Small Scale CHP Using the Organic Rankine Cycle

Case Studies from Europe


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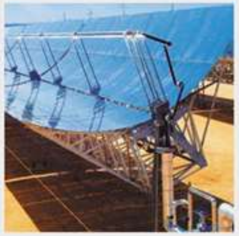



Ilaria Peretti

Manager, Sales and Business Development for North America

Denver - February 11th, 2015

LLOYD'S REGISTER - LRQA
ISO 9001

IDEA's 28th Annual Campus Energy Conference
CAMPUSENERGY2015
Clean Energy for the Next Generation | February 10-13, 2015 | Denver, Colorado

Biomass – Fuels & Applications

FUELS

- ❑ Wood biomass:
  - sawdust
  - woodchips
  - bark
  - treated wood
- ❑ Other biomass:
  - dried sewage sludge
  - straw
  - green cuttings
  - rice husk
- ❑ Waste material
- ❑ Waste recycling wood

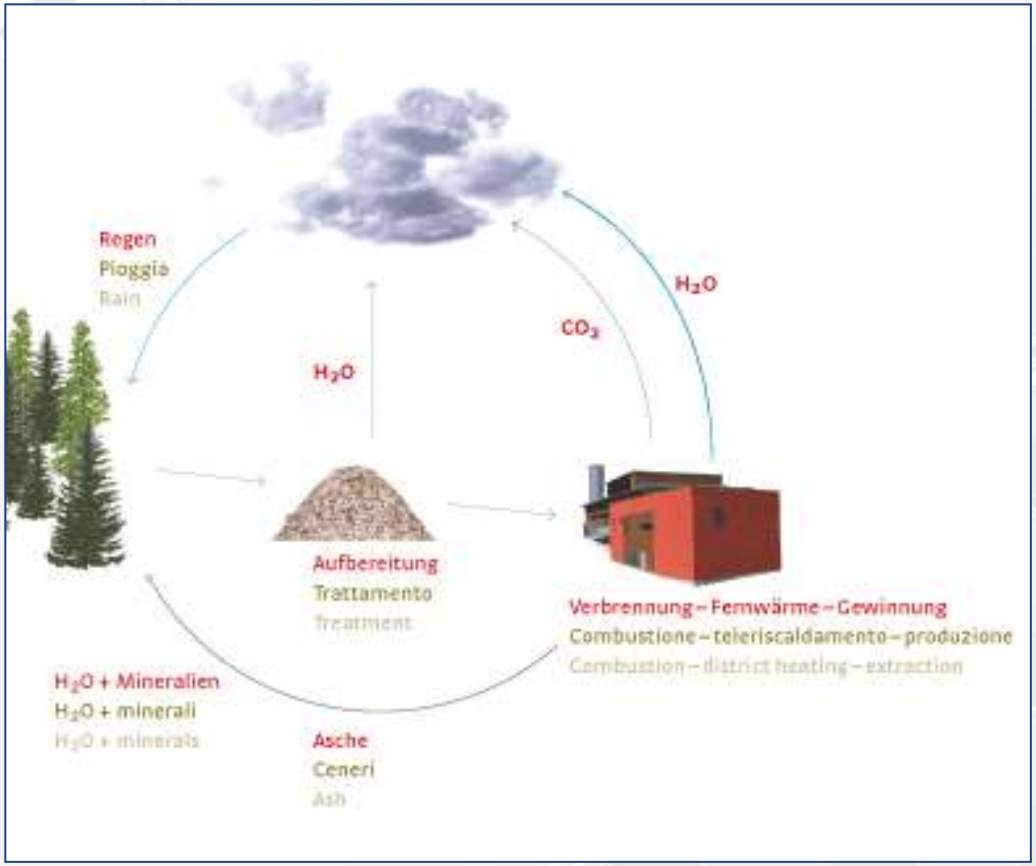
APPLICATIONS

- ❑ Timber drying in sawmills
- ❑ Saw dust drying in wood pellet factories
- ❑ Air pre-heating in MDF industry
- ❑ District heating networks
- ❑ Refrigeration / air conditioning

CHP
for cogeneration and/or trigeneration

Efficiency up to 20%

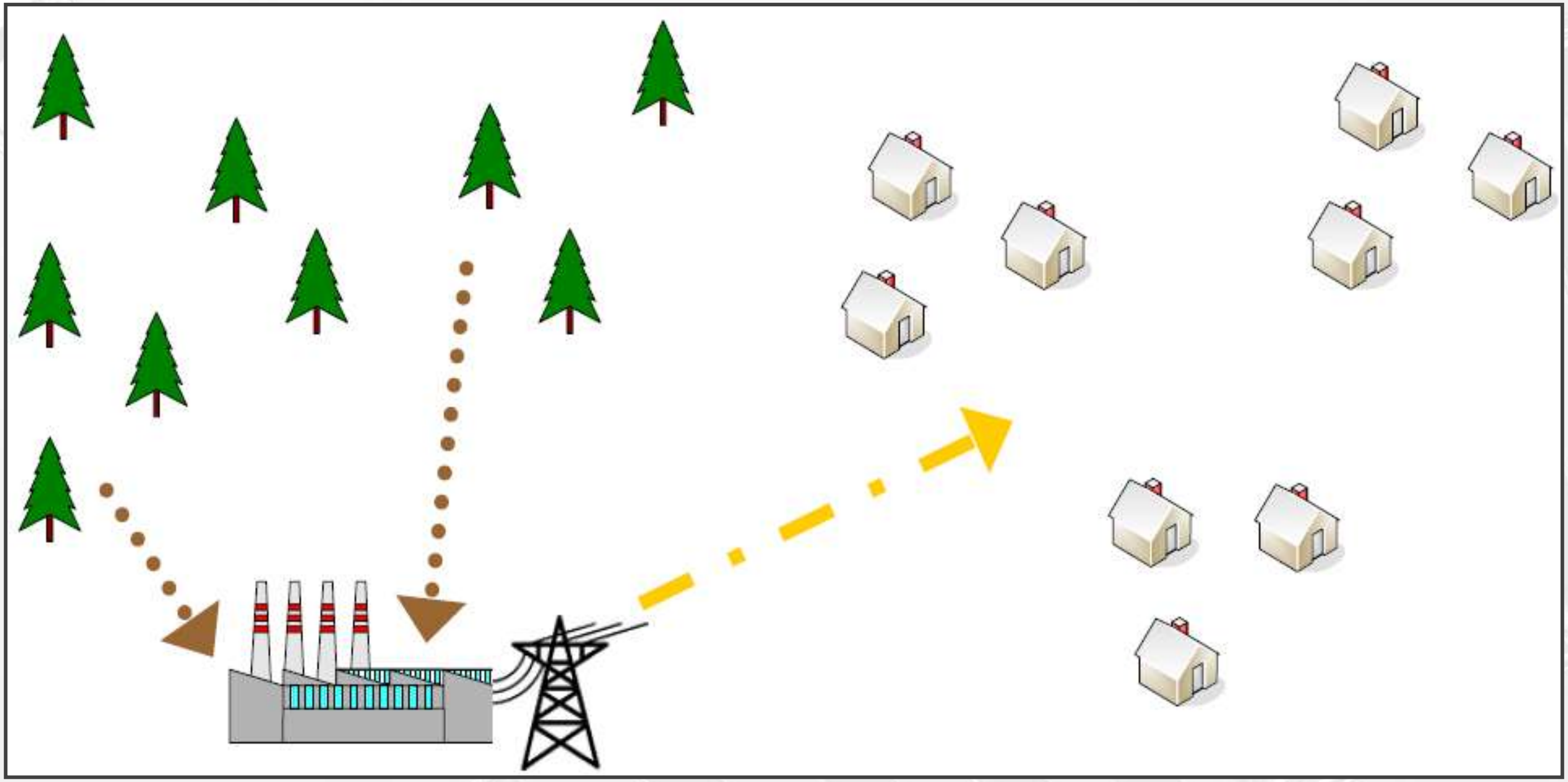
Why Distributed Biomass-Fueled CHP?



- sustainable & renewable: CO_2 neutral and re-growing fuel
- local energy source: no dependence on volatile global fossil fuel markets
- local base-load electric power: relief for congested transmission lines
- impact on economy: uses a local supply chain and keeps energy revenues local
- clean technology: small plants - easier permit

Graph source: "Der biologische geschlossene Kreislauf" www.biomasseverband.it (April 2010)

Biomass Energy: Centralized Electric Power



- optimized electric efficiency
- low total energy efficiency (< 40%; no use of heat)
- higher biomass transport cost & transmission losses

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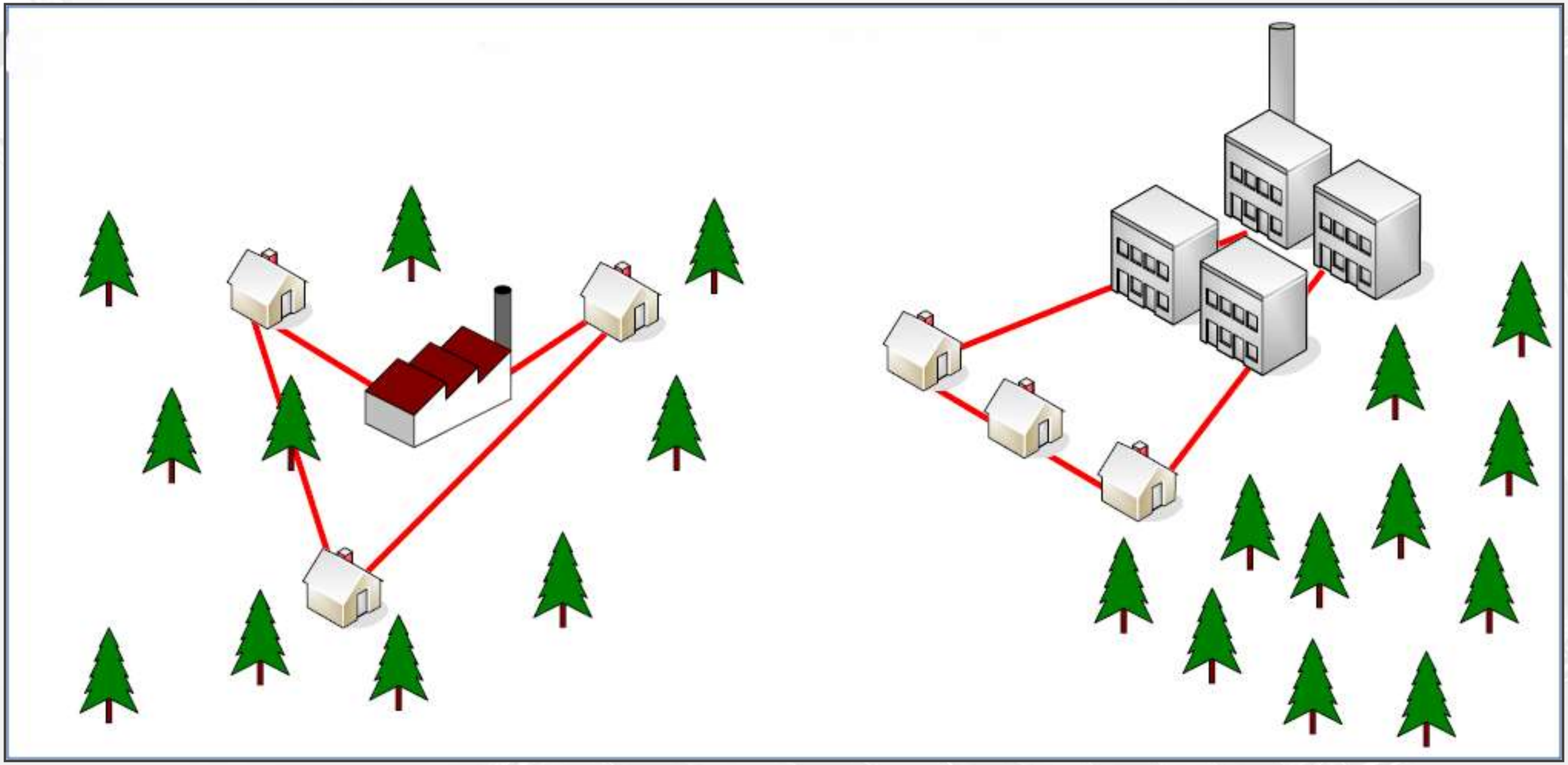
Graph source: Neil Harrison: „Wood burns: an urban myth?" Presentation held at „International Biomass Conference", Portland, OR, 2009

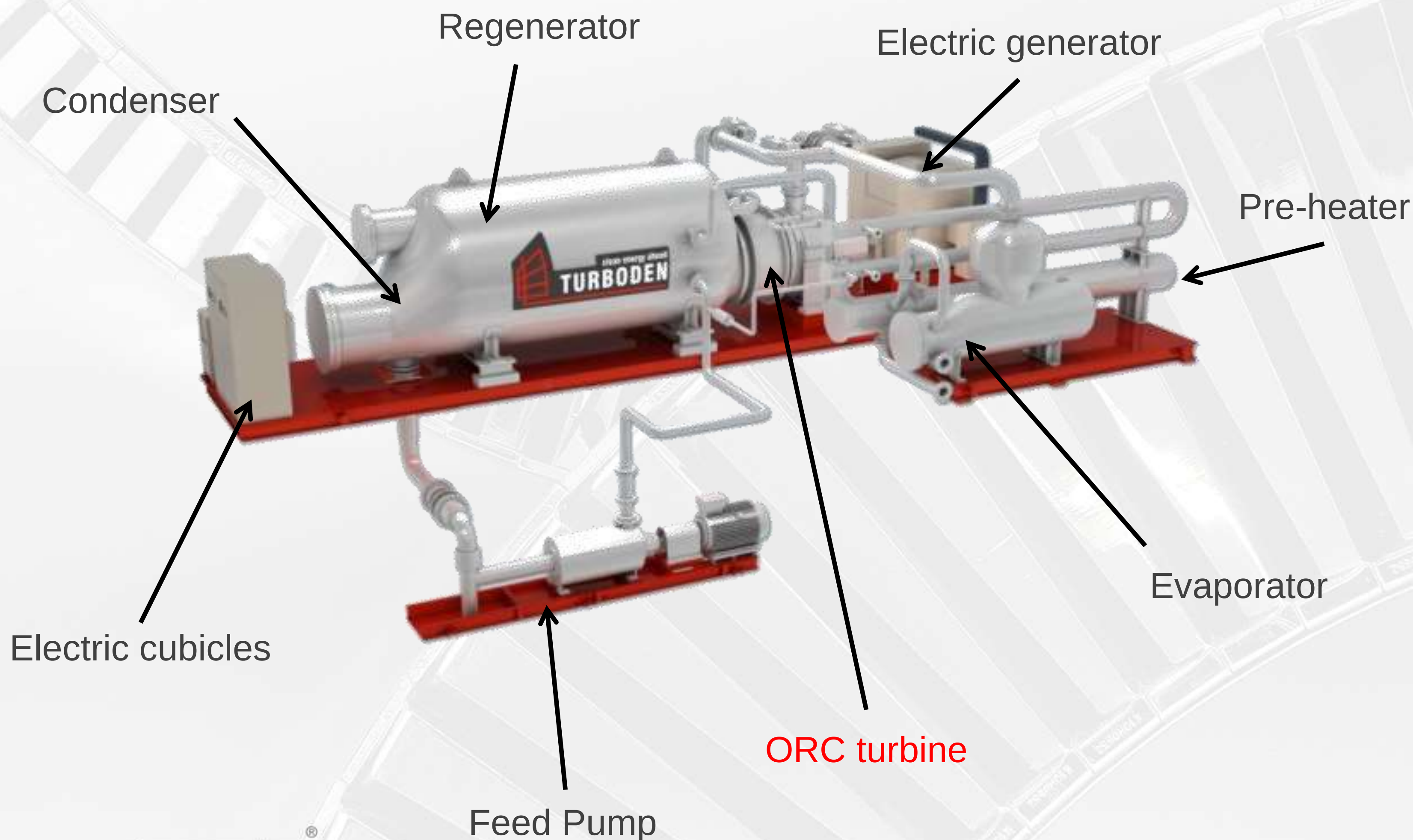
Biomass Energy: Distributed CHP



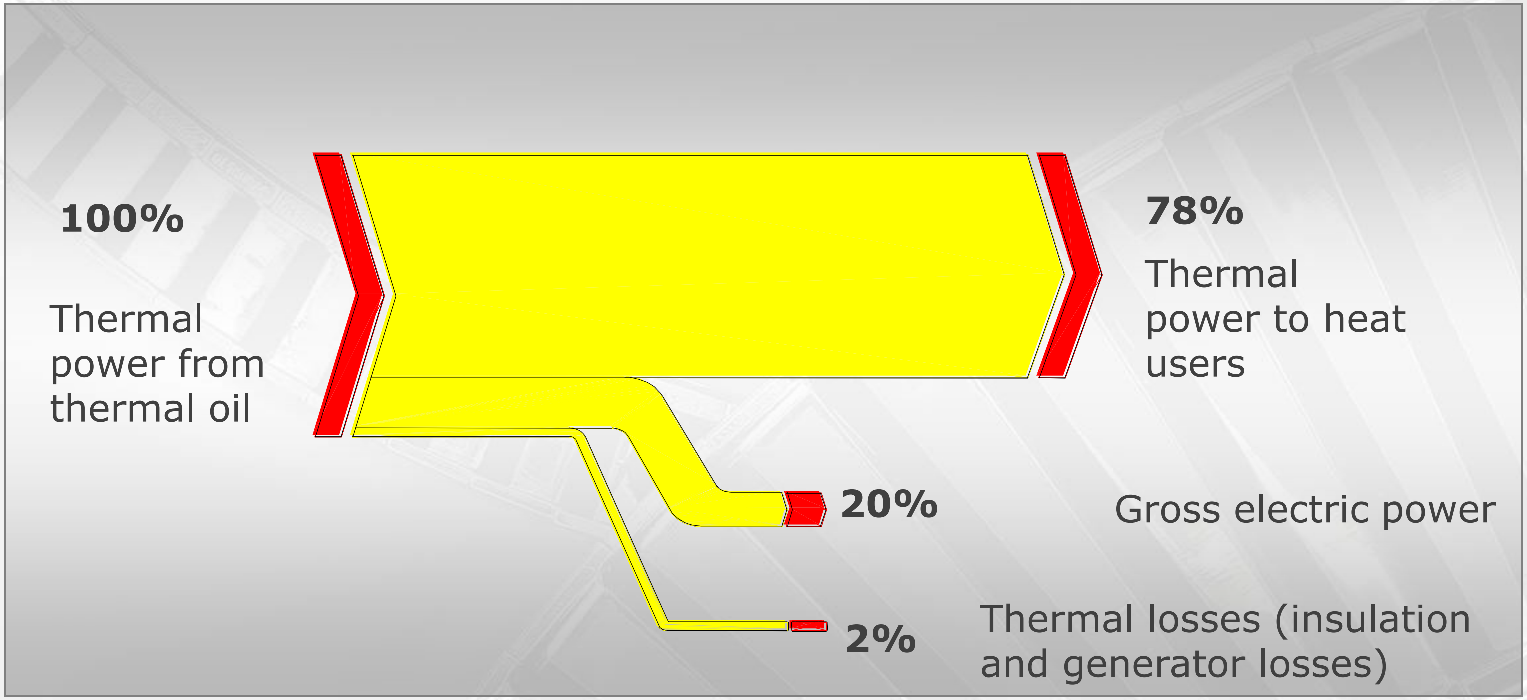
- very high total energy efficiency (CHP)
- higher specific investment cost
- low biomass transport cost & transmission losses

Graph source: Neil Harrison: „Wood burns: an urban myth?" Presentation held at „International Biomass Conference", Portland, OR, 2009

Modular ORC Units Layout

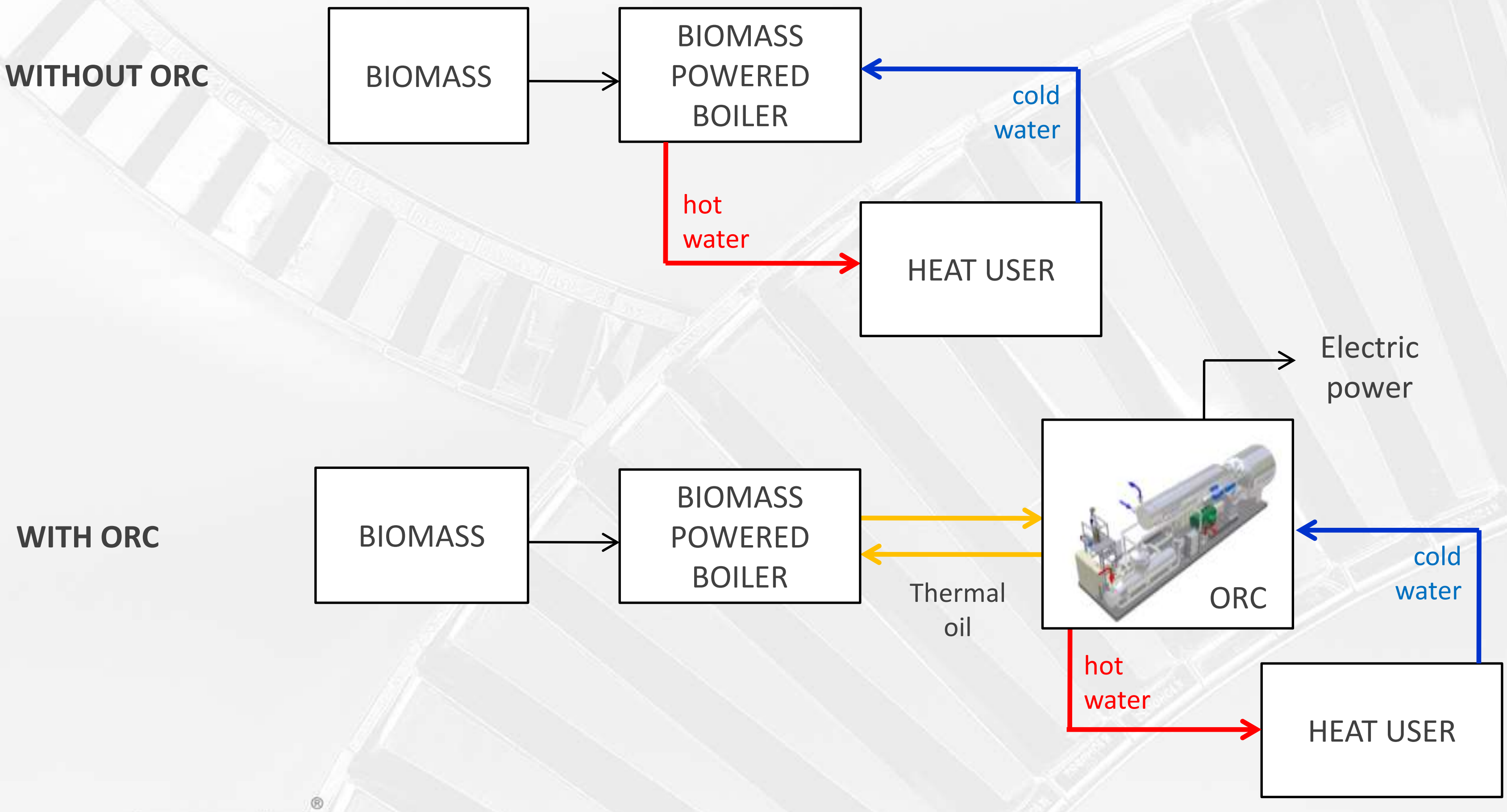


ORC Plants – Perfomances



- Gross electric efficiency: up to 20%
- Overall energy efficiency: 98%

CHP – District Heating Networks



Co-generation for district heating networks

For district heating networks:

- DH-Water temperature: 176 F to 203 F
- Need of increase incentives for CHP plants
- Need of optimization of existing power plant

- Hot water for district heating network
- Production of green energy
- Automatic operation
- Low operational costs:
  - ✓ no shift work needed
  - ✓ adapting to heat demand

Turboden ORCs for district heating networks

INPUT - Thermal Oil
Thermal Power Input:17.54 MMBtu/hr
Inlet/outlet Thermal oil Temperature:572/464 F

OUTPUT - Hot Water
Thermal Power to Hot Water circuit:13.92 MMBtu/hr
Inlet/Outlet Hot Water Termperature: 140/176 F

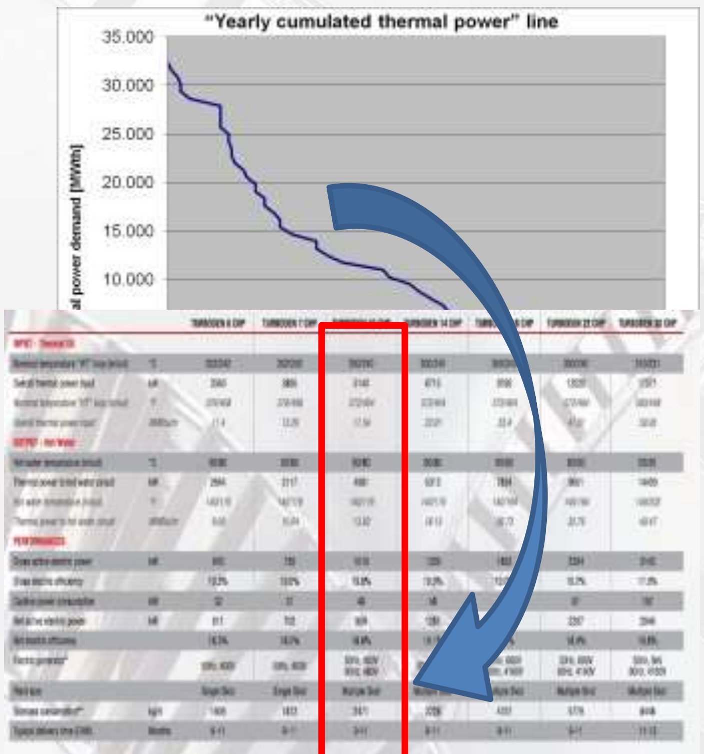
PERFORMANCES
Electric Power: 1 MWe
Yearly operation hours: 8,000

Turboden ORCs for district heating networks

Heat demand analysis

Diagram yearly cumulated thermal power

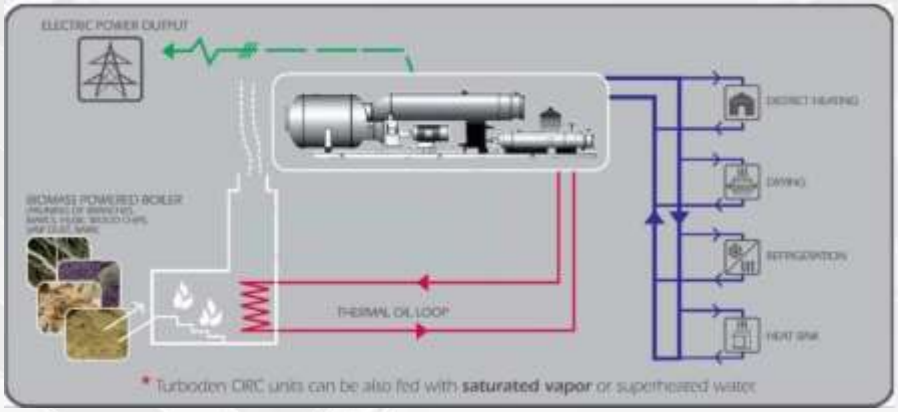
Base load of DH = ORC's OUT-thermal power



- **ORC all time at nominal load**
- **Highest efficiency, about 20%**
- **Electrical production full power**

Co-generation for district heating networks

- ORC reliable technology for power production: highly reliable
- Cogenerative solution (also trigeneration - CCHP) since more than 30 years
- Distributed power generation
- Green energy production: reduced emissions and increased efficiency
  → incentives & funds
- Optimization of existing power plants and ORC automatic operation:
  - adapting to thermal demand
  - low operational costs



Reference: Bioenergie Fernheizwerk Ritten

ORC characteristics:

Model: Turboden 8 CHP

Client: Bioenergie Fernheizwerk Ritten coop

Start-up: December 2008

Localisation: Renon (BZ) – Italy

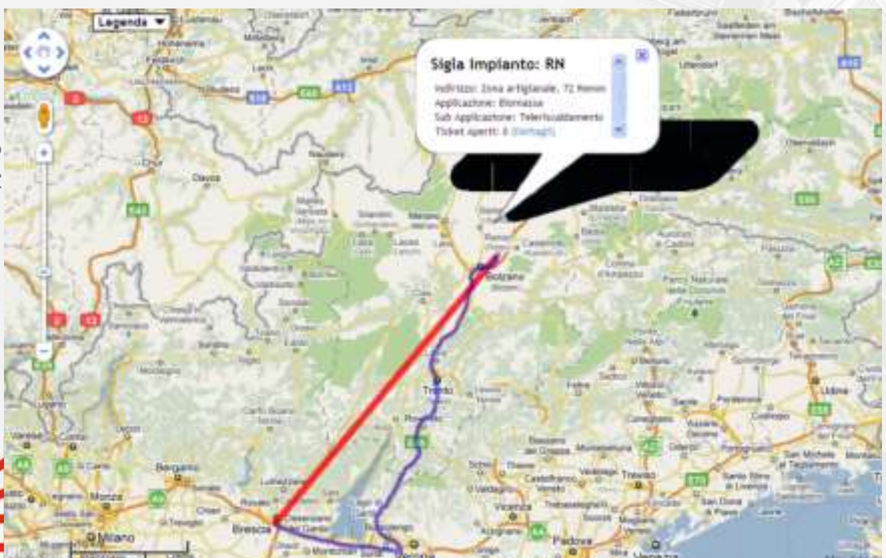
Fuel: Wood chips

Electric power generated: 990 kW

Thermal power application: district heating

Thermal power generated: 15 MMBtu/hr

Water temperature: 140 – 194 °F



Context / Special Feature

Total heat capacity production:

- 1 thermal oil biomass boiler: 17 MMBtu/hr

- 1 gasoil boiler for consumption pics: 13.65 MBtu/hr

Separated district heating water circuit

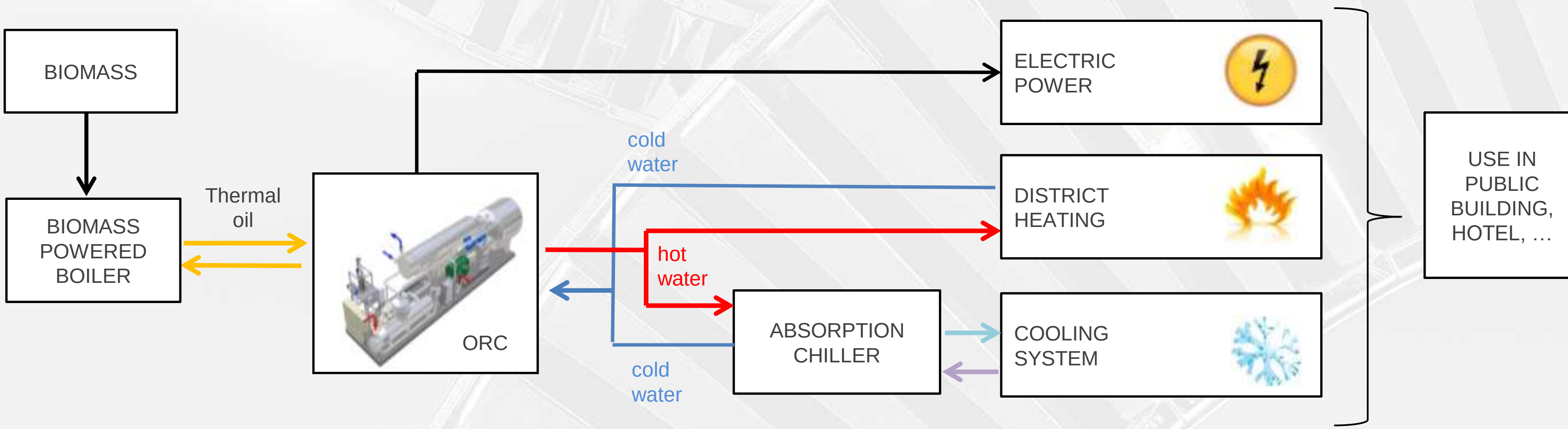
district heating: about 10 miles (main root)

Nr. of customers on the grid: about 250

Biomass storage for 7,000 cubic meter (srm)

Planned upgrade: a second biomass boiler (55 MMBtu/hr total thermal power for about 400 customers)

CCHP – Combined Cooling Heating Power



Example in Public building - TV Studios

Context / Special Feature

A/ Television studios, Sky headquarter in Europe

- As Europe's first Carbon neutral media company
- Space Area: 8,600 square feet, 113,000 cubic feet
- Thermal power: 5% heat the building, 50% to chiller and 45% as heating to a district heating loop around the campus
- Reason for Tri-generation: biomass-fuelled combined cooling and heating (CCHP) power plant, reducing the building's carbon footprint by at least 20 percent
- Planning driven, achieving 20% reduction in carbon and 20% usage of Renewable Energy

B/ Specificity CCHP

- Fuel: biomass

- Type of biomass: waste clean wood

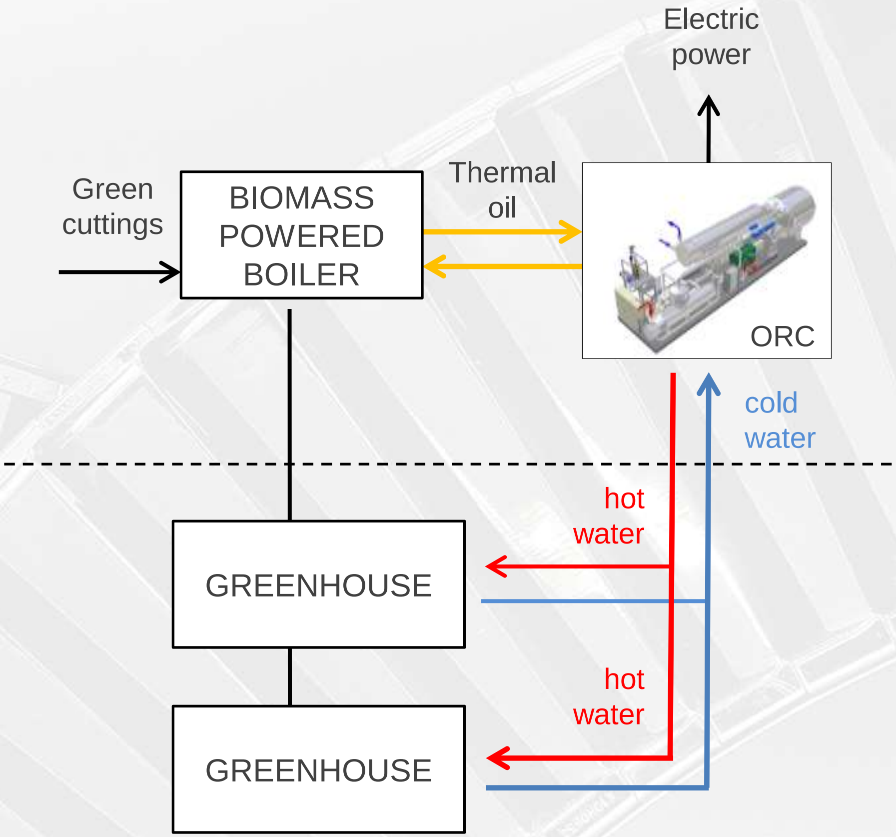
- Boiler supplier: VAS
- Thermal oil boiler capacity: 17.5 MMBtu/hr
- Cogeneration through ORC
- Cooling power produced by chiller
- Chiller supplier: Carrier (PWPS) / Sanyo

C/ Energy management due to:
- Natural air ventilation and wind turbine

ORC characteristics:

Model: Turboden 10 CHP Split
Client: Clearpower Limited
Start-up: 4th quarter 2011
Localisation: Osterley, West London, UK
Electric power generated: 968 kW
Thermal power application: space heating/cooling
Thermal power generated: 14 MMBtu/hr
Water temperature: 155-194 °F

Greenhouses



Example of greenhouses application

Context / Special Feature

Model: Turboden 18 CHP

Client: AGO AG - TOMSTAR

Start-up: December 2006

Localisation: Alperstedt, Germany

Fuel: Virgin wood chips

Electric power generated: 1,784 kW

Thermal power application: grenhouse heating

Thermal power generated: 26.73 MMBtu/hr

Water temperature: 140 – 194 °F

Boiler supplier: Mawera

Context / Special Feature

Business: Vine tomatoes greenhouse

Greenhouse size: 1 MM square feet

Yearly production: 4,800 ton

Nominal thermal power: 27 MMBtu/hr

CO_2 saving: 14,000 ton/year

Website: www.tomstar.gbt-alperstedt.de

Analysis of a cogenerative biomass plant
Turboden 22 CHP

Analysis: Hypotheses

Turboden 22 CHP
Fixed feed in tariff (15 c$/kWh)
Variable cost of biomass

INPUT PARAMETERS		
Electric energy cost	10	c$/kWh
Thermal energy cost	3	c$/kWh
Plant own consumption (ORC excluded)	250	kW
Interest rate	5	%
ORC maintenance costs	25,000	$/year

Analysis: Hypotheses

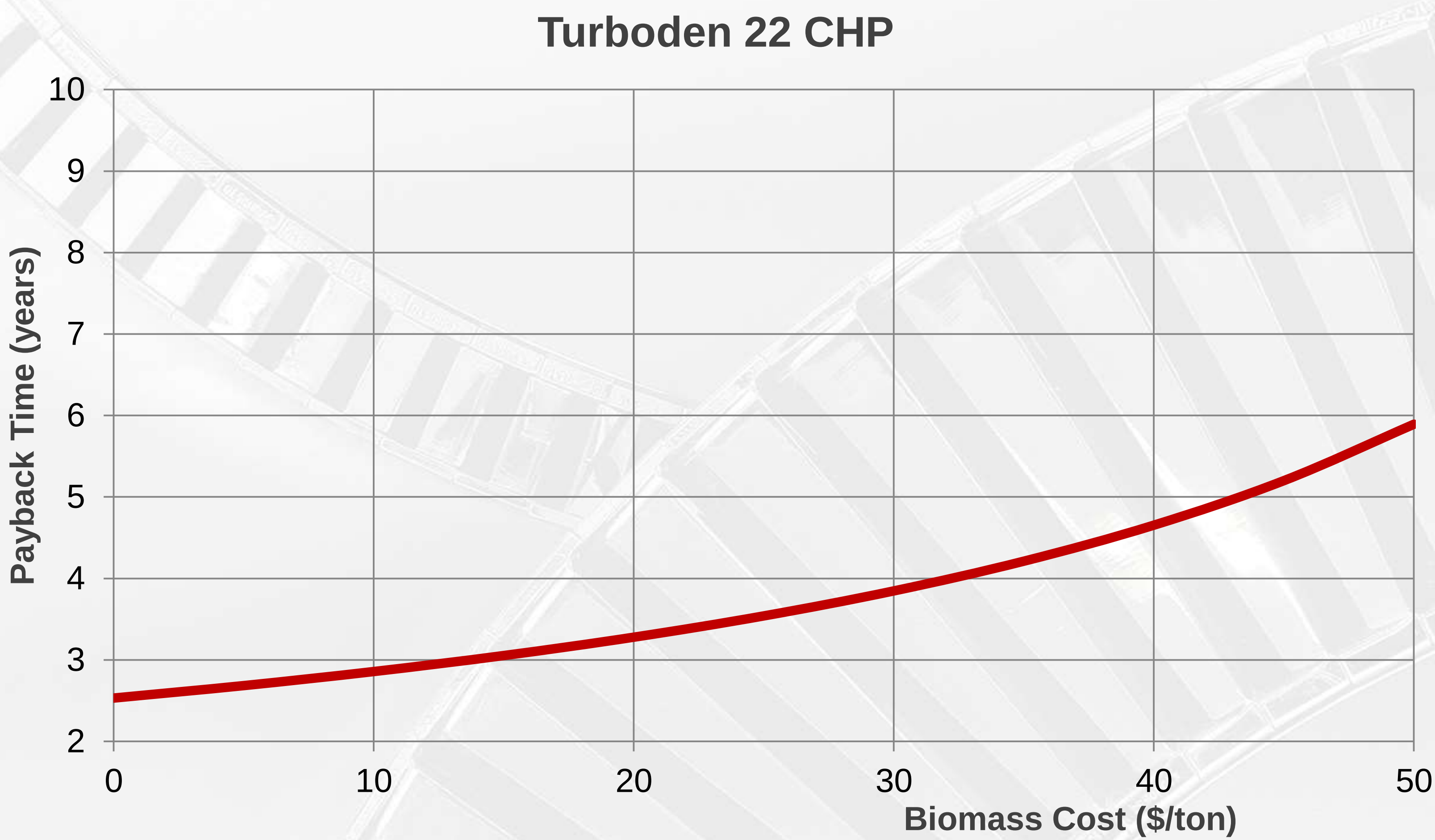
COGENERATION WITH TURBODEN 22 CHP		
Nominal power at the furnace*	50	MMBtu/hr
Boiler thermal power	41.01	MMBtu/hr
Net electric power from ORC	2,207	kW
Thermal power to the grid (at 194 F)	32.76	MMBtu/hr
Portion of thermal energy sold**	50%	
Plant own consumption (estimation)	250	kW
Yearly biomass consumption***	36,000	tons
Net electrical power sold to the grid	1,957	kW
ORC cost	2,628,000	$
Total investment (estimation)	13,000,000	$

* Assuming **82%** boiler efficiency

** Assuming **8,000** working hours a year, the overall thermal power produced results in **262,000 MMBtu per year**; it is assumed that **50%** (equivalent to **4,000** hours a year – i.e. **131,000 MMBtu per year) is sold** and **50% dissipated**

*** Assuming **17 MMbtu/ton** biomass HHV

Example: with feed in tariff (15 c$/kWh)



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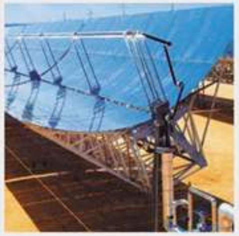


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