Sustainable Energy UK: Meeting the science and engineering challenge

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Integrated assessment of bioelectricity technology options

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Supergen Bioenergy

Work Package 1: Process and techno-economic analysis

- to perform technical analyses of whole process options, identifying emissions and environmental burdens
- to assess economic and life cycle performance
- to examine socio-economic factors (planning, perceptions, policy, employment)
- to bring qualitative and quantitative analysis together through multi-criteria evaluation and stakeholder engagement
UK Bioelectricity: 2003

13 dedicated biomass stations with 158 MW capacity
25 co-firing stations with 1.2 GW capacity
310 other stations (landfill gas, sewage gas, advanced waste) with 618 MW capacity
UK Bioelectricity: 2006

18 dedicated biomass stations with 207 MW capacity
32 co-firing stations with 3.3 GW capacity
445 other stations (landfill gas, sewage gas, advanced waste) with 848 MW capacity

UK RO target for 2005/06: 5.5% (source: Ofgem Renewables Obligation annual report 2006)

About 4.6% of electricity came from renewables with biomass supplying about half of that.
(source: UK biomass strategy, May 2007)
UK Bioelectricity: 2010?

RO target: 10% by 2010

Biomass task force: current resources
~7% of electricity

UK Biomass Strategy: technical potential
nearly 10% of electricity demand

European Environment Agency:
Resource ~16% of electricity demand
in 2010, 22% by 2020
• Bioelectricity needs to increase substantially to meet targets for renewables/carbon reduction

• TV Energy study: 85% wanted to increase renewables
  – Wind energy: 72% supported; 2% opposed
  – Biomass: 16% supported; 4.8% opposed
Supergen assessment

- Study the whole system
- Bring together technical, environmental, economic and social assessment
- Incorporate stakeholder views via multi criteria evaluation
- Accessible for non-specialist
Methodology

LCA framework

Energy crop production
- Spreadsheet models
- Industry data

Crop processing, transport & storage
- Spreadsheet models & highways agency formulae
- Industry data & published data

Thermal conversion
- Processing modelling
- ECLIPSE, ASPEN, spreadsheets
- Industry data & published data

Full bioenergy chain
- Energy balance
- Carbon balance
- Material & environmental balance
- Economic assessment
- Social assessment

42 extended LCA indicators for each bioenergy system

Entire bioenergy system
- Multi-criteria assessment
- LCA indicators & scenarios

Methodology
System scope

- **Agricultural**: eradication, establishment, growth, restoration; inputs have energy & carbon cost; emissions from agricultural vehicles quantified

- **Transport & logistics**: SRC winter harvest & chip, field dry; miscanthus winter harvest & bale, satellite bale store; < 2 MWe direct tractor transport; dry matter losses included; transport emissions included for tractors & dedicated haulage

- **Electricity production**: Power plant construction (no emissions), operation, decommissioning (no emissions)
## Systems studied

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<th>250 kWe</th>
<th>2 MWe</th>
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<td>Co-firing</td>
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=SRC =miscanthus =straw
Results
Efficiency

- 25 MWe press GCC wood
- 25 MWe press GCC misc
- Co-firing

Electrical efficiency

- 2 MWe CHP grate wood
- 5 MWe CHP grate wood
- 2 MWe CHP grate miscanthus
2 MWe grate CHP wood
5 MWe grate CHP wood
2 MWe grate CHP misc

25 MWe CHP grate wood
5 MWe pyr CHP wood
5 MWe pyr CHP misc
CO2 saved per unit electricity

- 25 MWe press GCC misc
- 25 MWe grate misc
- 25 MWe grate straw

CO2 saved per unit of electricity generated

- 2 MWe CHP grate wood
- 5 MWe CHP grate wood
- 2 MWe CHP grate miscanthus
CO2 saved per unit energy delivered (CHP only)

- 5 MWe gas-eng misc CHP
- 25 MWe grate wood CHP
- 5 MWe pyr eng wood CHP

- 2 MWe CHP grate wood
- 5 MWe CHP grate wood
- 2 MWe CHP grate miscanthus
CO2 saved per unit of energy harvested

2 MWe gas-eng wood CHP
5 MWe gas-eng wood CHP
2 MWe grate wood CHP

25 MWe press GCC wood
Co-firing

5 MWe grate misc
5 MWe grate wood
5 MWe pyr GT wood
CO2 saved per unit of land farmed

- 25 MWe press GCC misc
- 5 MWe gas-eng misc CHP
- 2 MWe grate misc CHP
- 5 MWe grate wood
- 25 MWe grate straw
- 2 MWe pyr GT wood
CO per unit electricity

25 MWe press GCC wood
25 MWe press GCC misc
25 MWe FBC wood

2 MWe CHP grate wood
5 MWe CHP grate wood
2 MWe CHP grate miscanthus
NOx per unit electricity

- 25 MWe atm GCC wood
- 25 MWe press GCC wood
- 25 MWe press GCC misc

- 5 MWe pyr GT wood
- 2 MWe grate wood
- 5 MWe pyr GT CHP
Particulates per unit electricity

- 25 MWe press GCC wood
- 5 MWe pyr eng wood
- 5 MWe pyr eng wood CHP
- 250 kWe gas-eng wood
- 250 kWe gas-eng wood CHP
- 2 MWe CHP grate wood
VOC’s per unit electricity

5 MWe pyr eng wood
Co-firing
5 MWe pyr eng wood CHP

25 MWe atm GCC wood
5 MWe CHP grate wood
2 MWe CHP grate miscanthus
Break-even electricity selling price

- 25 MWe grate wood
- 25 MWe grate misc
- Co-firing

Break even electricity selling price

- 2 MWe gas-eng CHP
- 2 MWe CHP grate wood
- 2 MWe CHP grate miscanthus
Specific investment per unit installed capacity

- 25 MWe grate wood
- 25 MWe grate misc
- Co-firing

- 2 MWe gas-eng CHP
- 2 MWe CHP grate wood
- 2 MWe CHP grate miscanthus
Employment per unit electricity

- 2 MWe grate wood CHP
- 2 MWe grate misc CHP
- 5 MWe pyr eng wood CHP

25 MWe grate misc
25 MWe grate straw
Cofiring
Land take per unit electricity

- 25 MWe pressGCC misc
- 25 MWe grate misc
- 5 MWe gas-eng misc CHP

- 2 MWe grate wood CHP
- 5 MWe grate wood CHP
- 5 MWe pyr GT wood CHP
Vehicles per unit time

250 kWe gas-eng wood
250 kWe CHP wood
2 MWe gas-eng CHP wood

Number of delivery vehicles per unit time

25 MWe grate wood
25 MWe grate misc
25 MWe grate straw
Vehicle distance per unit of electricity

- 250 kWe gas-eng wood
- 250 kWe gas-eng wood CHP
- 5 MWe gas-eng wood CHP
- 25 MWe grate misc
- 25 MWe grate straw
- 2 MWe grate misc
Footprint: 250 kWe gas-eng wood

250 kWe engine SRC PO
Footprint: 25 MWe GCC wood

25 MWe atmos GCC SRC PO

- Electrical efficiency
- Capacity factor
- CO2 saved per unit of energy in biomass at CO per unit of electricity generated
- Particulates per unit of electricity generated
- Bottom ash produced per unit of electricity
- Effluent produced per unit of electricity
- Specific investment per unit of electricity produced
- Land take per unit of electricity produced
- Total vehicle km per unit of electricity
Footprint: 25 MWe grate wood
Footprint: 25 MWe grate misc
Footprint: 25 MWe cofiring
Footprint: 5 MWe pyr-eng wood

5 MWe pyrolysis engine SRC PO

- Electrical efficiency
- Capacity factor
- CO2 saved per unit of energy in biomass at CO per unit of electricity
- CO2 in biomass at CO generated per unit of electricity
- Particulates in biomass at CO generated per unit of electricity
- Bottom ash produced per unit of electricity
- Effluent produced per unit of electricity
- Specific investment per unit of installed electricity
- Land take per unit of electricity
- Total vehicle km per unit of electricity
Footprint: 25 MWe grate misc
Footprint: 250 kWe gas-eng wood CHP
Footprint: 25 MWe grate misc

25 MWe grate misc PO

- Electrical efficiency
- Capacity factor
- CO2 saved per unit of energy in biomass at CO2 per unit of electricity generated
- CO per unit of electricity generated
- Particulates produced per unit of electricity generated
- Bottom ash produced per unit of electricity generated
- Effluent produced per unit of electricity generated
- Specific investment per unit of installed capacity
- Land take per unit of electricity produced
- Total vehicle km per unit of electricity
Early work: stakeholders & informed public

- Like small/medium CHP
- Higher energetic efficiency
- Better local employment & associated social benefits
- Better local environmental impact
Later work: stakeholders

- Preferences more diverse
- Large power plants – economies of scale, high power potential; transportation problems
- Scepticism of 250 kWe system: emissions, efficiency, grid
Stakeholder priorities

• Carbon savings
• Transport impacts
• Agricultural jobs
• Emissions
Conclusions – carbon savings

• Do not follow efficiency
• Do not vary much with technology/scale – except CHP
• Miscanthus better than SRC
• Cofiring as good as other technologies
Conclusions – transport impacts

Number of journeys minimized with smaller plants, SRC feedstocks and gasification

Transport per unit output is best for small and large gasification systems; with grates and CHP worst
Conclusions – agricultural jobs

- Jobs per unit of electricity is fairly constant across technologies/scales, but higher for CHP
- Miscanthus creates more agricultural jobs than SRC but both much less than arable farming
Conclusions - emissions

• Smaller facilities generally produce higher levels of emissions per unit of electrical output than larger ones
• Gasification facilitates a reduction in emissions for large plants
• Cofiring compares well for emission categories studied
• 44% of NOx & 70% of particulates can be upstream of conversion plant
• Contribution of haulage lorries not significant
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