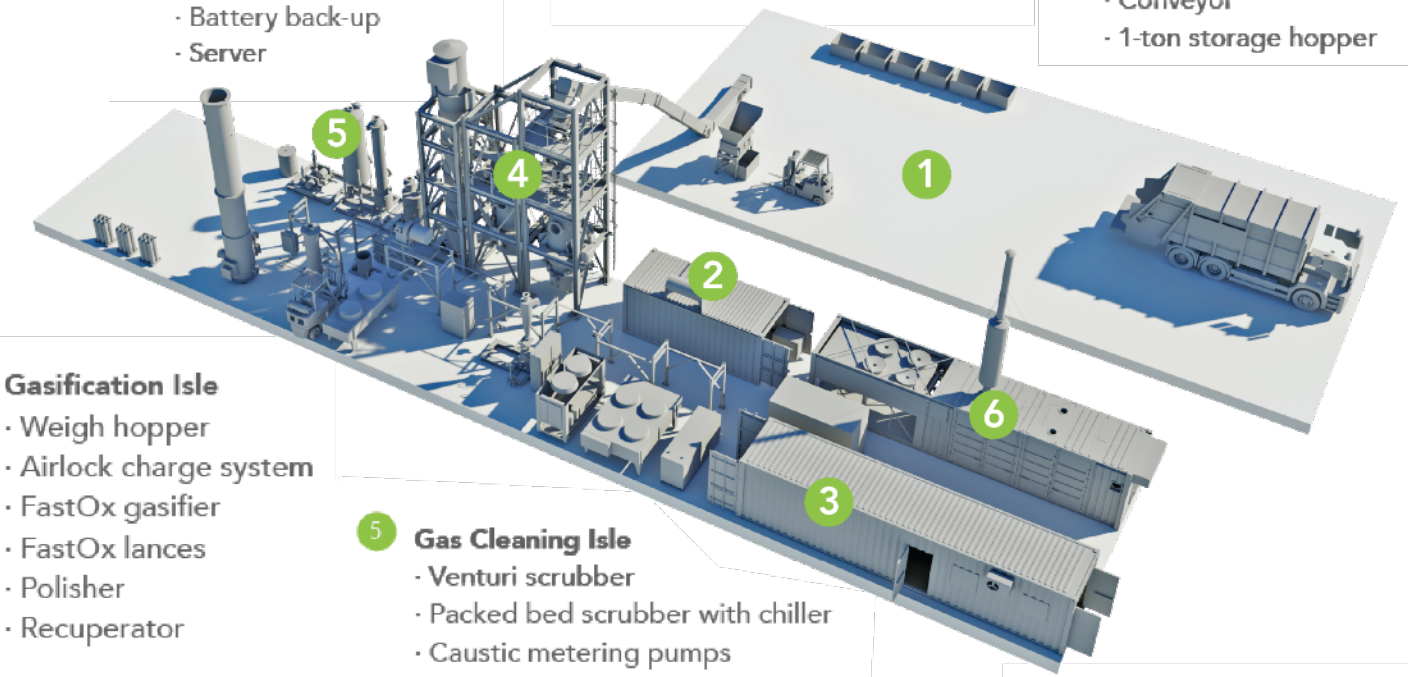
3 Controls Isle
- Motor control center
- Programmable logic controller
- Operator station
- Engineering station
- Electrical instruments and controls
- Battery back-up
- Server

2 Utilities Isle
- Air compressor
- Steam boiler
- Cooling water circulation tank and pump
- Nitrogen supply tank
- Oxygen concentrator

1 Feedstock Preparation Isle
- Quad shredder
- Conveyor
- 1-ton storage hopper



4 Gasification Isle
- Weigh hopper
- Airlock charge system
- FastOx gasifier
- FastOx lances
- Polisher
- Recuperator

5 Gas Cleaning Isle
- Venturi scrubber
- Packed bed scrubber with chiller
- Caustic metering pumps
- Sodium hydroxide tank
- Hydrogen sulfide (H2S) guard bed
- Syngas blower with cooler
- Carbon bed

6 End Product Isles
- Customizable depending on desired end product

Technology - FastOx® Gasification System

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Feedstock Preparation - The FastOx® system requires minimal pre-processing.

- Shredder - Resizes waste to smaller than 2 inches
- Weigh Hopper
- Conveyor

Technology - FastOx® Gasification System

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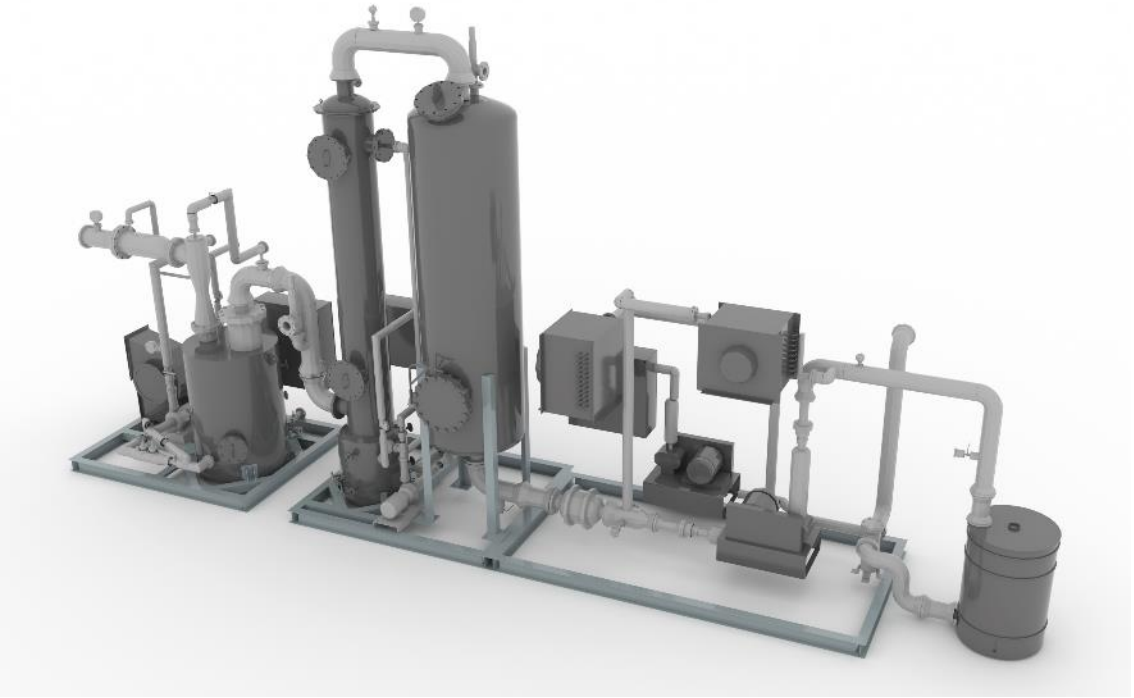
Gas Cleaning - Several levels of gas cleaning equipment purify syngas for the end-product.

Major components at FHL:

- Venturi scrubber
- Packed bed scrubber
- H_2S bed
- Carbon bed



Technology - FastOx® Gasification System

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Utilities - Utilities and auxiliary equipment are integrated into each system module.

Major utility equipment:

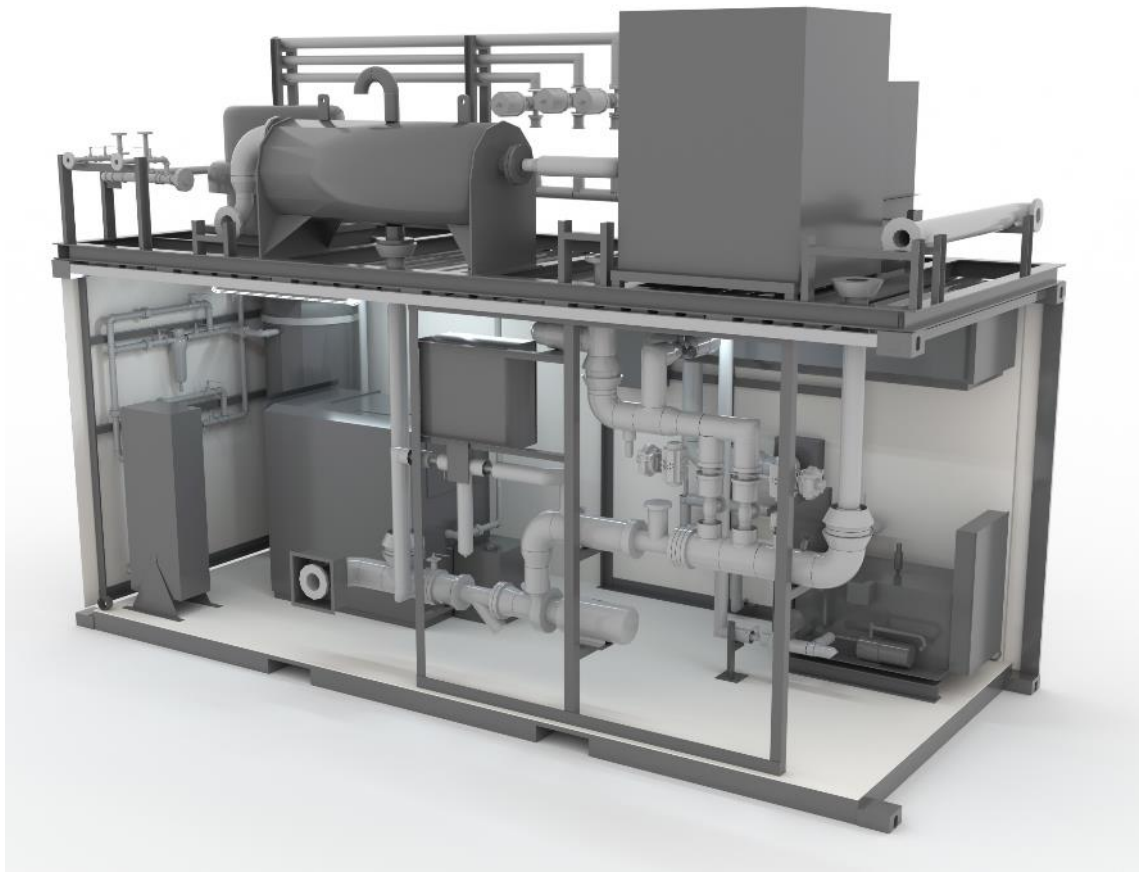
- Oxygen generator
- Nitrogen supply

Auxiliary equipment:

- Blowers
- Pumps
- Compressors

Standard utilities:

- Electricity
- Water
- Wastewater



Technology - FastOx® Gasification System

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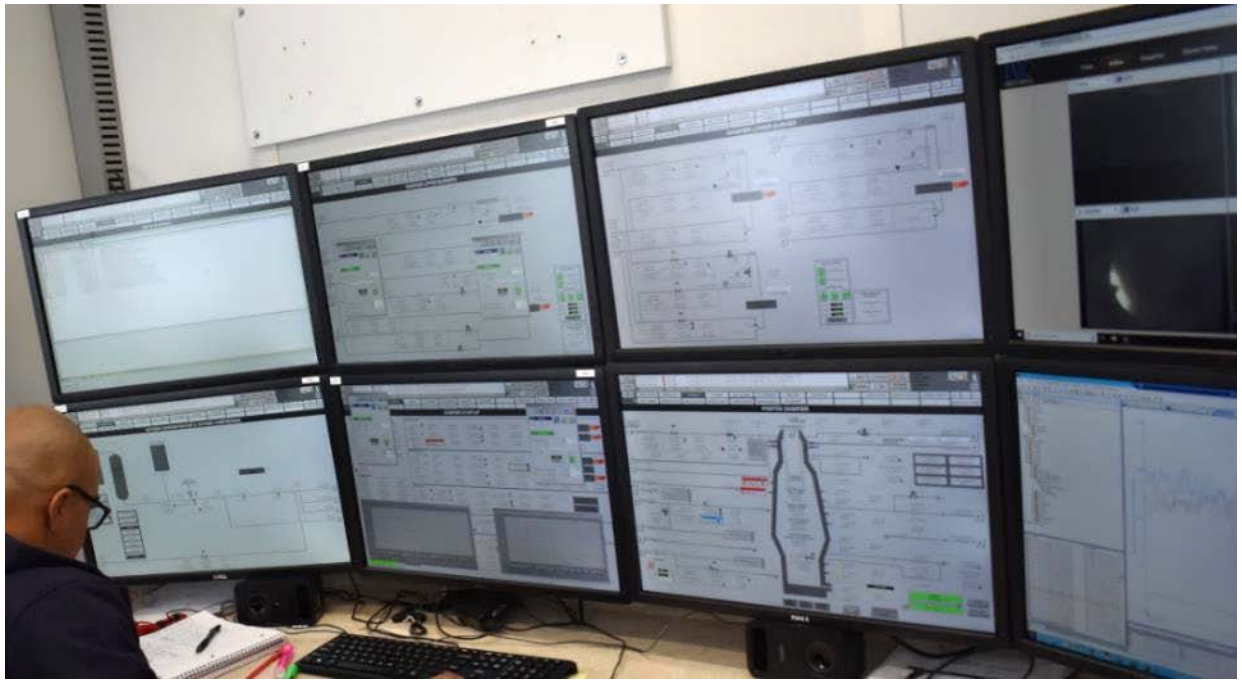
Control Room - Custom control system optimizes in real time.

- Monitor process
- Safety
- Collects data

*One board operator per shift



Technology – Liquid Fuels

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RTI Fischer-Tropsch Unit Operations

- Gas Conditioning module
- FT Reactors
- Product separation and collection

RTI INTERNATIONAL

Technology – Electricity Generation

Electricity Genset

- High-H2 genset
- 33.7% electrical efficiency
- Lean-burn, lower emissions than other fossil fuel derived electricity

Technology - Core GPRC

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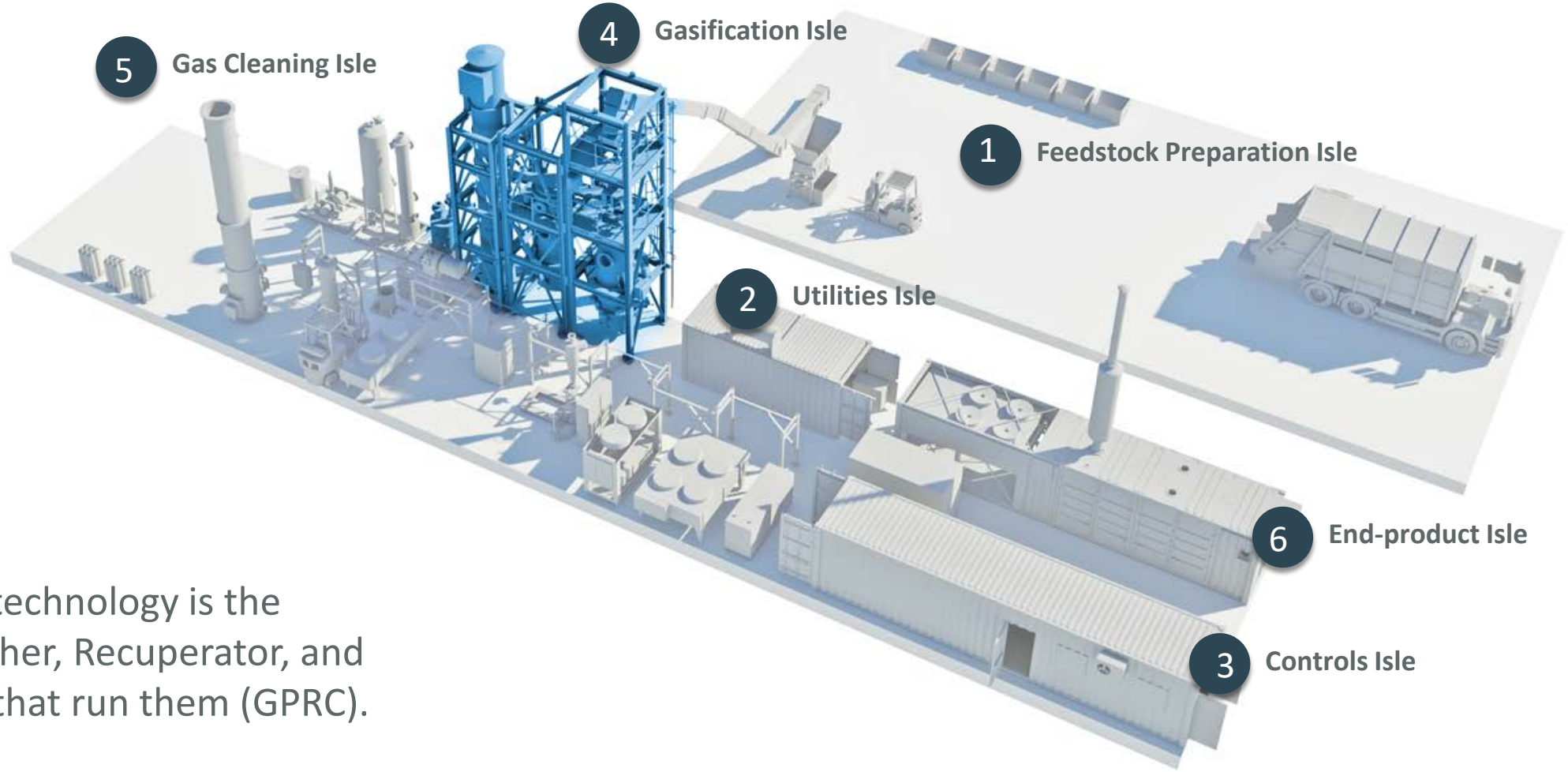

Sierra's core technology is the Gasifier, Polisher, Recuperator, and the Controls that run them (GPRC).

Technology - FastOx® Gasification System

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FastOx Gasification

- System gasifies virtually any waste with no sorting required
- No process emissions – closed system
- Low maintenance with high up-time
- All outputs are salable
- Reaches 4,000°F via oxygen and steam injection

FHL Plant Gasification vessel specifications

- Processes up to 20 tons per day of complex waste
- Total volume: 7 m^3

Technology - Yield Table Next System

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Output per Day | 50 tpd Feedstock Input

	Electricity (MWhe)	Diesel (gal)	Hydrogen (kg)	Ammonia (kg)
Post-Recycled MSW	47.8	1,697	3,073	17,400
Medical Waste	47.3	1,653	3,005	17,050
Tires	64.3	2,318	4,308	24,450
Biomass	61.0	2,072	3,725	21,100
Auto Shredder Residue	36.2	1,302	2,443	13,850

Technology – Multiple Tech Solution

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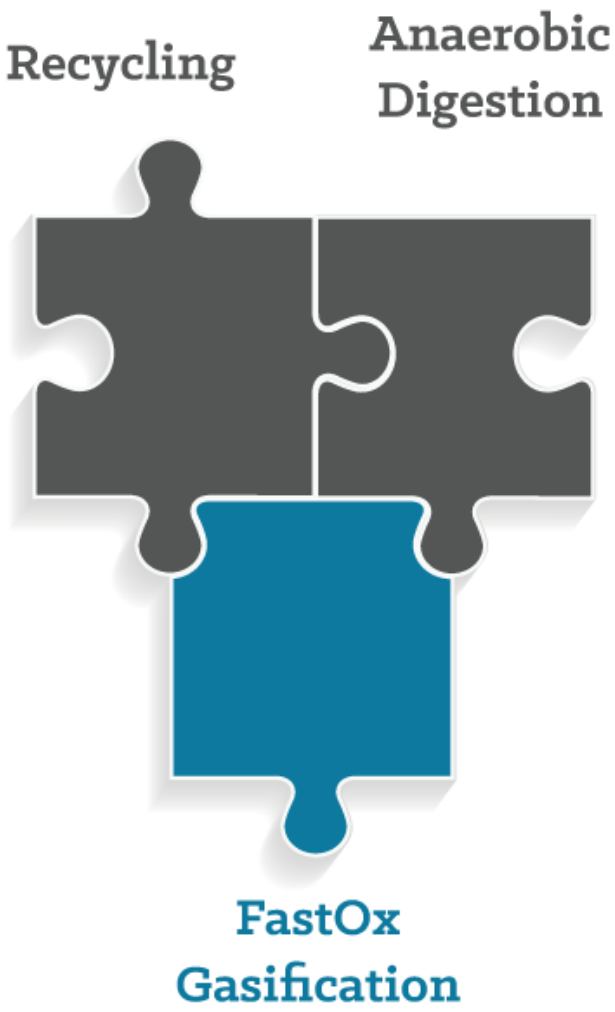

FastOx® Technology Collaborators

KAISER STEEL

UCDAVIS GRADUATE SCHOOL OF MANAGEMENT

LKAB

tss consultants

BAOSTEEL

AIST ASSOCIATION FOR IRON & STEEL TECHNOLOGY

McMaster University

Berry METAL COMPANY

U.S. ARMY RDECOM TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

CH2MHILL

UCDAVIS UNIVERSITY OF CALIFORNIA

COSTELLO

ATSI

exida

Rockwell Automation

Michael Baker INTERNATIONAL

Andy J. Egan Co., Inc.

BAKERRISK Combustible Dust Analysis

NFPA MEMBER 2018–2019

RTI INTERNATIONAL

unitel technologies

MAVERICK TECHNOLOGIES

AMERICAN SAFETY SERVICES INC

U.S. DEPARTMENT OF ENERGY

Lawrence Livermore National Laboratory

MATRIX PDM ENGINEERING

wood.

INL Idaho National Laboratory

LEHIGH UNIVERSITY

Demonstration - Fort Hunter Liggett

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STATE OF CALIFORNIA ENERGY COMMISSION

U.S.ARMY

DEPARTMENT OF DEFENSE ESTCP

DEFENSE LOGISTICS AGENCY

Demonstration – Installation

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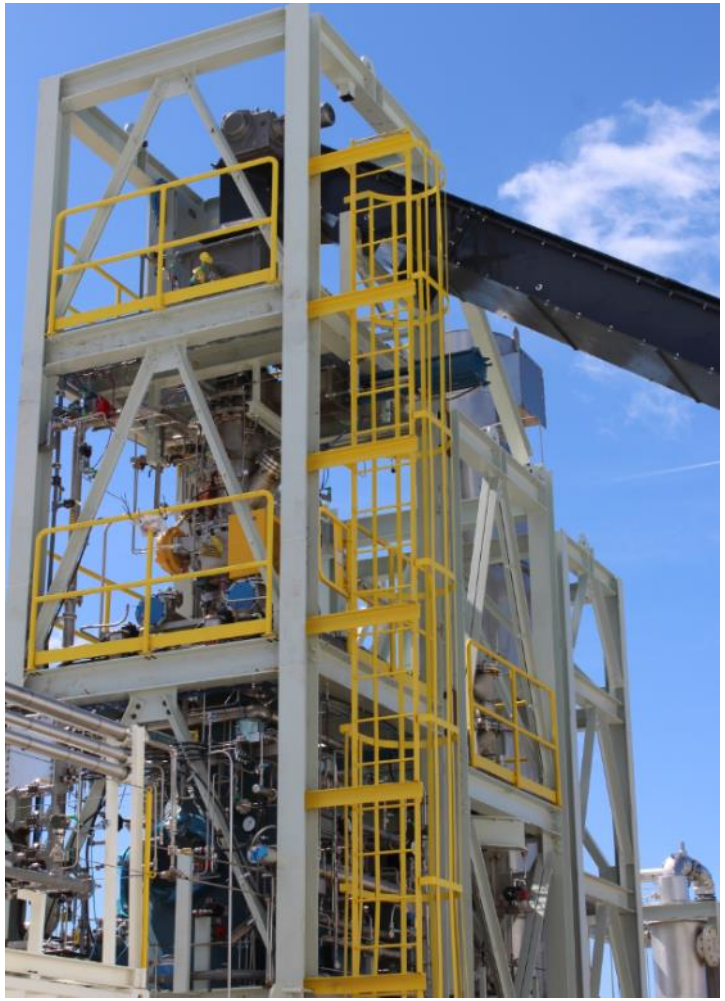

Demonstration - Commissioning

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Woody biomass feedstock used for vessel curing and commissioning.

Commissioning included:

- Site Acceptance Testing
- Subsystem Operational Testing
- Plant Performance Testing

Demonstration - Operations

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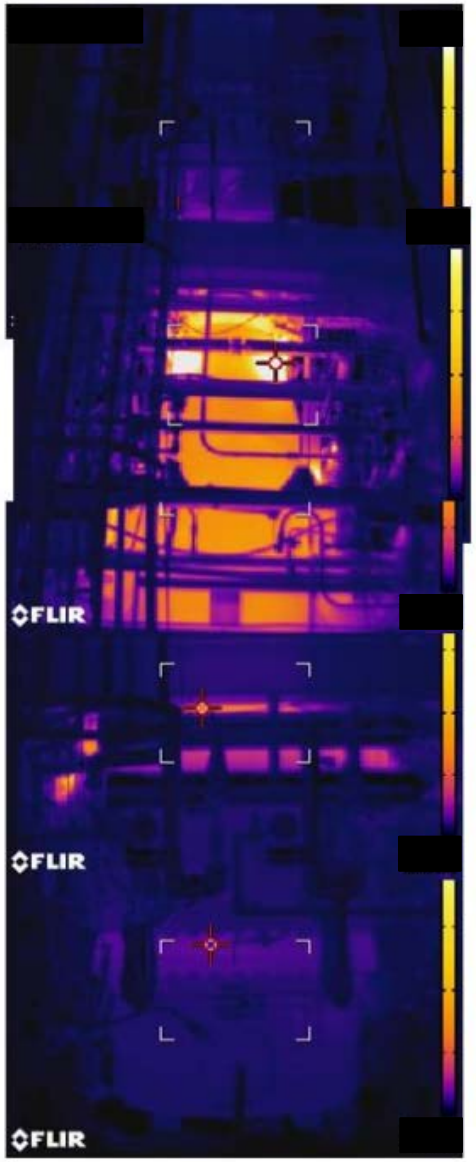

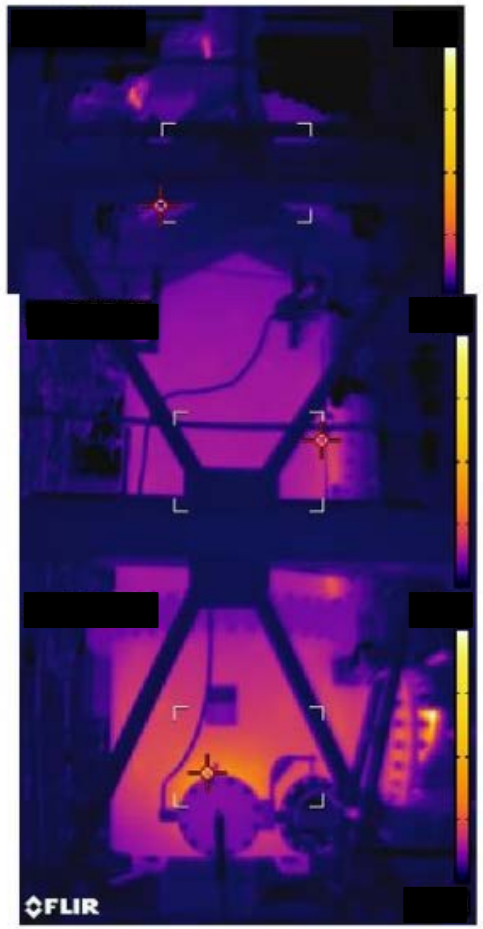

- Feed testing
- Vessel testing
- Campaign testing

Demonstration – Permitting

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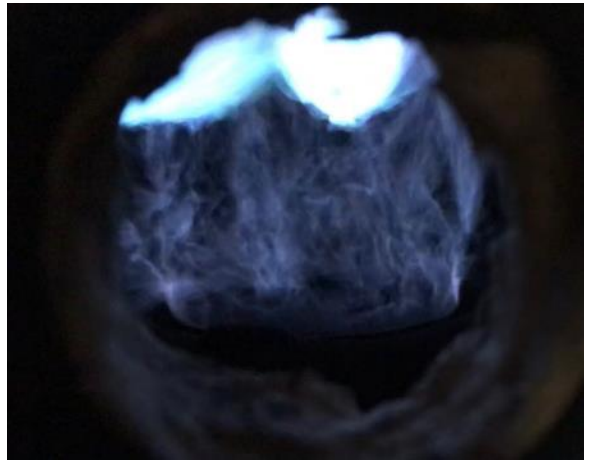
Topic	Agency	Requirement	Date Obtained
Air permit – Authority to Construct (ATC)	Monterey Bay Unified Air Pollution Control District	Permit to Procure and install equipment per the Air Board's requirement	5-Feb-2015 and updated 9-Jun-2017 and 1-Feb-2018 and 5-Dec-2018
Air Permit – Permit to Operate	Monterey Bay Unified Air Pollution Control District	Permit to operate the system / plant continuously	In progress
Solid Waste Permit Exemption	Monterey County DoH	Ensure system / plant meets all state and local requirements	1-Mar-2016
Water	FHL Dept. of Public Works (DPW)	Ensure backflow preventers meet all state and local requirements	12-Jul-2017
Waste Water (Discharge to FHL)	CCRWQCB	Confirmation that system does not require FHL to obtain new permit	8-Apr-2015
CEQA / NEPA	CEC (CCRWQCB, MBARD and FHL DPW)	Project needs to be CEQA compliant given the funding sources requirement	1-Jun-2015
Cal/OSHA	Cal/OSHA	Confirmation that the system does not trigger PSM (Process Safety Management)	24-Jan-2018
SPCC	FHL DPW	Double-wall tanks and concrete tertiary spill containment areas	Coordinated with FHL DPW
Pressure Vessels	Cal/OSHA Pressure Vessel Division and FHL DPW	Meets CA Dept. of Industrial Relations requirements	7-Jun-2016 – 9-Mar-2017
Boiler	Cal/OSHA Pressure Vessel Division	Permit to operate steam boiler	29-Jun-2017
Fire	FHL Fire Department	Inspections to confirm equipment, and layout meets FHL FD, California and Federal requirements	4-Apr-2017
Structural	FHL DPW	Meets CA requirements	27-Apr-2016 – 24-Feb-2017

Results – Demonstration Results

Milestone Achieved

Sierra Energy operated the FHL gasification unit at a minimum of 10 continuous hours of FastOx® oxy-steam injection gasification of clean wood waste at a maximum capacity of 5 metric tons per day (MTPD).



Component	Measured Syngas (corrected for N_2) [vol%]
CH_4	4.9%
CO	35.4%
CO_2	35.2%
H_2	24.6%
N_2	0.0%
Sum	100.1%

Results - Demonstration Results

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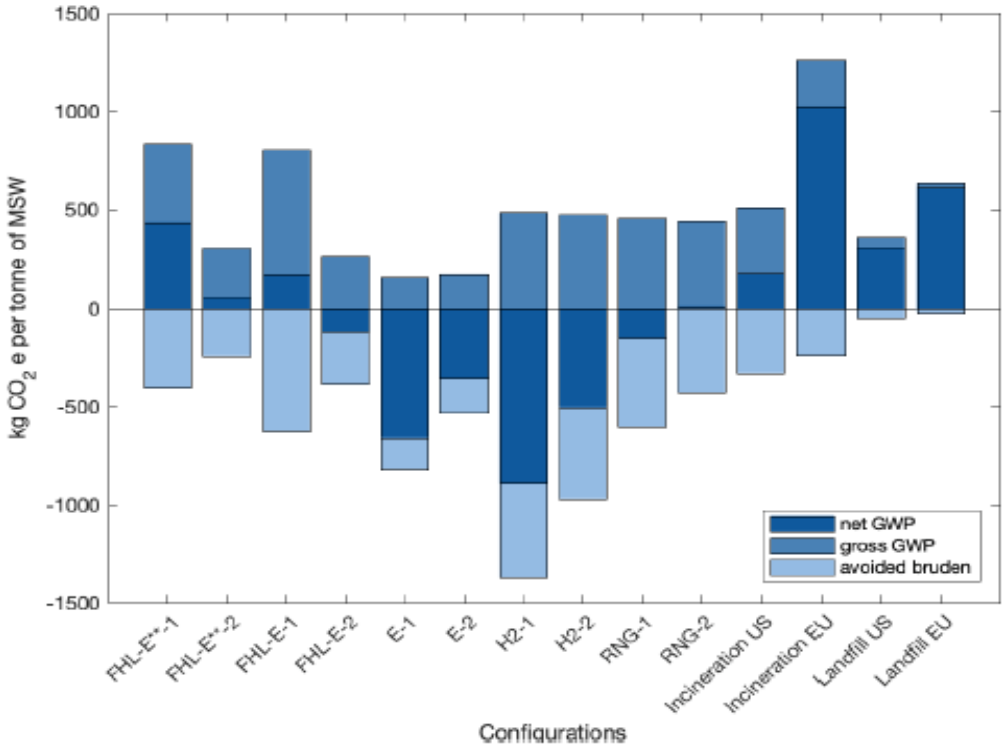
- Vitrified stone co-product confirmed non-hazardous, and therefore can be sold and reused

	TTLC					STLC			TCLP		
Elements (Symbol)	Regulatory Limit Limit	Result	Haz. Waste?	STLC Test req?	TCLP Test req?	Limit	Result	Haz. Waste?	Limit	Result	Haz. Waste?
	mg/Kg	mg/Kg	Yes / No	Yes / No	Yes / No	mg/L	mg/L	Yes / No	mg/L	mg/L	Yes / No
Antimony (Sb)	500	ND	No	No	--	15	ND	No	--	ND	No
Arsenic (As)	500	0.76	No	No	No	5	ND	No	5	ND	No
Barium (Ba)	10,000	960	No	No	No	100	5	No	100	0.59	No
Beryllium (Be)	75	0.86	No	No	--	0.75	ND	No	--	ND	No
Cadmium (Cd)	100	ND	No	No	No	1	ND	No	1	ND	No
Chromium (Cr)	2,500	160	No	Yes	Yes	5	1.1	No	5	ND	No
Cobalt (Co)	8,000	3	No	No	--	80	0.068	No	--	ND	No
Copper (Cu)	2,500	280	No	Yes	--	25	0.054	No	--	0.046	No
Lead (Pb)	1,000	ND	No	No	No	5	0.2	No	5	0.054	No
Mercury (Hg)	20	ND	No	No	No	0.2	ND	No	0.2	ND	No
Molybdenum (Mo)	3,500	11	No	No	--	350	0.15	No	--	ND	No
Nickel (Ni)	2,000	54	No	No	--	20	1.3	No	--	0.096	No
Selenium (Se)	100	0.71	No	No	No	1	ND	No	1	ND	No
Silver (Ag)	500	0.48	No	No	No	5	ND	No	5	ND	No
Thallium (Tl)	700	0.99	No	No	--	7	ND	No	--	ND	No
Vanadium (V)	2,400	12	No	No	--	24	0.081	No	--	ND	No
Zinc (Zn)	5,000	2	No	No	--	250	ND	No	--	ND	No

Results – UC Davis Life Cycle Assessment

UC Davis Institute for Energy and Efficiency visiting student from Germany presenting her masters thesis on FastOx technology



Comparison of the FastOx configuration for landfill and Incineration

Next Steps – FHL Operations

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Continued FHL Operations

- Wood waste testing
- MSW
- FT Isle Commissioning
- Permit to Operate

Future R&D

- New feedstocks campaigns
- H2 demonstration (DLA SBIR P2)

Next Steps – Outreach

Outreach:

- Facility tours
- Ribbon cutting
- Special events
- Speaking events

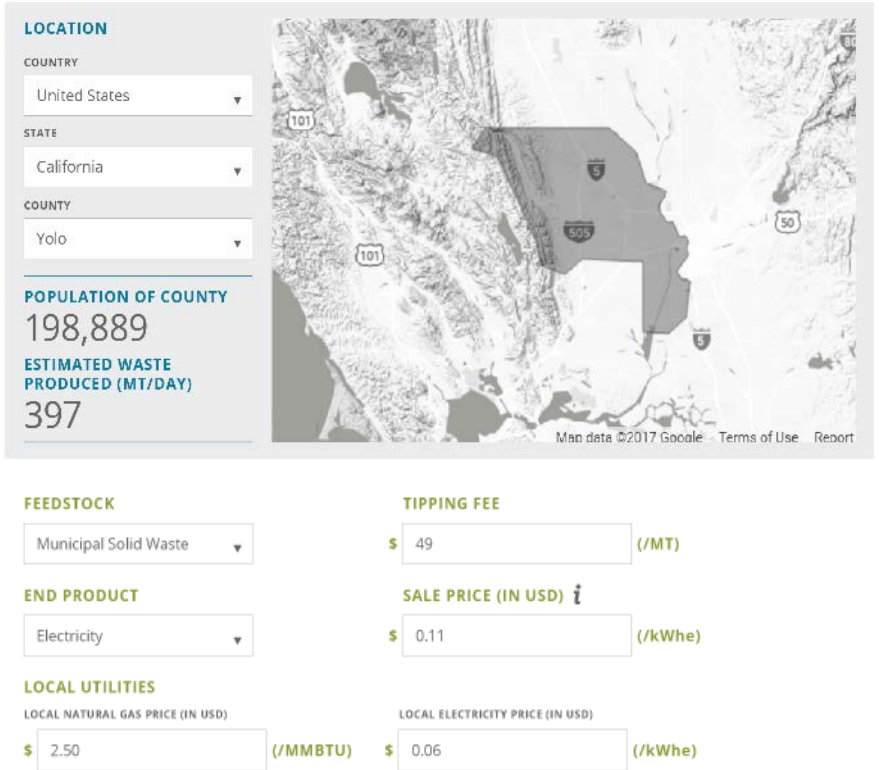
Research and Program Areas:

- Academic – student and research collaborations
- Institutions – national labs and other industry research entities
- Defense – federal installation and research
- SERP R&D facility at Davis

Team of researchers visiting from Idaho National Laboratory

Next Steps - Commercialization

Potential customers share valuable project data on local tipping fees, waste types, volumes and energy costs on the Sierra Energy calculator.



Next Steps - Commercialization

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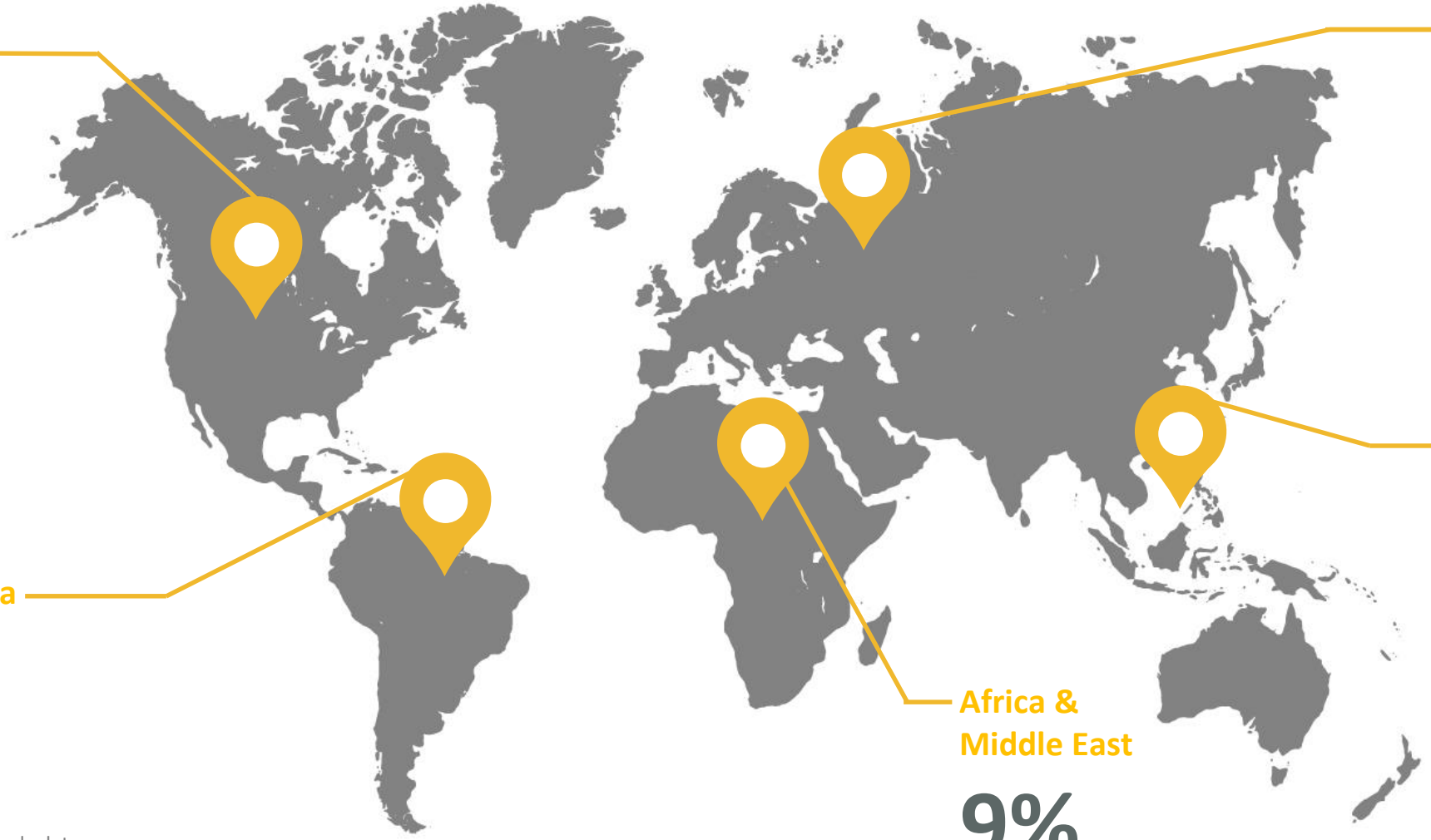

North America
53%

Europe
13%

South America & Caribbean
11%

Asia & Oceana
14%

Africa & Middle East
9%

Data Source: Sierra Energy online calculator.
1,200 recent calculator runs.

Next Steps - Commercialization

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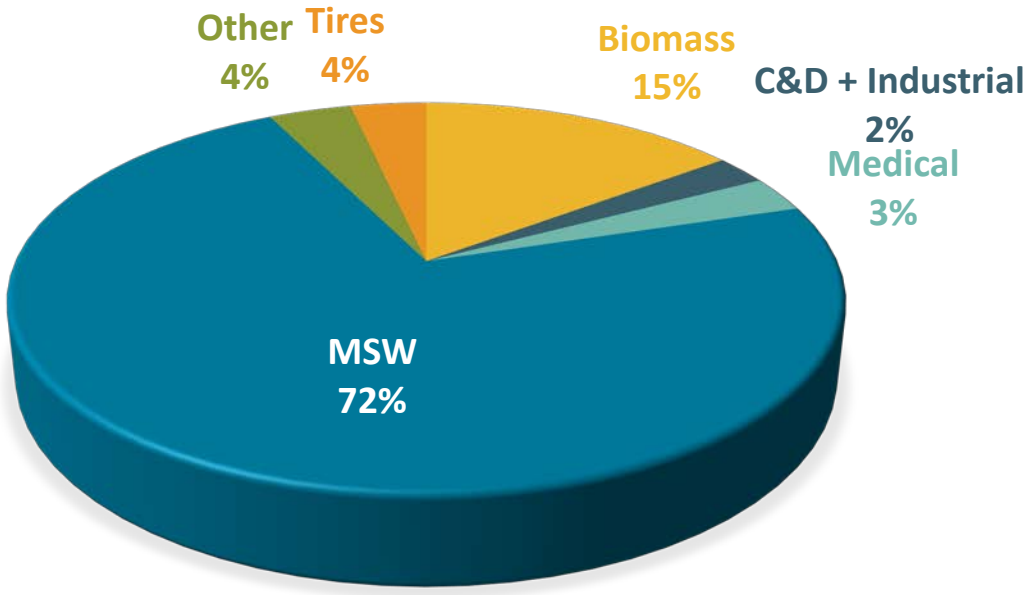
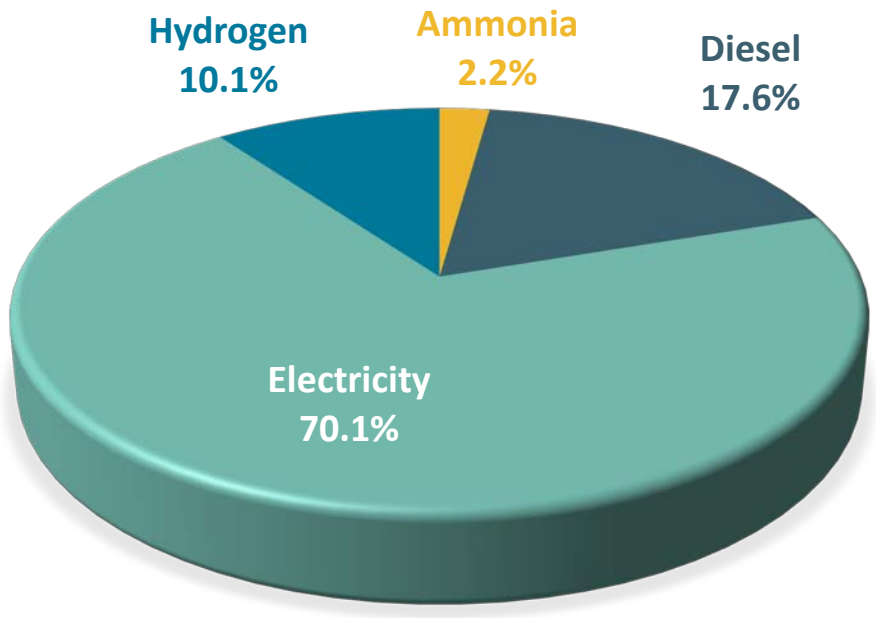
Majority of inquiries are MSW to Electricity systems





Data Source: Sierra Energy online calculator.
1,200 recent calculator runs.

Next Steps - Commercialization

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Global visitors to FHL plant:
Thailand, Poland, Turkey, Vietnam, Mexico, Trinidad and Tobago, Argentina.

Project Development

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Sierra Energy is looking to partner with project developers all over the world

- Sierra is not building to own and operate
- Sierra will license technology to partners and providing engineering support

Thank You

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Case Study: Landfill Waste to Electricity

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INVESTMENT ECONOMICS

Capital Investment:	$13,675,000
Annual Operating Income:	$1,650,000
Simple Payback:	**8.3 years**
Annual ROI:	**12.1%**

Case Study: Medical Waste to Electricity

SIERRA ENERGY

INVESTMENT ECONOMICS

Capital Investment:	$13,844,000
Annual Operating Income:	$9,538,000
Simple Payback:	**1.4 years**
Annual ROI:	**68.9%**

Case Study: Turning Used Tires into Electricity

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INVESTMENT ECONOMICS

Capital Investment:	$14,044,000
Annual Operating Income:	$2,834,000
Simple Payback:	**5.0 years**
Annual ROI:	**20.2%**

Case Study: Turning Used Railroad Ties into Diesel Fuels

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INVESTMENT ECONOMICS

Capital Investment:	$20,544,000
Annual Operating Income:	$2,948,000
Simple Payback:	**7.0 years**
Annual ROI:	**14.3%**

Case Study: Turning Used Railroad Ties into Fertilizer

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INVESTMENT ECONOMICS

Capital Investment:	$29,144,000
Annual Operating Income:	$3,423,000
Simple Payback:	**8.5 years**
Annual ROI:	**11.7%**