

Production of Hydrogen-Rich Syngas from Steam Gasification of Blend of Biosolids and Wood



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Biosolids (or Dried Sewage Sludge)

- Biosolids are the dried residues produced by treatment of domestic and industrial waste-water.
- Biosolids are a mixture of carbon (C), phosphate (P) and nitrogen (N) compounds with heavy metals and (in its wet state) microbial organisms.



Biosolids Disposal Methods

■ Land-filling



■ Land reclamation



■ Agricultural fertiliser

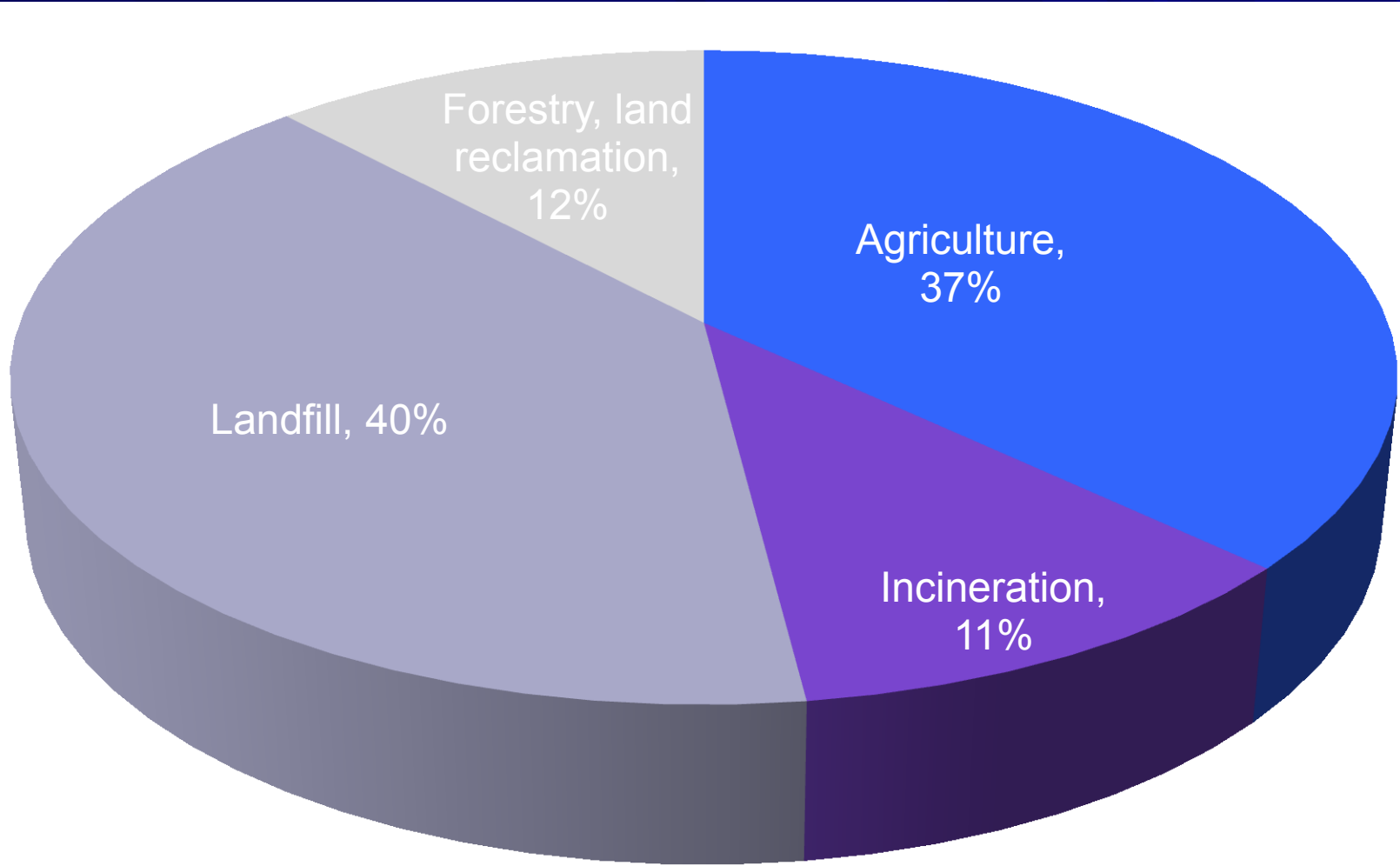
■ Incineration/Combustion



■ Gasification

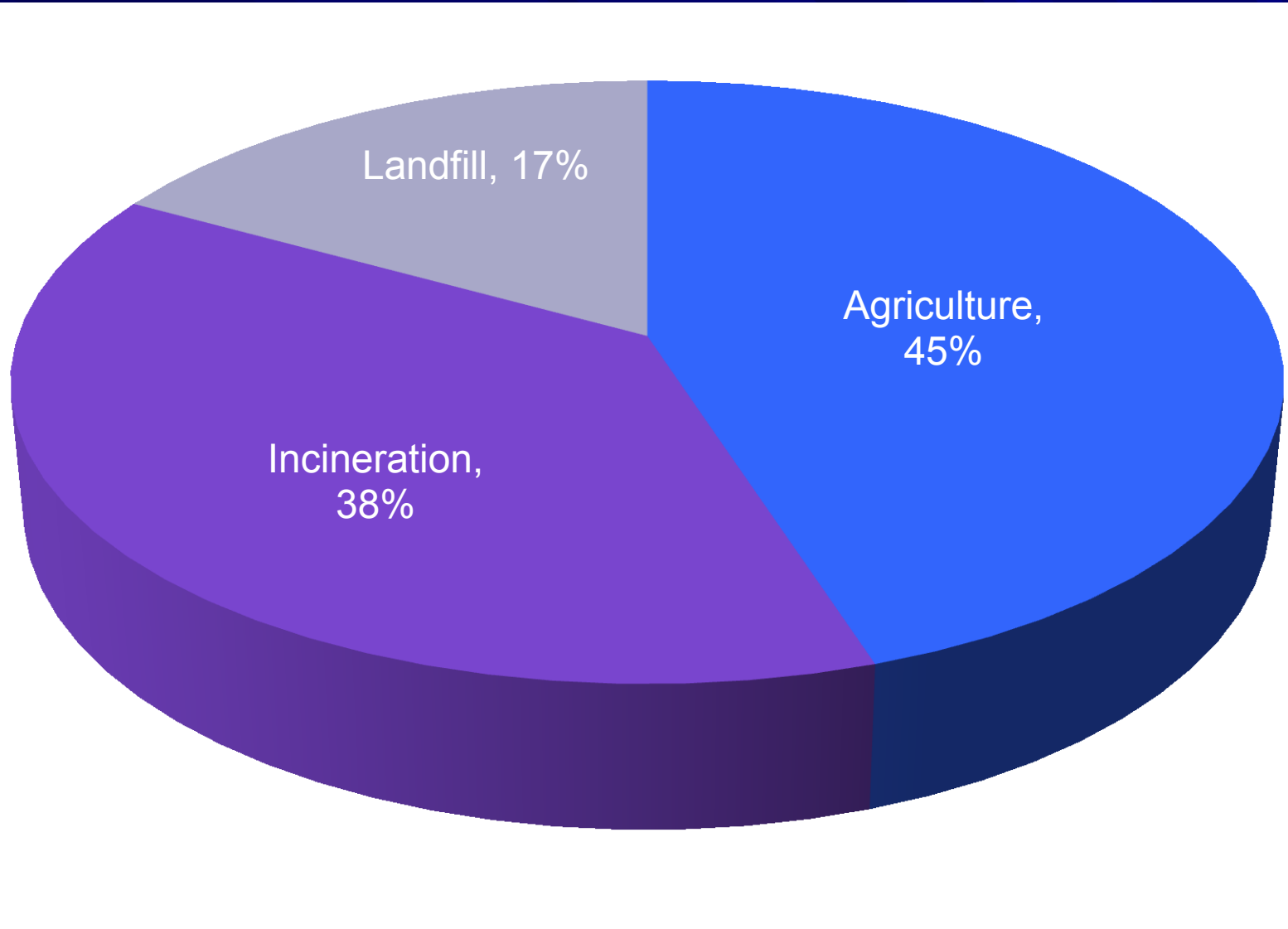


Biosolids Disposal Methods in EU



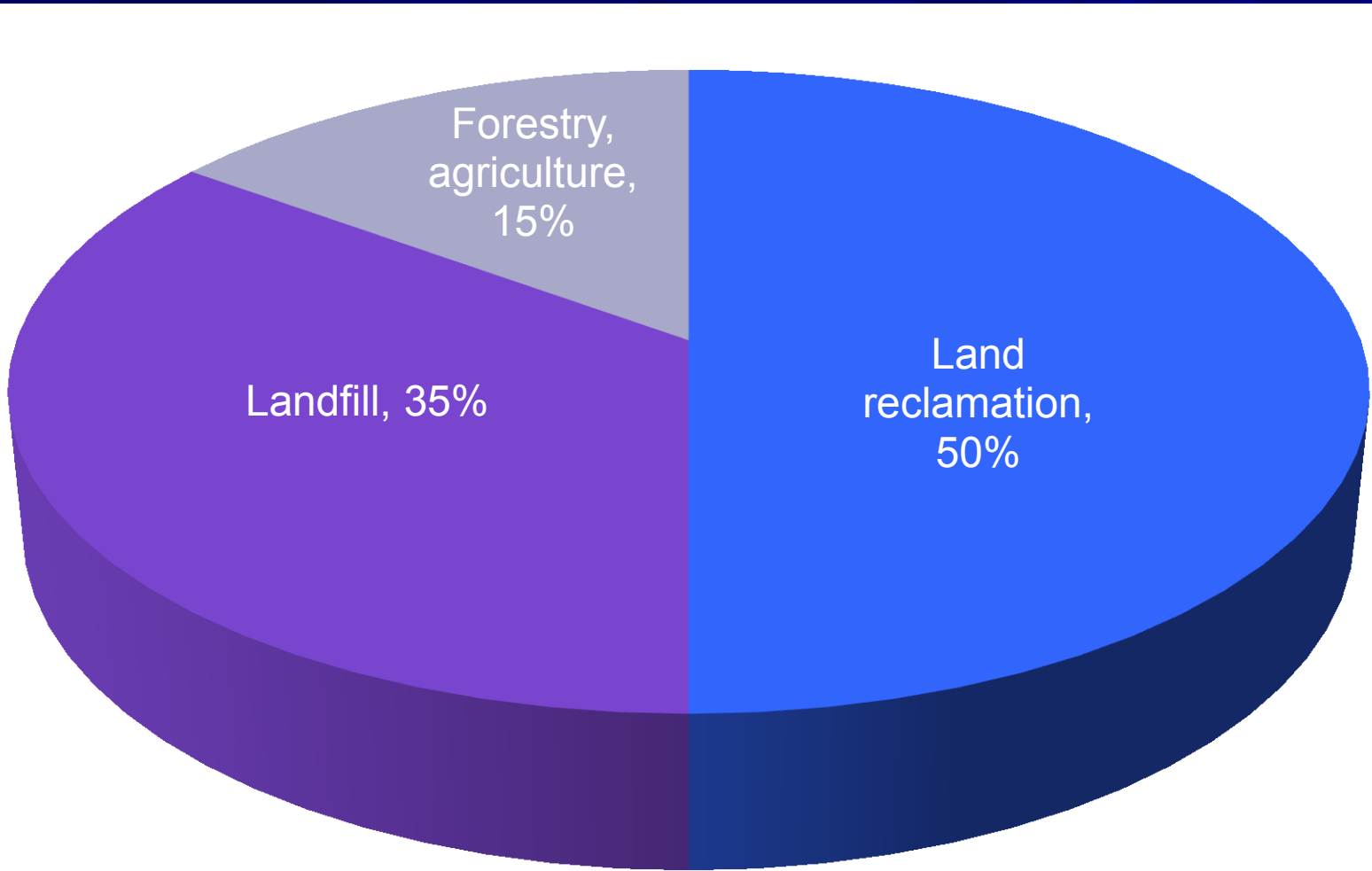
methods – A review, Renewable & Sustainable Energy Review, 12 (2008) 116-140.

Biosolids Disposal Methods in UK



sewage sludge in a spouted bed reactor; Fuel, 83 (2004) 1949-1960.

Biosolids Disposal Methods in NZ



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Gasification

- Gasification is a thermal-chemical conversion of carbonaceous materials (biomass, coal, biosolids) to produce a combustible gas consisting of H_2 , CO , CO_2 and CH_4 in a controlled environment with gasification agent (air/ O_2 /steam/ CO_2):
 - Calorific value - 4 to 20 MJ/Nm³
- The produced gas can be a feedstock for liquid fuels, chemicals or heat and power.
- However, tar is generated during gasification process
 - Tar - all organic compounds with a molecular weight higher than benzene (C_6H_6).
 - Causes blockage or fouling problems for downstream processes.

Technological Benefits for Biosolids Gasification in New Zealand

- Reduce the reliance of fossil fuel
- More efficient and more manageable process than incineration or combustion of biosolids for power generation
- Less quantity of greenhouse gases (NO_x and SO₂) generated, flying ash, dioxins and heavy metals emissions
- Reduce volume of biosolids
- Reduce cost of transportation
- Eliminate pathogenic bacteria
- No contribution of heavy metals to soil-plant system with biosolids ash compared with digested or composted biosolids

High Heating Value (HHV) and Chemical Analysis of biosolids and Wood

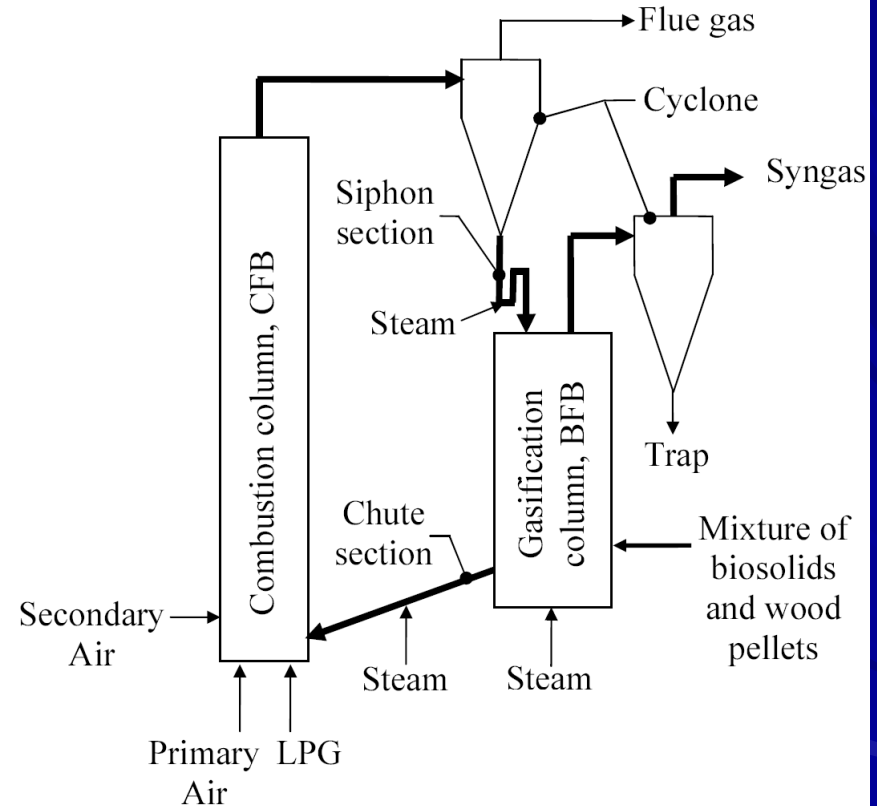
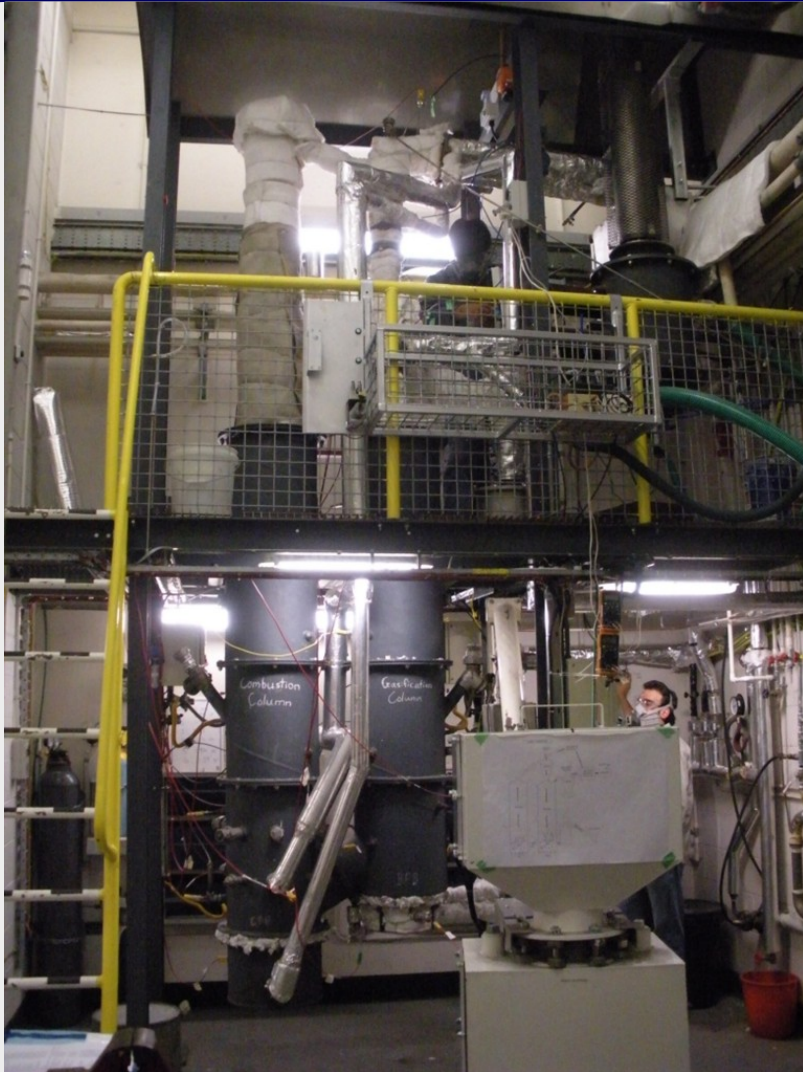
	Biosolids	Wood pellets
HHV (MJ/kg)	14	18
Proximate, %		
Moisture content	8.0	8.0
Volatile matter	43.5	77.4
Ash content	32.0	0.4
Fixed carbon	16.5	14.2
Ultimate, %		
Carbon	34.0	47.2
Nitrogen	5.1	<0.2
Sulphur	1.2	<0.1
Hydrogen	3.5	5.4
Oxygen	16.2	38.7

SiO ₂	CaO	P ₂ O ₅	Al ₂ O ₃	Fe ₂ O ₃	SO ₃	MgO	Na ₂ O	TiO ₂	K ₂ O	Mn ₃ O ₄
44.5	15.6	13.6	8.8	5.2	2.4	2.3	1.9	1.6	1.6	0.1

Objectives of the Project

- To investigate the performance of gasification of biosolid and biosolid/wood pellet blends using our newly developed dual fluidised bed gasifier.
- To investigate syngas and cold gas efficiency and syngas composition (with focus on H₂ content).
- To examine the tar concentration as a function of the biosolids proportion in the fuel.
- To compare the syngas composition of this study with the previous studies, which used air, O₂ and CO₂/N₂ as the gasification medium.

A 100kW Dual Fluidised Bed (DFB) Gasifier at University of Canterbury



Gasification Experiments

- Gasification temperature: 720°C
- Bed material: Greywacke sand
- Feed rate: 15.5kg/hr
- Steam to feedstock: 0.7 (kg/kg)
- Feedstock: 7 trials with different premixed blends of wood pellets and biosolids with biosolid proportions of: 100%, 80%, 60%, 40%, 20%, 10%, 0%.



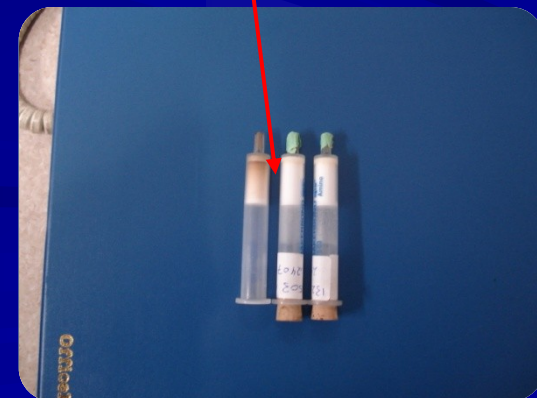
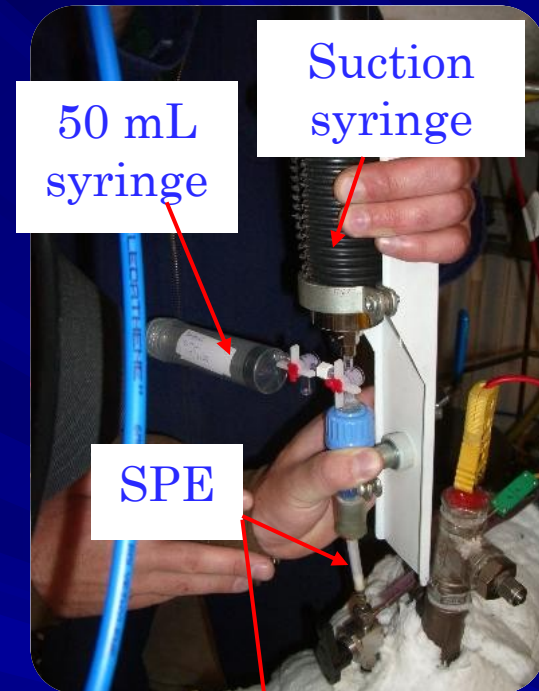
Methods of Sampling and Analysis

■ Syngas

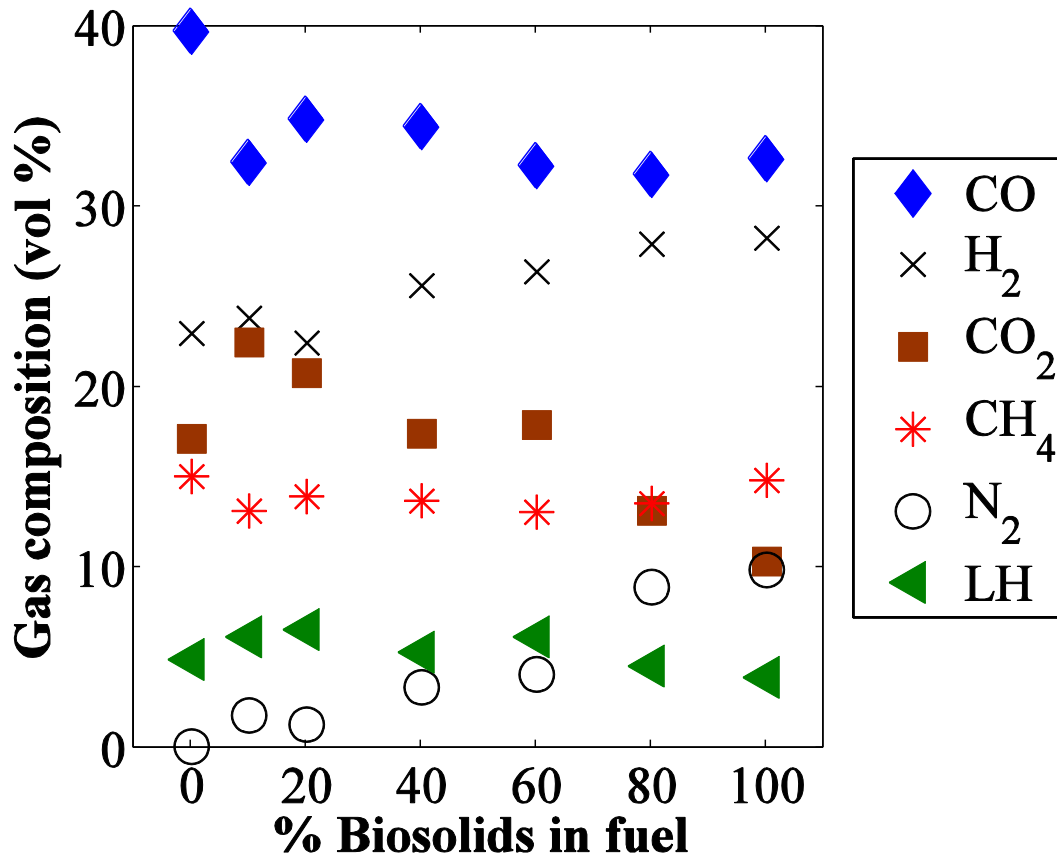
- 50mL syringe
- Agilent 3000 Micro-GC

■ Tar

- 3ml Bakerbond amino normal phase solid phase extraction (SPE)
- Evaporative analysis
 - Weigh the evaporating dish before and after sampling 100ml of syngas



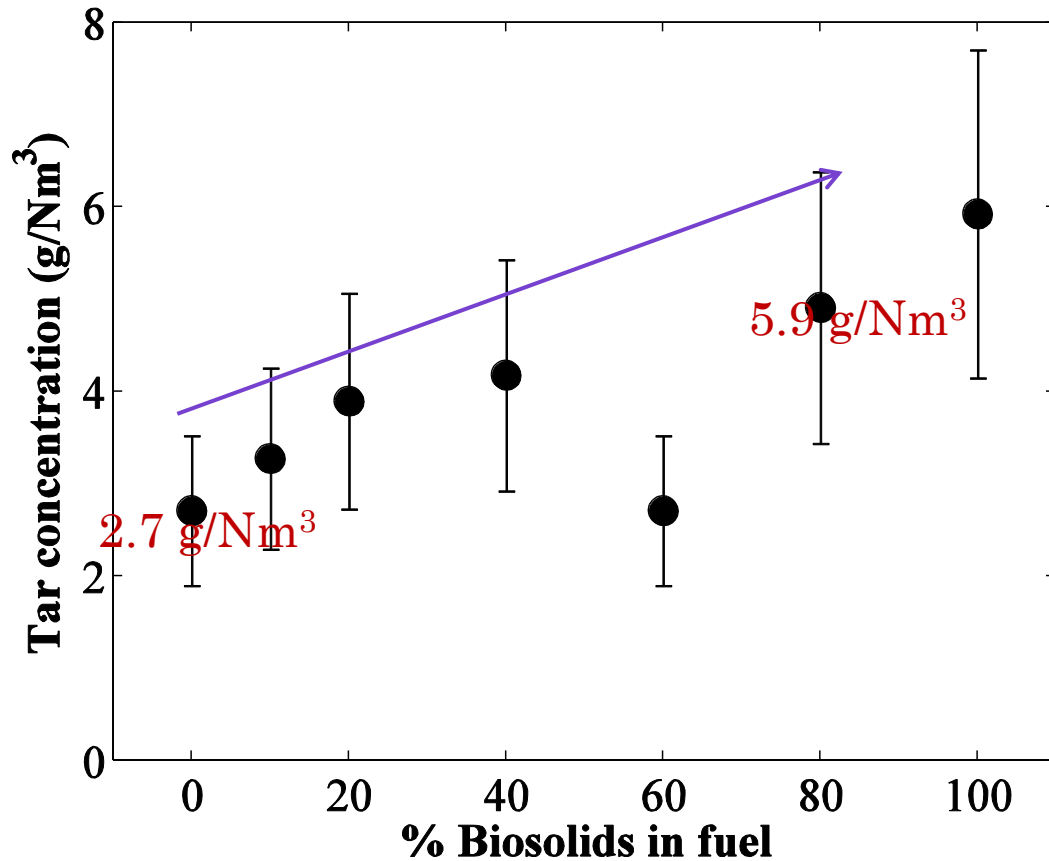
Results and Discussion: Syngas Composition



■ The increase of H₂ could be due to the presence of catalysts in the biosolids:

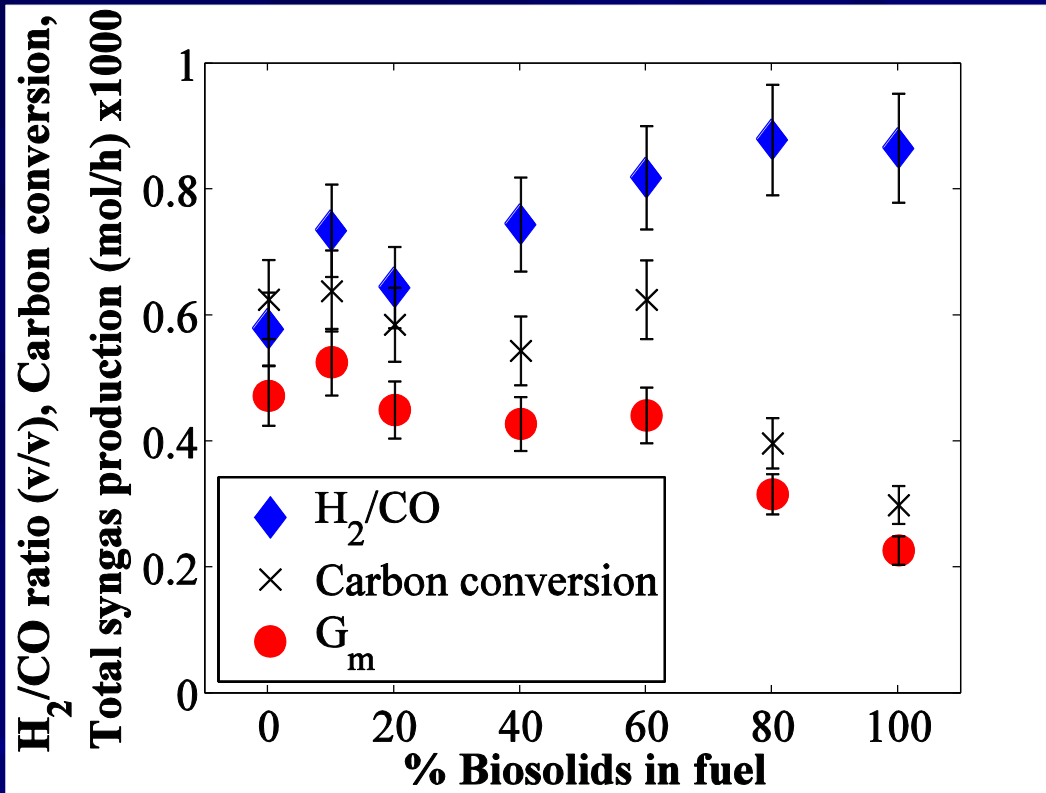
- CaO
- Fe
- Alkali salts (Na and K)

Results and Discussion: Total tar concentration



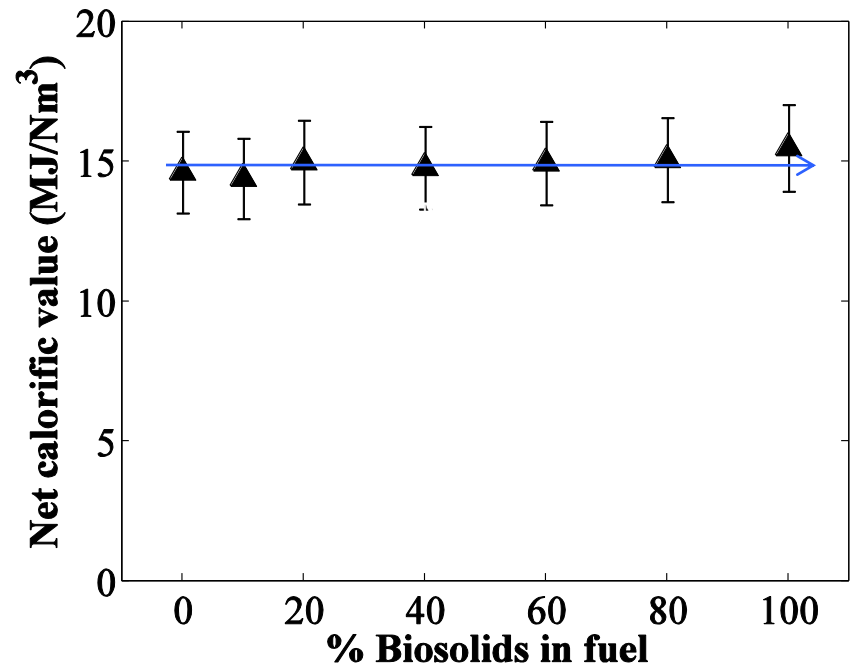
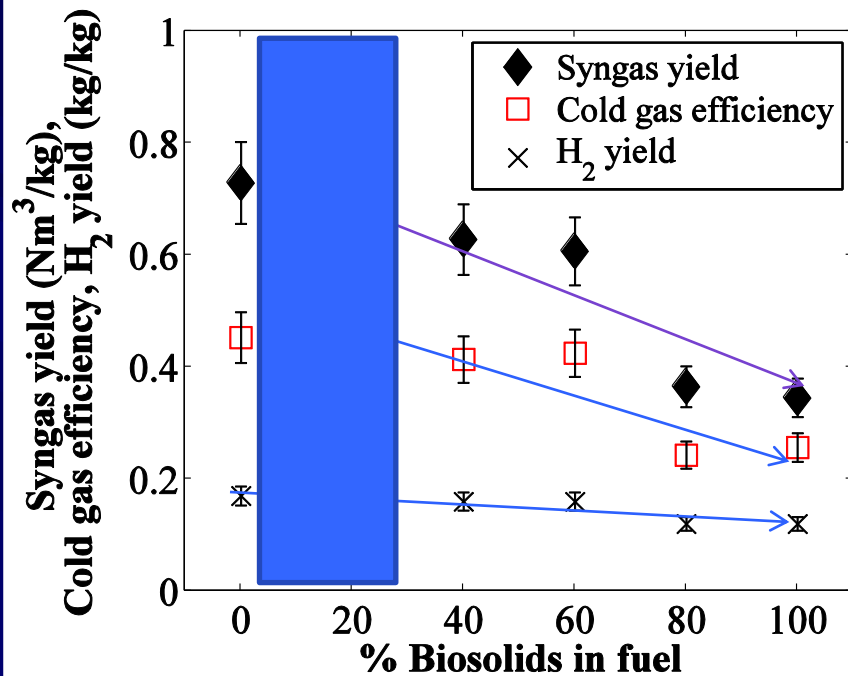
■ The increase of tar concentration could be resulted from the complex molecular structure

H₂/CO Ratio, C Conversion and Total Syngas Production



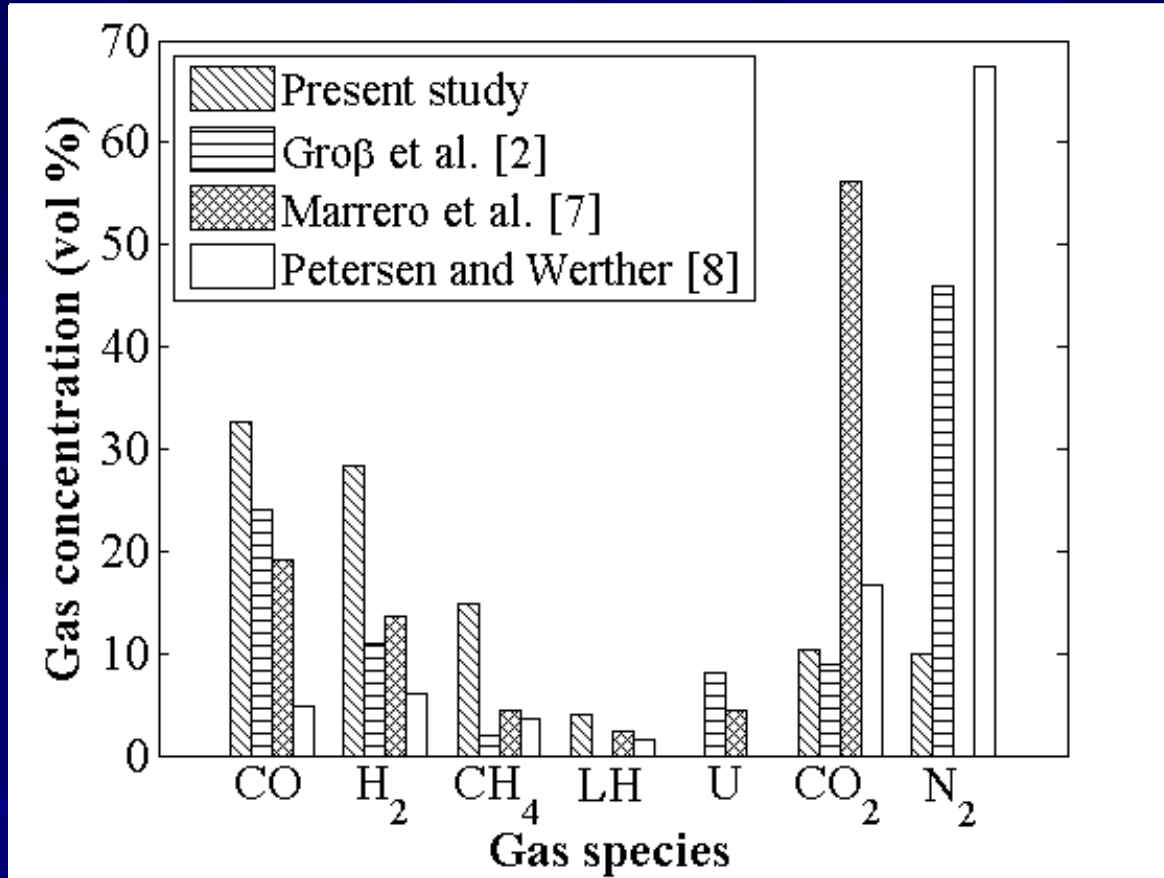
- The decrease in C conversion was due to
 - Entrainment of biosolids which induces fixed carbon loss.
- This issue can be reduced by densification, e.g. pelletising.
- Gas production decrease is due to high ash content in biosolids.

Syngas and H₂ Yields, Cold Gas Efficiency and Net Calorific Value



- The ash quantity per weight in biosolids is higher than wood pellets (32% vs 0.4%).
- The biosolids being biologically digested prior to gasification.

Comparison with Literature Data for Gasification of Pure Biosolids



Gasification medium /gasifier

- Present study: steam, DFB
- [2] Air, Two-stage BFB
- [7] O₂, Fixed bed
- [8] CO₂/N₂, CFB

- The H₂ and CO were found to be 40% higher than for those under other gasification media
- The CO₂ was found to be at least 30% lower than that under O₂ and CO₂/N₂

Conclusion

- Bio-solid can be gasified using our newly developed dual fluidised bed gasifier using steam as gasification agent.
- The syngas from biosolids has higher content of H_2 (29%) compared with that from pure wood (22%);
- The syngas and H_2 yields, and cold gas efficiency decreased with biosolid proportion in the feeding fuel.
- However, with 10 to 20% loading of biosolids in the fuel did not decrease the yields and the cold gas efficiency.
- The concentrations of H_2 and CO in this study with 100% biosolids was found to be at least 40% higher than those using O_2 , CO_2/N_2 or air as the gasification medium.
- High ash content and potential hazardous gas contaminants are being further investigated.

Acknowledgements

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