Life Cycle Assessment of Electricity Generation with Steam-Treated Pellets

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Study motivation

Biomass-based fuels can help to address concerns related to climate change, non-renewable energy use, air pollutant emissions, and energy security

Driven by GHG reduction targets and plans to phase out coal-fired electricity generation

Trade-offs between conventional "white" pellets and steam-treated pellets

- Cost of storage
- Compatibility with existing infrastructure
  - Fuel handling/dust suppression; Milling, Burners

Study objective

To estimate, on a life cycle basis, GHG (CO_2, CH_4 and N_2O) and air pollutant (NOx, SOx, PM_{10}) emissions and financial implications associated with electricity generation from steam-treated wood pellets, including **fuel cycle** and **infrastructure** impacts.

Compare with reference fossil fuel (coal and natural gas) and biomass (conventional pellet) pathways.

Electricity generation "pathways"

Reference Coal: Thunder Bay Generating Station (GS)

Reference Natural Gas: "Representative" natural gas combined cycle (NGCC) facility

Reference Pellet: Conventional "white" wood pellets at Thunder Bay GS

Steam-treated pellets: wood pellets at Thunder Bay GS.

- Advanced pellets produced at hypothetical facilities in northwestern Ontario, Alabama, Norway

What are advanced pellets?

"Steam-treated" or "Steam-exploded" pellets

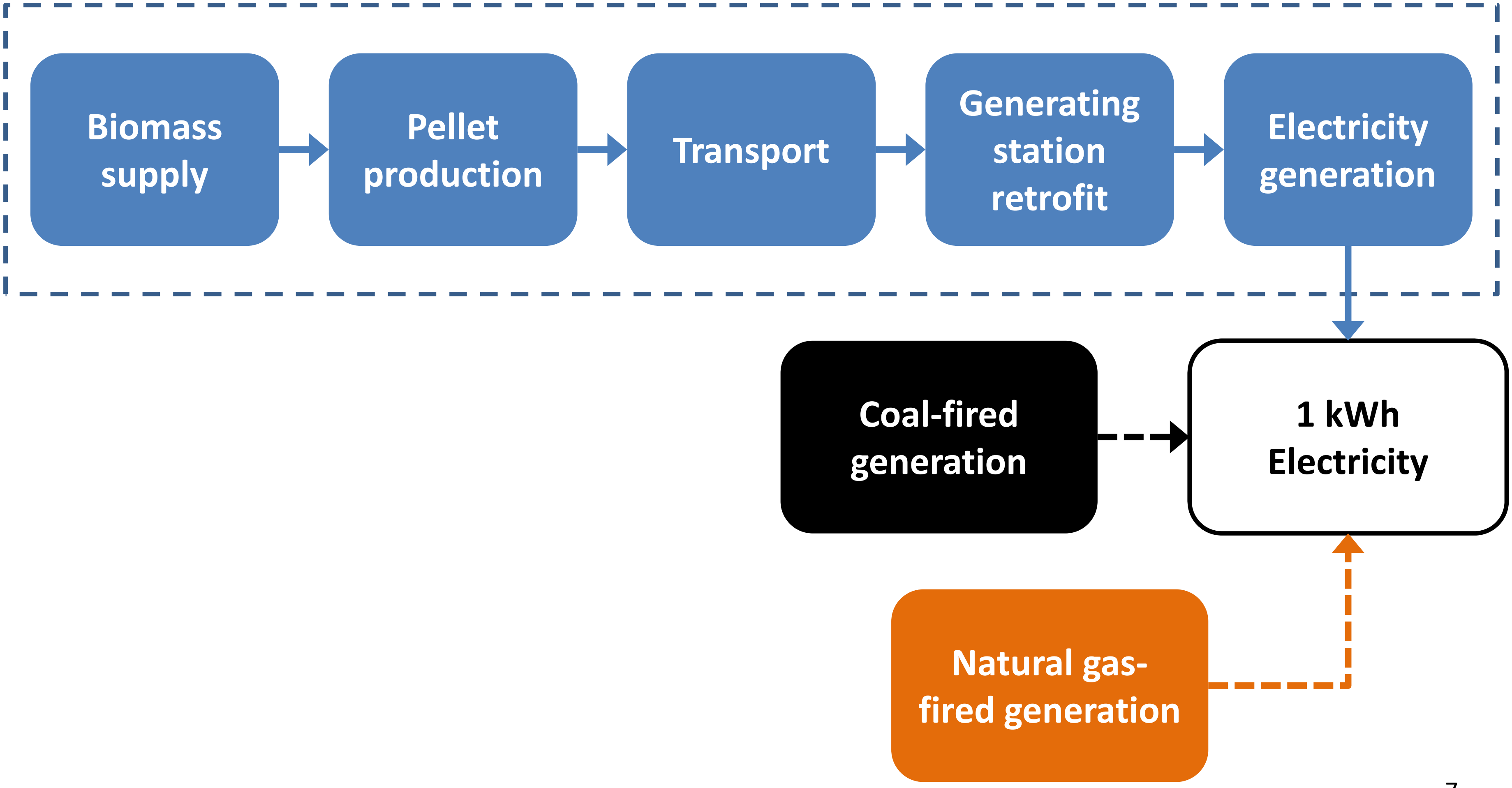
- Overcome conventional pellet challenges:
  - Low energy density
  - Moisture absorption and degradation during outdoor storage
  - Disintegration during handling/storage (dust explosion risk)
  - Milling properties and compatibility with coal pulverisers and burners

http://ru-bio.ukrbio.com/ru/news/14776/

Existing producers:
Arbaflame (Norway), Zilkha (Alabama)

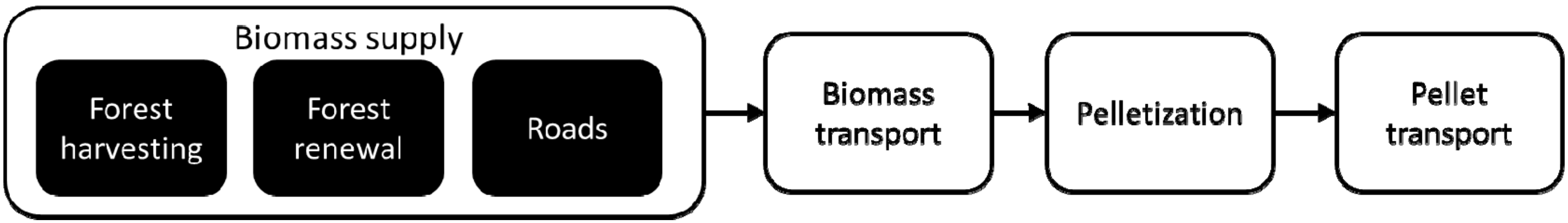
METHODS

Life cycle of electricity generation



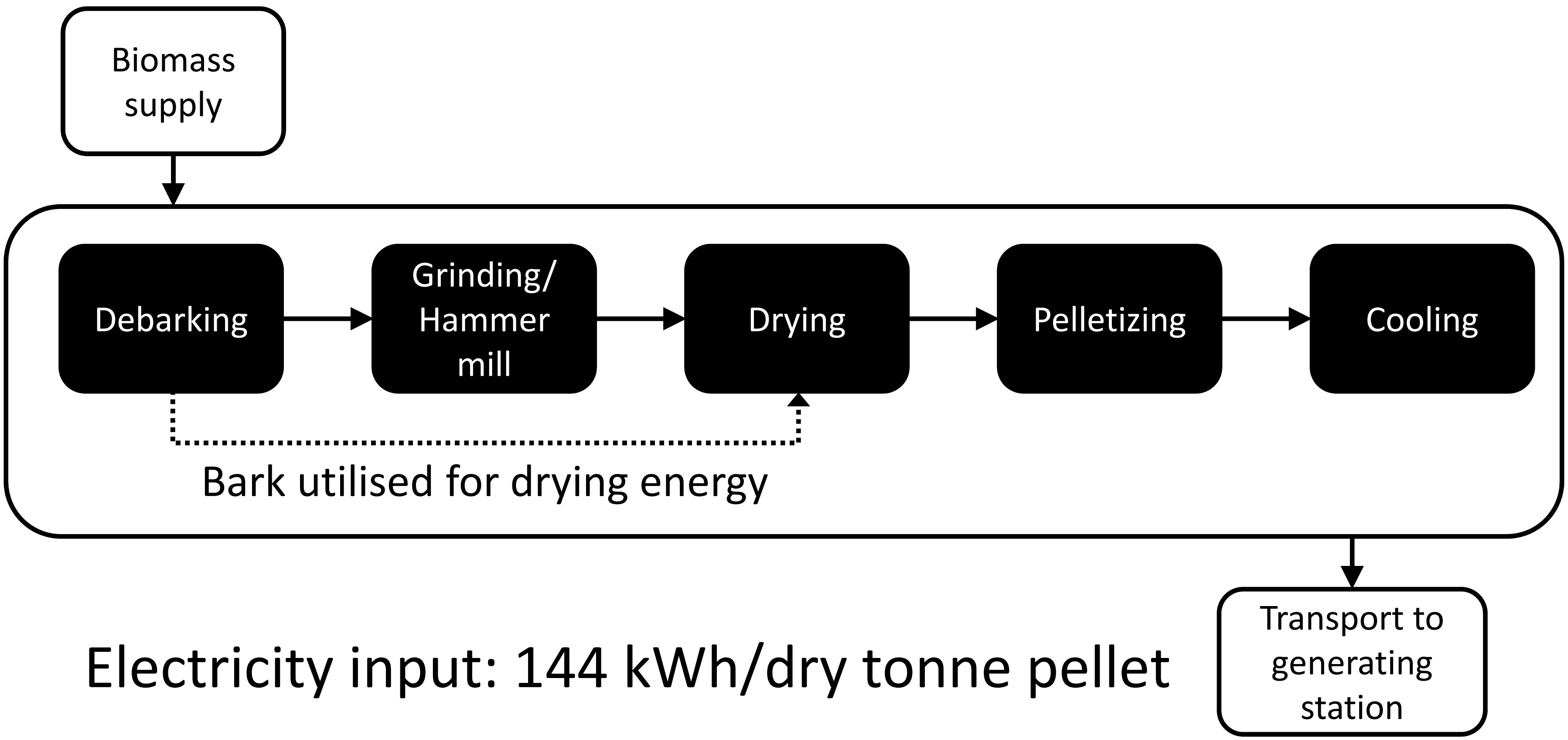
Life cycle of wood pellet production

- Biomass sourced from standing trees in NW Ontario; tops and branches not collected
- Forest management data (equipment, fuel use) from FPInnovations *(Pembina, 2012)*
- Forest to pellet mill: 115km
- NW Ontario data used as proxy for Alabama, Norway biomass production



Conventional pellet production process

Data from existing state-of-the-art pellet producer
(12 dry tonnes/hr) *Zhang et al. (2010)*

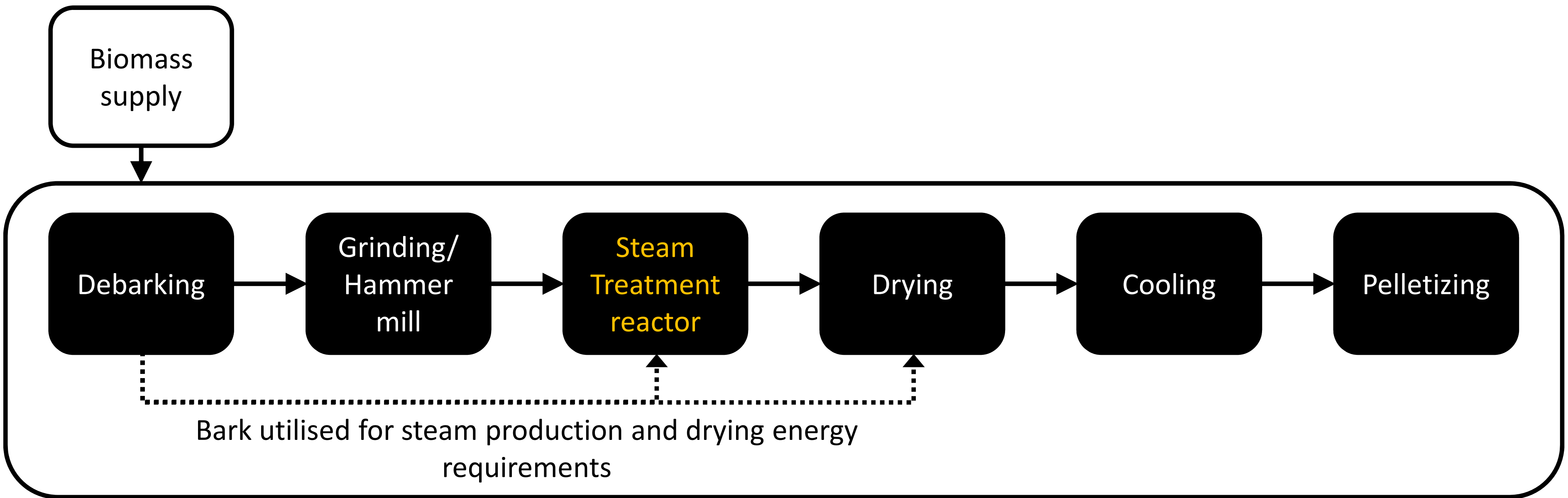


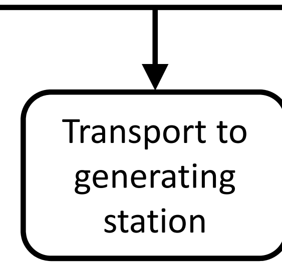
Electricity input: 144 kWh/dry tonne pellet

Advanced pellet production process

Data from Arbaflame (Norway) pilot plant

Energy balance data validated by process simulation





Electricity input: 173 kWh/dry tonne

Mass loss: 12%

Generating station

- Key technical data on pellet and coal combustion and electricity generation provided by OPG and public sources
  - Heat rate (MJ/kWh)
  - Emissions rates (NOx, SOx, PM_{10})

- Retrofit infrastructure based on existing OPG facilities with conventional pellet firing (Atikokan GS) and steam-treated pellets (Thunder Bay GS)
  - EIO-LCA approach as process data not available

Generating station

Conventional Pellets

Cost $770/kW

- Pellet silos
- Conveying/dust suppression
- Furnace, controls

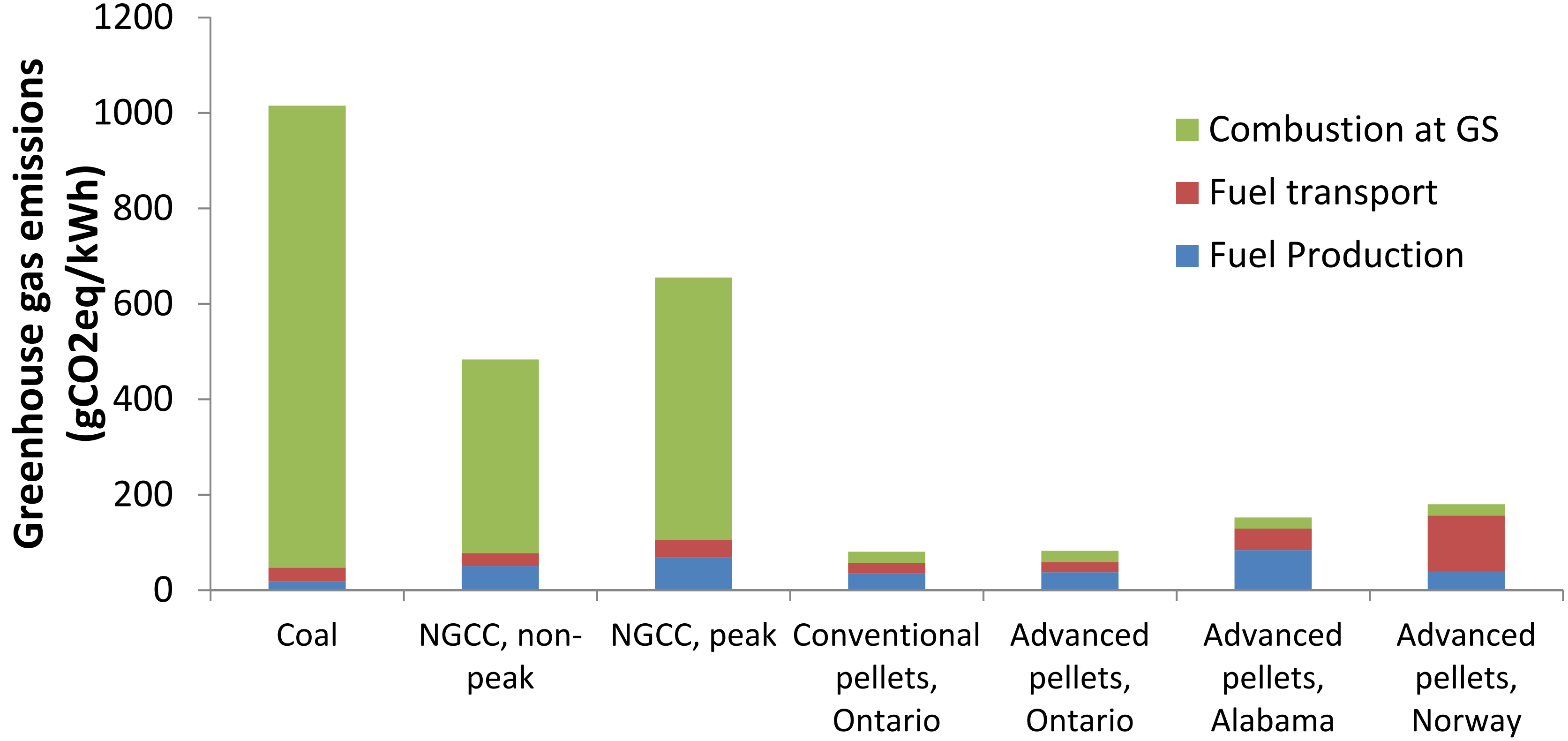
Steam-Treated Pellets

Cost $30/kW

- Outdoor storage
- Burner compatibility
- Minor conveying modification

LCA RESULTS

GHG emissions:
Electricity generation (fuel cycle only)

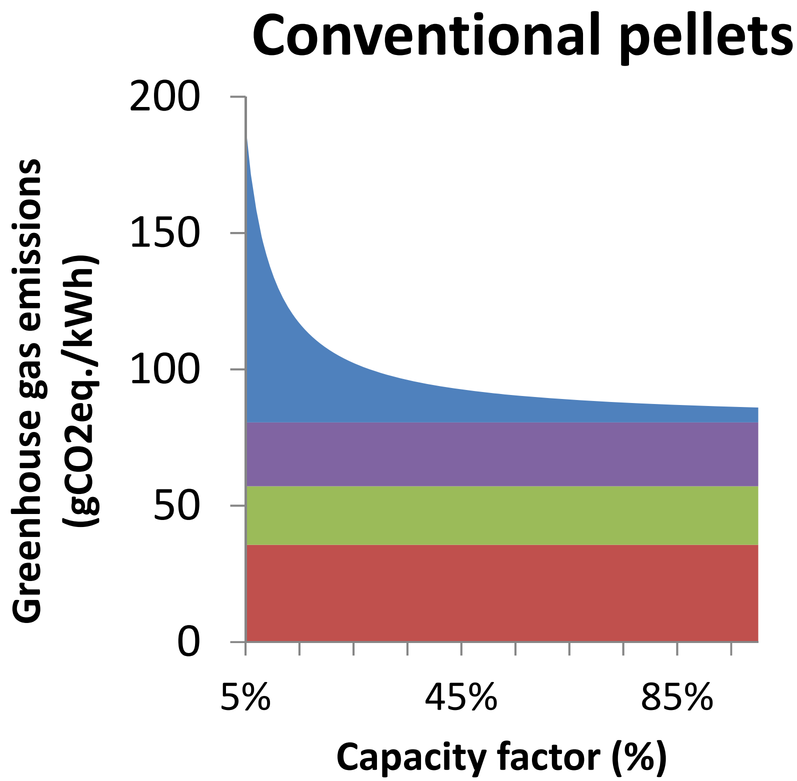


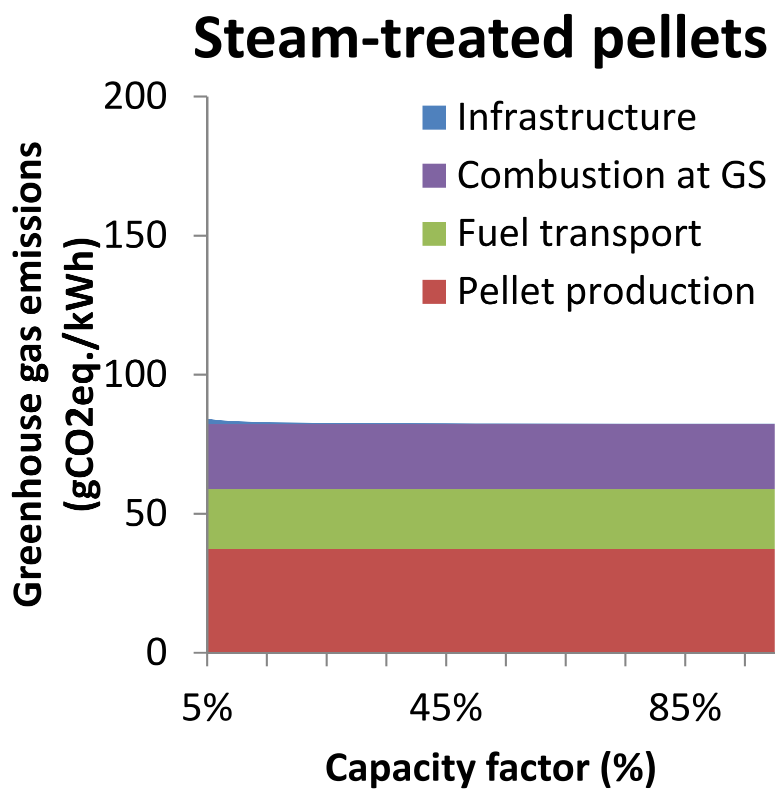
Domestic conventional and advanced pellets reduce GHG emissions relative to coal (92%) and NGCC, non-peak (85% and 83%)

Assumes biomass CO_2 emissions balanced by accumulation in forest

Note: 'Fuel Production' includes Forestry operations and Pelletization

GHG emissions: Electricity generation including GS retrofit infrastructure





- At 55% CF, infrastructure accounts for ~10% of total GHG emissions (conv. pellets), <1% (adv. pellets)
- Increasing infrastructure impact: as peaking plant, doubles fuel cycle emissions (conventional pellets)

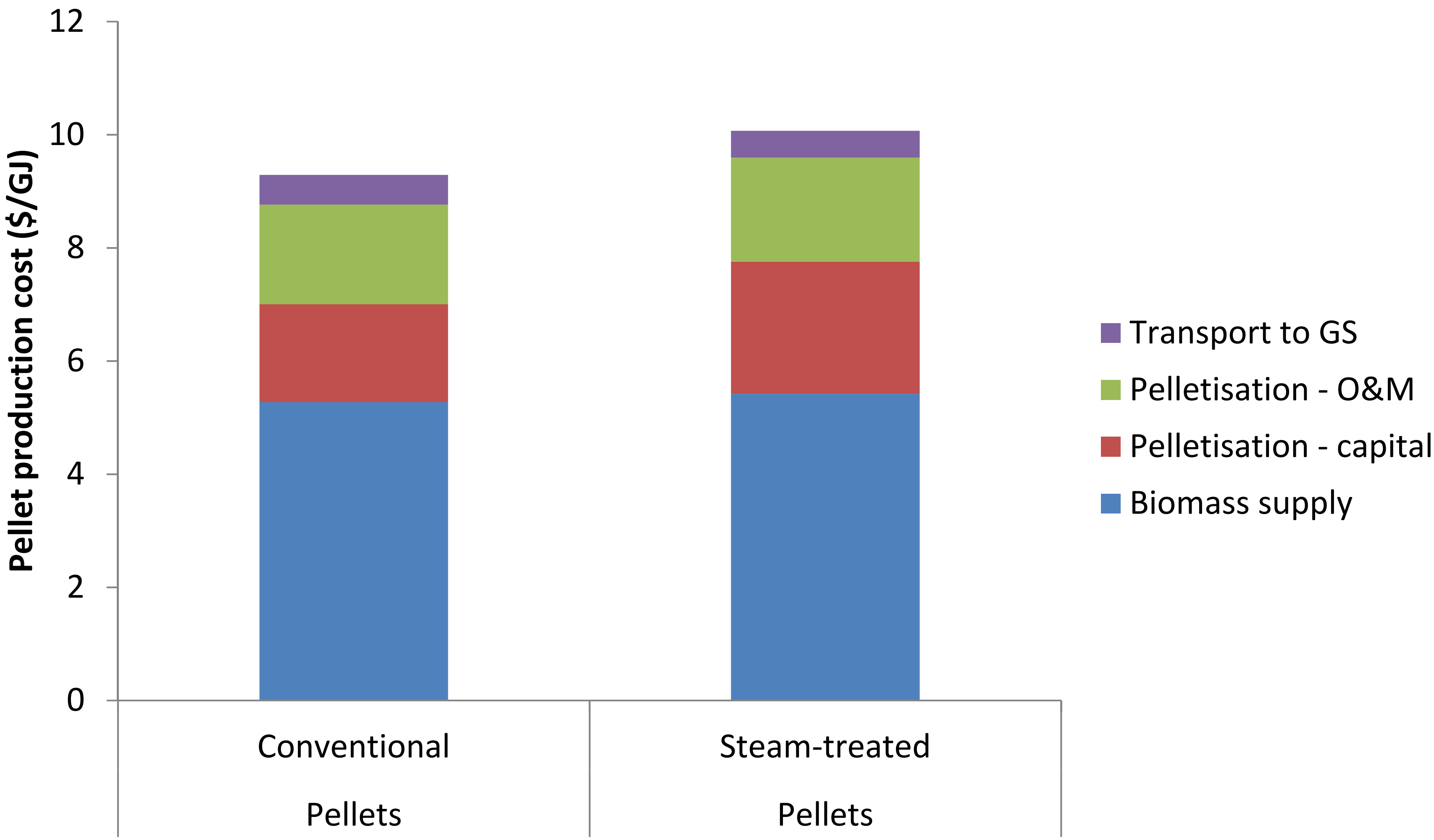
Financial analysis

Key data (Pellet production):

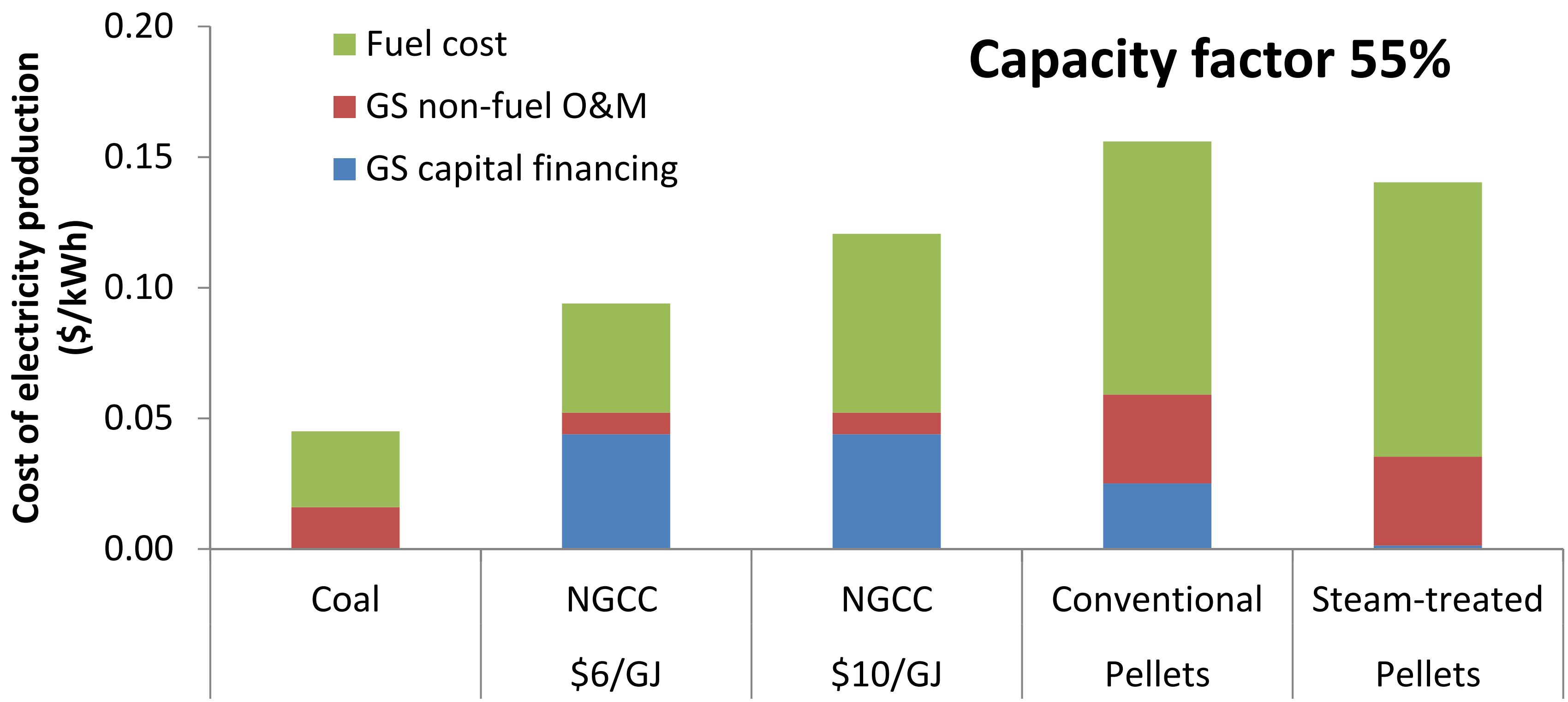
	Conventional pellets	Advanced pellets
Pellet mill characteristics		
Capacity	150,000 dry t/yr	
Feedstock (cost)	Roundwood ($100/dry t)	
Capital costs		
Total CAPEX	$157/t-yr	$234/t-yr
Economic life (yr)	20	20
Debt(%)/Equity(%)	50/50	50/50
Debt rate (Equity rate)	8% (20%)	8% (20%)
Operating costs		
Total OPEX	$33/dry t	$37/dry t

Data from KPMG/Deloitte pellet studies, Arbaflame

Pellet production costs



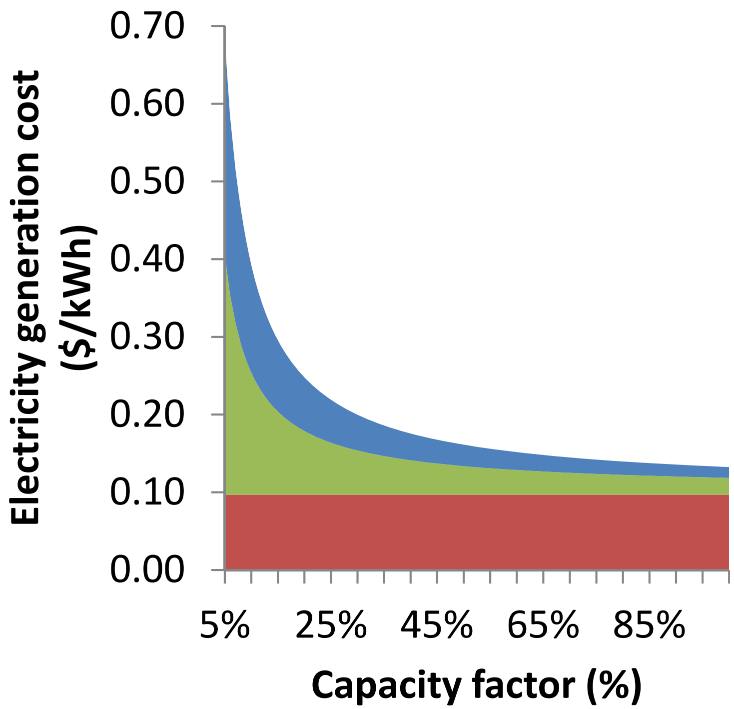
Financial analysis: Electricity generation



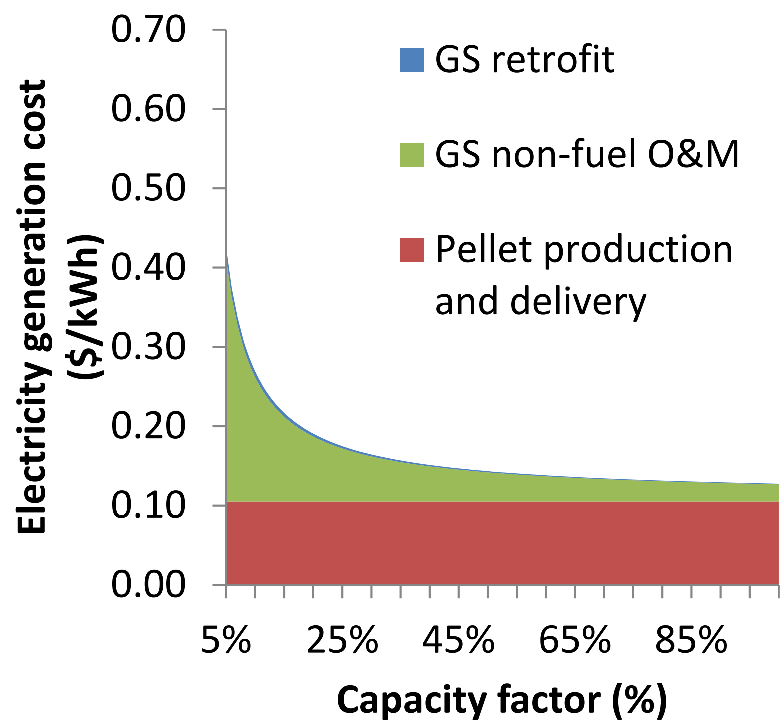
Electricity generation costs from conventional and advanced pellets are below current FIT rate for Renewable Biomass ($0.175/kWh)

Financial analysis
Electricity generation

Conventional pellets



Steam-treated pellets



Lower capacity factors favour advanced pellets due to lower retrofit costs

Similar costs at high capacity factors

Overall insights

Production of advanced pellets can result in similar GHG and air emissions and cost as conventional pellets

Electricity generation from conventional and advanced pellets results in considerably lower GHG emissions than from coal or natural gas

Cost of electricity production from pellets is strongly related to GS capacity factor

At low capacity factors, GS infrastructure requirements for conventional pellets increase costs and environmental impacts of electricity generation compared to advanced pellets

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Thank You

Questions?