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Update on Biomass Gasification in New Zealand

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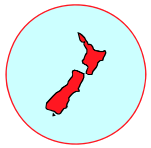

Presentation outline

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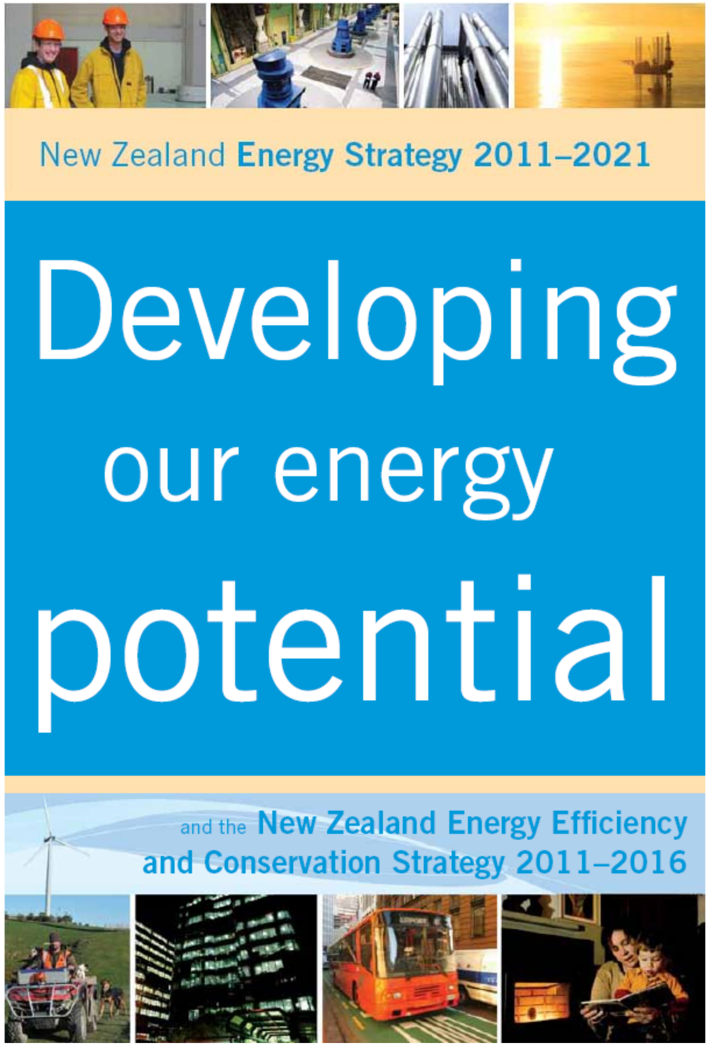
- The Government energy strategies and policies.
- National status of research, development and commercialisation of biomass gasification.
- Research progress of biomass gasification at the University of Canterbury (UC).

NZ energy strategy



- The Government released the two strategies on 30 August 2011 to replace the 2007 version.
- The goal is to make the most of its abundant energy potential through the environmentally responsible development and efficient use of the country's diverse energy resources.
- The aim is to achieve a 50% reduction in our greenhouse gas emissions from 1990 levels by 2050.

NZ renewable energy strategy (NZSE)

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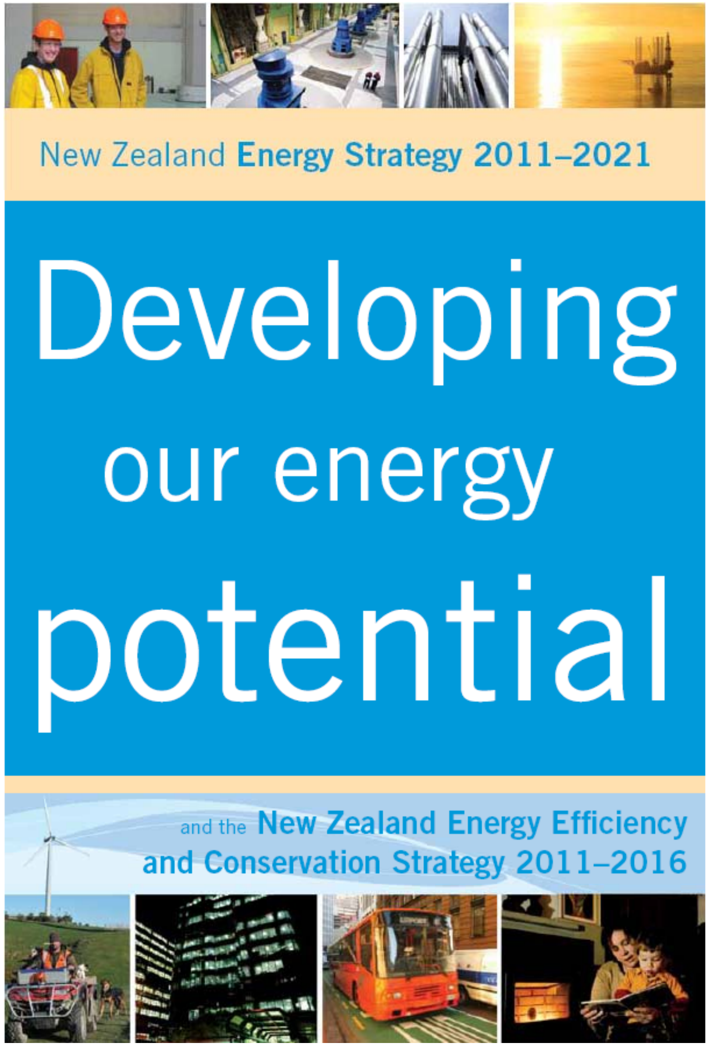
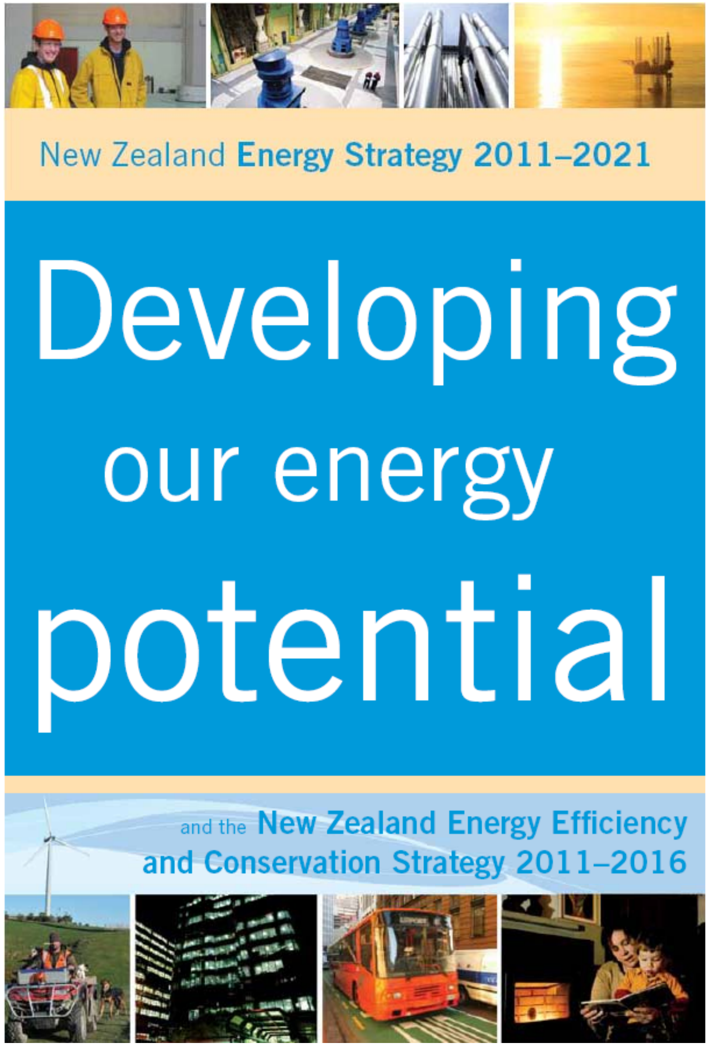


- Renewable energy resources: hydro, geothermal, wind and biomass.
- Target: 90% of the electricity from renewable resources by 2015 (currently it is 79%).
- Government joined in the International Renewable Energy Agency, effective on 1 May 2011.
- Government will continue to ensure market incentives and regulatory framework support for further investment in appropriate renewable projects by removing unnecessary regulatory barriers.

NZ energy efficiency and conservation strategy



- It is a companion to the NZES for energy saving and productivity improvement.
- It aims to encourage energy consumers to make wise decisions and choose efficient products.
- The energy efficiency target is to achieve energy intensity improvement of 1.3% per annum.

The biodiesel grants scheme (2009)

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- It aims to kick-start biodiesel production industry in New Zealand.
- A grant of up to 42.5 cents/litre for biodiesel (or biodiesel content of a biodiesel blend) has been available to biodiesel producers in NZ.
- The grant is paid monthly to NZ producers who sell 10,000 L or more biodiesel each month.

The emission trading scheme (2009)

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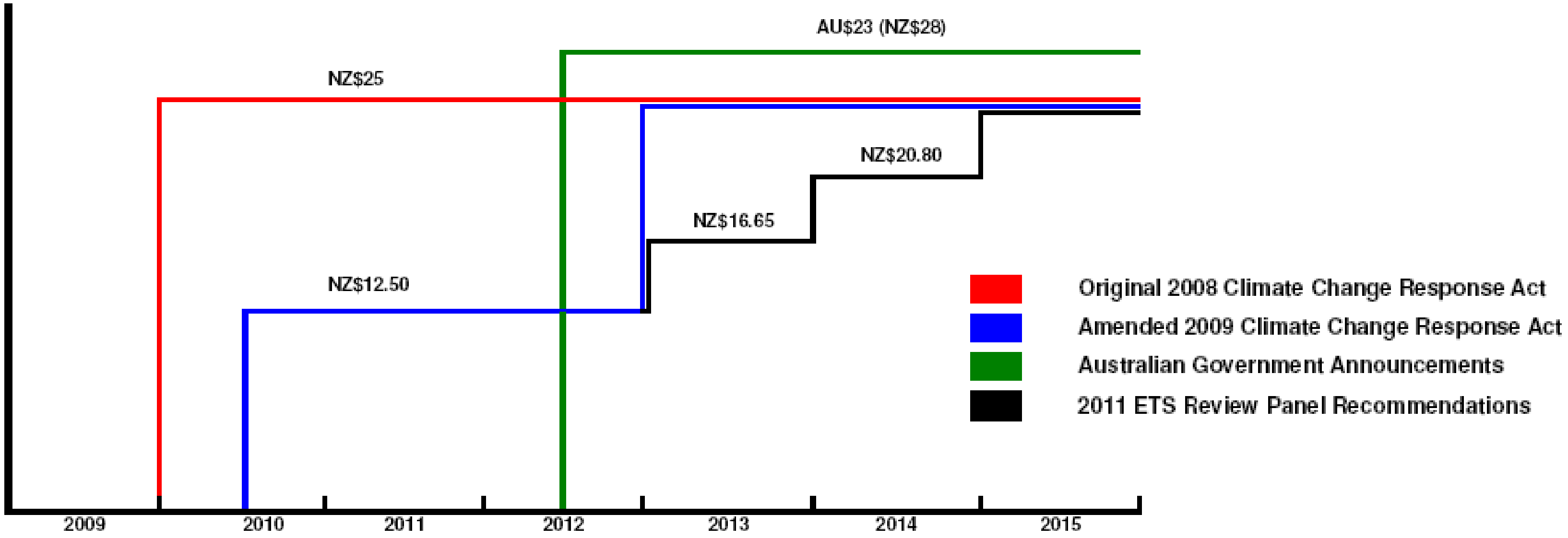
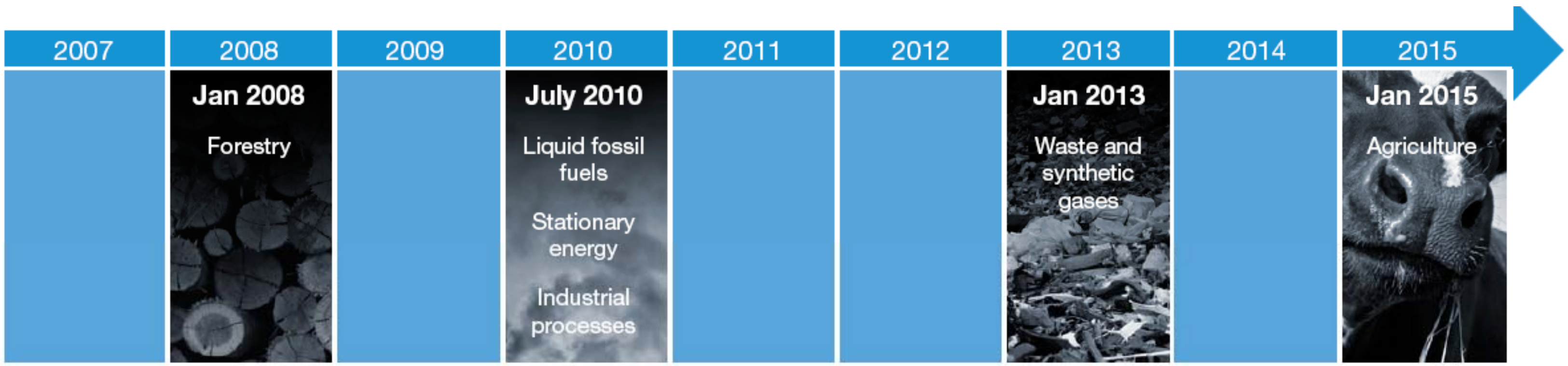
Transition and Timing of Carbon Pricing





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Biomass energy strategy 2010

- It was proposed by BANZ in corporation with the NZ Forest Owners Association.
- It aims at economic growth by increasing production and use of biomass energy and biofuels in New Zealand.
- Target is to increase bioenergy use from current 8.5% (consumer energy) to 25% by 2040 including 30% of the country's transport fuels.
- The target will be implemented in three phases.
  - Foundation building phase (2010-2015).
  - Development phase (2015 – 2020).
  - Expansion phase (2020-2040).

Commercial biomass gasification: Fluidyne Gasification Ltd.

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Fluidyne is active overseas with its downdraft process (100kWe-2MWe).

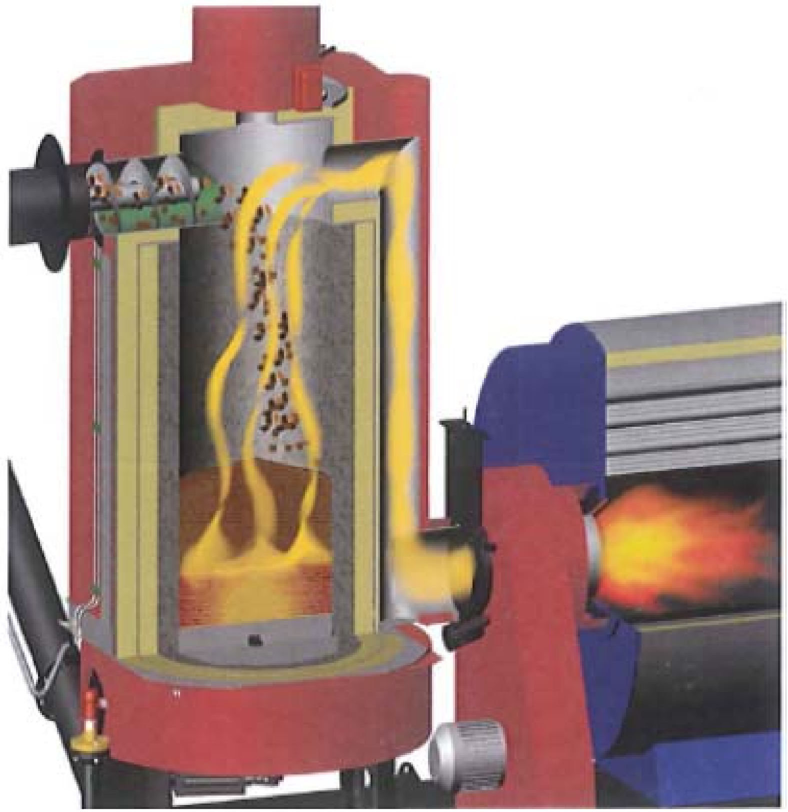
- 100kWe Andes Class development programme in California, to replace the use of LPG to heat the CalForests Forestry Tree Nursery.
- Gasifiers with larger gas outputs equivalent to 250-500 kWe are to be built with a change of design concept containing the oxidizing bed parameters by 2013-15.
- West Biofuels in Woodland, California (shown here).
- The technology is currently licensed for sale in Australia through Flow Force Technologies
- Biocharcoal utilisation:
  - in potting mix for seedling trees.
  - activated carbon.

Demonstration of biomass gasification: Windsor Engineering

- Windsor™ is a manufacturer mainly for timber drying kilns.
- A 1.5MW Agder Biocom (Norway) gasifier is built and in commissioning in Rotorua, Central North Island, NZ, by a joint venture between the Waiariki Institute of Technology (WIT), Windsor ™ and EECA.
  - As a training facility for wood processing students at the WIT.
  - As a R&D test facility.
  - To replace natural gas for existing boiler to generate steam for two Windsor timber drying kilns of 20 and 30 m³ timber capacity respectively.

Demonstration of biomass gasification: Windsor Engineering

- The gasifier specification
  - Updraft type
  - Thermal output 1.2 MW with 78% net efficiency using wood fuel with MC of up to 35%.
  - Fuels: mixed shavings, hogging, sawdust and bark.
  - Particulate emissions not greater than 50mg/Nm³.



Potential commercialisation opportunity

- Gasification of demolished timber from the earthquake damaged buildings in Christchurch.
- Proposal of our collaboration with the city council is in process for generation of heat or CHP to heat the inner city.

Research on biomass gasification: CRL Energy Ltd.

- It has constructed a 200kW fluidized bed gasifier with a gas cleaning system to undertake R&D on lignite gasification for hydrogen.
- It is currently collaborating with UC research team on co-gasification of biomass and coal.
  - Making coal-biomass blend pellets.
  - Lab scale test of co-gasification.
  - Proof of concept of O_2 as gasification agent integrated with water electrolysis.

CRL Energy Ltd: a new O_2 blown FB gasifier of 50kW in construction

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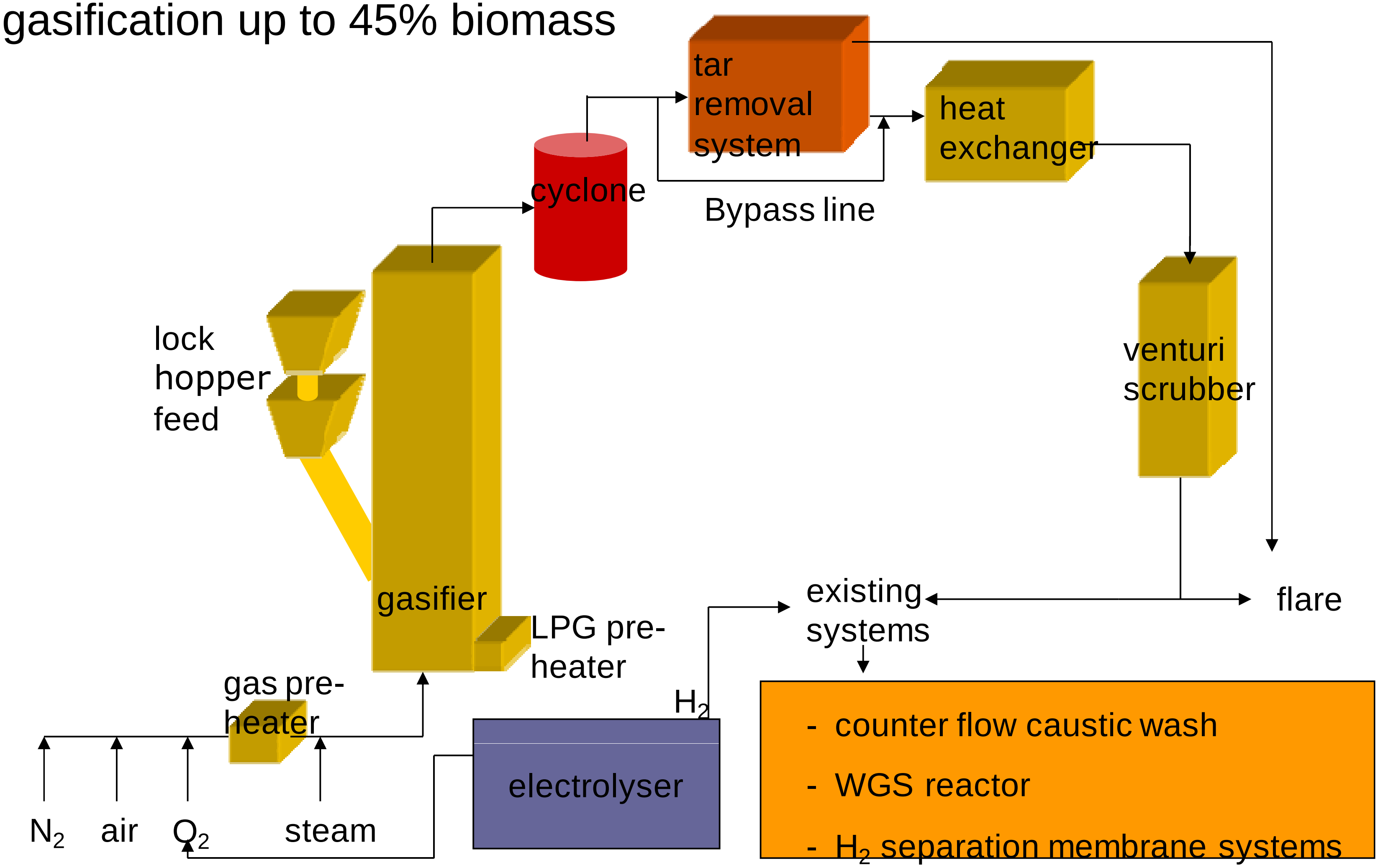
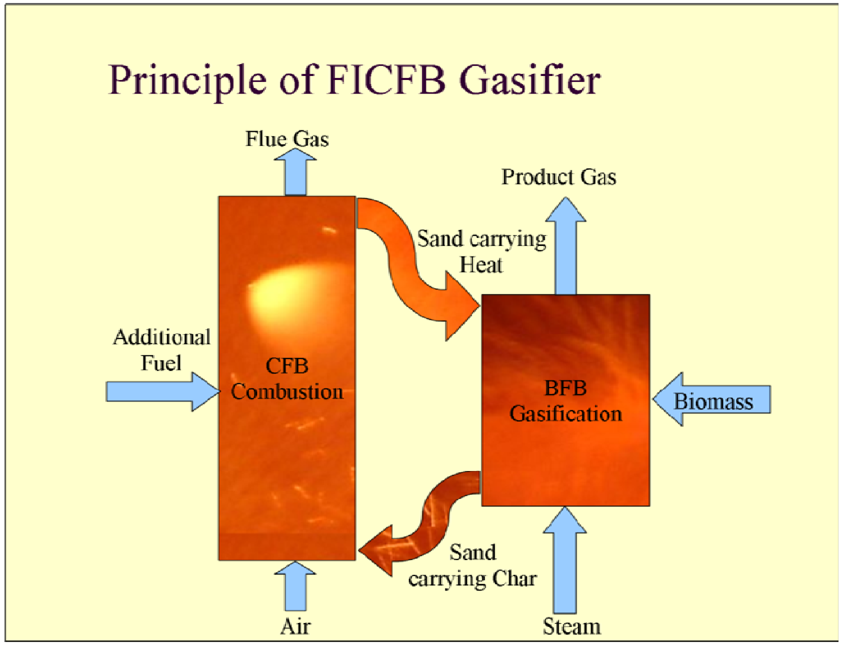
Co-gasification up to 45% biomass



Progress of biomass gasification in the BTSL at UoC

- Optimisation of the DFB gasifier operation
- Cold model studies on hydrodynamics of the DFB



100kW or 20kg/hr of dry biomass

Optimisation of the DFB gasifier operation

- Effect of gas contact time or BFB bed height.
- Effect of calcite catalytic bed material.

Effect of gas residence time

- To investigate the effect on
  - producer gas composition;
  - carbon conversion;
  - gas yield;
  - gasification efficiency;
  - and tar concentration.
- Gas contact time τ_b is defined as:

$$\tau_b \text{ (s)} = \frac{\text{Initial bed height of BFB, } L_o \text{ (m)}}{\text{Superficial gas velocity, } U_o \text{ (m/s)}}$$

Experiment conditions of the DFB gasifier

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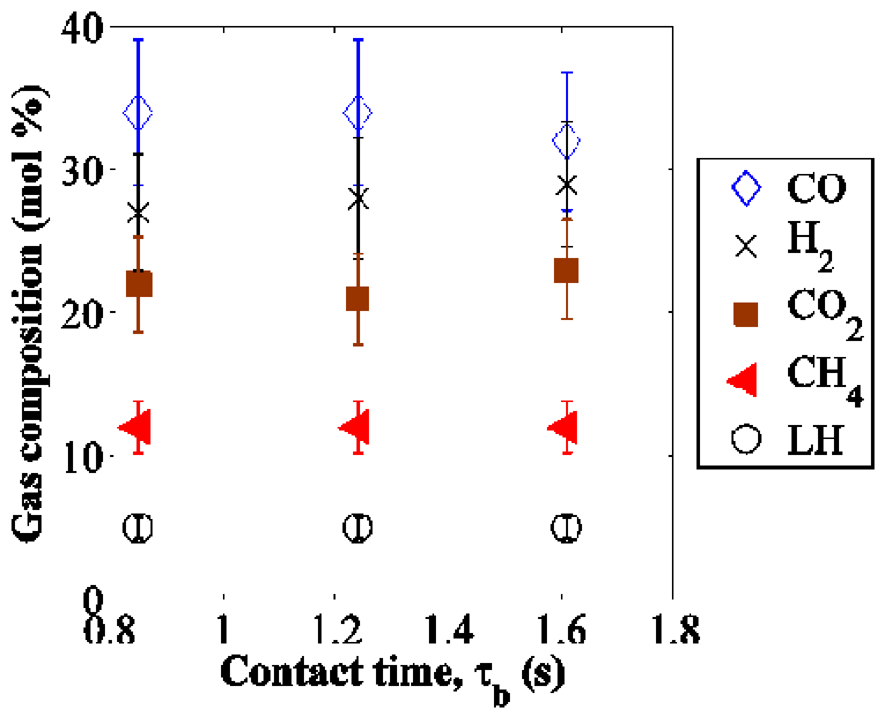
BFB temperature (°C)	730-750
Average particle size of the sand (µm)	250
Sand bulk density, ρ_b (kg/m^3)	1600
Steam to biomass ratio	0.8
Biomass feed rate (kg/h)	14
Gas velocity at inlet, U_o (m/s)	0.14
Total bed material in the DFB, M_t (kg)	12-18
Total bed material in the BFB, M_b (kg)	5.8-12.1
Gas contact time in the BFB, τ_b (s)	0.85-1.61

Effect of contact time on producer gas composition

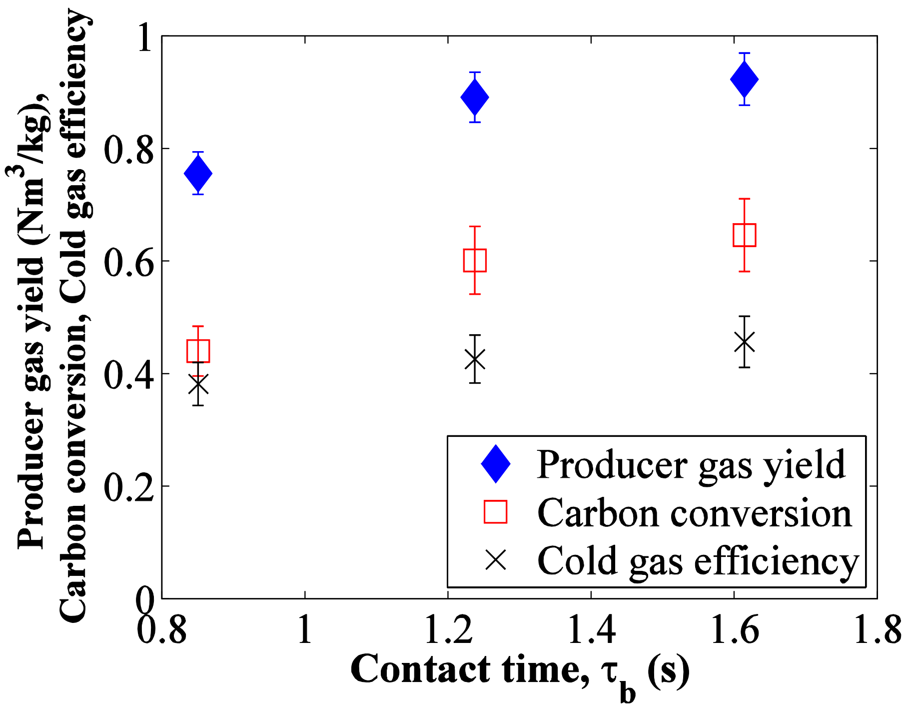
- τ_b had noticeable influence on CO, H_2 and CO_2, but not for CH_4 and the heating value.
- The influence was due to

$$CO+H_2O \leftarrow\rightarrow H_2+CO_2$$



Effect of contact time on carbon conversion

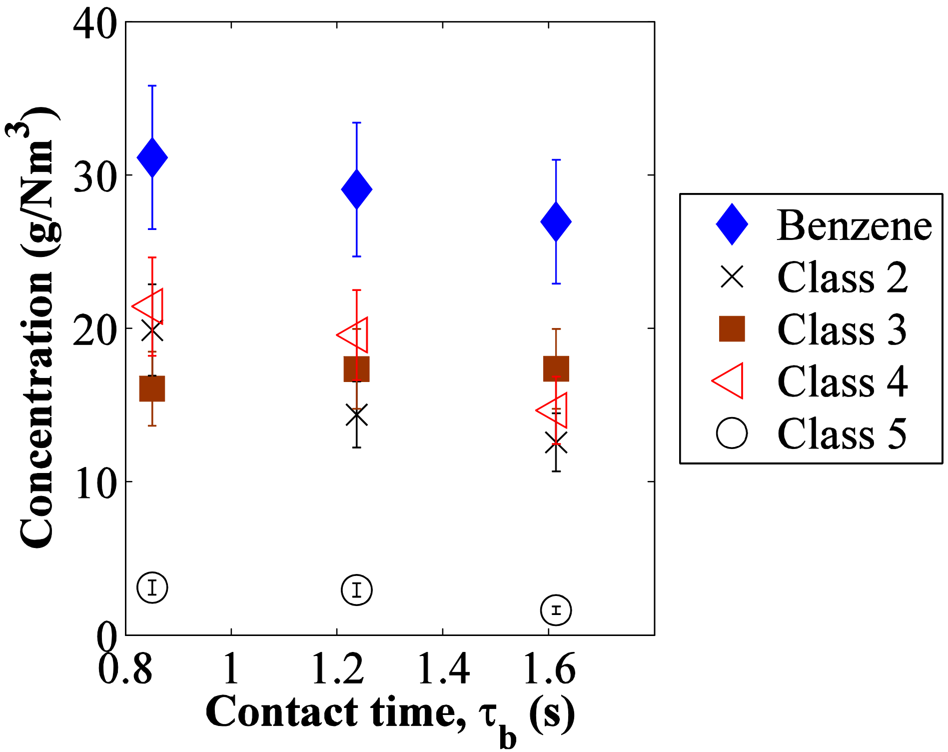
- Carbon conversion rate increased by 47% with τ increasing from 0.8 1.6s, thus:
  - the producer gas yield increased by 22%.
  - the cold gas efficiency increased by 20%.



Effect of contact time on tar concentration

With τ_b increaed from 0.8 to 1.6s:

- Benzene reduced by 13%; Class 2 tar reduced by 40%
- No influence on Class 3 tar
- Class 4 tar reduced by 30%; Class 5 tar reduced by 50%
- The total tar concentration in the producer gas reduced by 24%.



Calcite bed material

- To increase the H_2 yield or H_2/CO ratio by reducing CO_2;
  - Low BFB temperature
    - 650°C (optimum temperature for carbonisation)
    - $CaO + CO_2 \rightarrow CaCO_3$ -181.4kJ/mol
  - High CFB temperature
    - 850°C (optimum temperature for calcination)
    - $CaCO_3 \rightarrow CaO + CO_2$ +181.4kJ/mol
- To investigate the effect on gas composition, conversion efficiency and tar concentration.

Operating conditions of the DFB gasifier

▪ BFB temperature (°C)	700-720
▪ CFB temperature (°C)	800
▪ Average particle size of calcite (μm)	600
▪ Steam to biomass ratio	0.7-1.0
▪ Biomass feed rate (kg/h)	15
▪ Total amount of bed material in the gasifier (kg)	>18
▪ Calcite in the calcite (C)-greywake (G) bed material (%)	0, 50, 100

Effect of calcite on ratio of H_2/CO

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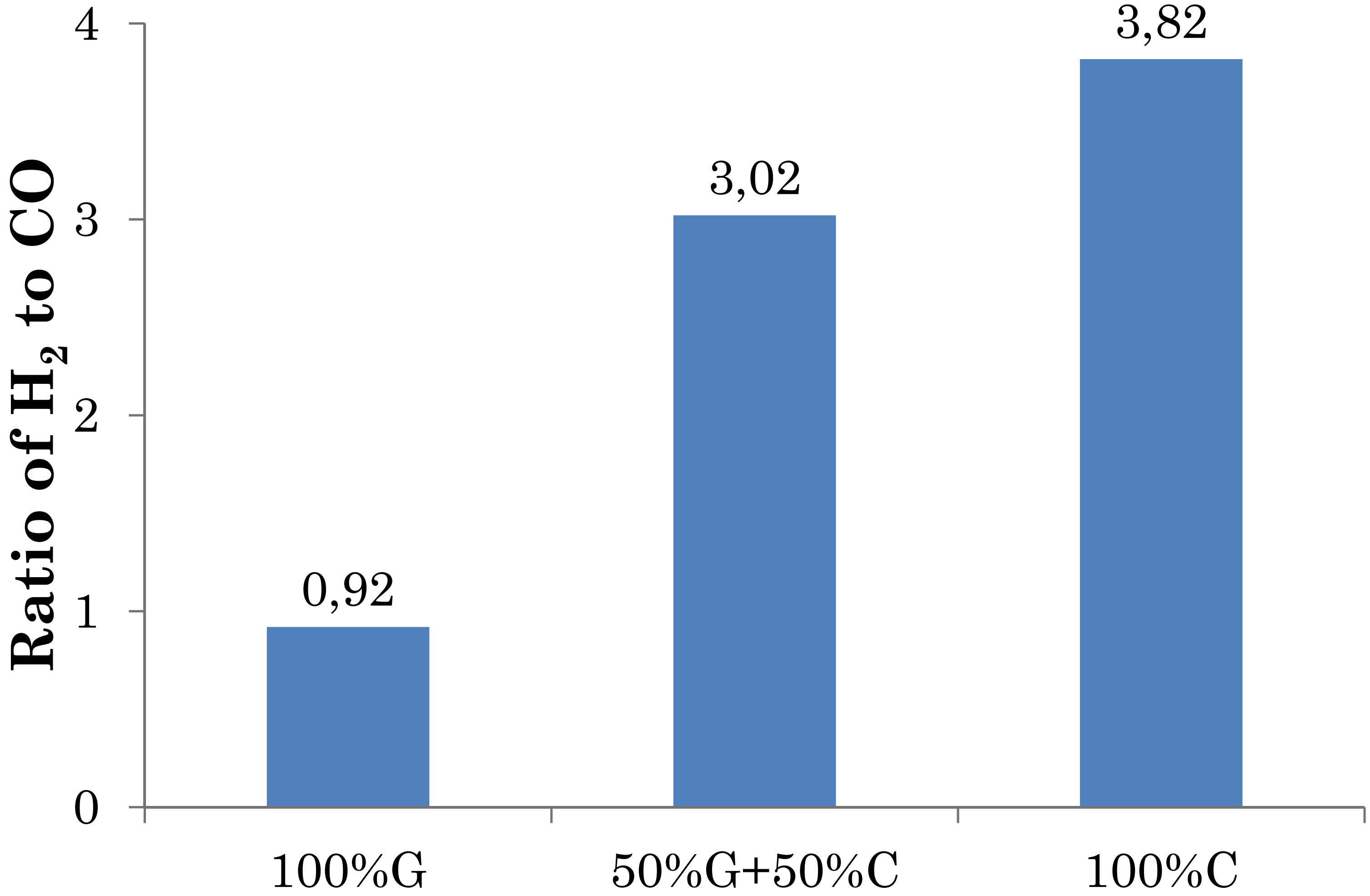
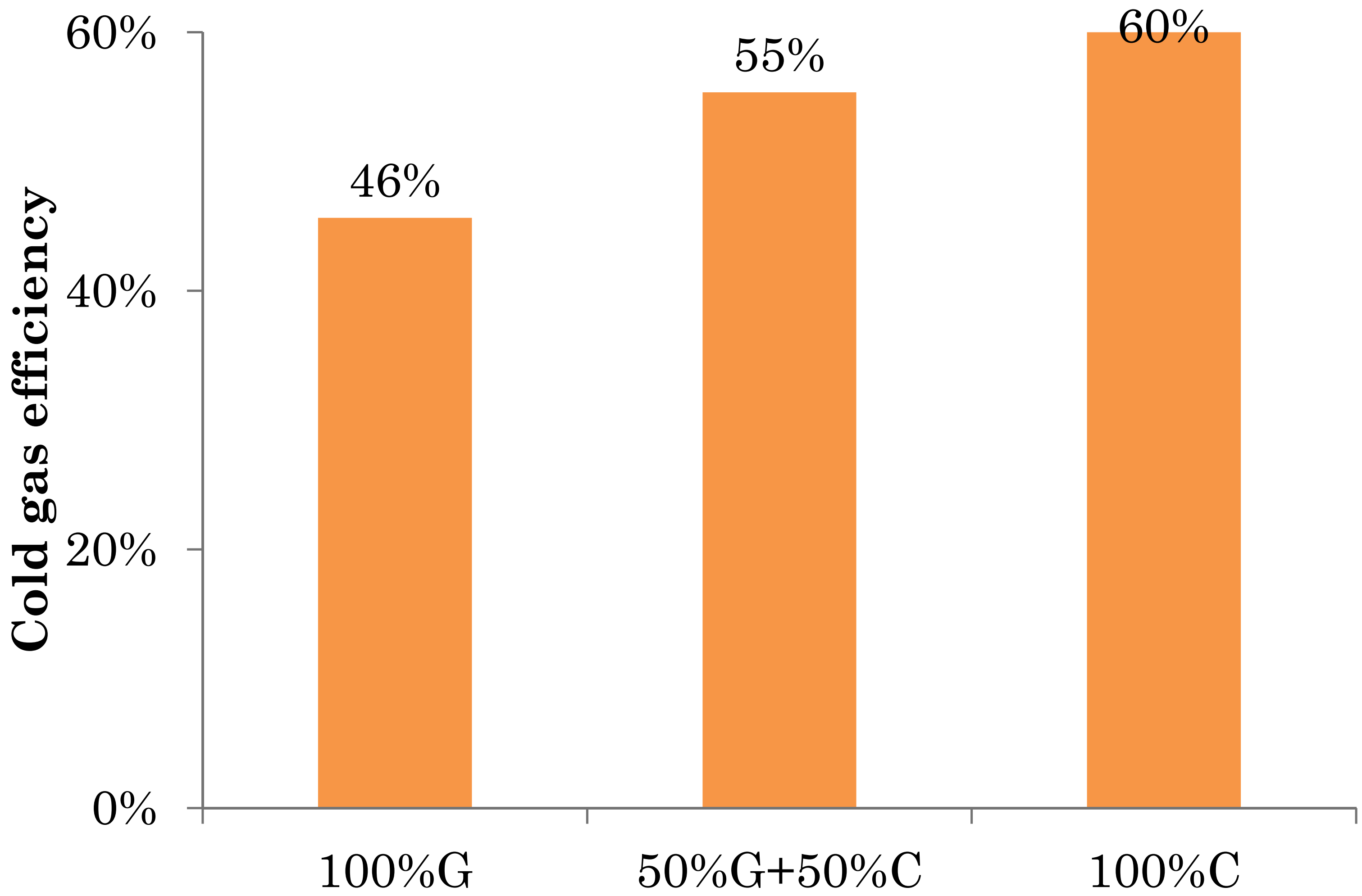


Effect of calcite on conversion efficiency



Effect of calcite on tar concentration

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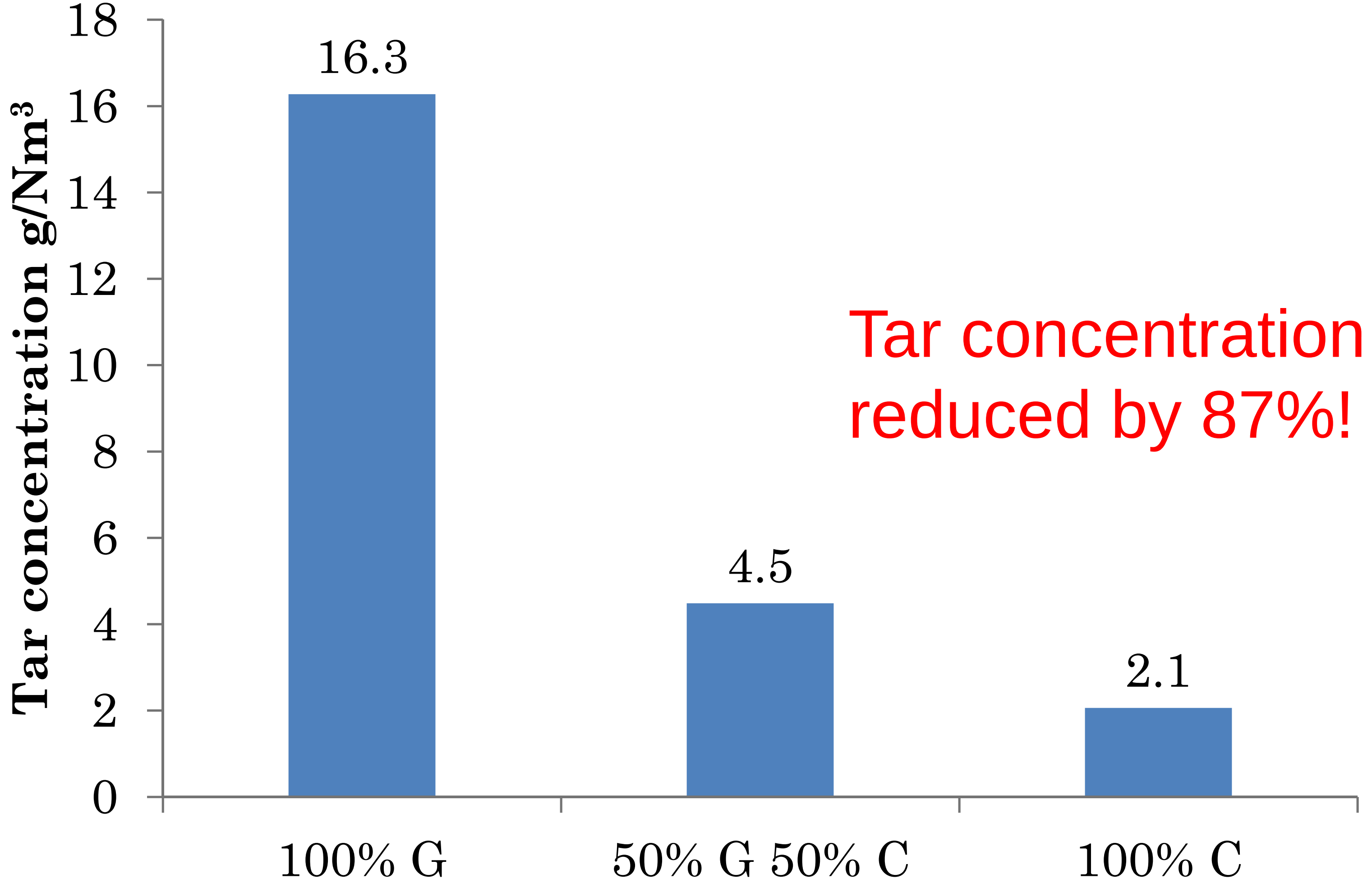

Disadvantage

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- High attrition rate ~3-4 kg/hr

A cold transparent DFB model for hydrodynamic study

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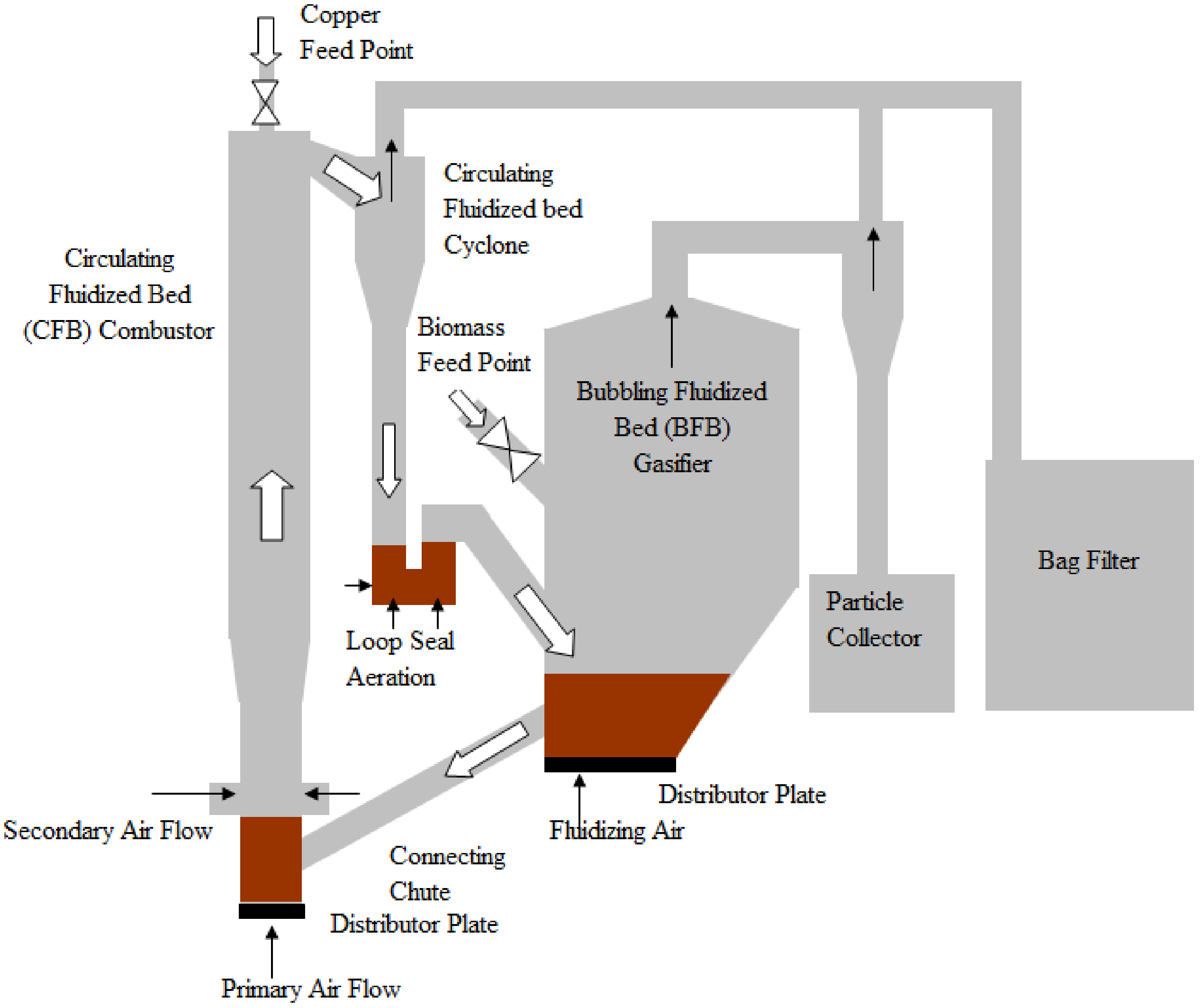
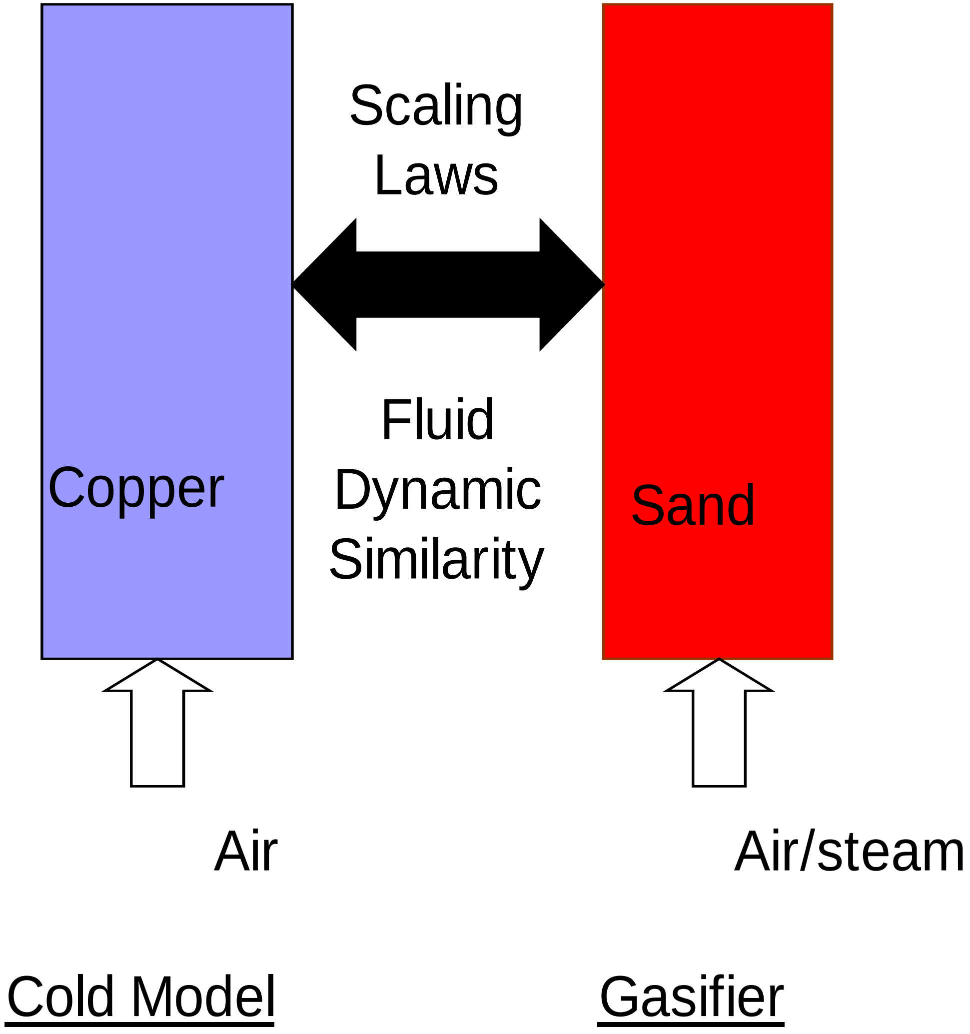
Objective is to develop design tools for scaling up of the DFB gasifier.

- Develop an operational map for steady state operation of the DFB gasifer.
  - Establishing boundaries for primary and secondary airflows in order to achieve required hydrodynamics in the DFB gasifier.
- Predict solid circulation rate in the CFB.
- Investigate effect of airflow on hydrodynamic parameters including pressure drop, solid fraction and flow pattern.

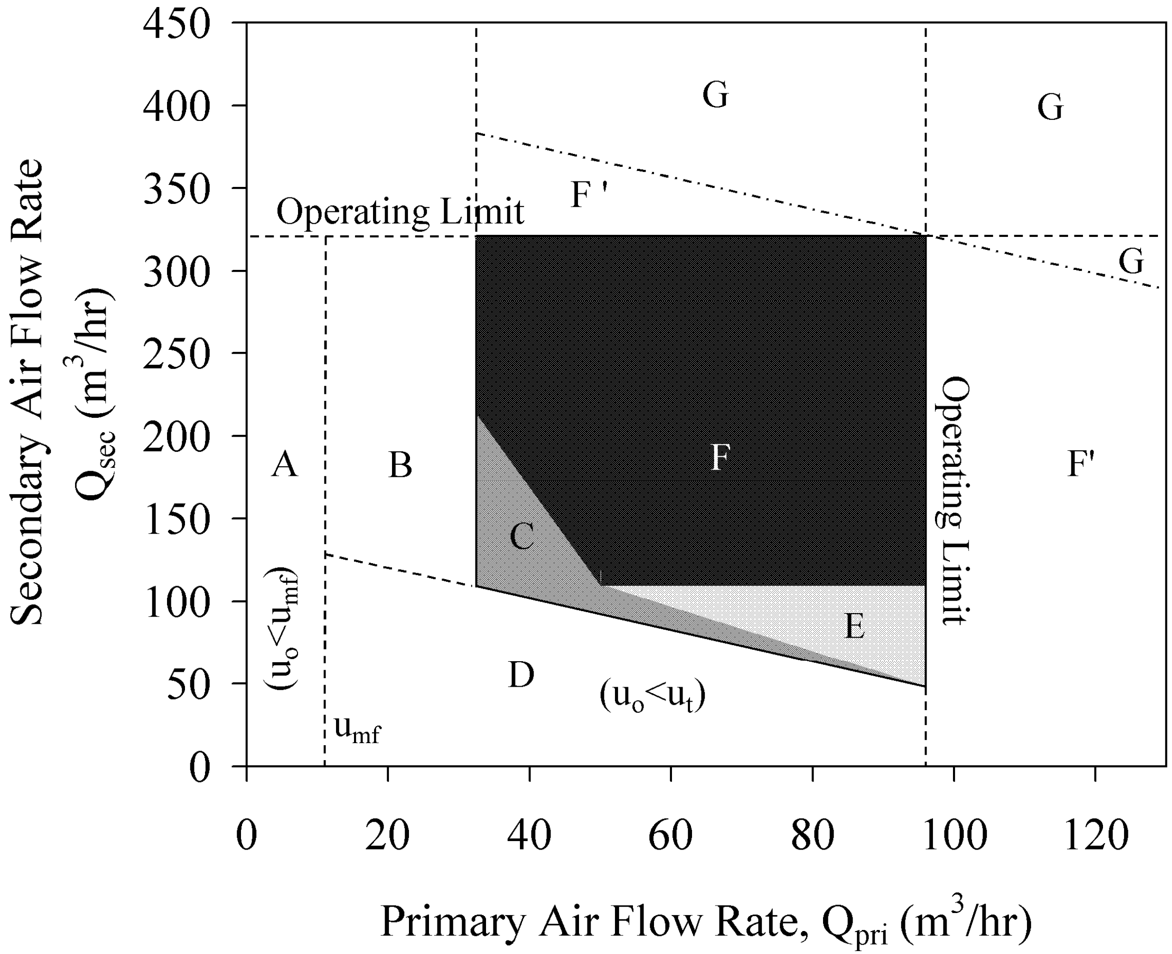
Flow diagram of the DFB cold model



Designing principle of the cold model



Operational map for steady state operation of the CFB



A: No fluidization

B: Slugging

C: Loop-seal bypass

D: Bubbling fluidzation

E: Elutriation regime

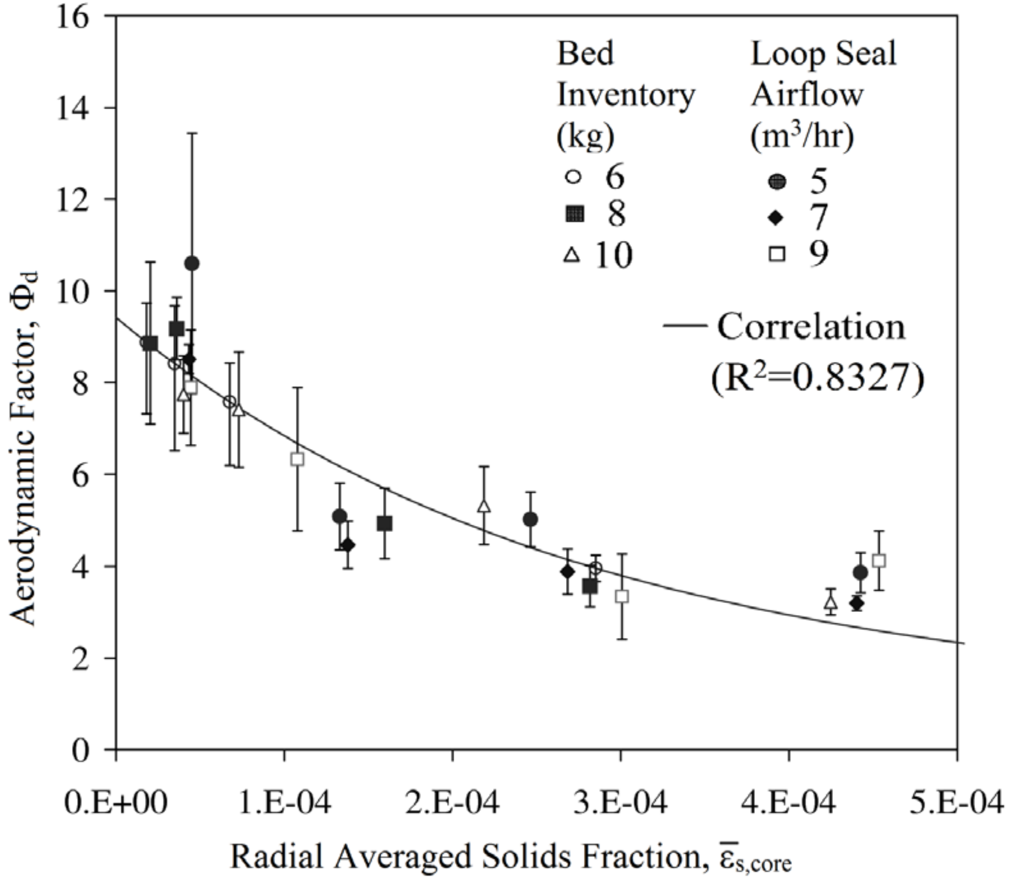
F: Fast fluidization regime

F': Hypothetical fast fluidization regime

G: Loop seal overload

Aerodynamic factor

- For modeling of solid circulation rate in the DFB system



Solid outflow, kg/s

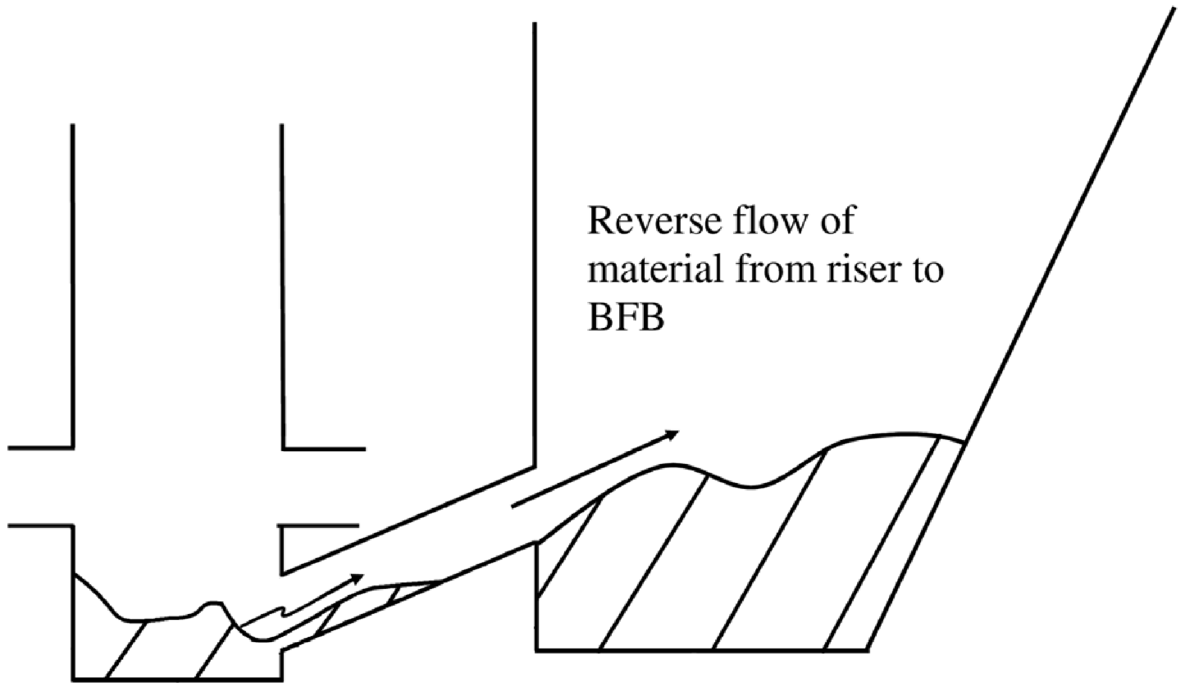
$$\dot{m}_{so} = \Phi_d\left(\frac{w}{\pi D}\right)\dot{m}_{core}$$

$$\Phi_d = \left(\frac{\pi D}{w} - 1\right)exp(-a\bar{\varepsilon}_{s,core}) + 1$$

$\Phi_d =$
- $\pi D / w$ at low solid fraction
- 1.0 at higher solids fraction

Chute bypass condition

- Chute pressure drop should be kept sufficient high (≥200 pa) for steady state operation of the DFB.



Conclusion

- The Government’s renewable energy strategies and related schemes support the research, development & commercialisation of biomass gasification technologies, but not sufficient to attract investors.
- A demonstration project currently in NZ is the Windsor wood waste gasification in Wairaiki Institute of Technology, Rotorua.
- UC and CRL Energy are the research organisations working on biomass gasification.
- The DFB gasifier developed in UC is ready for demonstration in gasification of wood pellets for heat or CHP.

Acknowledgment

- The Ministry of Science and Innovation, New Zealand for the funding to the BTSL programme.
- The research team members of the BTSL programme.