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Bioenergy: A Part of Yukon's Energy Future

Fernando Preto

CanmetENERGY, Natural Resources Canada

Yukon Energy Charrette

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Introduction:
CanmetENERGY Biomass Conversion Laboratories

A Role For Bioenergy

- Biomass-derived fuels can substitute for fossil fuels in existing energy supply infrastructure without contributing to the build-up of greenhouse gases in the atmosphere. Intermittent renewable sources, such as wind and solar energy, are more challenging to fit into existing distribution and consumption schemes.

- The potential resource base is significant but must be sustainably managed and restricted to residues and use of land not required or unsuitable for food production. An assessment of potential bioenergy development must also address potential health and environmental issues.

Yukon: Window of opportunity

- **Clean energy deficit by 2014 when “Faro Surplus” will be gone**
- **New supply for diesel generated electricity has been pegged at ~30 cents per kWh**
- **What should YEC Do?**

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What should Yukon Energy Do?

- **Build a Wood Pellet Plant?**

Energy Conversion

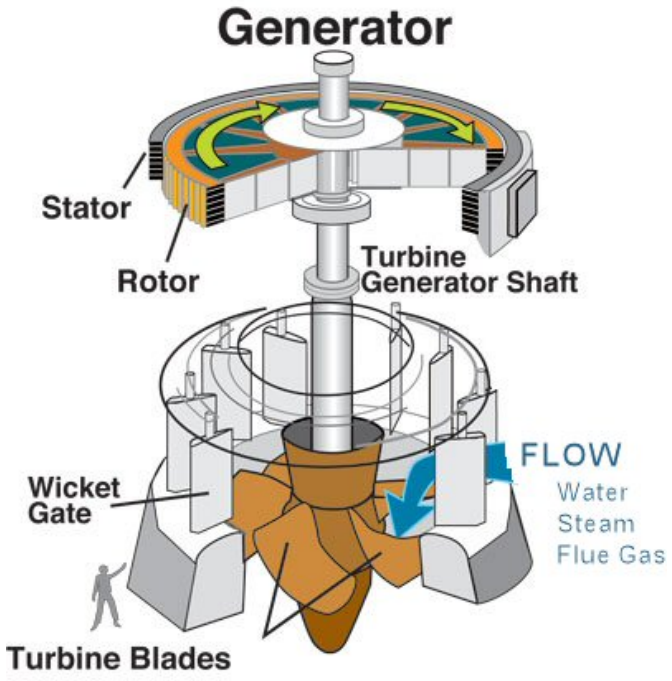
- **Energy Content**
  - Dry Wood 18 MJ/kg
  - Diesel 45 MJ/kg
- **Wood Stove**
  - Roaring Fire 3 kg/h
  - Thermal Efficiency (75% of heat stays in house)

  - Net = 3 kg/h * 18 MJ/kg * (75/100) = 40.5 MJ/h
  - Watts? 40.5 MJ/h * 1 h/3600 s) = 0.01125 MJ/s
  - 1 Watt = 1 J/s so we have 0.01125 MW

  - Or 11.25 kW [of heat]

Electrical Efficiency

- How much of the energy in the fuel is converted to electricity?
  - Efficiency of converting kW of heat to kW of electricity
  - Large Coal Plant ~ 35%
  - Large Biomass Plant ~25%
  - Diesel Generator .3 - .4 L/kWh(e) (~25%)



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Provide 10 kWh of Heat

- 10 kW wood stove (3 kg/h) for 1 hour
- Cost is 3 kg * 0.20 cents per kg ($200/tonne) = 60 cents

- Electricity 10 kWh of electricity = 10 kWh of heat
- Cost is 10 * 15 cents per kWh = 150 cents

- Burning Fuel Oil - for 10 kWh need 1.2 kg
- Cost is 1.4 L * 130 cents per liter = 182 cents

To Provide 10 kWh of Heat

- Electricity 10 kWh of electricity = 10 kWh of heat
- Cost is 10 * 15 cents per kWh = 150 cents

- **BUT**

- YEC typically needs 3-4 liters to generate 10 kWh
- Cost to generate 10 kWh = 3 * 130 = 390 cents

Yukon Electricity Generation Capacity (megawatts)

Yukon Energy		The Yukon Electrical Company Ltd.	
Hydro		**Hydro**	
Whitehorse	40.0	Fish Lake	1.3
Aishihik*	30.0	**Diesel**	
Mayo	5.0	Carmacks	1.3
Total	75.0	Haines Junction	1.3
Diesel		Teslin	1.3
Whitehorse	22.6	Ross River	1.0
Faro	5.4	Watson Lake	5.0
Dawson	6.0	Beaver Creek	0.9
Mayo	2.0	Destruction Bay	0.9
Total	36.0	Old Crow	0.7
Wind		Pelly Crossing	0.7
Haeckel Hill	0.8	Stewart Crossing	0.3
		Swift River	0.3
		Total	13.7

Total Yukon Energy Capacity	112.0 MW
Total YECL Capacity	15.0 MW
Total Yukon Capacity	127.0 MW
Total Yukon Hydro Capacity – Summer	76.3 MW
Total Yukon Hydro Capacity – Winter	60.0 MW
Total Yukon Diesel Capacity	49.7 MW
Total Yukon Wind Capacity	0.8 MW

Source: Yukon Energy Corporation *2006 Annual Report.*

Energy Conversion Technologies Options

Combustion - Heat

Madsens's Custom Cabinets, Kalwa Biogenics Inc.
Edmonton, Alberta

Combustion - CHP

Grande Prairie EcoPower Centre
Grande Prairie, Alberta

Gasification - Heat

Nexterra/Tolko
Heffley Creek, British Columbia

Pyrolysis – Bio-Oil

Advanced Biorefinery
Portable
Pyrolysis Unit
Ontario

Dynamotive Erie Flooring Plant
West Lorne, Ontario

Enzymatic Fermentation – Ethanol

Iogen Enzymatic Cellulose Ethanol Plant
Ottawa, Ontario

Gasification - Power

Dapp Power Plant
Dapp, Alberta

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Slide Courtesy: Derek Sidders, Canadian Wood Fibre Centre

Energy Conversion Basics

- **Combustion** produces heat which can be used directly or used to produce steam for industrial processes or power generation
- **CHP (Combined Heat and Power)** plant is designed to produce both heat and electricity from a single heat source
- **Gasification** produces a mixture of low molecular gases known as syngas, which can be used to synthesize renewable fuels, polymers, and commodity chemicals
- **Fast Pyrolysis** produces “bio-oil”, which is not really an oil but a liquid mixture of oxygenated organic compounds that can be used as a biofuel a source of specialty chemicals

Available Combustion Technologies

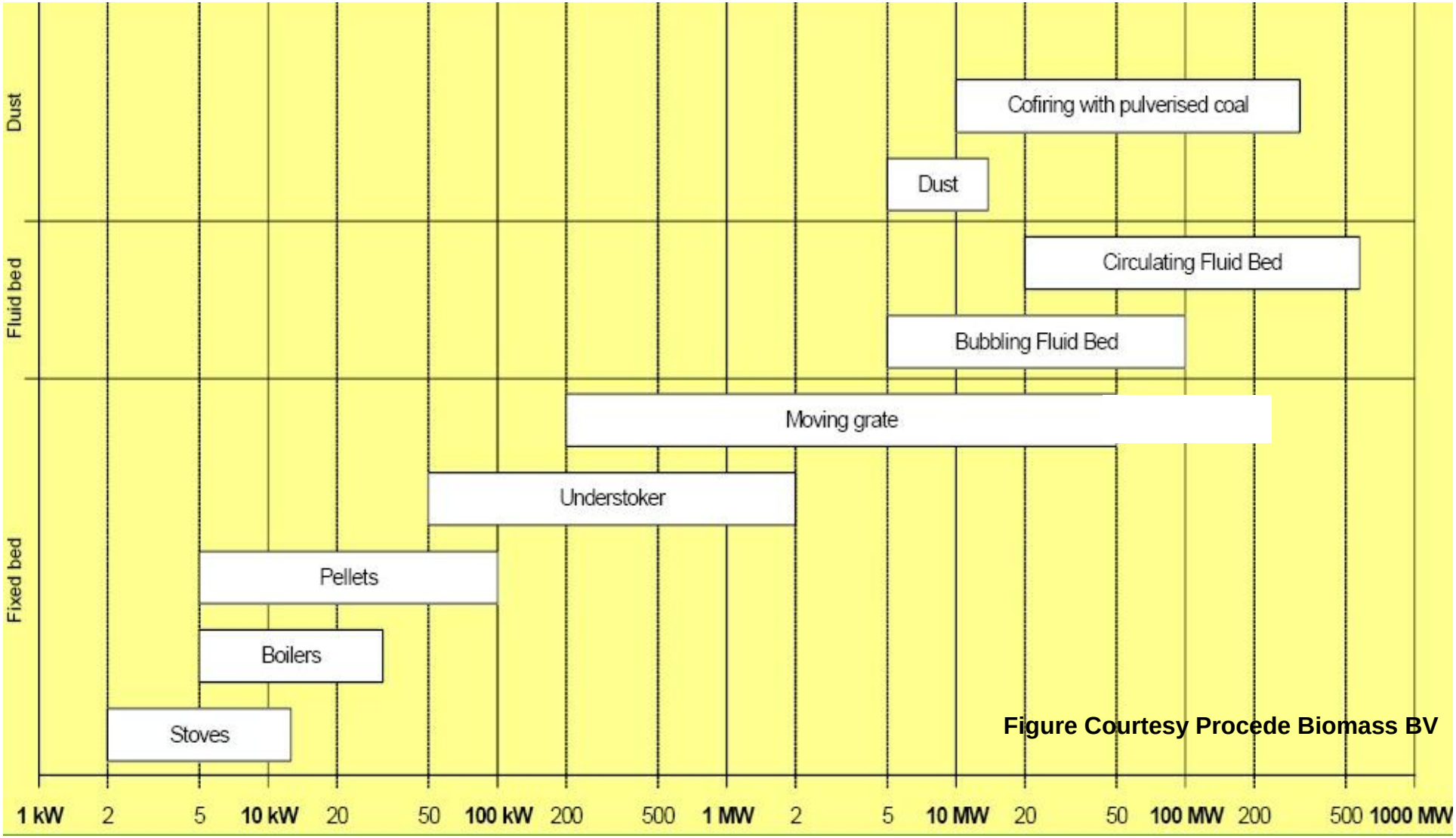

Figure Courtesy Procede Biomass BV

Biomass Combustion Canadian Suppliers

- **Canadian manufacturers of industrial/commercial biomass combustion equipment:**
- **http://www.blueflamestoker.com/**
- **http://www.boilerclub.com/**
- **http://www.braymo.com/**
- **http://www.deltech.ca/**
- **http://www.falmecboiler.com/**
- **Grove Wood Heat Inc (PEI) Tel: (902) 672-2090**
- **http://www.hutterianbrethren.com/boilers.htm**
- **http://www.ideal-combustion.com/en/wetbiomass.aspx**
- **http://www.kmwenergy.com/**
- **http://www.krann.ca/index.htm**
- **http://www.nexterra.ca/**
- **http://www.profab.org/products/pelco/index.html**
- **http://www.wellons.ca/**
- This list is provided for information only. NRCan does not endorse or recommend any specific supplier and this list is not intended to be comprehensive - any omissions from the list are unintentional

60 MWe Williams Lake GS

Largest Biomass Plant in North America

770,000 tonnes/y

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25 MWe Biomass Power Plant

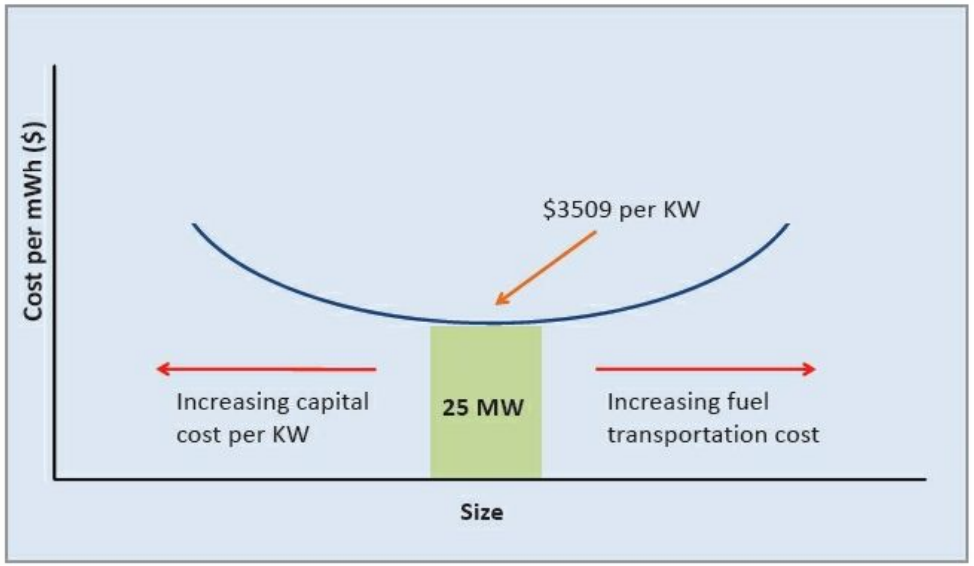
Capital Cost $86.5 million

Courtesy COOK Engineering
A Division of Genivar

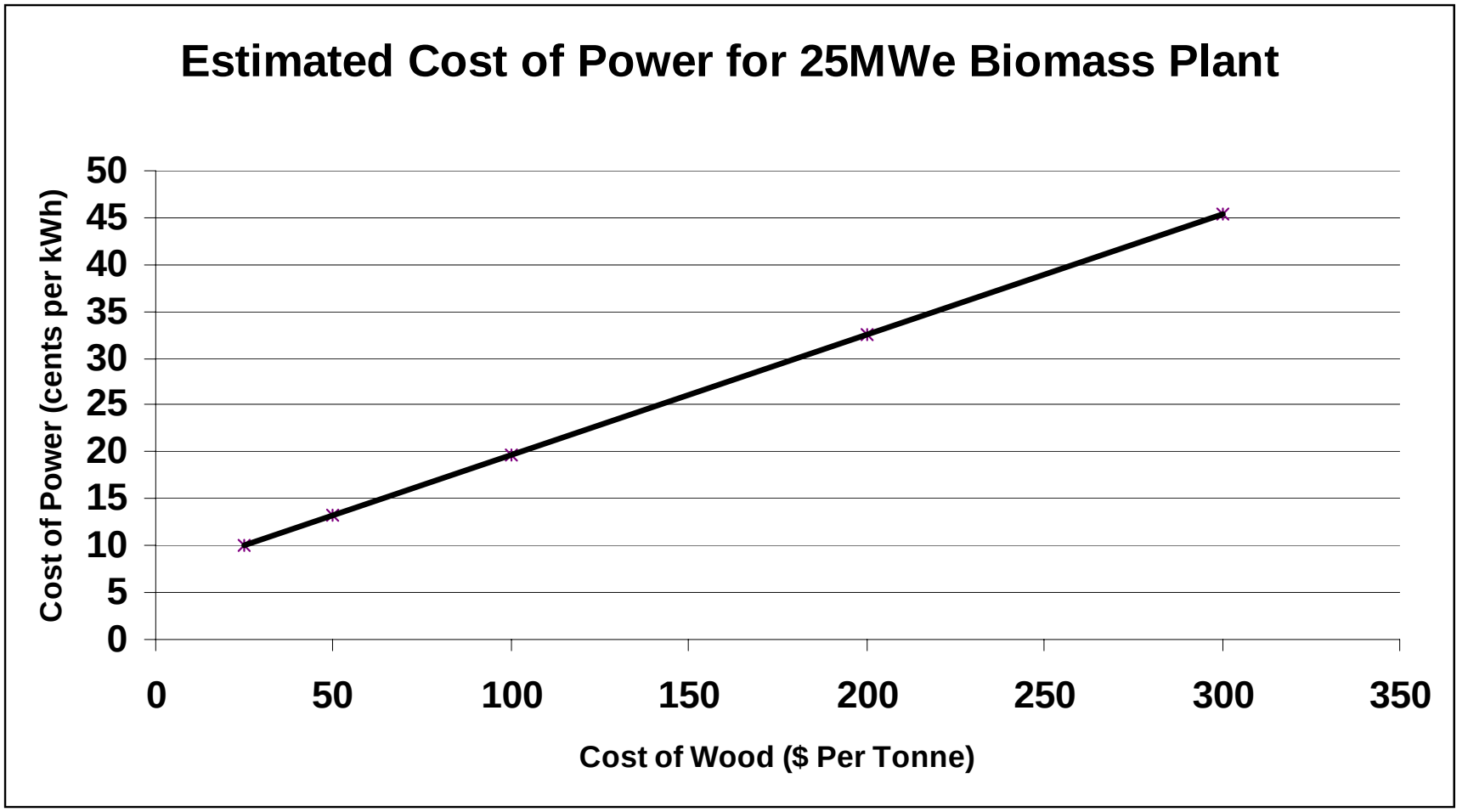
25 MWe Biomass Power Plant

Why 25 MW Biomass?

25 MW = Optimum Cost



Courtesy COOK Engineering
A Division of Genivar



Based on 25 yr plant life and 27 employees to operate plant

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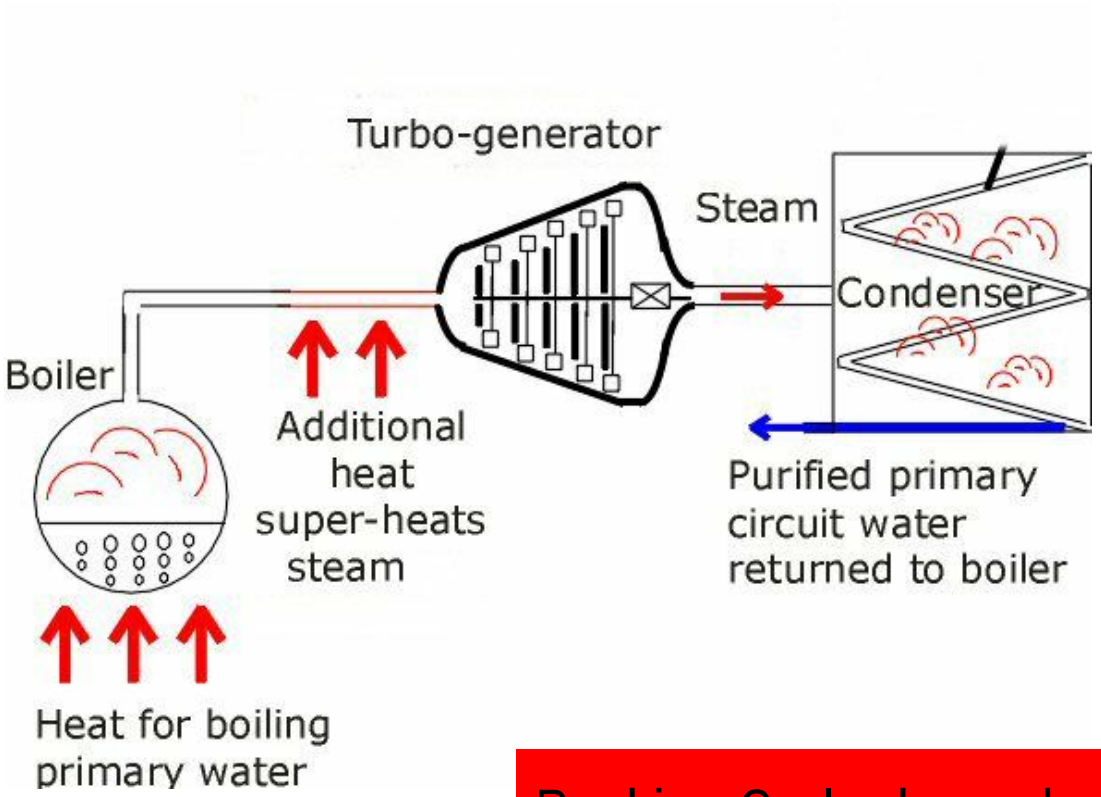
Combustion technologies are commercially available in sizes from 2 kW to 500 MW.

What about Community Scale or <10 MWe power generation?

Conventional Power Generation



Rankine Cycle depends on high pressure steam and associated manpower requirements

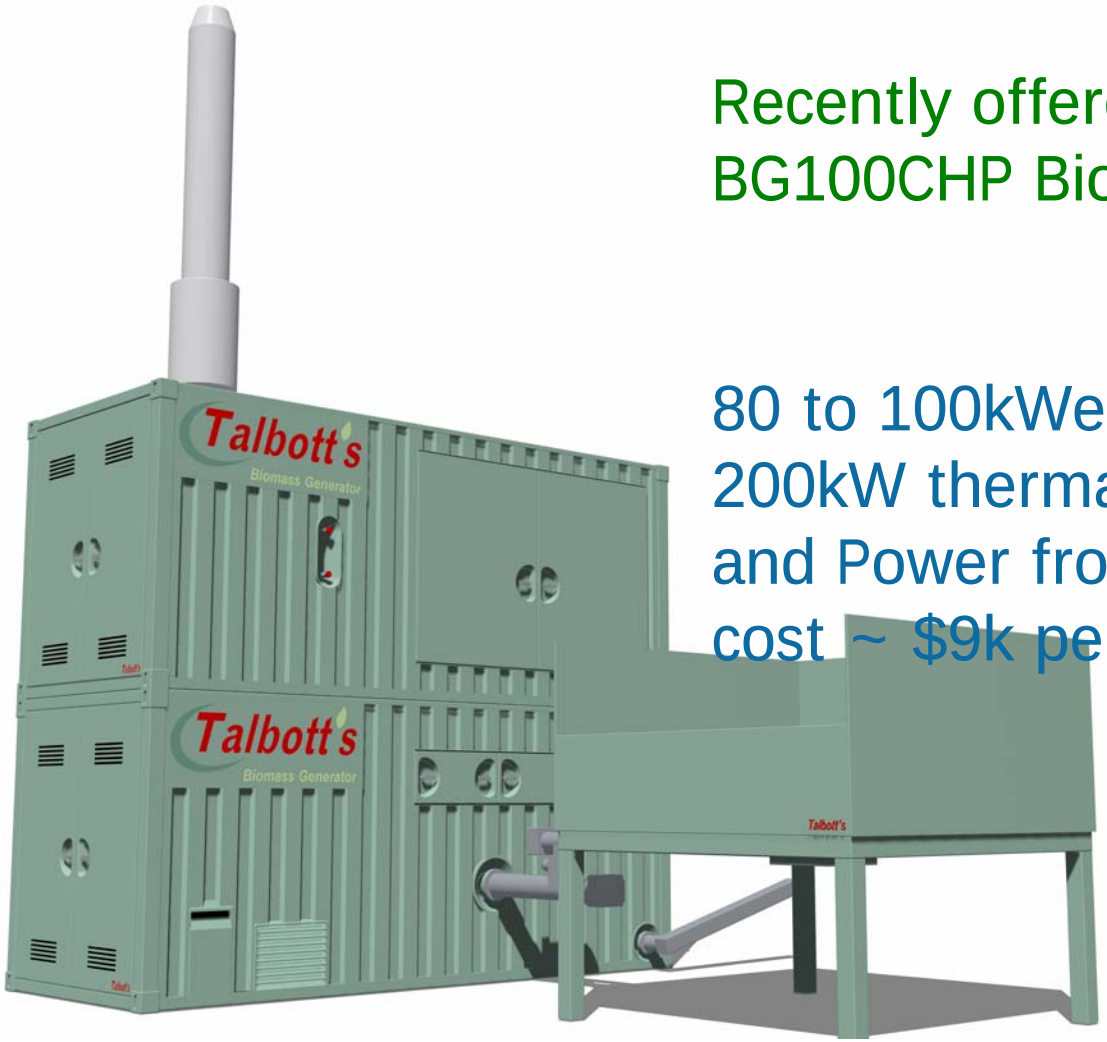
Small-Scale Power Generation

Generally, Rankine Cycle (steam turbine) based systems are not economically feasible below 10 MWe

Organic Rankine Cycles

A number of units have been operating in Europe since 2000. Efficiency limited by low temperatures of organic fluids. Costs for 1- 3 MWe plant estimated at $7M per MWe. Small (100-200 kWe) refrigerant based add-on ORC for existing boiler estimated at $5k per kWe

Brayton Cycle



Recently offered for sale:
BG100CHP Biomass Generator

80 to 100kWe Electrical output with 200kW thermal output Combined Heat and Power from each unit (Estimated cost ~ $9k per kWe)

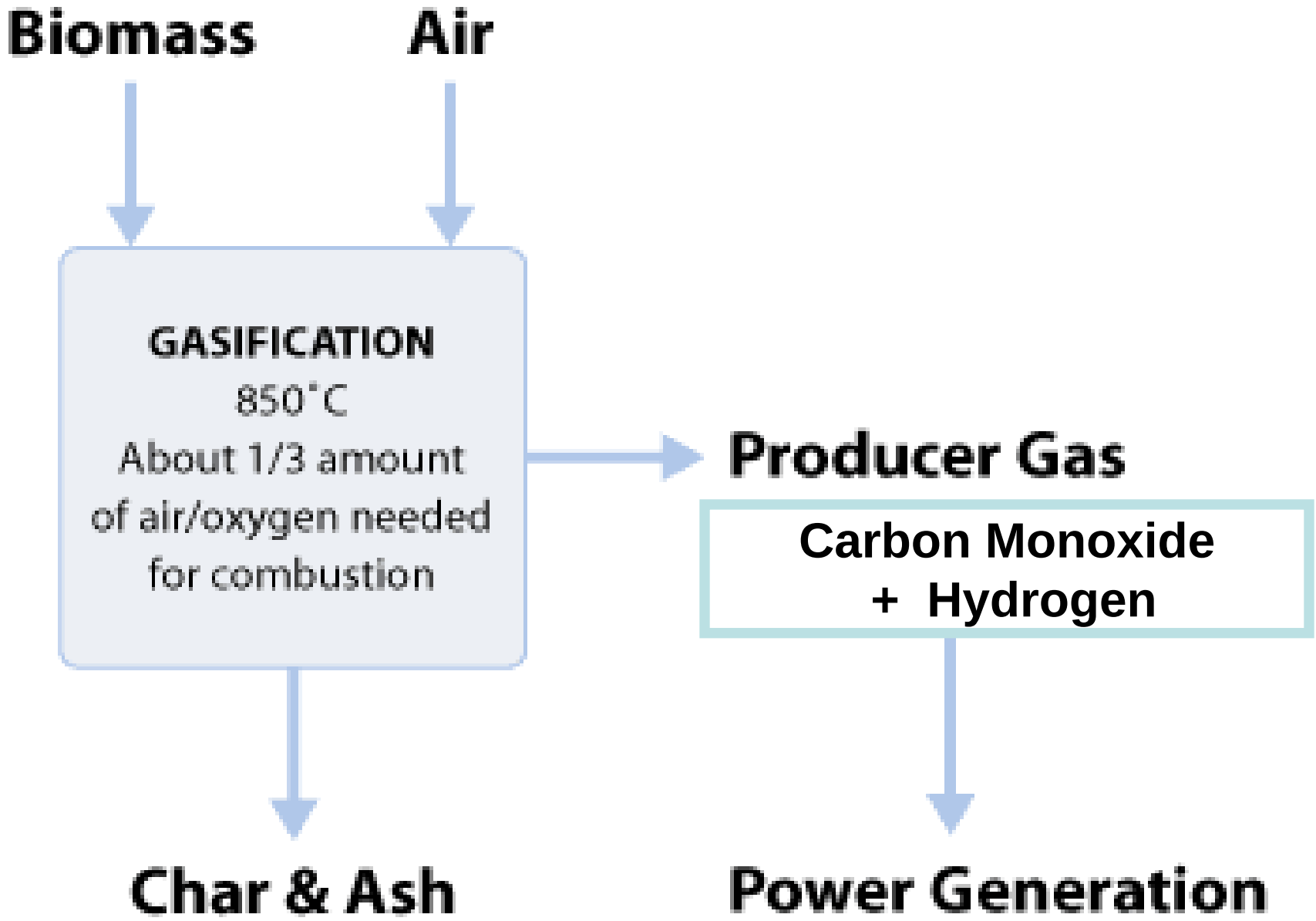
Stirling Engine

Stirling Engines are typically less than 50 kWe

Cost estimate $5 – 7k per kWe

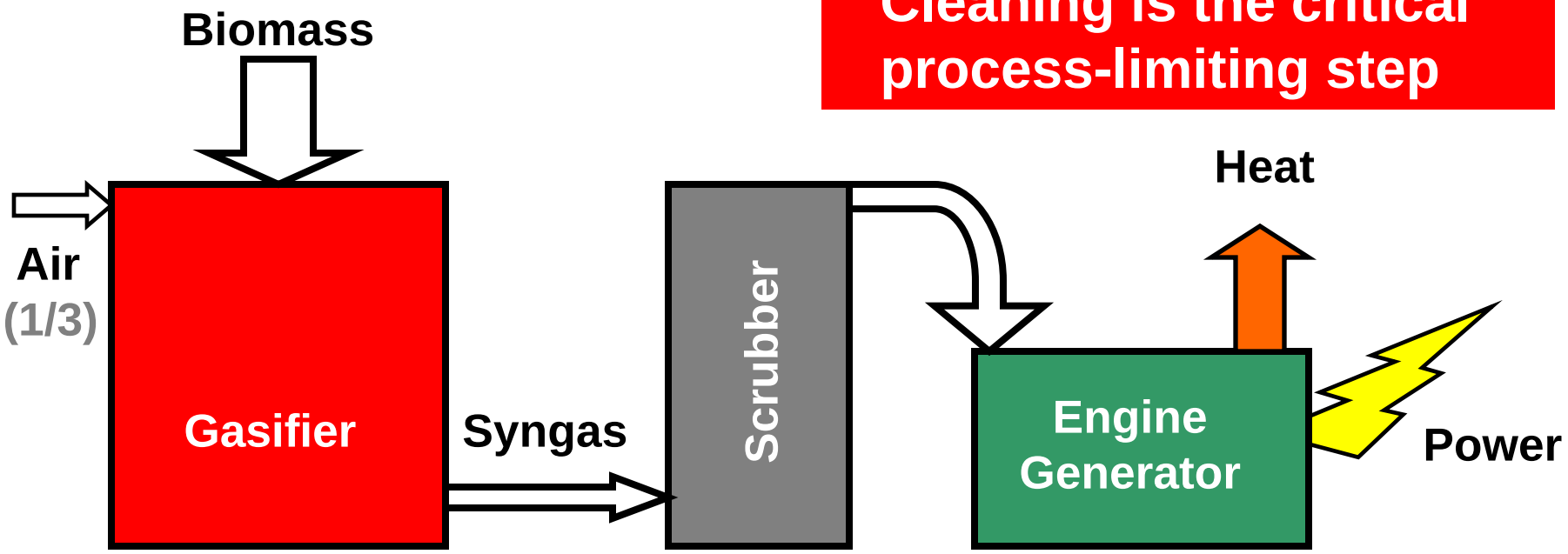
Stirling Danmark: Wood Chip Fired

Gasification for Syngas



Gasifier and GenSet

Comprehensive Syngas Cleaning is the critical process-limiting step



Gasification allows you to convert a relatively heterogeneous feedstock into a consistent synthetic gas (syngas) which can be used as a fuel for power generation or as a feedstock for production of fuels and chemicals.

European Experiences: CHP Gasification

Many demonstrations but availability still too low <75%

<u>Fixed bed gasifier (Updraft & Downdraft)</u>
Harboore, Denmark intermittent operation since 2000
Capital Cost: ~ $ 5-10,000/ kWe
Electricity costs >25 cents per kWh

<u>Fluidized bed</u>
Operating experience >60,000 hours Gussing, Austria
Capital Cost: ~ $ 5-8,000/ kWe
Electricity costs 15-25 cents per kWh

MUST Operate as Combined Heat and Power for Economic Feasibility

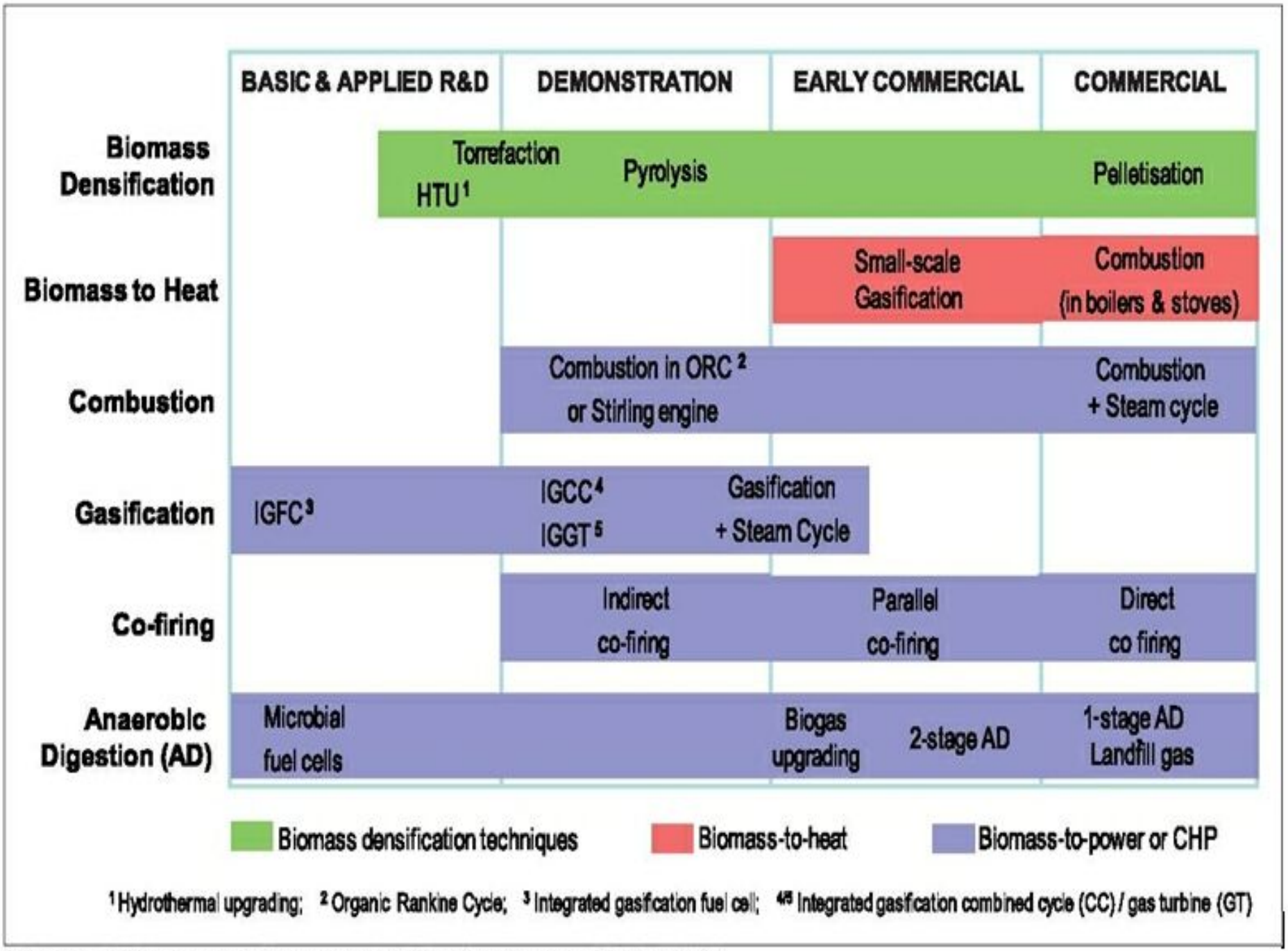
Nexterra's UBC Demonstration Project

GE Energy

nexterra

UBC – 2 MW Biomass CHP Project

- Fuel Req'd: 12,500 BDMT/year (2/3 trucks/day)
- Gross Power: 1.95 MW
- Net Thermal: 10 MMBTU/hr (80,000 MMBTU/yr)
- CO2 Red: 4,000 tpy (thermal only)
- Footprint: 180' X 90'



Status of Bioenergy Conversion Technologies (IEA, 2009)

Manitoba Hydro Demonstration Projects

- **Pyrolysis Oil** (*low moisture content, solid biomass to liquid fuel to CHP*)
- **Syngas** (*low moisture content solid, biomass to combustible gas to CHP*)
- **Heat Recovery** (*medium moisture content, solid biomass to thermal energy to CHP*)
- **Biogas** (*high moisture content, solid biomass to combustible gas to CHP*)
- **Biocarbon** (*low moisture content, solid biomass to char to CHP*)

Contact: Dennis St. George, drstgeorge@hydro.mb.ca

Project Financially Supported by Natural Resources Canada (CEF)

Pyrolysis Oil Demonstration
Biomass → Pyrolysis Oil → CHP

- Replacement of heavy fuel oil with pyrolysis oil to fuel a 15 MWe boiler & steam turbine CHP system

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POWER SMART

Syngas Demonstration
Biomass → Syngas → CHP

- Gasification of wood wastes to fuel a 100 kWe internal combustion engine driven generator CHP system

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Heat Recovery Demonstration
Biomass → Thermal Energy → CHP

- Conversion of wood wastes to heat recovered by a 100 kWe Organic Rankine Cycle CHP system

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Biocarbon Demonstration
Biomass → Char → CHP

- Conversion of wood wastes to biocarbon to fuel separate solid fuel combustion systems and utilization of residual heat from carbonization for a 50 kWe Stirling engine CHP system

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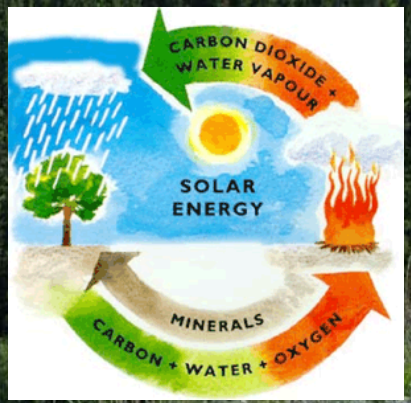
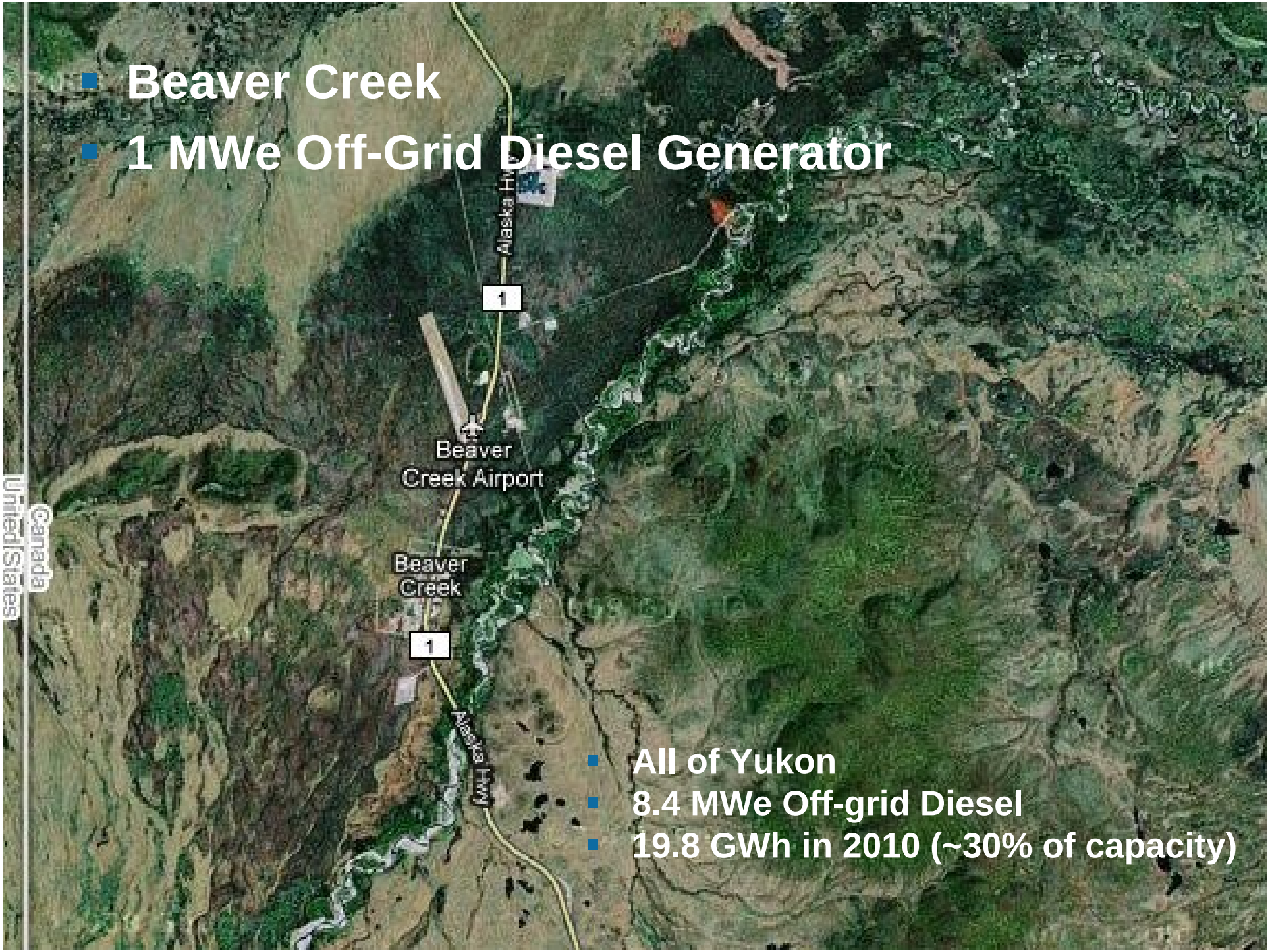
Bioenergy Supply?



Mean Annual Increment

- The mean annual increment (MAI) is the average net annual increase in the yield of living trees to a given age, and is calculated by dividing the yield of a stand of trees by its mean age. The MAI is dependent on a number of factors, including climate and elevation, soil conditions and forest management practices. MAI is a measure of the net biomass production of the forest in m3/(hectare·year).
- Based on CFS data a conservative number would be an MAI of 1.1 for the area around Whitehorse. For comparison purpose, spruce in the Pacific Maritime region have an MAI of 3.8.

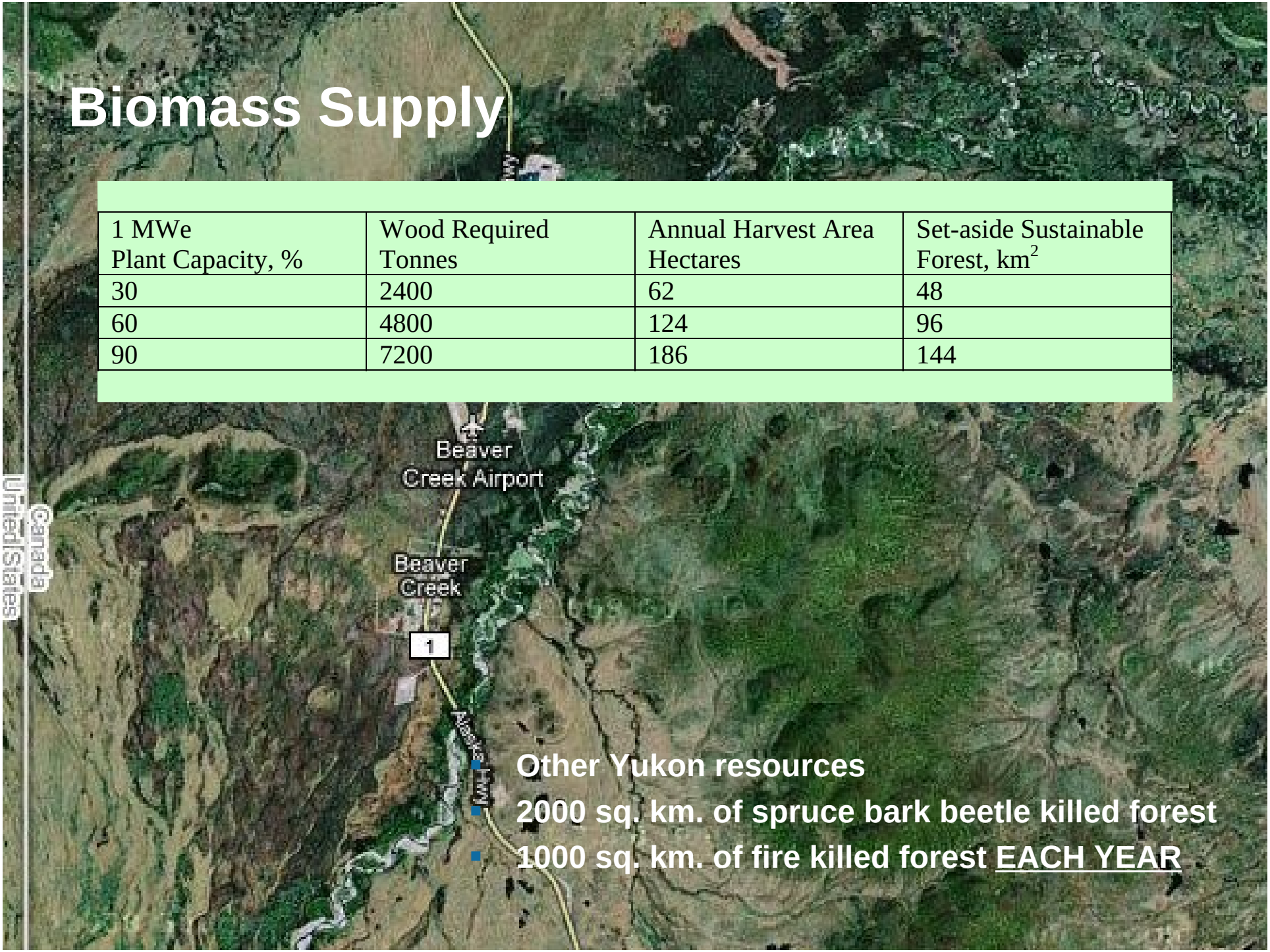


- **Beaver Creek**
- **1 MWe Off-Grid Diesel Generator**

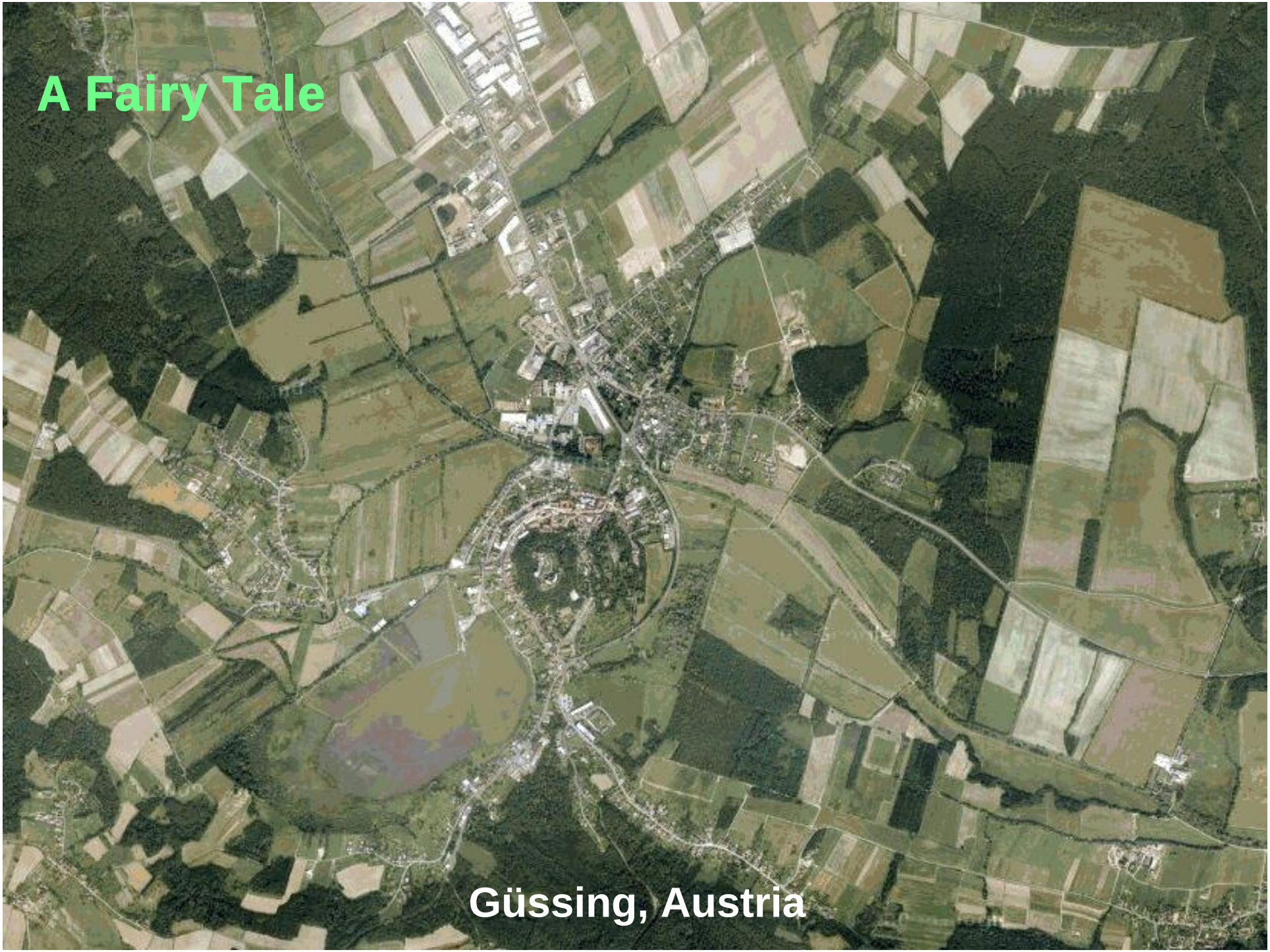
- **All of Yukon**
- **8.4 MWe Off-grid Diesel**
- **19.8 GWh in 2010 (~30% of capacity)**

Biomass Supply

1 MWe Plant Capacity, %	Wood Required Tonnes	Annual Harvest Area Hectares	Set-aside Sustainable Forest, km^2
30	2400	62	48
60	4800	124	96
90	7200	186	144



- Other Yukon resources
- 2000 sq. km. of spruce bark beetle killed forest
- 1000 sq. km. of fire killed forest EACH YEAR


A Fairy Tale
Güssing, Austria

Güssing in the late 80‘s

- Minor local industry
- High local unemployment
- Town population ~ 4,000 (Burgenland District ~ 27,000)
- 70% population commuted to Vienna…(2 hrs)...high migration rate
- Small structured agricultural fields and forestry operations
- Over 6 million euros per year left the region to pay for fuels and electricity

Then Güssing saw the light

Then Güssing saw the light

Güssing – Biomass Gasification Power Plant

Based on new technology developed at Technical University of Vienna

Güssing - District Heating Plant

Güssing Power Plant II & Solar

Güssing – Biogas Power Plant

Gasification Plant became a Research Centre

… creating new products and training skilled personnel

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… And an SNG (Natural Gas) Plant

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… And bioenergy became more popular

… and they had to build new hotels to accommodate all the visitors

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Benefits to Güssing

- New jobs
- Less traffic due to less commuters
- Independency
- Stable prices
- Secured supply
- CO2 - reduction

- 50 new companies
- Over 1,100 new jobs

- Due to 45% self-sufficiency in total energy supply, the region profits 18 million euros per year

- Potential when 100% self-sufficiency goal is achieved: 37 million euros

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Welcome to Whitehorse:
Site of Canada's "First" Biomass Gasifier

Yukon College Gasifier

- Built 1987
- Never Commissioned
- Nominal Capacity
  - 400 kg/h
  - 2000 kW
  - 7 million BTU/h

Canada

Thank You

Fernando Preto
preto@nrcan.gc.ca
Tel: 613-996-5589