NIMBLE, NET NEGATIVE CO$_2$
ELECTRICITY FROM BIOMASS

Louis Wibberley, Juerg Rusterholz, Coralie Lewis
CSIRO Energy
... using the *bioDICE* fuel cycle

1. Biomass
2. Low temp carbonisation
3. Water-based slurry fuel (MRC)
4. Ultra efficient generator (DICE)
Basis

1. The superior thermal efficiency, flexibility, fuel tolerance and lower capital cost of the diesel
2. Adapted diesel engines can directly and efficiently use a range of water-based slurries of carbonaceous biomass – avoids costs and losses of refining to distillate quality
3. No insurmountable technical barriers to commercialisation
4. When used to displace coal-based generation leads to nett-negative CO$_2$ emissions

These factors could provide a step enabling technology for bioenergy – double the benefit and halve the cost of electricity – unlocking the full potential of the Cinderella of renewable energy … biomass
Micronised refined carbon (MRC) has been produced from a range of sources
- chars
- char:coal blends

Feed mix determines carbon footprint

Processing is relatively simple giving high conversion efficiency
- low temperature carbonisation + milling

Waste heat from engine can be used for processing, waste gases can be ingested (diesel engines operate with very high excess air)
Diesel engine – efficient, flexible and fuel tolerant (but some adaptation required for MRC)

Gas turbine

Continuous combustion - hot section is exposed continuously to 1450-1500°C gas at 2-4 MPa
Exotic alloys, hot strength, oxidation
Fouling issues for impure fuels

Turbocharged diesel engine

Higher “Carnot” efficiency
Cyclic hot space allows dirtier fuel without fouling or the need for exotic alloys
Large expansion ratio = smaller waste heat recovery

Batch combustion - hot section hot for <10% of the time, cyclic @ 1-5 Hz (larger engines)
Higher T & P possible and without fouling, >1500°C, 15-25 MPa
Recent evolution/revolution of using the reciprocating engine for larger scale power generation – especially using natural gas

- high average efficiency
- lowest capex (for the efficiency)
- highest flexibility
- modular installation
- fuel flexibility
- hybrid/renewable plants
- grid support, ensuring highest power quality
Higher efficiency and lower capex at small unit capacity which greatly improves economics
- allows smaller more distributed/decentralised power plants without losing efficiency or accruing higher capital costs
- reduces transportation costs and impacts

Fuel flexibility reduces need for extensive processing
- efficient use of a range of solids, gases and liquid
- higher quality waste heat for process integration
- reduced fuel processing for slurry fuels increases biomass-to-fuel conversion efficiency and reduces cost

Nimbleness and high part load efficiency could support increased intermittent renewables without storage (batteries, pumped hydro …
Overall step improvement in benefits, cost and CO$_2$

• **Approx doubling the benefits** from biomass due to higher conversion efficiency (and halving the capital cost)

• Increased value for co-products/wastes from production of higher value products
  - efficient utilisation of char/sludge/gaseous by-products or residues

• Avoids the need to produce high specification fuels to use bioenergy in diesel engines
  - slurries, emulsions and crude biooils (DICE is a rugidised engine)

• Could be commercial within 5 years

• **Potential to replace 25-30%** of Australia’s coal-based electricity
CSIRO activities

R&D
- mostly around low temperature carbonisation of biomass to produce optimum fuel properties/overall conversion efficiency (depending on the biomass ~320°C appears to give overall best result)
- engine R&D based on development of DICE for Victorian lignites
- tests in Switzerland using biomass-coal blend for low speed engines
- long duration injection and engine tests shortly
- overlap and synergies with ammonia combustion engine (ACE) RD&D (low speed engines)

New projects
- ARENA-Foreco: “Dispatchable, cost effective power from forest and mill waste using DICE”
- Latrobe Fertilisers Ltd: Mallee and ammonia for distributed electricity to provide grid security, backup and power quality (and large carbon credits) using DICE
Biomass processing options

1. Hydrothermal
   - coarse mill
   - hydrothermal
   - partial dewatering & micronising
   - Other products

2. Low temp carbonisation - torrefaction
   - predrying
   - low temperature carbonisation
   - slurrying & micronising
   - condensibles
   - NC combustible gases

3. Pyrolysis
   - drying (10-12%)
   - pyrolysis
   - Biocrudes
   - residues
   - slurrying & micronising

- water recycle
- most of the drying water
- combustible gases
- NC combustible gases
- combustible gases
- residues
Processing trade-offs for best fuel cycle efficiency

- Mostly to enable micronising to below 75µm
  - easier with increased processing temperature, but lower energy recovery as fuel
- Lower processing temp means engine efficiency slightly lower from lower SE fuel
- Highest efficiency with high viscosity paste fuel – but needs a more complicated atomiser
- Engine waste heat is in excess of that for drying/process heat
  - direct use of exhaust gases for drying
In DICE so far only light ash fouling to date even with relatively high alkali MRC

- fouling due to alkalis is an issue with biomass in boilers and in gas turbines using simple biomass gasification

RWE/German engine specialist achieved excellent combustion for Rhenish lignites in combustion simulator – very similar chemistry to biomass derived MRC

Industry risk reviews (3) identified logistics and next stage funding as major obstacles

- no technical show stoppers identified
Favourable economics

Ref: Jenny Hayward
Net-negative CO₂ ...
(example: basis 1 tonne wet forest waste, Victorian brown coal electricity)

Basis: 1 tonne forest waste
- 920 kg CO₂
  +12-15 kg CO₂
  +935 kg CO₂
  +30 kg CO₂

Forest collection, chipping, transport
Low temp carboniser, micronising
DICE power plant
Electricity, waste heat
MRC & gases
Liquid fuels
Diesel (starting)

Displaced system
- 920 kg CO₂
  +920-950 kg CO₂
  +1,430 – 1,690 kg CO₂
  +1,430-1,720 kg CO₂

Forest
Decay and wild fire
Brown coal mining and power station

1000 kg biomass (wet)
Concluding comments

1. DICE could provide bioenergy with an enabling technology to increase its cost competitiveness and impact

2. Barriers to commercialisation are mostly engineering
   - adaptation of commercial process & engine technologies

3. Rapid development possible as bioDICE can be demonstrated at commercial scale at a relatively small cost
   - short lead time between technology development/implementation

4. Currently focus of RD&D is a 2-5MW genset demonstration project

5. Commercialisation of the fuel cycle needs broad inter- and intra-industry support … internationally for maximum benefit
Questions?