Modelling woody biomass energy system supply chain costs

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Today's talk

- High level comparison of biomass energy sector in Australia and Austria
- Generic biomass energy supply chain composition
- Austrian biomass energy supply chain features
- Some context for Australian biomass energy supply chains
- High level introduction to commercial wood energy conversion systems
- Costs and sensitivities

Wood energy: Austria vs Australia

- European nations using Advanced Wood Combustion technology and burning more biomass in response to greenhouse and energy security concerns

- Austria:
  - Natural gas from Russia, oil supply imported and subject to disruption, very little indigenous energy resources
  - 15% of primary energy from biomass
  - Ambitious plans to get up to 30% of primary energy from biomass
  - Strong greenhouse mitigation programs
  - Substantial subsidies for renewable energy sources including wood thermal

- Australia:
  - Large indigenous energy supplies (although increasing oil imports)
  - Negligible primary energy from biomass
  - Substantial interest in energy from biomass but very much a greenfield
  - Limited greenhouse emissions mitigation programs ; REC's
  - Subsidies to remove residential wood heating, extend natural gas reticulation grid. No subsidies for wood thermal systems

Generic commercial biomass supply chain

- Collation of resource at harvest site
- Residue chipped at site and taken to wood energy plant.
- Larger (non-commercial) logs transported to centralised chipping site
- Chip stored at wood energy plant
- Wood energy conversion system combusts chip to produce heat and/or electricity
- Other supply chain paths include use of chip to make pellets

Austrian supply chain

- Supply chain can include:
  - large logs from poplar weed removal program
  - small residue piles at roadside landings; often left for 6months+ to reduce moisture content
  - logs stored at buffers to cater for bad weather interrupting supply
  - chip stores at plant

- Variety of transportation systems used:
  - Tractor pulling 40m^3 trailer
  - Chip and log trucks

- Chipping:
  - Integrated grapple and chipper for infield residue chipping
  - 1MW+ chipper in Vienna for Simmering plant

- Large number of wood energy systems distributed geographically.
  - Thermal for district heating systems
  - Some electricity co-generation systems with heat used for process heat or district heating

- Wood energy systems range from around 100kWth to 25MWe Simmering system in Vienna

Factors influencing commercial biomass supply chains in Australia

- **Limited subsidies so cheap is good**
- **Residue resource:**
  - **Highly situational; heterogeneous geographical distribution**
  - **Concentrated in several areas**
    - **Green triangle**
    - **SW WA**
- **Substantial local experience in moving large amounts of sawlog and woodchip**
- **Little local experience of harvesting and transport modes used in Europe for biomass energy systems**
- **Small number of local commercial scale Advanced Wood Combustion systems**

Wood energy systems: scale, efficiency and energy

- Steam Rankine Cycle electricity generation systems
  - Technology used in large coal, nuclear and gas fired systems
  - Doesn't scale well downwards
  - Well engineered 1MWe system ~16% efficient, 5MWe ~24%, 25MWe ~33%
  - Can improve efficiency by using heat (cogeneration)

- Thermal systems
  - Heat used for space heating, process heat or cooling by absorption technique
  - Up to 85+% efficient from 10's of kWth to 100's of MWth
  - Much cheaper than electricity generation as don't need specialised labour, turbines
  - Uses more limited than electricity and restricted economical reticulation distance

Wood energy systems at different scales

10kWth pellet heater; space heat for house in South Caulfield. Photo David Coote

90kWth small district heating system. Photo David Coote

2MWe cogeneration plant in Lower Austria. Photo David Coote

25MWe cogeneration plant turbine in Vienna. Photo Erlan Caliskan

Stages in woody biomass supply chain

Calculating levelised energy cost

$$LEC = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

"With:

LEC = Average lifetime levelised electricity generation cost

I_t = Investment expenditures in the year t

M_t = Operations and maintenance expenditures in the year t

F_t = Fuel expenditures in the year t.

E_t = Electricity [heat] generation in the year t

r = Discount rate

n = System life" (IEA 2005, p174)

Biomass wood energy system supply chain costs – 5MWe

- Nominal $10/tonne to grower for residue
- Chipped cost at roadside: $23/tonne, 12 tonnes/hectare (19% recovery)
- Transportation cost; needs 70,00tonnes/annum, 6,000 hectares of residue/annum, assume average distance of 50km @ $0.25 per km/tonne, $12.5/tonne
- Plant gate cost of $45/tonne
- Residue:
  - 20MJ/kg (dry basis)
  - 47% Moisture Content
- Plant:
  - 24% efficient
  - 8000hours/annum
  - 20 year system lifetime
  - Capital cost $20million
  - Operations and maintenance cost of 8% of initial capital expenditure
  - 10% discount rate

Biomass levelised energy cost – 5MWe system

$/kWh for 5MWe plant for range of installation and fuel costs

Plant cost	Fuel cost/tonne					
	$0.0	$10.0	$20.0	$30.0	$40.0	$50.0
$20,000,000	$0.101	$0.118	$0.135	$0.152	$0.169	$0.186
$21,000,000	$0.106	$0.123	$0.140	$0.157	$0.174	$0.191
$22,000,000	$0.111	$0.128	$0.145	$0.162	$0.179	$0.197
$23,000,000	$0.116	$0.133	$0.150	$0.167	$0.184	$0.202
$24,000,000	$0.121	$0.138	$0.155	$0.172	$0.189	$0.207
$25,000,000	$0.126	$0.143	$0.160	$0.177	$0.194	$0.212

$/kWh for 5MWe plant with REC's at $40/MWh

Plant cost	Fuel cost/tonne					
	$0.0	$10.0	$20.0	$30.0	$40.0	$50.0
$20,000,000	$0.061	$0.078	$0.095	$0.112	$0.129	$0.146
$21,000,000	$0.066	$0.083	$0.100	$0.117	$0.134	$0.151
$22,000,000	$0.071	$0.088	$0.105	$0.122	$0.139	$0.157
$23,000,000	$0.076	$0.093	$0.110	$0.127	$0.144	$0.162
$24,000,000	$0.081	$0.098	$0.115	$0.132	$0.149	$0.167
$25,000,000	$0.086	$0.103	$0.120	$0.137	$0.154	$0.172

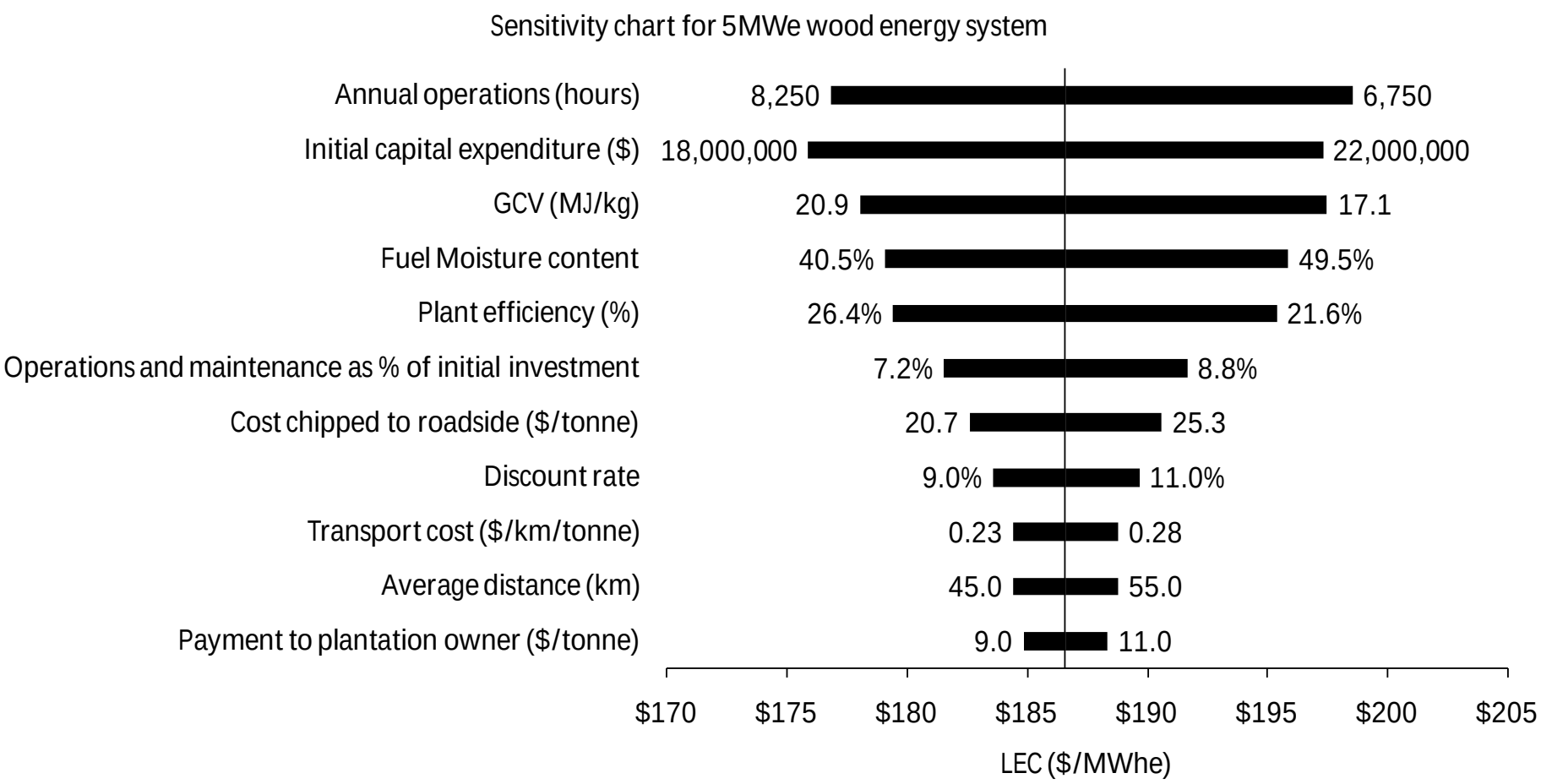
Note: Orange cell indicates plant profitable selling to co-sited customers at indicative peak price of $100/MWh.

Biomass wood energy system supply chain costs – 1MWth system

- Transportation cost: needs ~4,000tonnes/annum, 330hectares/annum, assume average distance of 15km @ $0.40/km/tonne = $6/tonne
- Plant gate cost of $39/tonne
- Plant:
  - 85% efficient
  - 8000hours/annum supplying heat
  - 20 year system lifetime
  - Capital cost $500-750k
  - Operations and maintenance cost of 2% initial capital expenditure
  - 10% discount rate

	$0.0	$10.0	$20.0	$30.0	$40.0	$50.0
$500,000	$0.008	$0.013	$0.018	$0.022	$0.027	$0.032
$550,000	$0.009	$0.014	$0.018	$0.023	$0.028	$0.033
$600,000	$0.010	$0.015	$0.020	$0.025	$0.030	$0.034
$650,000	$0.013	$0.018	$0.022	$0.027	$0.032	$0.037
$700,000	$0.016	$0.021	$0.026	$0.030	$0.035	$0.040
$750,000	$0.020	$0.025	$0.029	$0.034	$0.039	$0.044

Tornado chart– 5MWe system with inputs varied by +/- 10%



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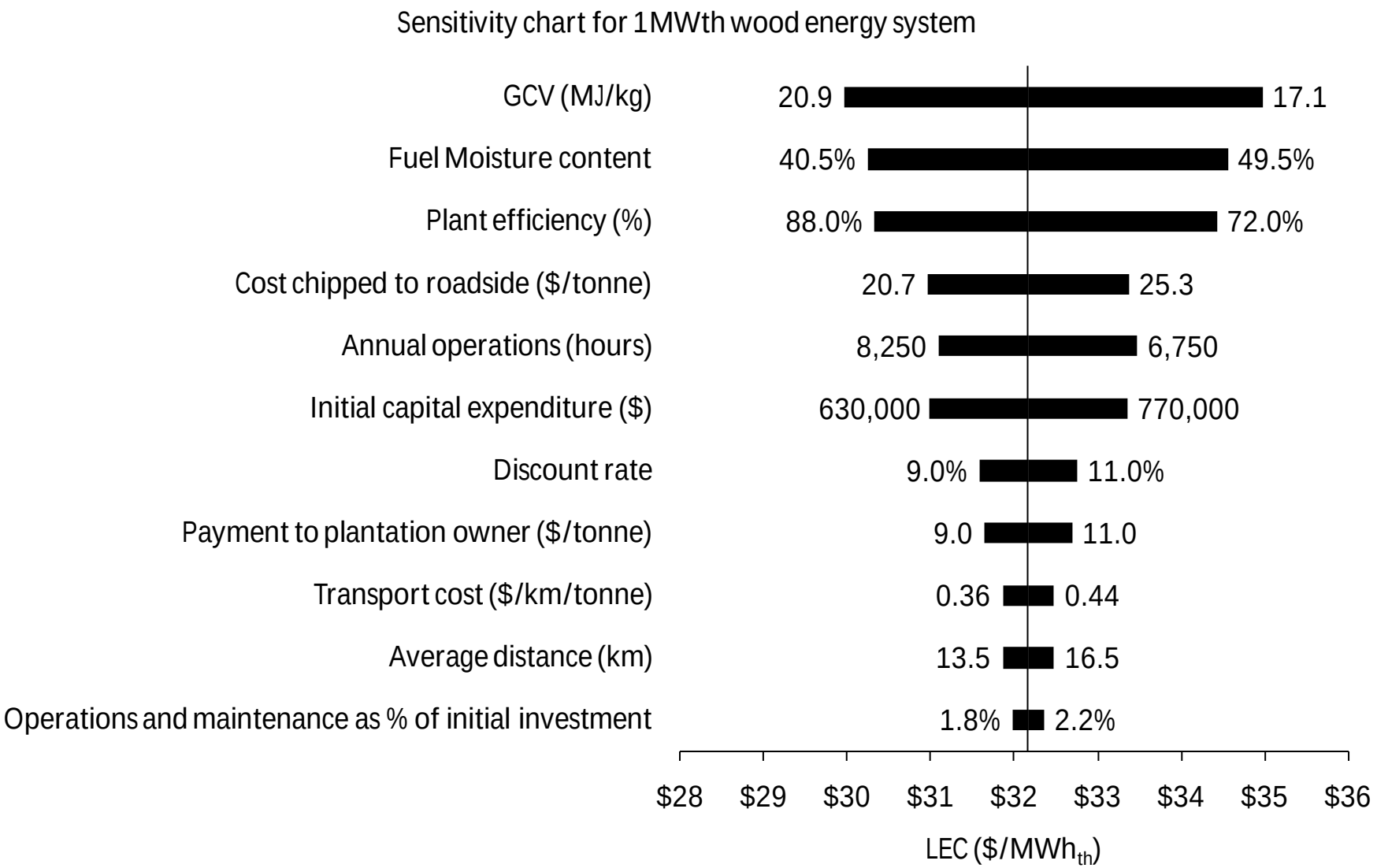

Conclusions

- Levelised energy cost sensitive to different inputs for heat and electricity systems. Moisture and energy content important for both.

- More efficient to transport reduced moisture content residue
  - Should plant pay by energy content?
  - Drying residue in field or at landing interferes with re-planting or other plantation management
  - Drying at buffer site requires double handling

- Heat has a number of advantages for the right site

- Biomass electricity will struggle to compete if supplying to grid
  - Co-located consumption of electricity (and heat) helps economics.
  - Or incentives!

- Biomass supply chain costing model opens up a number of research areas

Questions

?

20kWe system - electricity

- Gasifies wood
- Gas is burnt in commodity diesel generator
- Instrumented pallet mounted system around $50,000 installed
- Still requires substantial operator time
- Could use water jacket on engine to supply heat
- Use woody biomass from Ararat landfill
- 50-100kWe system generate electricity and heat for Ararat swimming pool
- Simple supply chain; feedstock delivered “for free” to landfill