Bioenergy in Australia:

Status and opportunities

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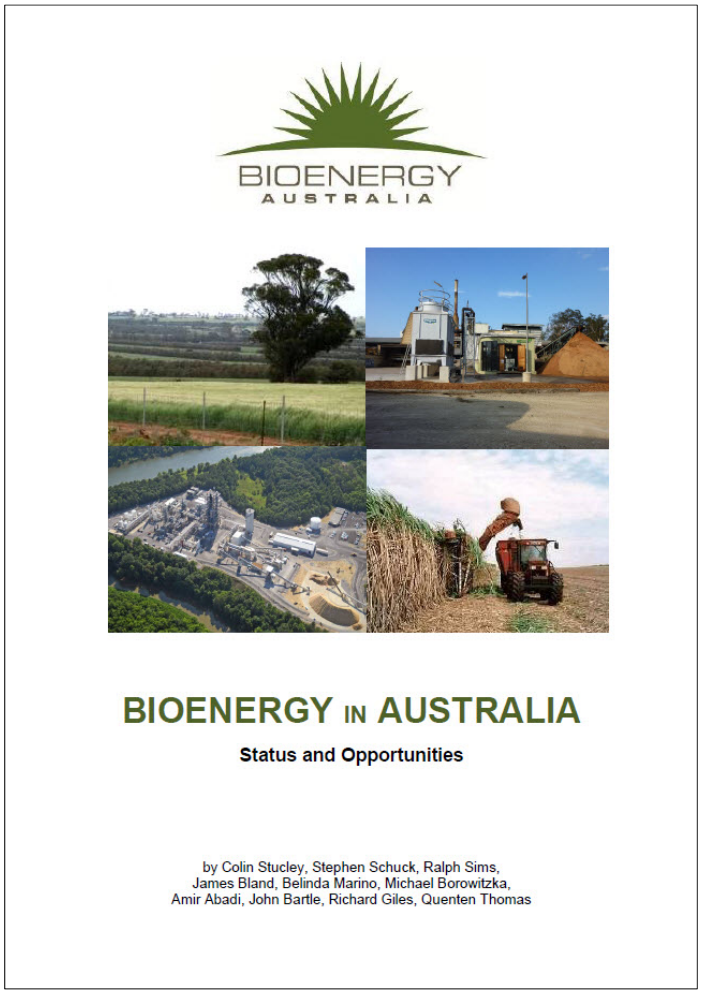
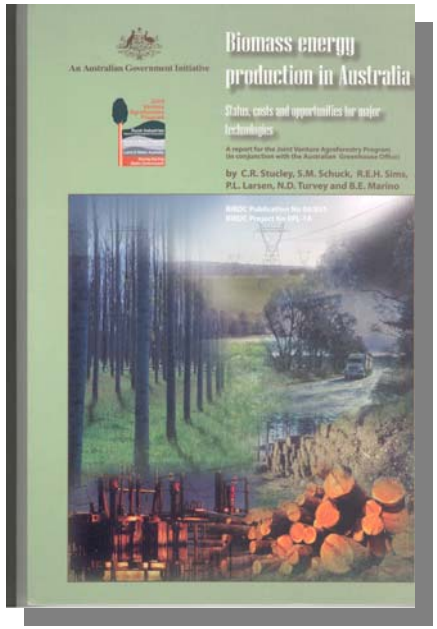
Australian engineering consultants. Specialists in bioenergy since 1998.

This talk:

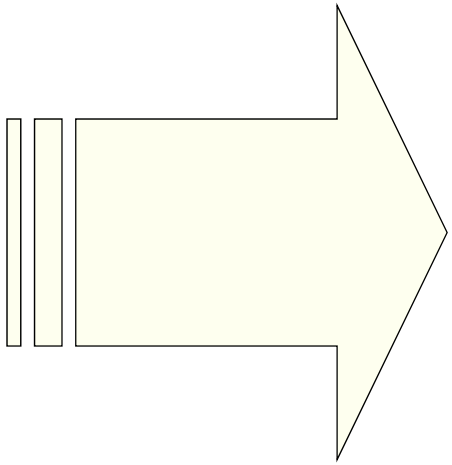
- Summary of new report
- Organic Rankine Cycle units
- Gasification and pyrolysis
- Liquid fuels from wood
- Government incentives
- Questions

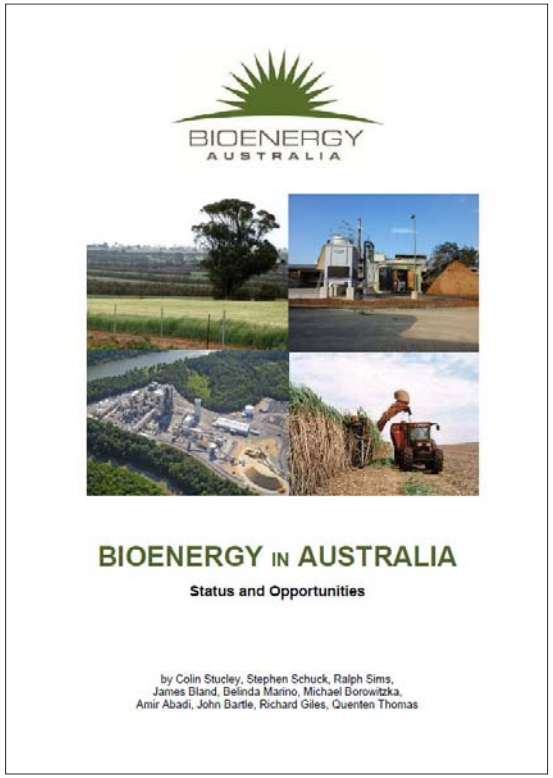


Major revision to earlier document



2004





2012

New report is available as download on Bioenergy Australia website

Twenty chapters, including overviews of:

- Energy use in Australia: now and future
- Biomass: overview and thermal properties
- General supply chain (harvesting & costs)
- Wood pellets
- Specific supply chains: mallees, pongamia, straw & grass
- Sustainability
- Electricity and heat: technologies and costs
- Biofuels: characteristics, first & advanced gen., microalgae

Authors

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Written for reader that is technically competent but inexperienced in forest industry and bioenergy.

Bioenergy: now and in the future

Bioenergy worldwide now:

- More than 70 GW of electricity capacity
- More than 100 billion litres ethanol and 10 billion litres biodiesel/year

Bioenergy in Australia now:

- Electricity – 867 MW in 2009 (mainly bagasse and landfill gas)
- Ethanol, biodiesel – more than 650 Ml/year capacity in 2012

Australia's bioenergy future:

- Electricity, advanced generation biofuels
- Feedstock available for significant growth
- Need to understand & develop existing and new feedstocks

Biomass to electricity

Main differences between Europe and Australia:

- Mandates and power pricing
- District heating

Difficulties we see in Australia:

- High capex means 24/7 for good cost recovery
- Not always good at load following
- External electricity sales – low price, costly to set up
- Not core business
- Lack of precedents

Biomass to electricity

- Organic Rankine Cycle units
- Gasification
- Pyrolysis and charcoal

Combustion and ORC units

- Organic Rankine Cycle – same Rankine cycle as steam turbines but with organic fluid in closed loop
- This allows a wide range of input and output temperatures
- Used worldwide with geothermal heat and industrial waste heat
- Bioenergy use is increasing

Large scale ORC unit in Europe

Combustion and ORC units

- Sizes from 25 kWe to many MWe
- Waste heat or dedicated heat supply, as steam or hot oil
- Electrical efficiency <10% to >25%
- Useful exhaust heat possible for cogeneration
- Local and o'seas manufacture

250 kW Purecycle unit at Gympie Timbers, Qld

gTET unit under construction for WA forest industry client

Gasification to electricity

Small gasifiers (hundreds of kWe)

- Downdraft
- Commercial in India (but not used in western countries)
- Several European suppliers have closed
- One or two US suppliers emerging
- Several demonstration units in Aust and NZ
- Watch for: guaranteed availability, gas cleaning system & staffing levels

Large gasifiers:

- Entech & New Energy Corp. - waste to energy
- Westinghouse Plasma - waste to energy
- Andritz Carbona - commercial demo unit
- PRM - rice hulls
- Others overseas - biofuels
- IGCC - no major interest

Biomass to charcoal

Charcoal is co-product in gasification and pyrolysis processes.

Charcoal must add to the revenue stream:

- Biochar for enhanced plant growth & C sequestration in soil
- Metallurgical uses
- Renewable energy

All these uses provide GHG reduction.

Look at markets and selling prices.

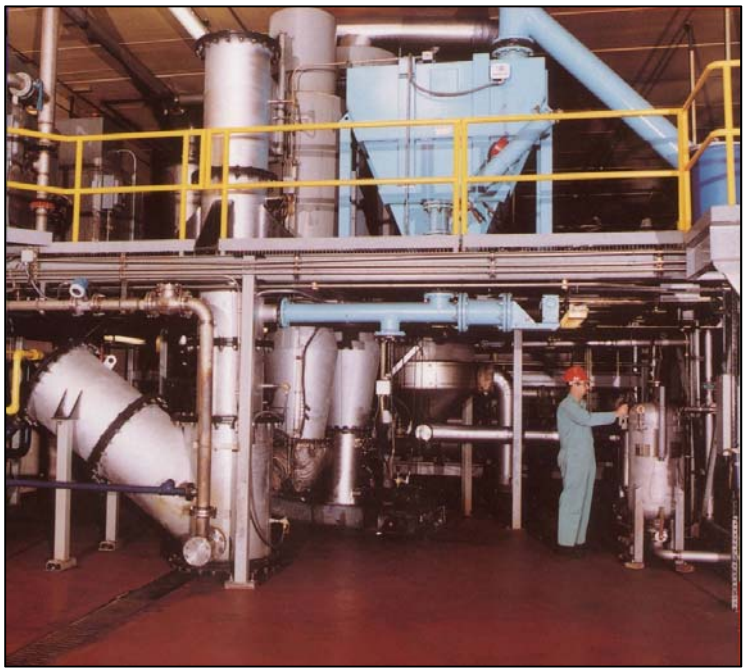
Biomass to charcoal – slow pyrolysis

Slow pyrolysis of logs for charcoal, Victoria

Slow pyrolysis for electricity and charcoal, NSW

Biomass to liquids & charcoal – fast pyrolysis

Fast pyrolysis for liquids and charcoal, 200 TPD Canada



Fast pyrolysis for liquids and charcoal, 45 TPD USA

Biomass to liquid fuels

Australia uses over 40 billion litres of fuel per year.

Why make liquid fuels from biomass?

Consider one dry tonne of biomass:

- If used to generate electricity at ~ 25% efficiency and electricity sold into grid at $100/MWh, revenue will be $140.
- If used to make biofuel at 300 litre/dry tonne and fuel sold at $1.40/litre, revenue will be $420.

First generation and advanced generation fuels

First generation:

- Ethanol – sugar and starch
- Biodiesel – vegetable oils, animal fats

Advanced generation:

- Ethanol from biomass
- Hydrocarbons from biomass
- Biodiesel from non-food crops
- Microalgae

<u>Commercial</u> developments:

1. *Ethanol*
2. *FT synthesis*
3. *Fast pyrolysis*

1. Consider **ethanol** from biomass

Several different processes. All break the biomass into components then reform these into ethanol.

Sugars:

1. Acid hydrolysis, then fermentation
2. Enzyme hydrolysis, then fermentation

Syngas:

3. Gasification then fermentation
4. Gasification then reforming

Conc. acid hydrolysis & fermentation: Bluefire

Demonstration facility in Japan.

Comm. plant site preparation, USA.

Now waiting for further funding.

Enzymic hydrolysis & fermentation: Abengoa

Biomass to fuel demonstration plant in Spain operated more than 6,000 hours.
Targeting 300 litres per tonne of straw.

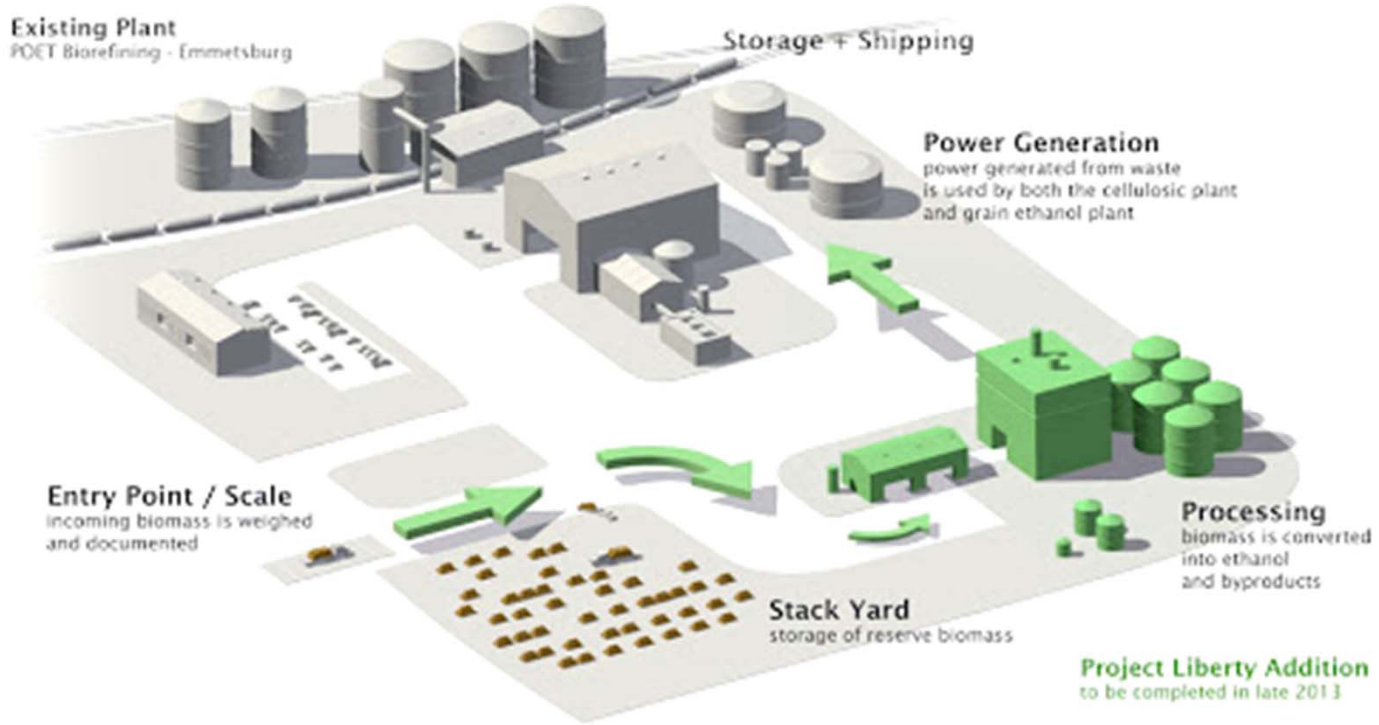
Commercial plant under construction during 2013, at Hugoton, USA.

1,000 dry tonne per day straw feed, for 100 Ml/year ethanol plus electricity.

Enzymic hydrolysis & fermentation: POET

Already active in first gen. fuels. 75,000 l/y biomass pilot plant operated.

75 Ml/y commercial plant now under construction at Emmetsburg, USA. Corn stover as feed.



Enzymic hydrolysis & fermentation: Beta Renewables

Commercial plant began operations late 2012 at Crescentino, Italy.

50 Ml/year ethanol plus electricity. Straw and grasses as feed.

Enzymic hydrolysis & fermentation: DuPont

Demonstration unit operated in Tennessee since 2009.

Commercial plant now under construction in Iowa, USA.

Operation planned for 2014, producing 110 Ml/year ethanol. Capital cost US$225 M.

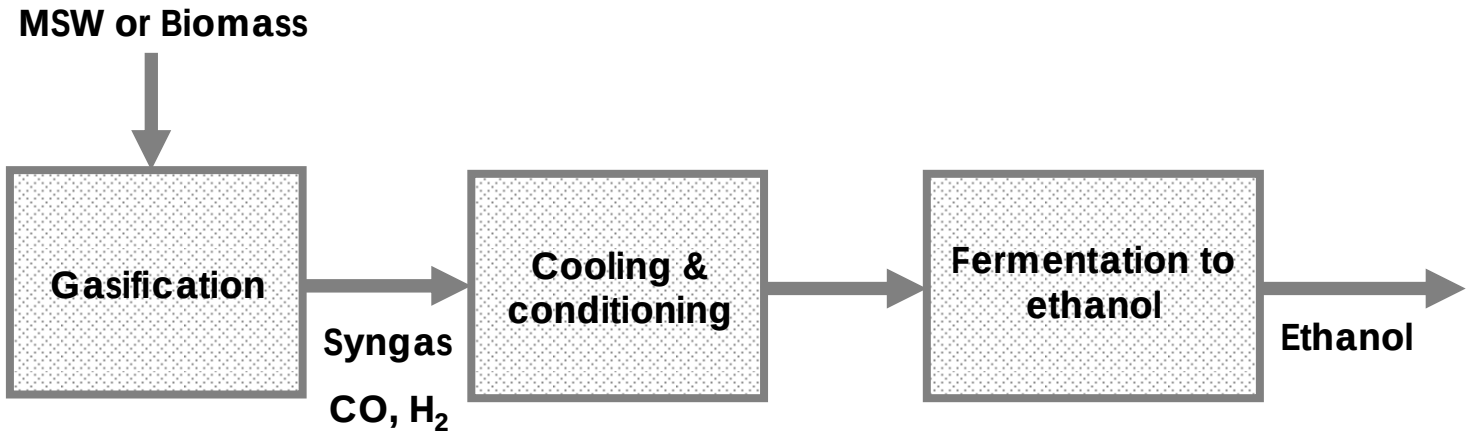
Corn stover as feed.

Enzymic hydrolysis & fermentation: COFCO

50,000 t/year ethanol, plant under construction in China.

Corn stover planned as feed.

Gasification and fermentation for ethanol



Gasification and fermentation: Ineos Bio

Commercial plant, Indian River Fl – began operation in 2012.

Mixed biomass feed for 30 Ml/y of ethanol and 6MW of electricity.

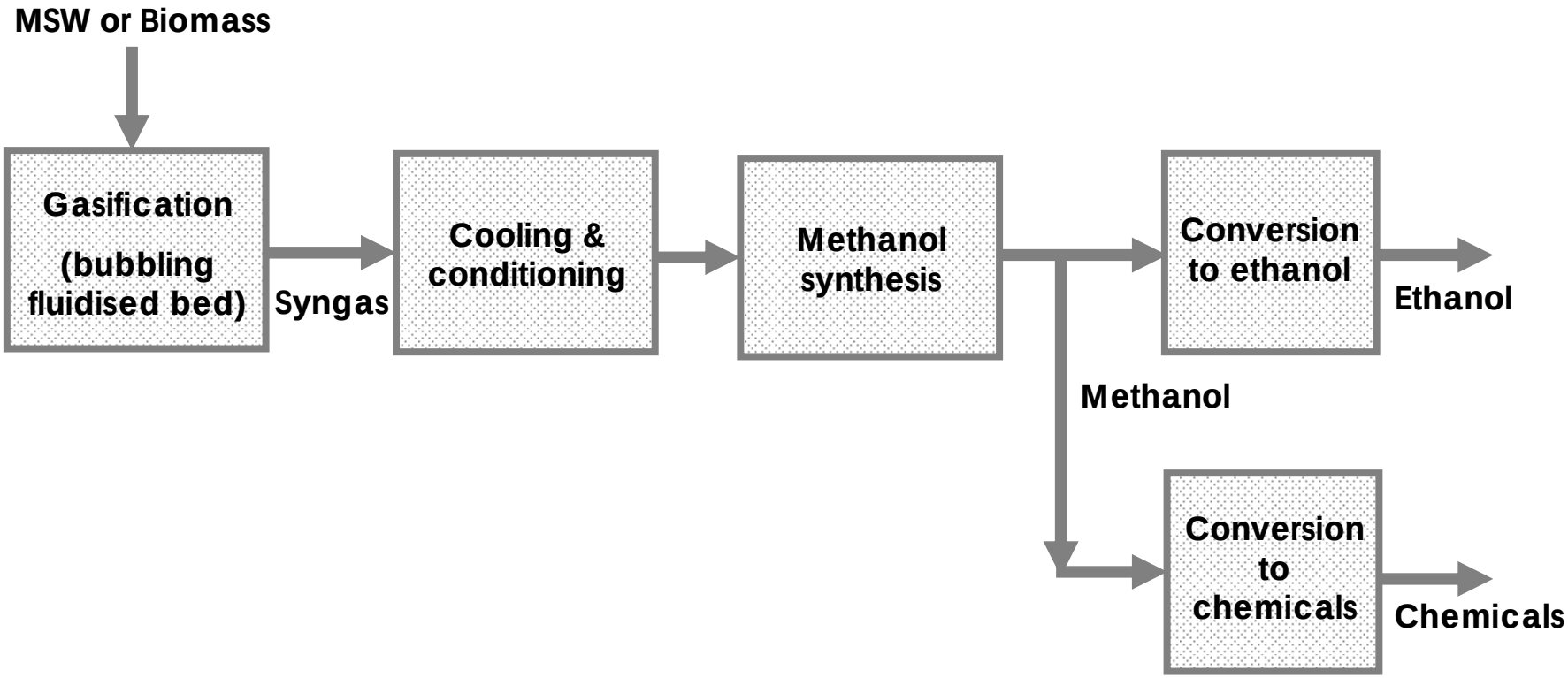
Gasification and fermentation: Coskata

150,000 l/y demonstration facility, started in 2009

2010: Collaboration announced with GM, Holden

July 2012: Plans for first commercial plant in the USA using biomass put on hold while company focuses on cheap natural gas as (non-renewable) feedstock.

Gasification and reforming for ethanol



Gasification and reforming for ethanol: Enerkem

Demonstration facility

40 Ml/y commercial plant under construction in Edmonton, Canada. MSW as feed.

Gasification and reforming for ethanol: Fulcrum

Demonstration facility has produced ethanol and, in May 2013, produced "drop in" hydrocarbons.

40 Ml/y commercial facility for Nevada, USA. MSW feed.

Due to start up in 2015

Gasification and reforming for ethanol: Range Fuels

First commercial plant – Soperton, Ga – Company stopped trading before the plant operated commercially. Site sold to LanzaTech in 2012.

2. **Hydrocarbons** via Fischer Tropsch synthesis

FT reforms syngas into hydrocarbon fuels and chemicals.

- FT first developed in Germany a century ago.
- Large scale use with coal as feed in South Africa and China.

SASOL III under construction – 50,000 tonne/day coal to fuels and chemicals

FT: Choren/Linde

FT technology can also work with gasified biomass.

Choren's 18 Ml/y demonstration plant, Freiburg Germany.

Gasification technology sold to Linde.

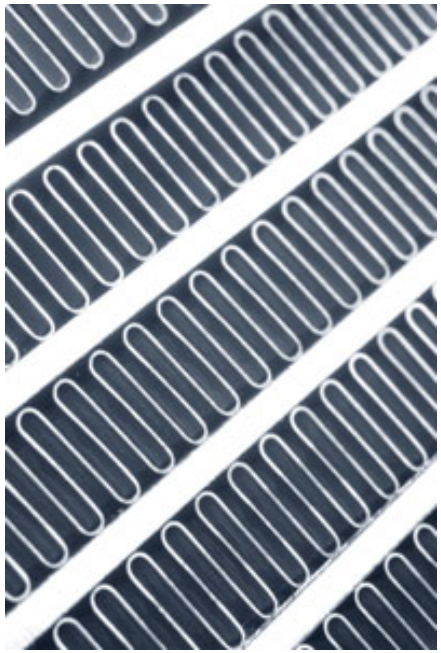
First commercial project is for Forest BtL in Finland.

130,000 t/y liquids from 1.5 Mt/y wood.

NER 300 funding offered. Initial plant operation targeted for 2016.

FT: Oxford Catalysts & Velocys

Oxford Catalysts is developing “micro channel” technology to achieve FT reforming at smaller scale:



Small scale developments (~ 1.5 Ml/year) now underway with biomass or natural gas as feed.

FT: Rentech

1,500 litre/day demonstration facility in Colorado. 20 ton/day gasifier added in 2011. Commercial projects on hold pending funding partners.

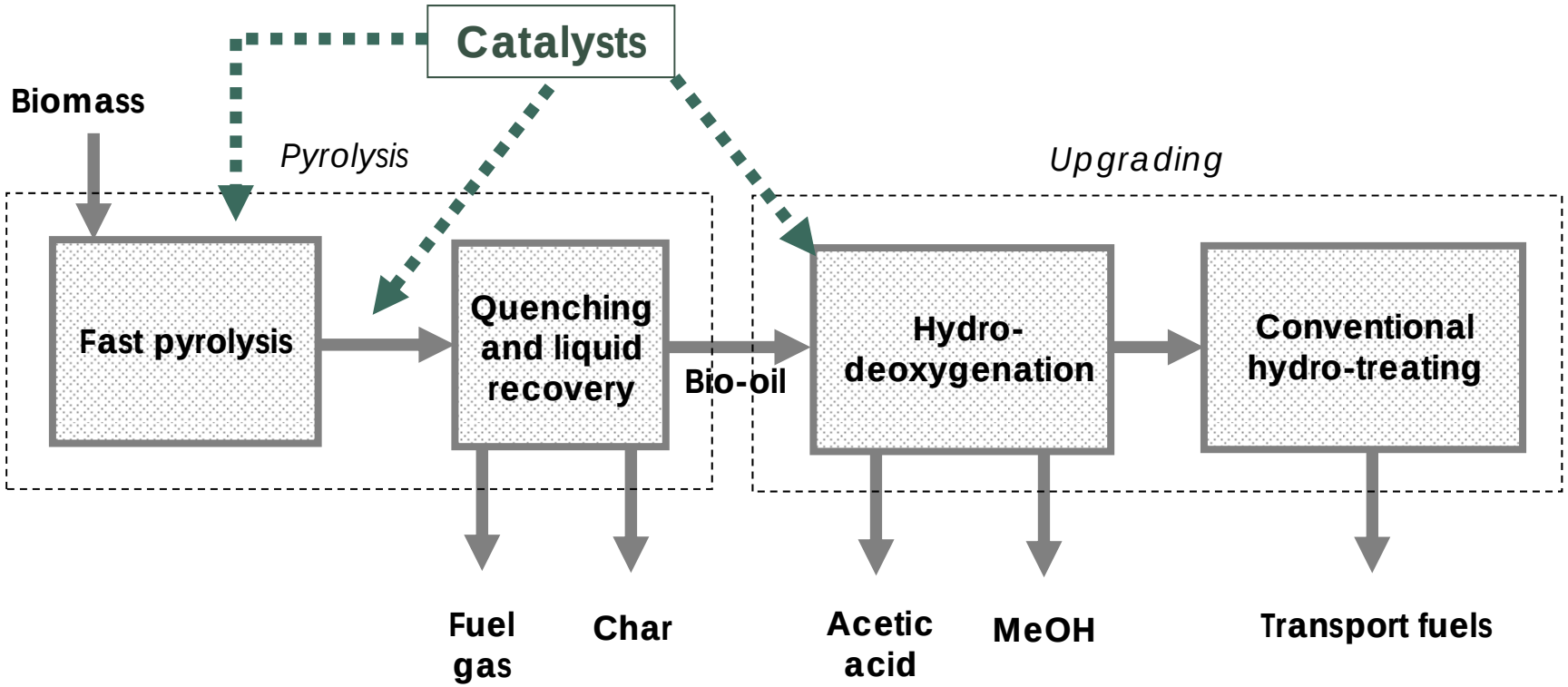
FT: Thermochem Recovery International

4 ton/day integrated demonstration plant in USA, built in 2009.

1,000 hour run in 2012.

First commercial plant to be at Flambeau River Wisconsin. Seek to reinvigorate an existing paper mill and use ~800 TPD wood to make fuels and steam.

3. **Hydrocarbons** via fast pyrolysis & upgrading



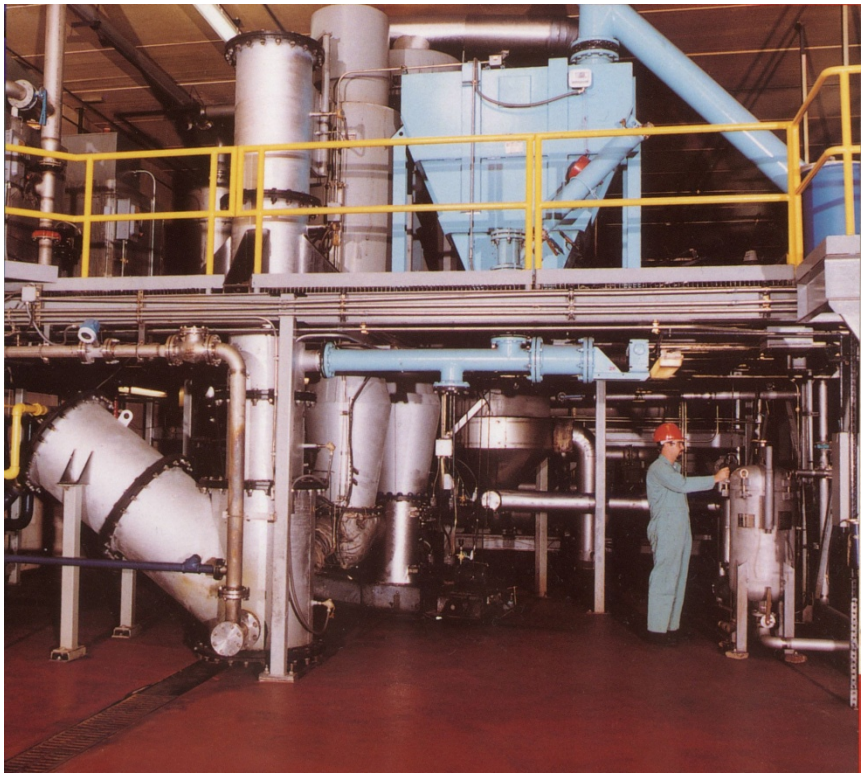
Fast pyrolysis & upgrading: KiOR

Demonstration facility in USA

500 dry ton/day commercial prototype just started in USA.

Feed is southern yellow pine. Next plant 1,500 ton/day.

Fast pyrolysis & upgrading: Envergent



Ensyn: commercial-scale plants (up to 100 TPD) operated in USA & Canada for 20 years.

Wood residues as feed.

Joint venture with UOP: upgrading bio-oil through to hydrocarbon fuels.

$US25 M grant to build demo plant in Hawaii, for operation in 2014.

Fast pyrolysis & upgrading: Dynamotive & IFPEN/Axens

Commercial plants for fast pyrolysis in Canada. Multiple wood feeds

100 TPD

200 TPD

Upgrading to hydrocarbon transport fuels demonstrated in 2009.

Agreement to commercialise upgrading technology signed with IFPEN and Axens in 2012.

Biomass to fuels….summary:

Commercial scale plants operating or under construction:

Product	**Pathway**	**Feed**	**Feed scale**
			(dry tonne/year)
Ethanol	conc. acid hydrolysis	MSW, wood	??
Ethanol	enzyme hydrolysis	straw, stover	150,000 to > 300,000
Ethanol	gasification & fermentation	wood	~ 150,000
Ethanol	gasification & reforming	MSW	~ 100,000
Hydrocarbons	pyrolysis & upgrading	wood	50,000 – 450,000
Not commercial for biomass yet:			
Hydrocarbons	gasification & FT synthesis	wood, MSW	up to > 600,000

Competitive fuel costs expected:

Organisation	A$/litre (petrol equiv.)	Feed
NREL	0.85	Corn Stover
KiOR	0.68	Southern Pine
Dynamotive/IFPEN	0.47 – 0.85	Various (to US$130/dry ton)

Research or commercial scale?

1 kg/h pyrolysis unit at University of Twente

There are multiple scale up stages to move from pilot plants to commercial plants.

New technologies:

- Will need > $100 M to reach commercial prototype
- Should be able to demonstrate that they compete globally with existing technologies

Biofuels from Australian residues?

Biofuel technologies are starting commercial operation overseas. Can we utilise them in Australia?

1. The good news: biofuels = major, profitable, long term market
2. Technology: great progress but still at early commercial stage
3. Technologies de-risked overseas mean lower costs for capital
4. Residue type must be matched to the right technology
5. Residue quantity must be matched to the right technology
6. Residue supply must be consistent: high plant capex means difficult to develop “one off” or “part-time” feedstocks

Government programs

1. Large Scale Renewable Energy Target (LRET)
2. Clean fuel rebates (and NSW mandate)
3. CEFC (possibly ERF after September 2013)
4. Australian Renewable Energy Agency
   - Emerging Renewables Program (open)
   - Regional Australia's Renewables (EOI soon)
5. Ausindustry
   - Clean Technology Investment Program
   - Commercialisation Australia

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Thank you. Questions?