Dr. Matthew Summers leads the operations of West Biofuels, a company that develops and manufactures advanced bio-energy technologies, converting biomass to power, heat, biochar and synthetic fuels. Dr. Summers has lead the design, construction, and operation of numerous biomass conversion systems and has authored reports and publications on bio-energy systems, air quality and climate change. He is a California licensed professional engineer and holds engineering degrees from Harvey Mudd College (B.S.), Stanford University (M.S.) and UC Davis (Ph.D.).

WestBiofuels

WESTBIOFUELS

PROS AND CONS OF THERMAL TECHNOLOGIES FOR ALMOND BIOMASS CONVERSION

June, 2018

Matthew D. Summers, COO

Company Profile

What?

- Biomass thermochemical conversion technology provider

Why?

- Biomass will continue to be made
- New and innovative approaches to creating a reliable, value-added product are needed

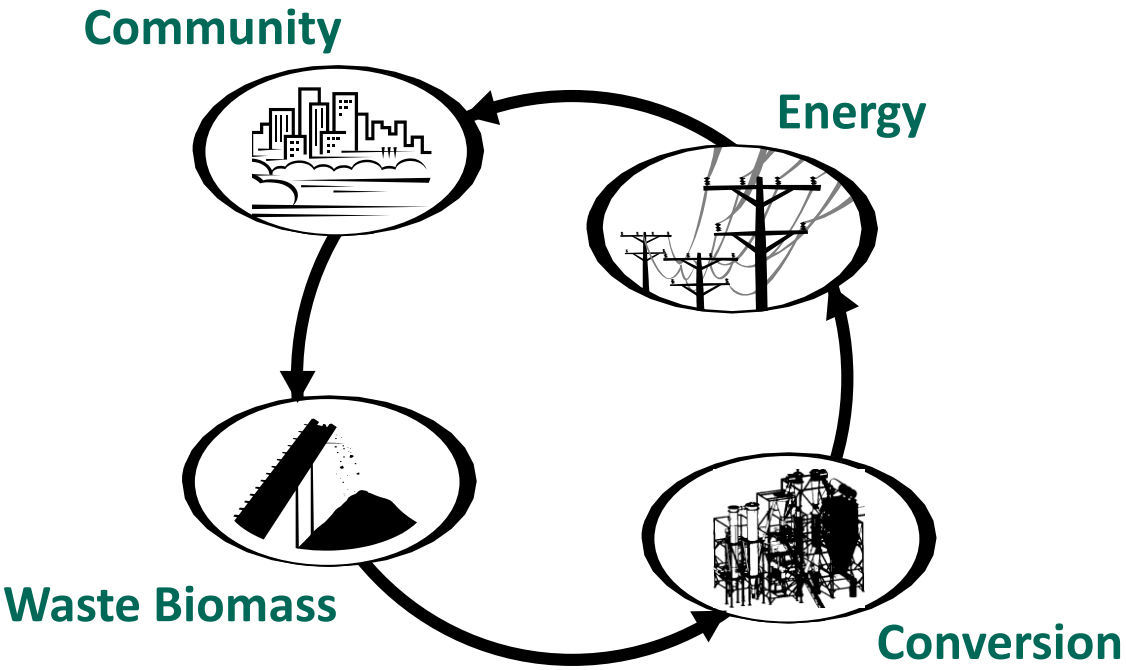
Where?

- Woodland, CA (outside of Sacramento)

WestBiofuels

West Biofuels Mission

To reinvent energy production in ways that help us become energy independent, lower our carbon footprint, create local green jobs and foster economic growth.



WestBiofuels

Renewable Biomass

Products
- Agriculture
- Forest

Wastes
- Agriculture
- Forest
- Municipal
- Industrial

Thermal Conversion Technology

Renewable Products

Electricity & Heat

Biochar

Fuels
- Alcohols
- Diesels

Biobased Products

WestBiofuels

The Biomass Challenge and Opportunity

- Waste materials continually generated
- High disposal costs
- Lack of recycling markets
- Petroleum costs for trucking and heavy equipment
- Energy costs for facilities
- Methane emissions
- Desire to increase sustainability
- Desire to increase recycling
- Needs to increase the lifetime of landfills

WestBiofuels

California Biomass Feedstock

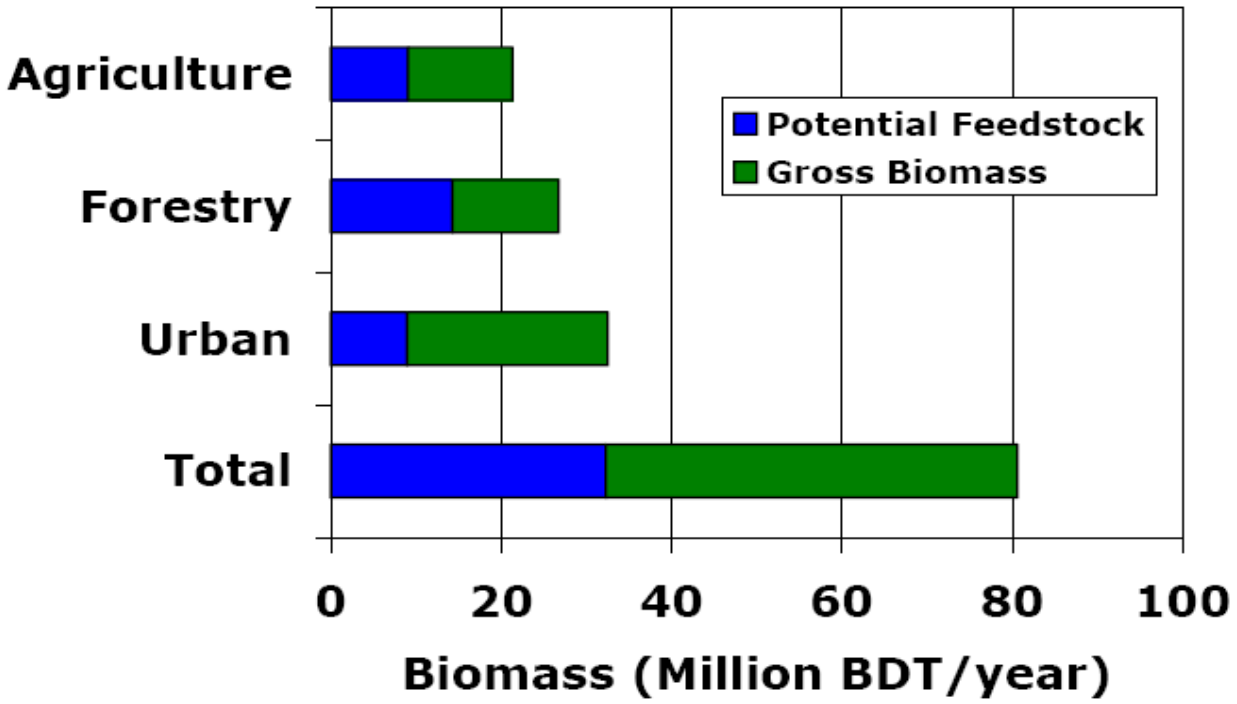


Figure 1.3. Gross annual biomass production in California (2005) and amounts estimated to be available for sustainable use. BDT = bone dry tons.

From: Road Map for Development of Biomass in California – CEC contract 500-01-016 Sept. 2006
Bryan Jenkins, Executive Director

WestBiofuels

Almond Biomass Feedstock In California

Type	*Current Industry Potential*	*Power Potential (MW)*	*Recovered Heat (MMBTU)*
Almond Shell	650,000 tons	100	4,500,000
Almond Sticks	90,000 tons	15	700,000
Almond Prunings	710,000 tons	110	5,000,000
TOTAL		225	10,200,000

* Based on California Almond Board - 2017 Almond Almanac almond kernel yields and typical generation factors for shell, sticks, and prunings

Almond Shell

Almond Pruning

WestBiofuels

Opportunity

- Current markets
  - No long term off-take
  - Diminishing market value, <$20/ton
  - Pressure to minimize open burning
- New markets
  - Electricity: $187/MWh
    - ~ $120/BDT of feedstock
  - Biochar: $300 - $2,000+/BDT of biochar
    - ~$45 - $300/BDT of feedstock
  - Total Potential: **$165 - $420/BDT of feedstock**

WestBiofuels

Opportunity

- Biomass Market Adjusting Tariff
  - Offers 10, 15, or 20 year power purchase agreements (PPA)
  - 3MW or small size – designed to fit biomass supply
  - Contracts are available for procurement until December 2020.
- Current price is $187/MWh ($0.187/kWh)
- Utilities to purchase 250 MW of bio-power by 2020 in this program (~100 projects)

WestBiofuels

The Biomass Energy Solution

- Generate gas, electricity or liquid fuels on-site
- Heat and biochar coproducts
- Displace fossil fuels
- Eliminate disposal and costs
- Create green jobs
- Reduce carbon footprint
- Feedstock is renewable and sustainable
- Greenhouse gas neutral
- Increase energy independence

WestBiofuels

Renewable Biomass

Products
- Agriculture
- Forest

Wastes
- Agriculture
- Forest
- Municipal
- Industrial

Thermal Conversion Technology

Renewable Products

Electricity & Heat

Biochar

Fuels
- Alcohols
- Diesels

Biobased Products

WestBiofuels

Conventional Combustion

Advantages

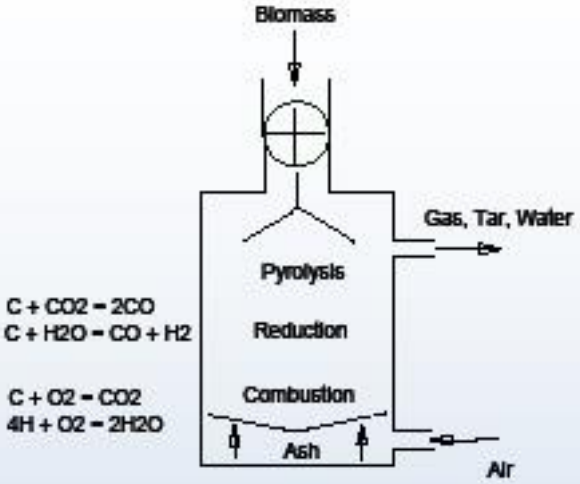
- Proven for woody feedstock
- Works well for utility scale projects (>20MWe, >150,000 tons/yr)

Disadvantages

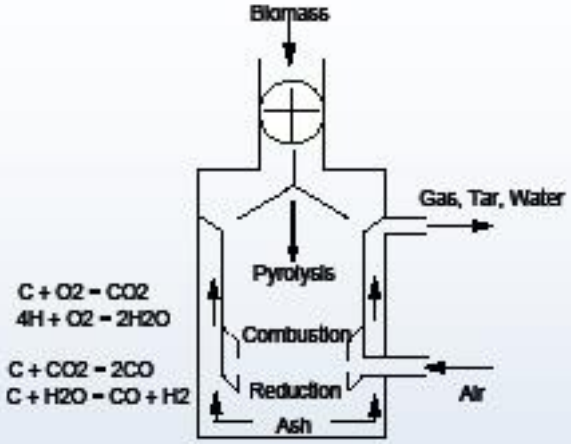
- Ag residual biomass like shells can cause slagging and agglomeration issues
- Does not scale down well for on-site systems (<3MWe, <40,000 tons/yr)
- Emissions can be difficult to control

WestBiofuels

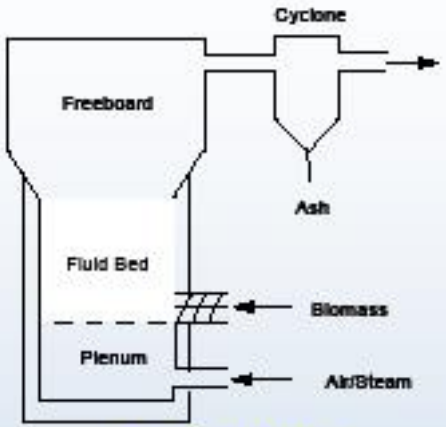
Gasification



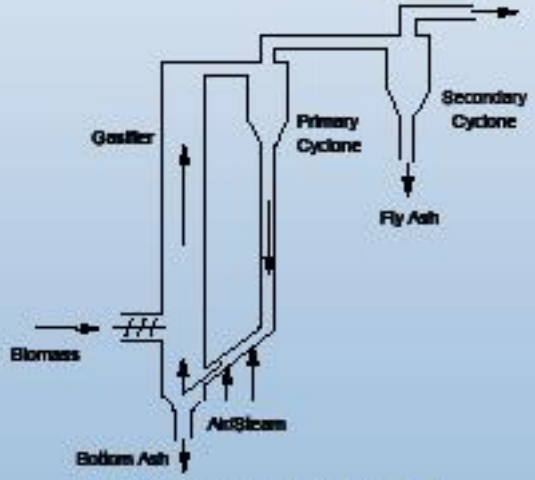
Updraft Gasifier



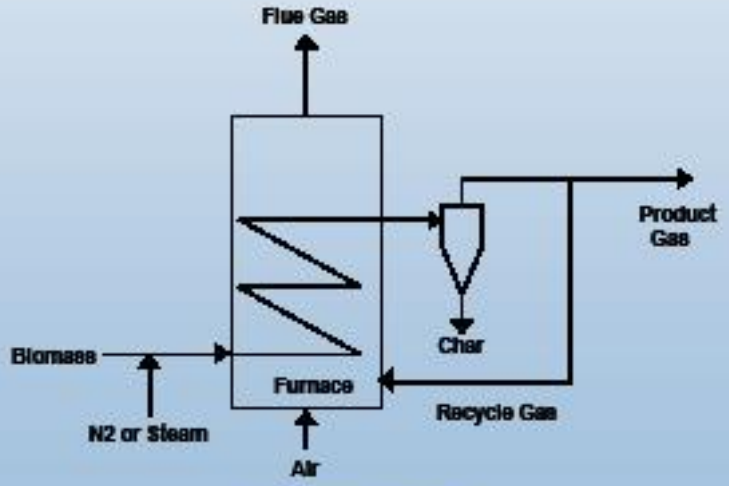
Downdraft Gasifier



Fluid-Bed Gasifier



Circulating Fluid-Bed Gasifier



Entrained Flow Gasifier

Gasifier Types – Advantages and Disadvantages

Gasifier	Advantages	Disadvantages
Updraft	Mature for heat Small scale applications Can handle high moisture No carbon in ash	Feed size limits High tar yields Scale limitations Producer gas Slagging potential
Downdraft	Small scale applications Low particulates Low tar	Feed size limits Scale limitations Producer gas Moisture sensitive
Fluid Bed	Large scale applications Feed characteristics Direct/indirect heating Can produce syngas	Medium tar yield Higher particle loading
Circulating Fluid Bed	Large scale applications Feed characteristics Can produce syngas	Medium tar yield Higher particle loading
Entrained Flow	Can be scaled Potential for low tar Can produce syngas	Large amount of carrier gas Higher particle loading Potentially high S/C Particle size limits

Gasifier Types – Typical Heating Values

Gasifier	Inlet Gas	Product Gas Type	Product Gas HHV MJ/Nm^3
Partial Oxidation	Air	Producer Gas	7
Partial Oxidation	Oxygen	Synthesis Gas	10
Indirect	Steam	Synthesis Gas	15
		Natural Gas	38
		Methane	41

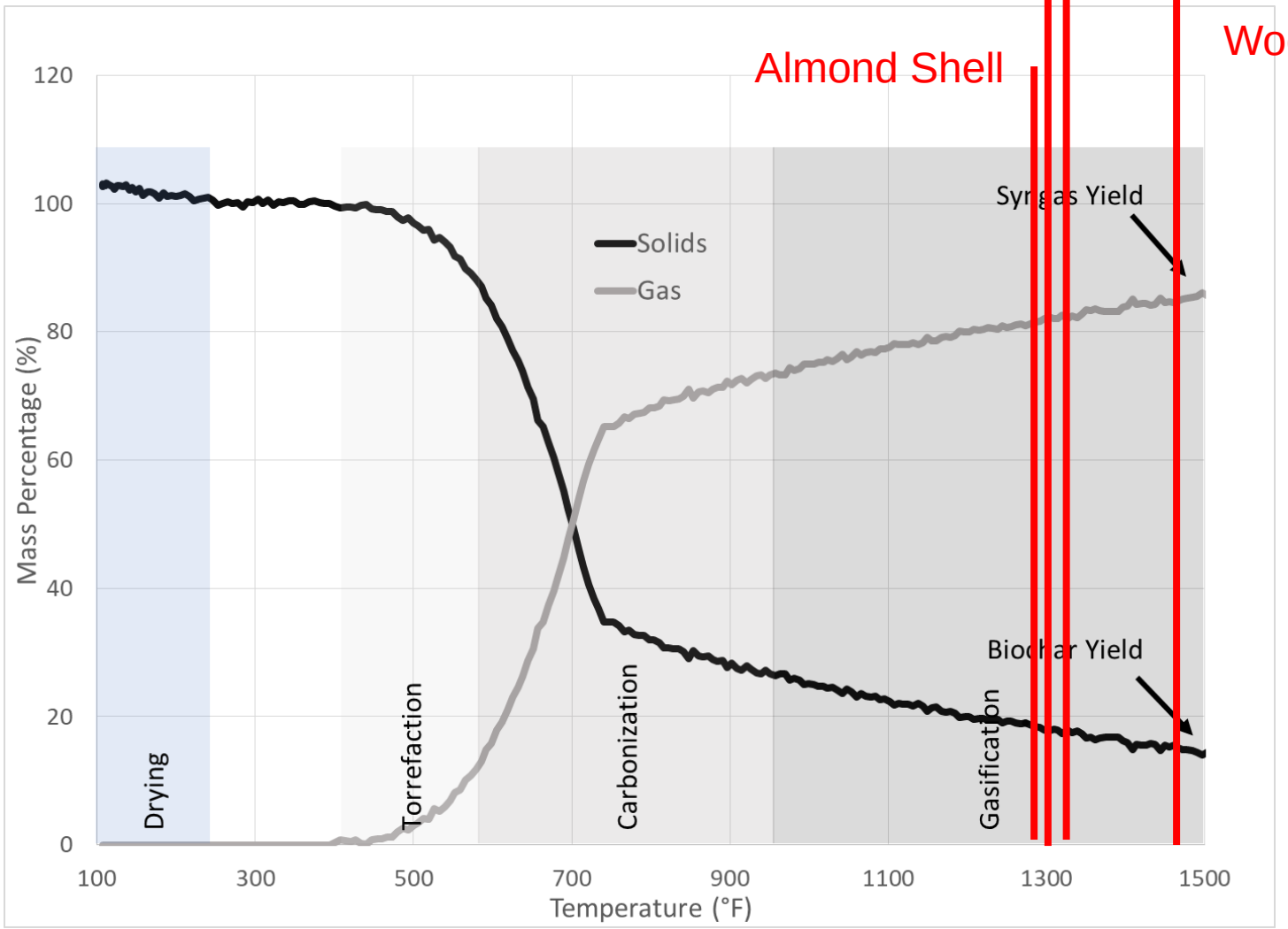
Feedstock

- Gasification should be specifically engineered to accommodate the feedstock

Feedstock Type	Avg. Ash Content
Almond Shell	3.6%
Almond Sticks	2.8%
Pollinator Hulls	7.8%
Nonpareil Hulls	7.7%
Almond Wood	2.1%
Walnut Shell	1.1%
Forest Wood	0.9%
RDF (Urban)	15.1%
Biosolids	28.9%

WestBiofuels

Temperature

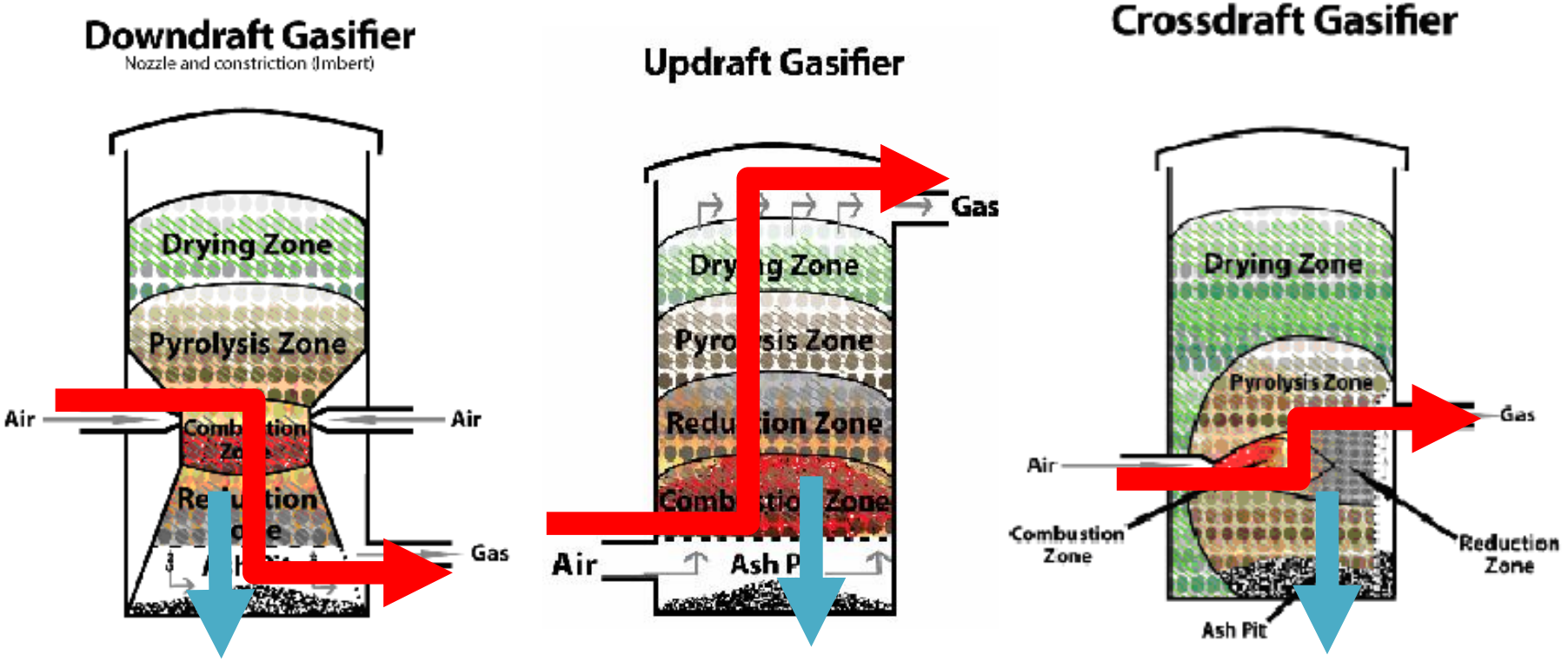


Indicates when slag will form based on the hottest (not average) temp in the system

WestBiofuels

Technology

To make a good co-product, biochar can't be used as a syngas filter to remove tars



Source: http://www.enggcyclopedia.com/2012/01/types-gasifier/

WestBiofuels

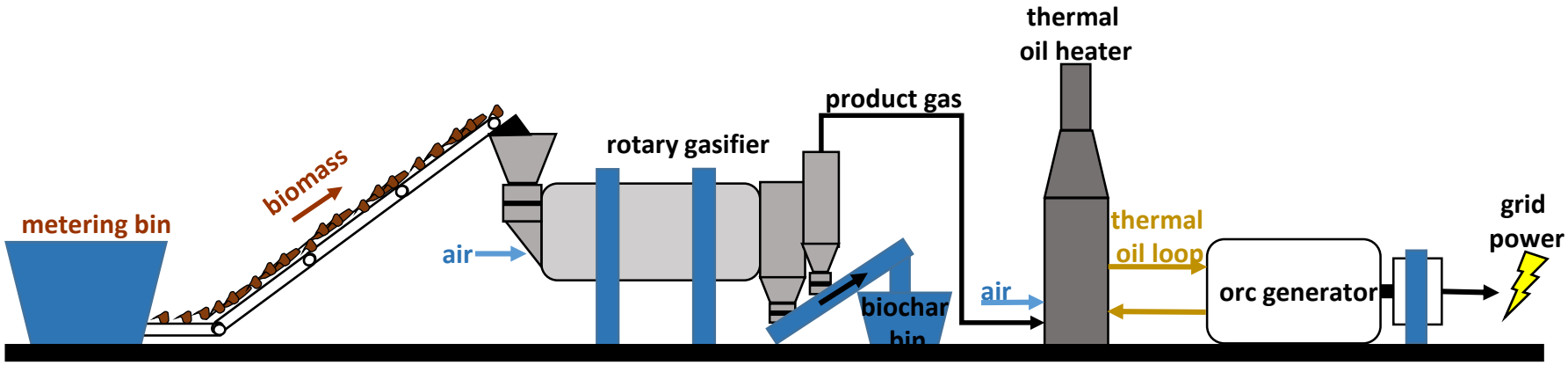
Biochar Opportunity

Biochar market

- Young market with limited supply
- Wholesale:
  - $250 to $2,000+ per BDT
- Retail:
  - $0.75 - $8 per pound ($1,500 to $16,000 per ton)
  - Sold across Home Depot, Amazon, Sears, and nurseries

WestBiofuels

Co-production of Bioenergy and Biochar



- Integrates proven technology to generate renewable power
  - Rotary drum gasifier produces a uniform and consistent gas and biochar in a reactor designed to optimize thermal transfer to biomass without blockages or hot spots
  - Thermal oil heater consumes product gas to heat thermal oil
  - Organic Rankine cycle (ORC) generator produces electricity by utilizing the heat transferred from the thermal oil

WestBiofuels

Facility Scale System – At Ag Processor

In White Castle, LA processes bagasse at sugar plant into torrefied biomass product

1.5 MW equivalent

WestBiofuels

Rotary Drum Gasification Advantages

- Fixed bed gasification has material flow challenges associated with many California feedstock (e.g. bridging, nesting, channeling)
- Fluidized bed systems require complex and expensive components that are not economic for community-scale generations
- Rotary drum dryers have proven experience as effective means for applying heat to biomass
- Scalable approach

WestBiofuels

Facility Scale System – Organic Rankine Cycle Generator

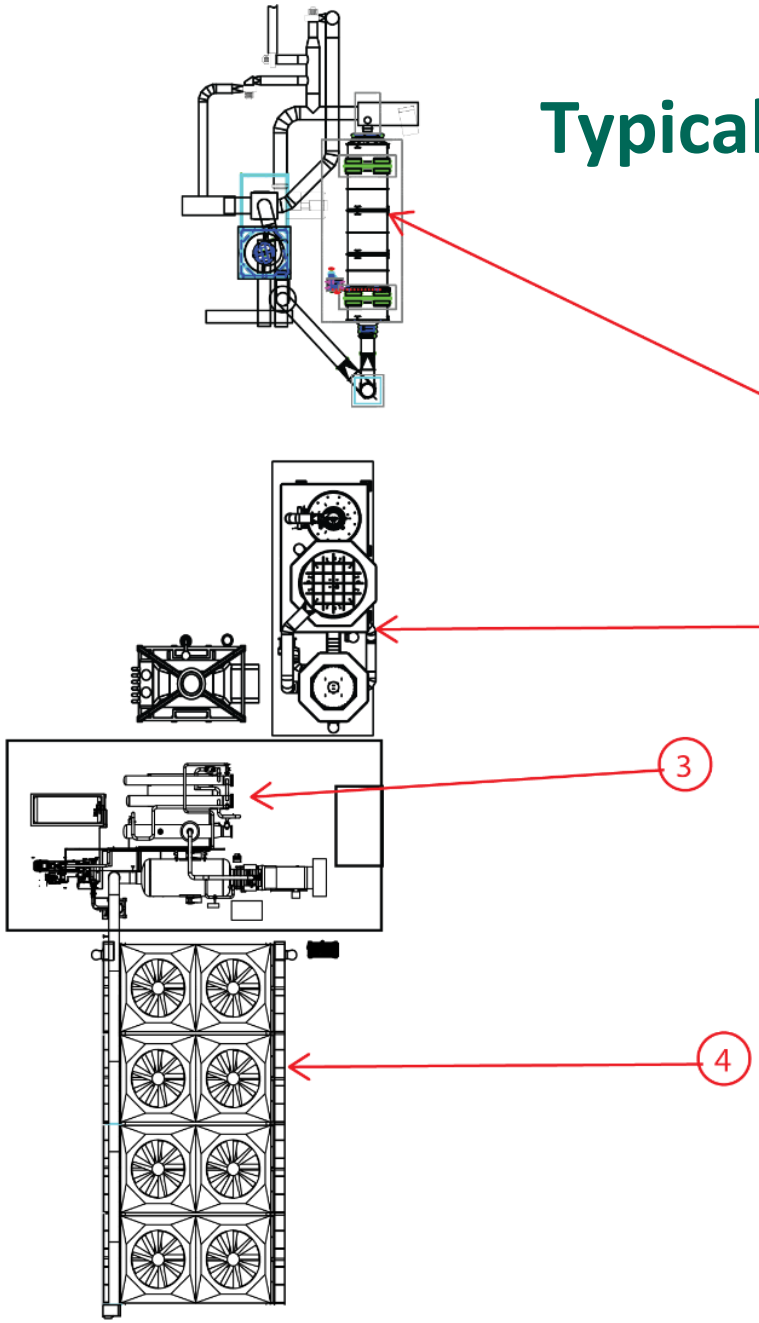
WestBiofuels

ORC Generation Advantages

- Engine systems introduce syngas directly into the engine creating significant technology and warranty risk
  - Syngas quality creates frequent downtime and engine failures
- ORC offers a closed loop system that decouples syngas from energy production
  - Heat is provided to the ORC through a thermal oil heater
  - Heater has a high degree of control and emissions are minimized
- Focus is on O&M cost minimization
  - No boiler operator is required and system is remote monitored
  - No complex and high maintenance syngas conditioning equipment
  - Very high capacity factors have been achieved (95%)

WestBiofuels

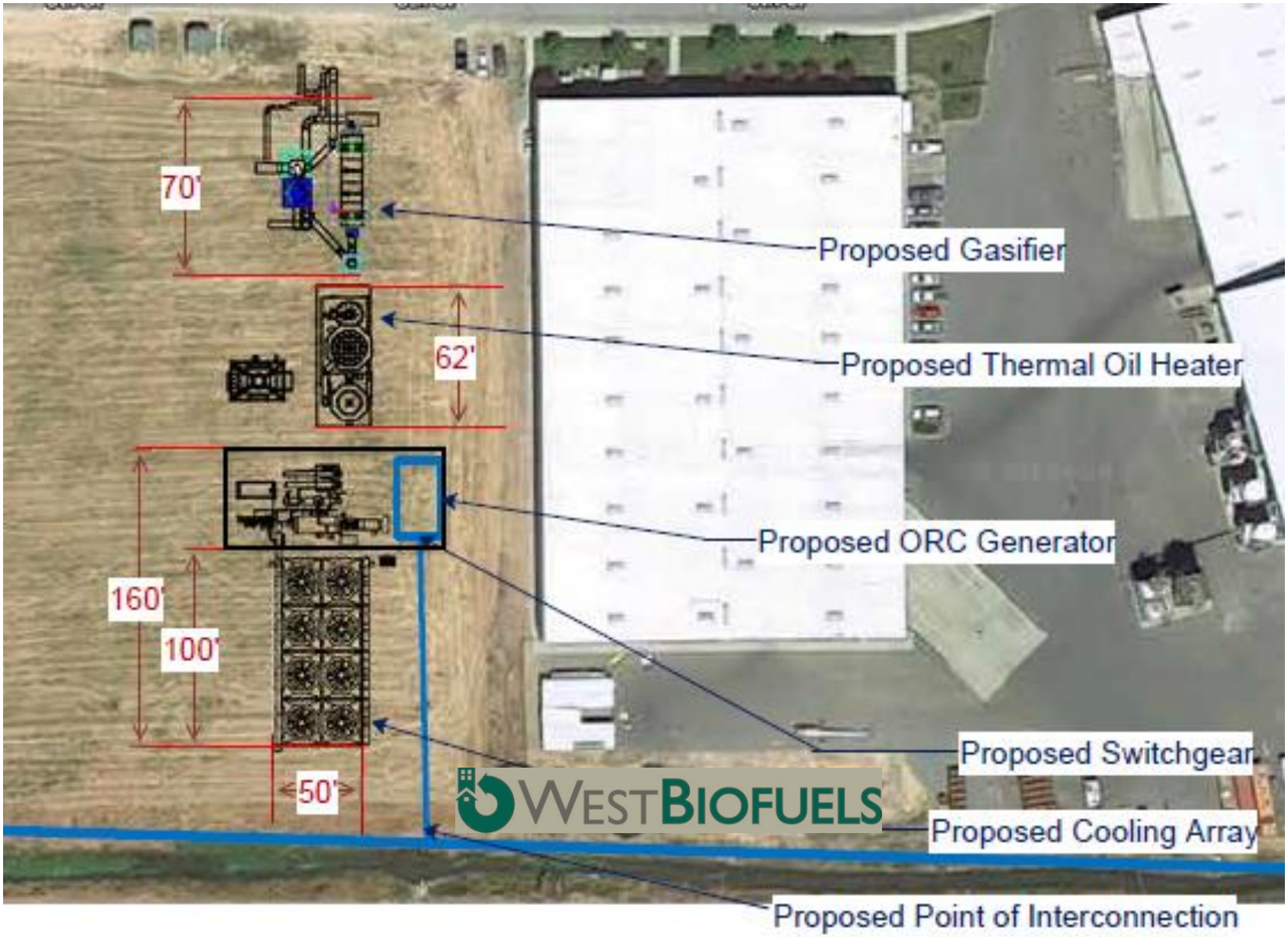
Typical Plant Layout for Ag Biomass



1. Rotary Drum Gasifier
2. Thermal Oil Heater
3. ORC Generator & Switchgear
4. ORC Cooling Array

WestBiofuels

3MWe Project Site Example



System advantages for small-scale bioenergy

- Trouble-free and automated systems at small scale
- Remote monitoring and maintenance by supplier
- Based on rotary dryer technology for maximizing uptime
- Based on ORC turbine technology for minimizing O&M
- Biochar production as co-product for added value
- Systems have proven operating histories at this scale
- Ability to increase biomass consumption if needed
- Additional waste heat can be recovered for drying

WestBiofuels

Investor Opportunities

- Prices offered in the BioMAT program have attracted outside investors
- Investor groups are interested in build/own model
- Potential upsides for biomass processors/generators
  - No capital investment required
  - Lease contract for the project site
  - Feedstock contract for biomass
  - Operations and labor contract
  - Profit sharing

WestBiofuels

What Is Needed to Make it Happen

- Secure the facility
- Secure the feedstock
- Secure the permitting to install the project
- Secure a contract with the Utility
  - Need interconnection study
  - Need to enter the BioMat queue
  - Execute the Power Purchase Agreement (PPA)
- Secure the financing package for the plant

WestBiofuels

Contact West Biofuels

Woodland Biomass Research Center

14958 County Road 100B

Woodland, CA 95776

Matt Summers

Chief Operating Officer

(530) 383-8260

matt.summers@westbiofuels.com

WestBiofuels