Biomass Combined Heat and Power – An Overview of Small-Scale Systems

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Overview

Small biomass-to-energy systems are emerging as a potential winner for regions in the U.S.

- Feedstock can include wood waste, agricultural residue, energy crops, animal waste, and municipal waste.

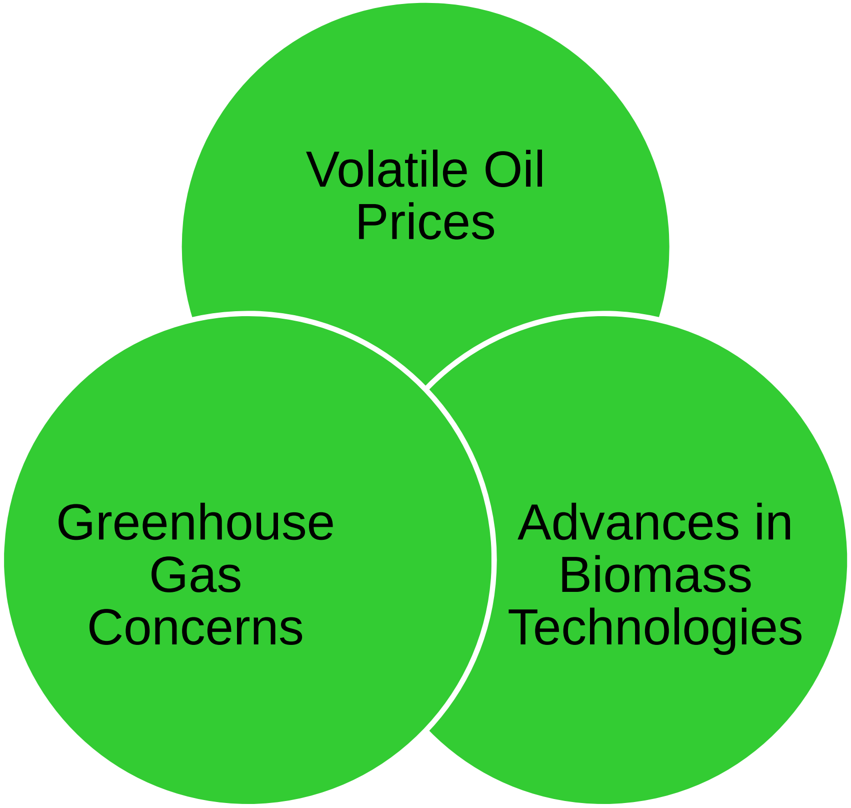
- Combined Heat and Power options include….
  - Electricity generated by customized topping and bottoming cycles.
  - Thermal energy for public buildings, industrial processes, water desalinization, agricultural drying, college campuses and district heating

- Plants are sized from 30 kW to 1500 kW, or more, in order to match local feedstock resources and site energy needs. They can process 0.7-35 tons per day of feedstock.

- Benefits include…
  - Production of Green Energy, Renewable Credits
  - Reduction of waste disposal problems
  - Reduction in energy costs
  - Reduced dependence on fossil fuels
  - Grid independence

Driving Forces for Biomass Power

- Increasing prices of conventional fossil fuels and electricity; Low delivered price of biomass feedstock
- Biomass creates more jobs
- Natural fit for rural U.S.- Biomass power is 40X greater than wind and 7X solar in the US (DOE data)
- Hydro is nearly tapped out; Nuclear has problems near term
- Sustainable indigenous biomass waste is available and underutilized
- New technologies for more durable and clean biogas engines and gasifiers have been developed.
- Biomass harvesting for heat only (or power only) leaves 50% value on the table…it pays to look at CHP.



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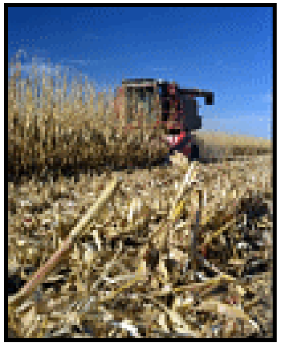
There is a need for a balanced critical assessment of Biomass Power

- Biomass power has advocates and detractors, but lacks an independent critical assessment
- Confusion exists over net GHG impacts long term.
- What size plants make most sense for biomass to energy, given the 50-75 mile threshold for economical feedstock transport?
- What gasifier technologies are truly commercially proven?
- What is the cost of effective emission control and preferred technologies?
- Are there specific proof points of regional sustainable indigenous biomass waste? Which feedstocks will emerge as winners and why?
- What technologies for more durable and clean biogas engines and gasifiers have been developed?
- Does the feedstock need preprocessing and at what cost?
- Who will be the early adopters?
- What will be the role of utilities in biomass to power?

Biomass CHP systems rely on local year-round harvesting of waste wood, agricultural waste and other renewable fuels



Wood Residues

- Sawdust
- Wood chips

Agricultural Residue

- Corn stover
- Rice hulls
- Sugarcane fiber (Bagasse)
- Animal waste

Energy Crops

- Hybrid poplar
- Switchgrass
- Willow

Urban Waste

- MSW
- Construction Waste
- Wood yard trimmings
- Pallets and crates
- Sewage sludge

Opportunity to extract value from nuisance materials to avoid tipping fees and fires.

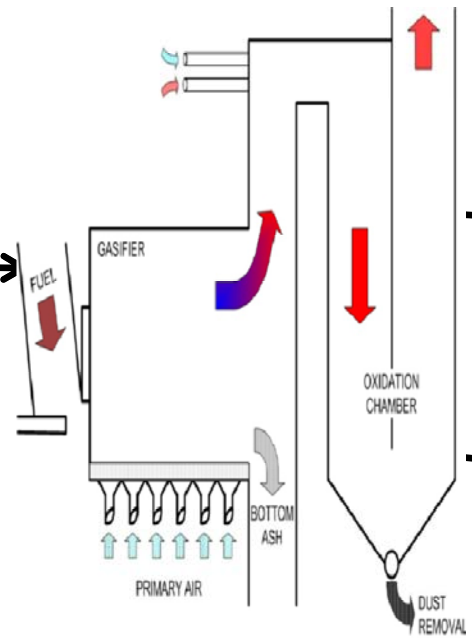
Biomass Conversion Technology

Example of a 24 Ton per day cogeneration plant design:

Wood Waste (dry)

14 MMBtu/hr (24 tpd)

State of the Art Biomass Gasifier



BioGas Fuel

Engine/Generator

1000 kW to local grid

8 MMBtu/hr District Heating

Example: Approximately 8,000 tons/year biomass waste will produce electricity worth $1 mill plus district heat worth $0.6 mill in this hypothetical example, offering a two year payback at $3200/kW Capex assuming net zero fuel cost (best case).

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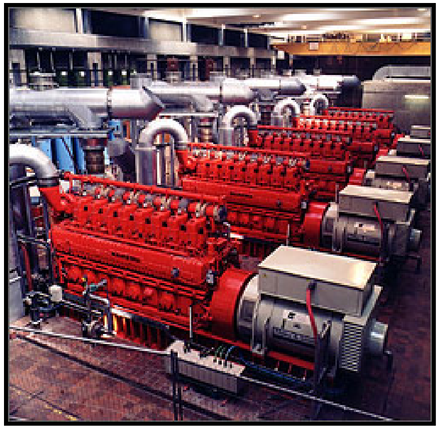
Selection of Prime Mover will depend on a range of factors

- Capital cost
- Operating cost
- Power Rating to meet plant demand
- Efficiency
- Maintenance
- Life
- Fuel Flexibility
- Opportunities to utilize
  waste heat



STEAM TURBINE – OFTEN SELECTED FOR LARGER PLANTS

RECIPROCATING ENGINE – HIGHER EFFICIENCY, BUT REQUIRES CLEAN GAS FROM BIOMASS.

OTHER OPTIONS INCLUDE ORGANIC RANKINE CYCLE, STIRLING ENGINE AND EXTERNAL (HOT AIR) BRAYTON

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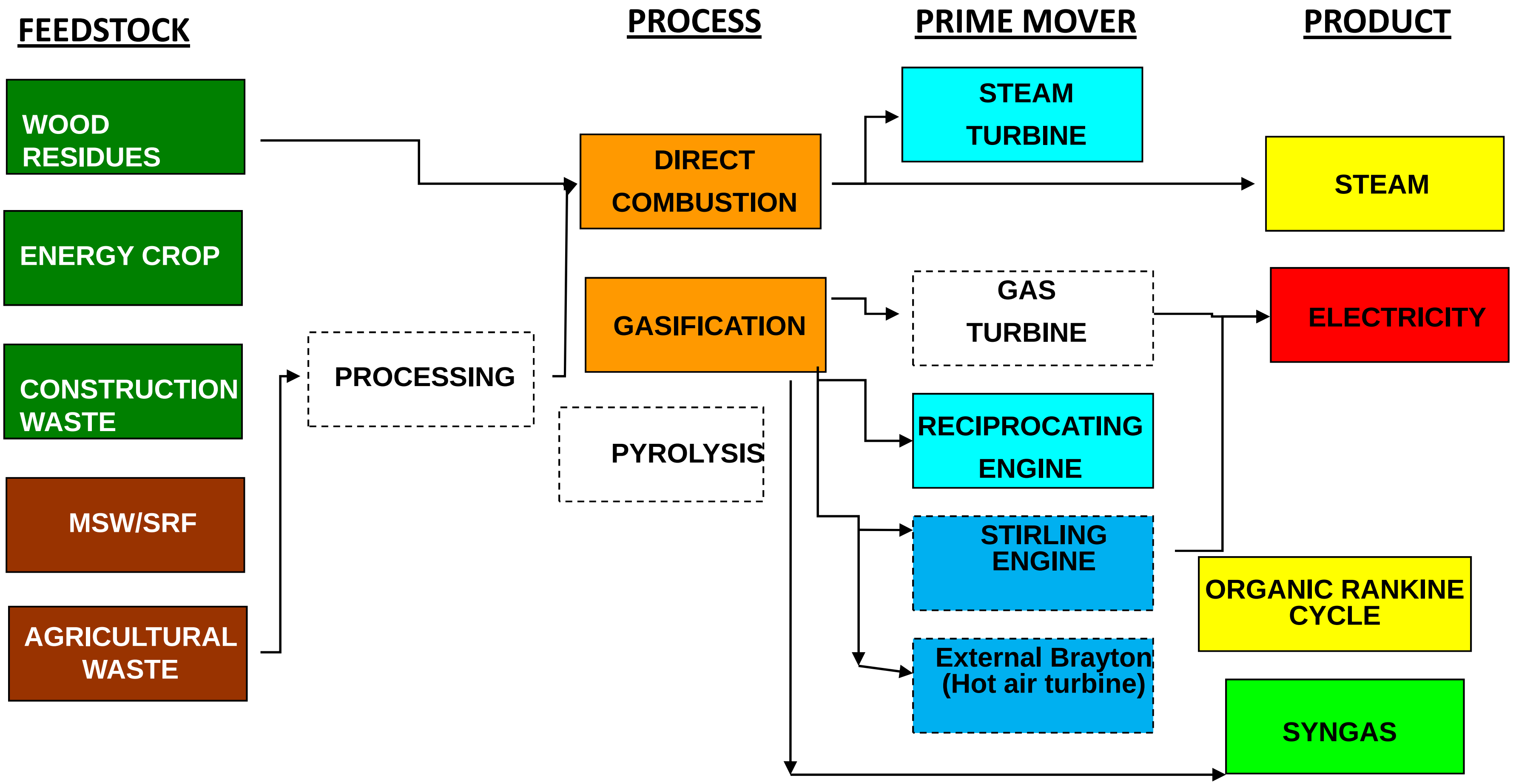
Matrix of Options

Scoping Studies are performed for each site to select the best configuration to increase the utilization of its waste biomass resources and decrease its energy costs.



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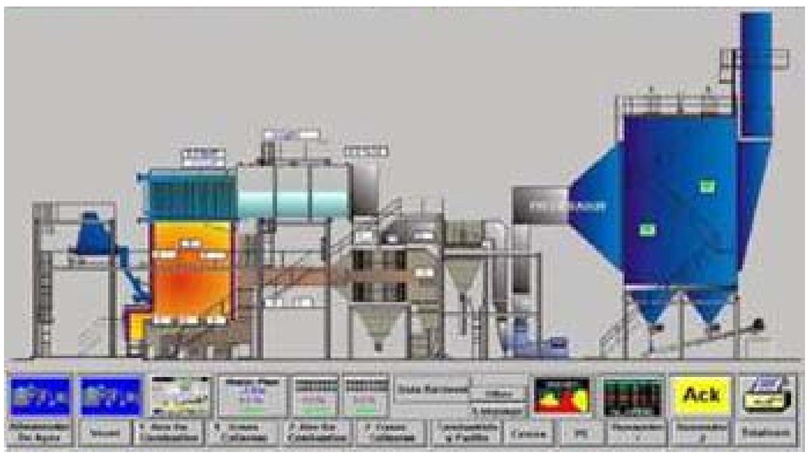
Each Biomass System Option offers unique Strong Points

System Option	Hot Gas Generator	Power Source	Technology Suppliers	Typical Effic.	Capex	Emissions Control	Demon. Scale & Consid-erations
Biomass Rankine Cycle	Gasification or boiler combustion	Steam Turbine	Chiptec, Carbona, Hurst	MED (25%)	High ($3000/kW)	Straight-forward	500 to 20,000 kW; mature
Gasifier and engine	Gasifier plus gas clean up	ICE or Turbine	Gauscor, CPC, Xylowatt, Nexterra, Jenbacher, Wartsila, Ankur,	MED-HIGH (25-30%)	Medium ($2000/kW)	Tar control is key	Preferred for smaller systems 30 to 1500 kW
Indirect Brayton (Hot-Air Turbine)	Gasification or boiler combustion	Hot-air Turbine	Proeschel, Elmegaard, HEI	LOW (15-20%)	TBD	Straight-forward	100 to 750 kW; Recuperato r is key
Biomass Stirling Cycle	Gasification or boiler combustion	Stirling Engine	Stirling DK, Infinia, Sunpower	LOW (15-20%)	High ($3000/kW)	Tar control is key; low NOx	3 to 140 kW; Heater head interface
Biomass Organic Rankine Cycle	Gasification or boiler combustion	Rankine Cycle on working fluid	Pratt-Whitney and Turboden, Viessman	LOW (15-20%)	Medium ($2000/kW)	Tar control is key; low NOx	250 kW; Gasifier availability

Spreader Stokers 500 kWe and up



3 MWe Wood Boiler, Chile
www.mcburney.com

0.5 MWe Turbine + Dry Kilns
www.hurstboiler.com

Gasifiers Power Boilers and Engines

Nexterra Gasifiers and Boiler at Hefley Plywood, Tolko, BC (2006)-photo by Tom Miles

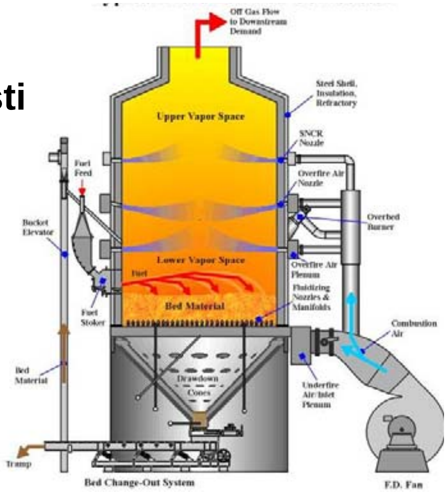
1. **Wood Fuel Bin**
2. **Gasification Hearth**
3. **Ash removal**
4. **Gas exit**

Engine applications to 2 MWe in development

www.nexterra.ca

Energy Products of Idaho Gasifier at BFC Gas & Electric, IA (1998)- photo by Tom Miles

- **Fluidized Bed gasification/combusti on**
- **Staged gasification**
- **Ag waste fuels**



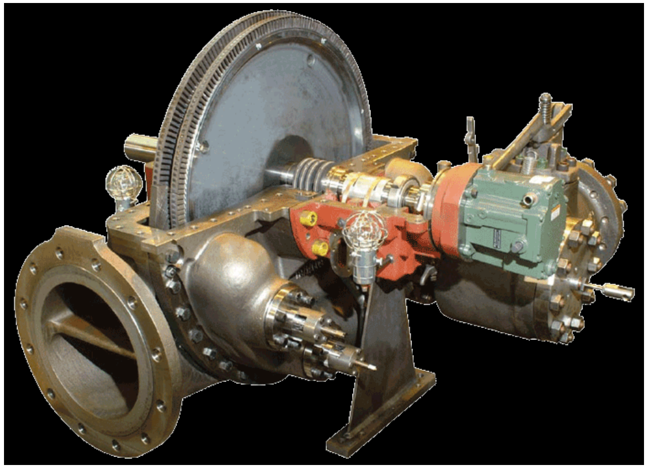
www.energyproducts.com

Steam Turbines are critical for Biomass Rankine Systems

500 kWe Back Pressure Turbine NH

800 kWe 1930s Skinner Steam Engine, WA

(No recent US steam engine installations)



AESI Turbine 500 kWe+

Courtesy: T R Miles Technical Consultants, Inc.

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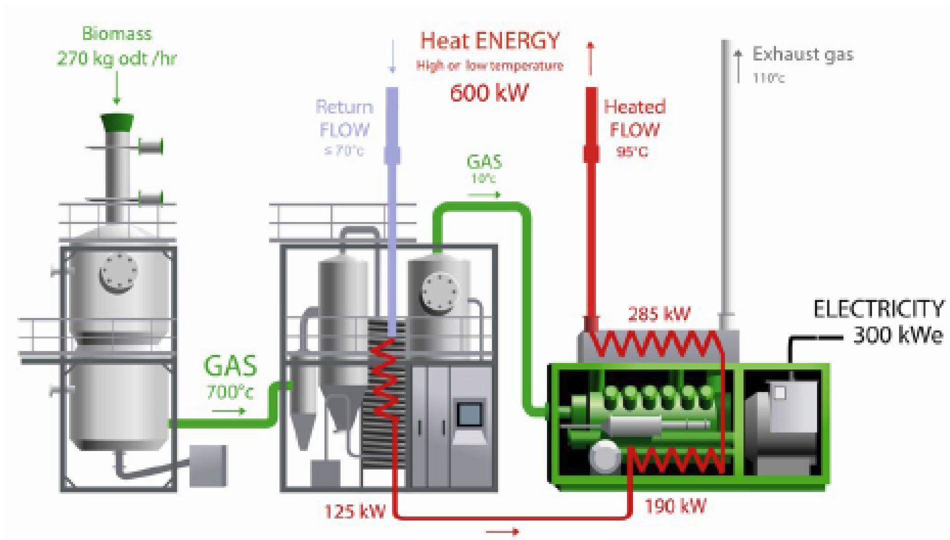
European Suppliers offer 300-1500 kW Biomass CHP Systems

- Xylowatt NOTAR Gasifier

Combined Heat & Power plant: heat & electricity (xW300 model)



Global efficiency = 75% (25% electricity, 50% heat)

300 kWe Module

info@xylowatt.com

XYLOWATT sa

Courtesy: T R Miles Technical Consultants, Inc.

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Nexterra 2 MWe CHP Project: University of British Columbia

Capacity: 2 MW electricity and 9,600 lbs/hr steam

Process:

•Wood biomass is gasified to produce syngas

•Syngas goes through a conditioning system to remove impurities

•Syngas is then directly fired into a GE Jenbacher gas engine to produce heat and electricity

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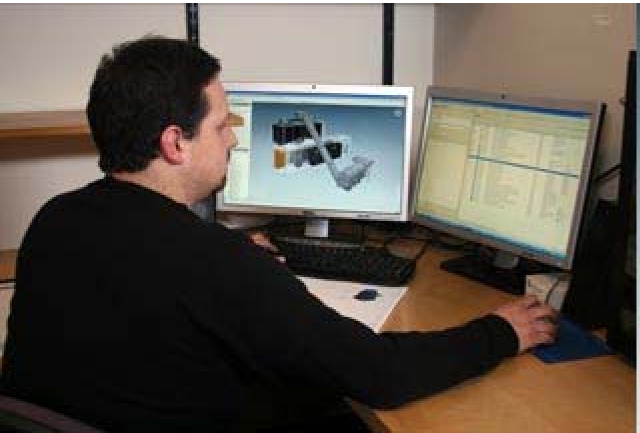
Community Power Corporation 100 kWe Development and Demonstration Gasifier-Generator

Dixon Ridge Walnut Farm 17,000 hrs CHP demonstration

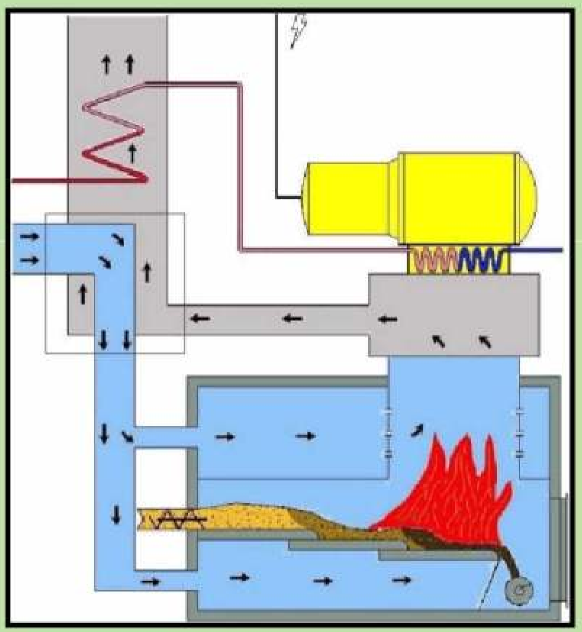
www.gocpc.com



Stirling Engines are protected from biomass hot gas products

Stirling Engine Principle

Engine Driven by External Heat Source



Combined heat and power Stirling Engine modules with an output of 35-140 kWe power and 140-560 kWth heat.

All Heat and 60% of Power and biochar to Danish Organic Farm

www.blackcarbon.dk

Engine and Combustion Chamber

Gasifier

www.stirling.dk

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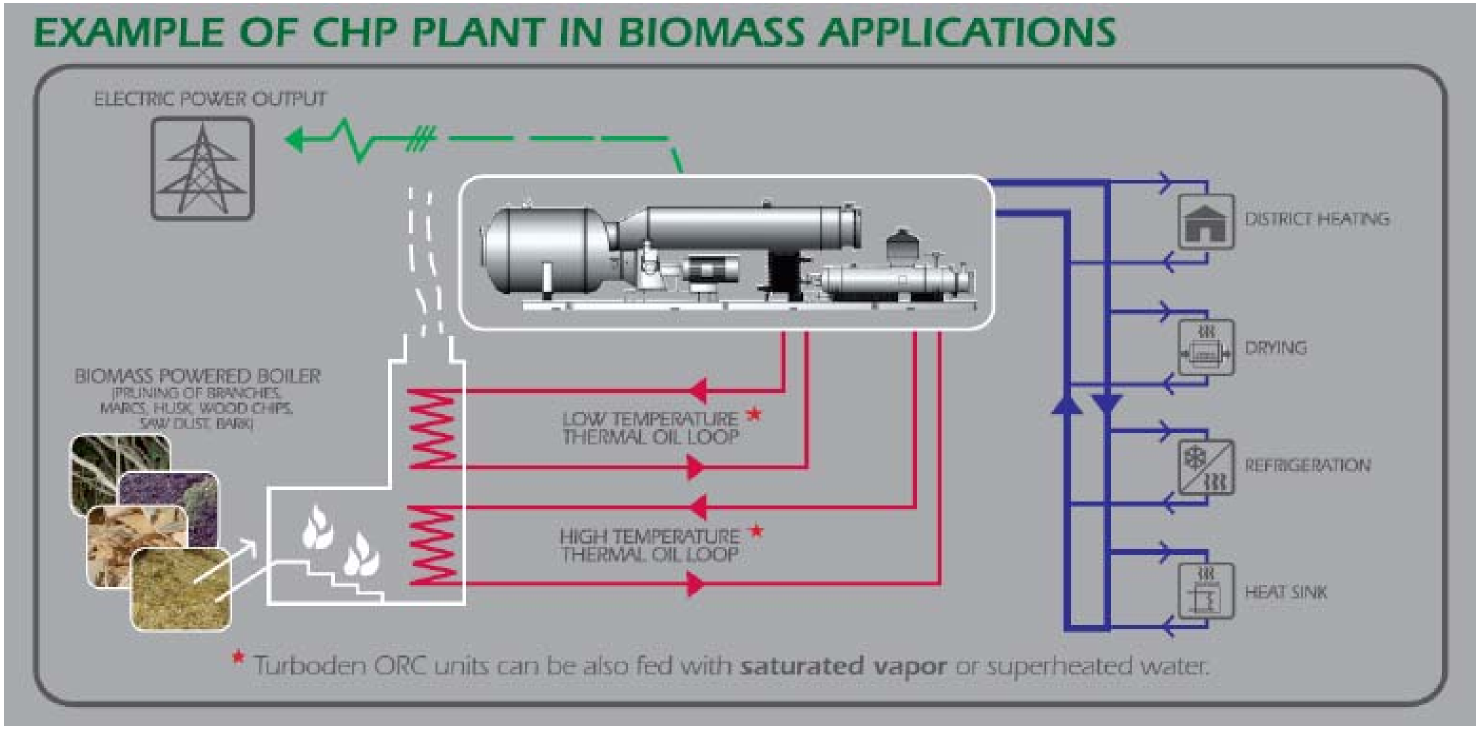
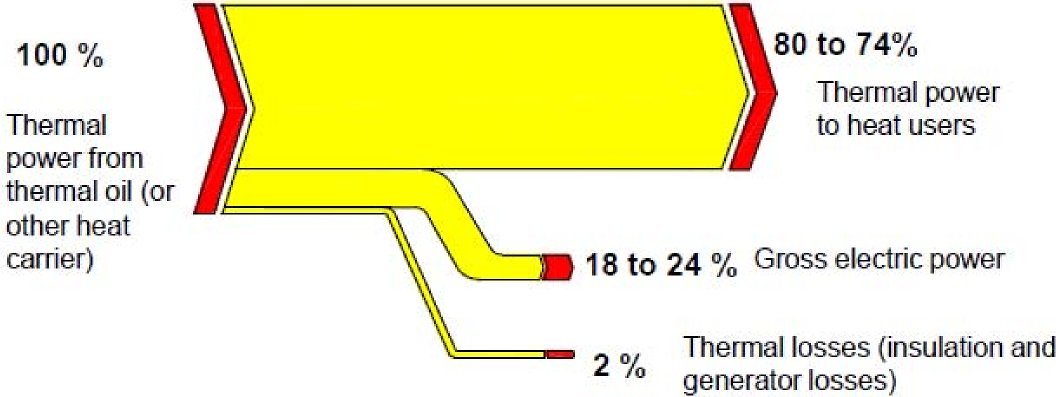
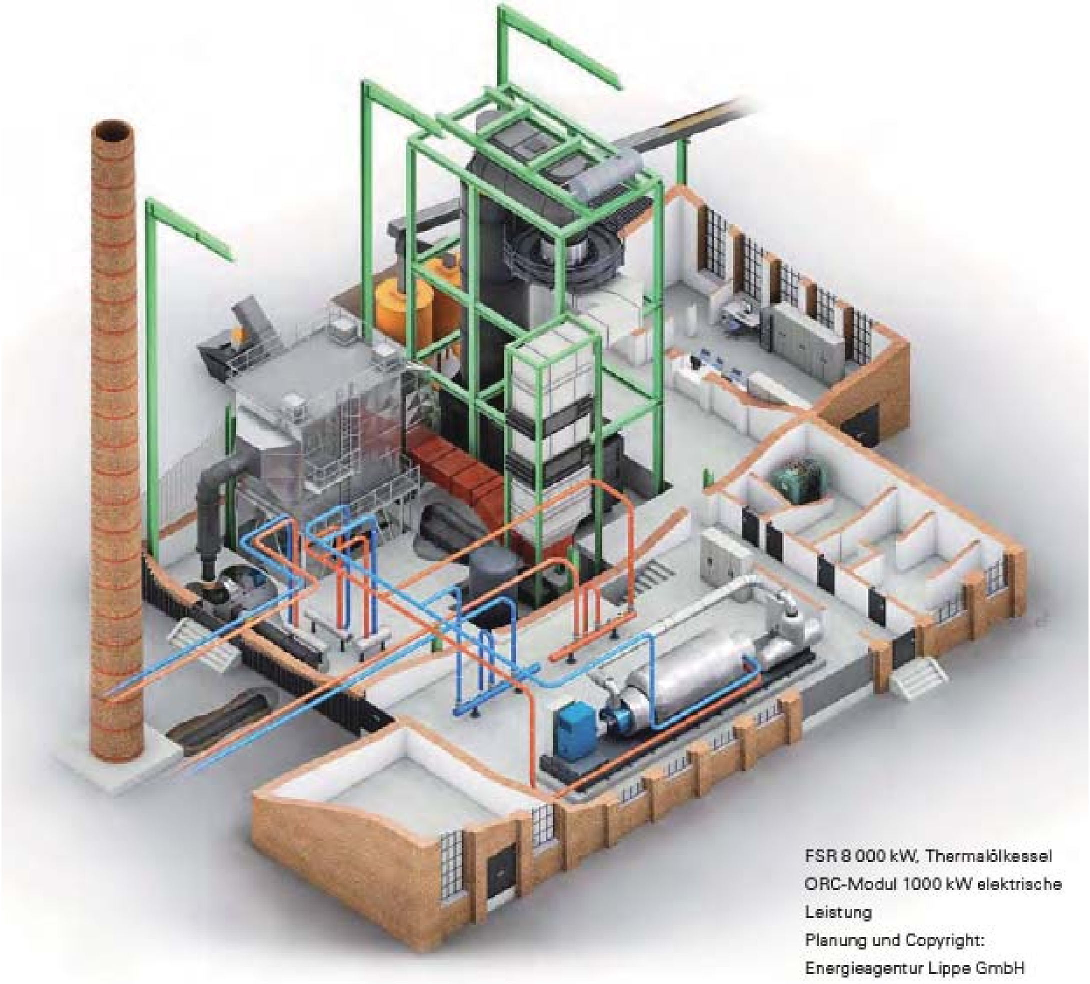
180 Turboden and Pratt & Whitney Industrial ORC Installations Convert Low Quality Heat from Biomass boiler fluid to Power



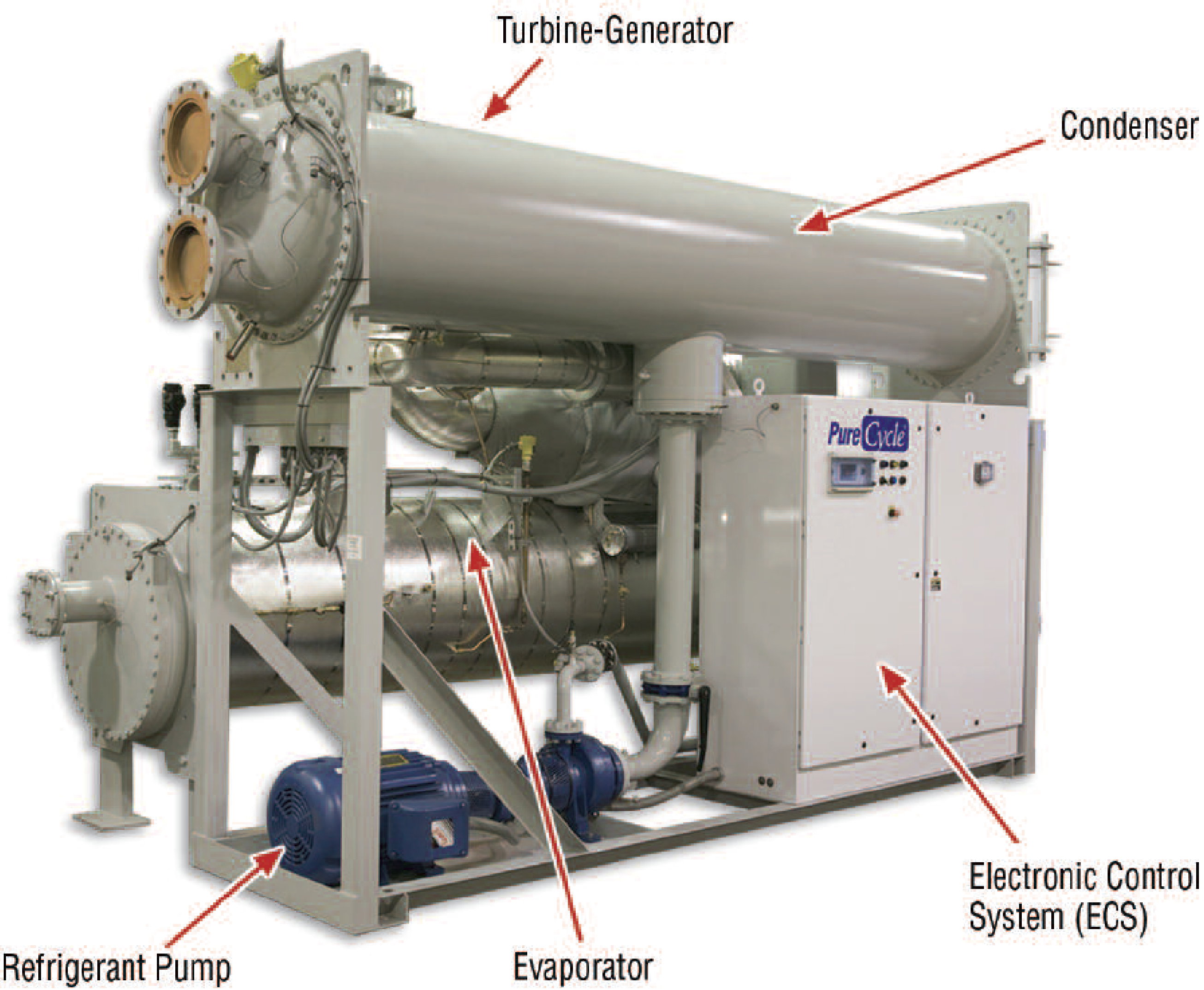


1000 kWe Turboden ORC CHP System (Viessman, GER)



www.viessmann.de/de/Industrie-Gewerbe/Produkte/Holzfeuerungsanlagen.html

250 kWe PureCycle ORS by Pratt & Whitney



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About etaPartners

- etaPartners offers clients expertise in the development and commercialization of a broad range of clean energy technologies.
- We are active in the development of novel combustion, heat transfer and energy conversion technologies for commercial, industrial, and transportation applications.
- We apply state-of-the-art design tools such as chemical kinetics analysis, thermal analysis, computational fluid dynamics, and process simulation.
- We also provide technology-based consulting services to clients in a wide variety of industries. These assignments focus on technology assessments, energy efficiency improvements, air pollution controls, and utilization of alternative fuels.
- Relevant strengths of our group include…
  - Industrial heating and power generation using renewable fuels
  - Application engineering for prime movers (engines)
  - Combustion system development
  - Solid fuels and gasification
  - High efficiency boilers and furnaces
  - Emissions control technologies
  - Assisting equipment manufacturers with pre-production prototypes, packaging and cost reduction