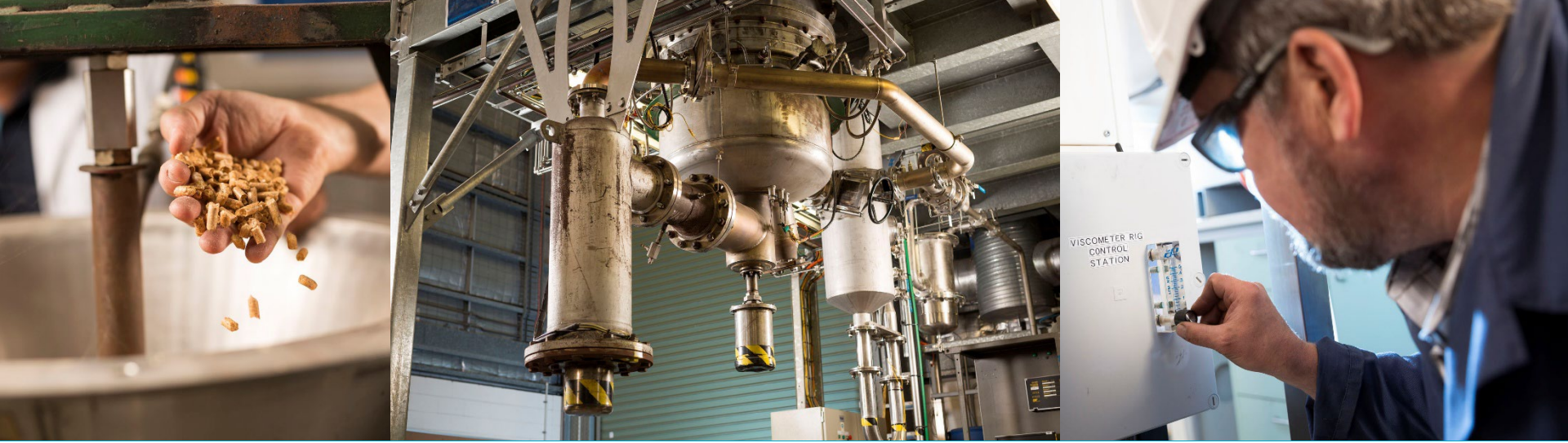


Gasification and syngas potential for biomass and waste feedstocks

Vahid Shadravan, San Shwe Hla, David Harris
CSIRO Energy

Outline

- CSIRO Energy R&D
- Decarbonisation of Australia's energy and industrial systems
  - Sustainable fuels and energy systems
    - Biomass and waste resources (sustainable hydrocarbon pathways)
    - Heavy industry and sustainable liquid fuels (syngas pathways)
- Key enabling technologies
  - Gasification and supply-chain linking challenges
- Scale and pace of transition
  - Facilitating practical industrial demonstration
  - Leveraging established technologies and infrastructure

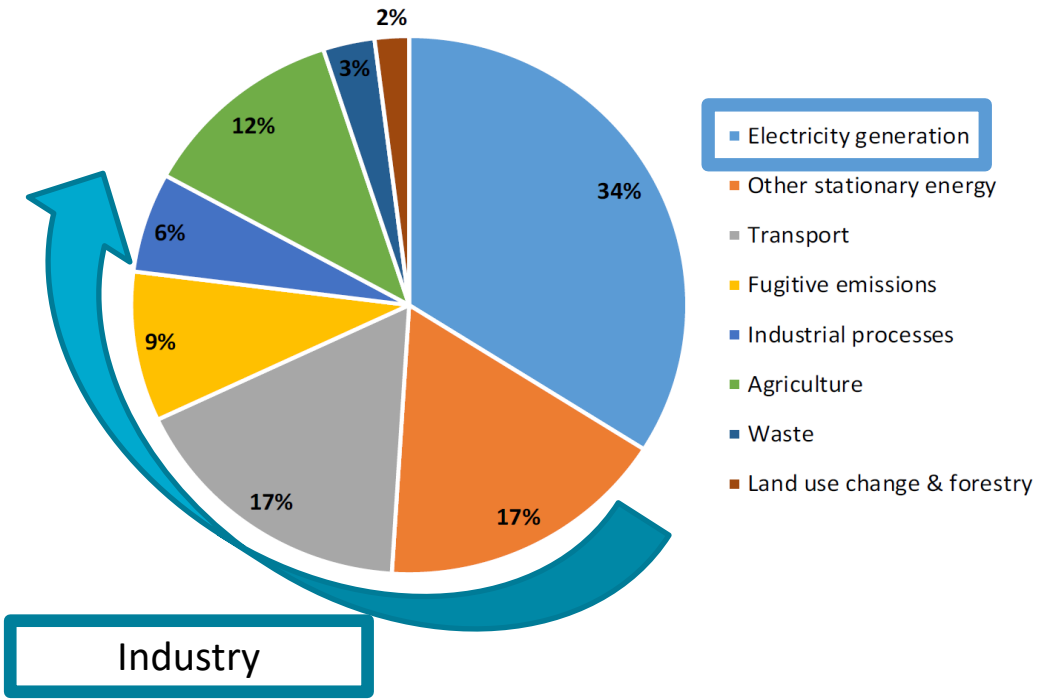
CSIRO Energy R&D:
Sustainable Energy Systems

- **Renewables**
  - Hydrogen and carriers, solar PV, solar thermal
  - **Bioenergy for power, heat, and fuels**
  - Energy storage technologies and systems (electrical, chemical, thermal)
  - New technologies, hybrid systems, and solutions development
  - **Derisking new pathways and value chains**

- **Industrial Decarbonisation**
  - CO_2 capture from industrial processes … and the air
  - CO_2 utilisation pathways
  - **Alternative fuels (e.g. SAF, Ammonia)**
  - **Heavy industry decarbonisation**
  - Hydrogen systems (inc. ammonia)

- **Circular Economy**
  - Battery second life and recycling
  - **Waste management, energy recovery,** and advanced recycling

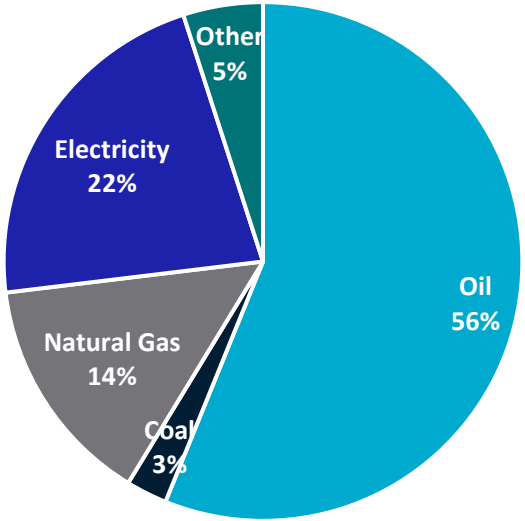
Electricity generation directly accounts for about 1/3 of Australia's CO_2 emissions…



- Major efforts to decarbonise electricity *generation* sector
- 2/3 emissions from transport, agriculture and industrial sectors
  - Decarbonisation via **electrification, sustainable fuels**, **energy storage** (chemical, thermal, battery, hydro…), integration, diversification, efficiency,

Final Energy Consumption in Australia 2022-23

Total energy consumption: 3900 PJ (1083 TWh)

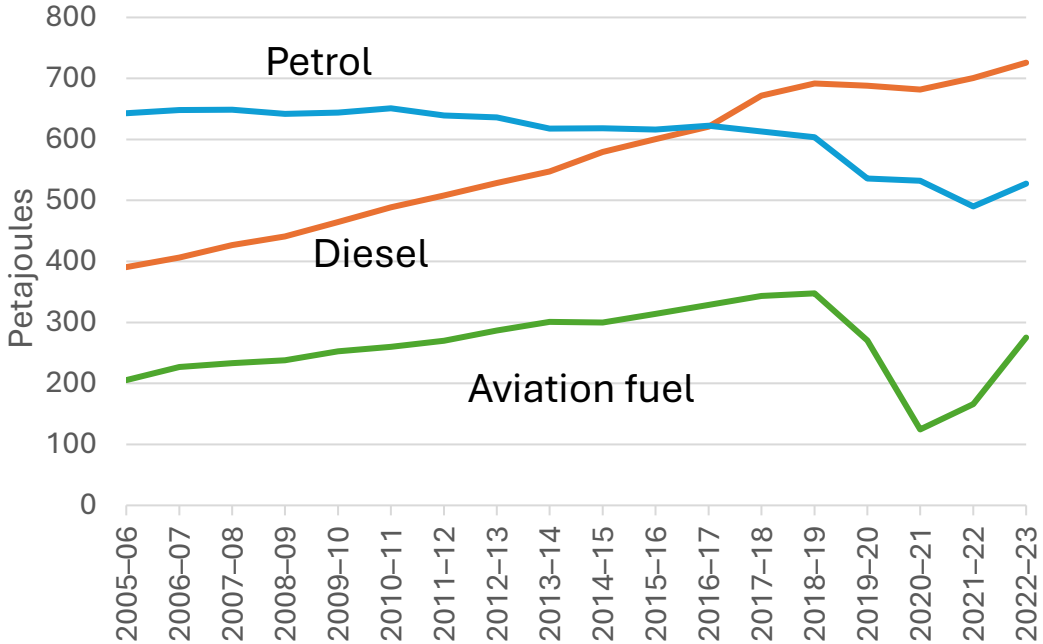


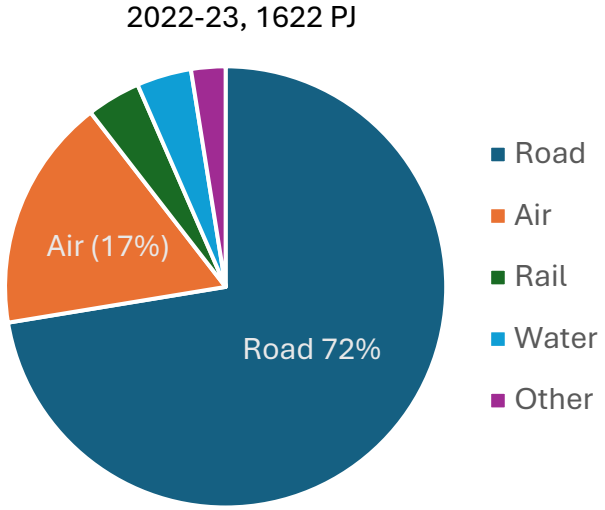
- **Electricity**: 22% (238 TWh)
  - Major efforts to decarbonize electricity generation sector
  - up to 34% of electricity from renewable sources
    - only 7% of total domestic energy use from renewable electricity
- **Transport**: Single largest sector (41%, 1.5% electric)
  - Refined oil & LPG imports: (1846 PJ, 47%)
    - Crude oil imports: (626 PJ, 16%)
- **Major expansion of low emissions power and sustainable fuels essential across all sectors**

NB: 1 PJ ~ 0.278TWh (278GWh)

Source: Australian Energy Statistics, 2024

Australian Transport Fuel consumption (PJ)





- 90% of all Australian liquid fuel is imported

Source: Australian Energy Statistics, 2024

Biomass/Waste Resources in Australia

Australian Biomass and Wastes Resources

AGRICULTURAL BY-PRODUCTS/RESIDUES

- **Wheat straw**
- **Barley straw**
- **Canola straw**
- **Sugarcane trash**
- Oat straw
- Rice straw
- Cereal stubble
- Cotton stalks
- Animal farm manure
- Fish farm residues

FORESTRY BY-PRODUCTS/RESIDUES

- Top stem
- Branch
- Bark
- Leaves/twigs

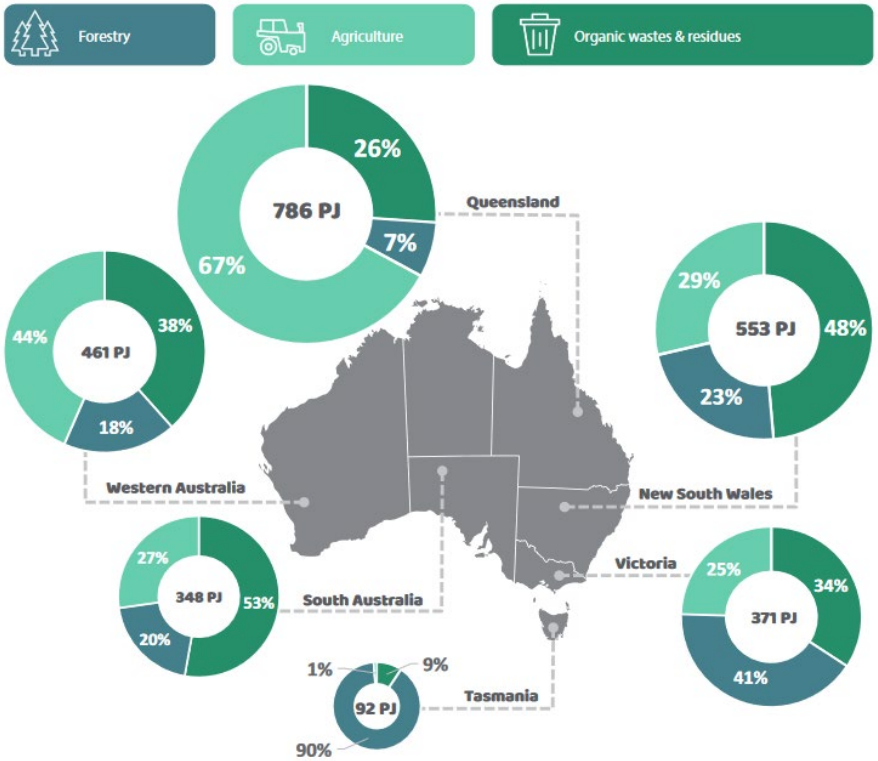
INDUSTRY-PROCESSING BY-PRODUCTS/WASTES

- **Wood chips**
- **Sawdust → wood pellets**
- **Bagasse**
- Woody wastes
- Rice husk
- Cotton gin
- Macadamia nuts

WASTES

- **Municipal Solid Waste (MSW)**
- **Commercial and Industrial Waste (C&I)**
- **Construction and Demolition (C&D)**
- Green Wastes and Biosolids

Australia’s bioenergy resource ‘potential’



- Total 2,600 PJ per year
- 40% of Australia’s current primary energy supply
- 10 times current bioenergy production

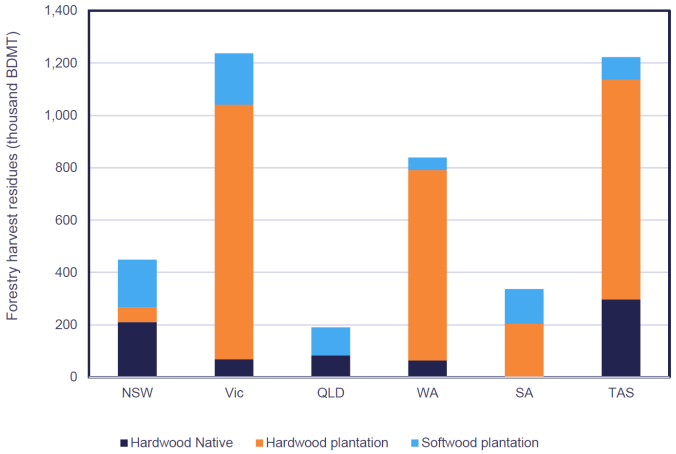
Source: ARENA Australia’s Energy Roadmap, 2020

Forestry By-products/Residues

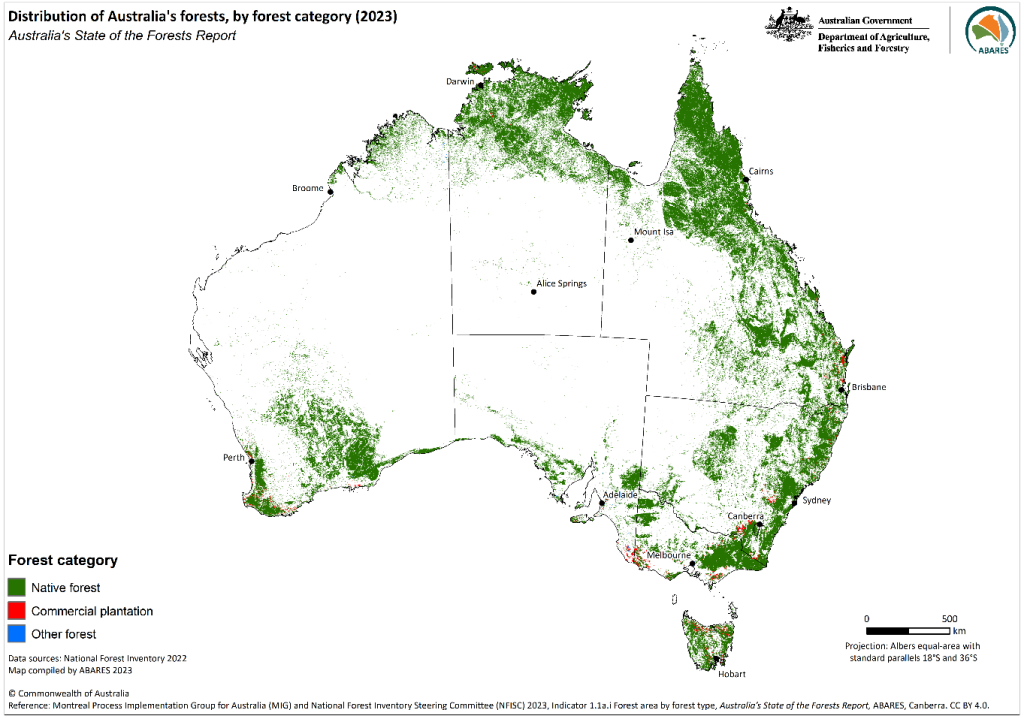
Understanding Harvest Residues

	Timber Products	Forest residue proportion by type			
		Cone/ Stump	Bark	Branches	Needels/ Foliage
Softwood	81.2%	1.9%	0.8%	12.2%	3.9%
Hardwood	42.5%	10%	7.5%	34%	6%

Estimated Quantities of Harvest Residues



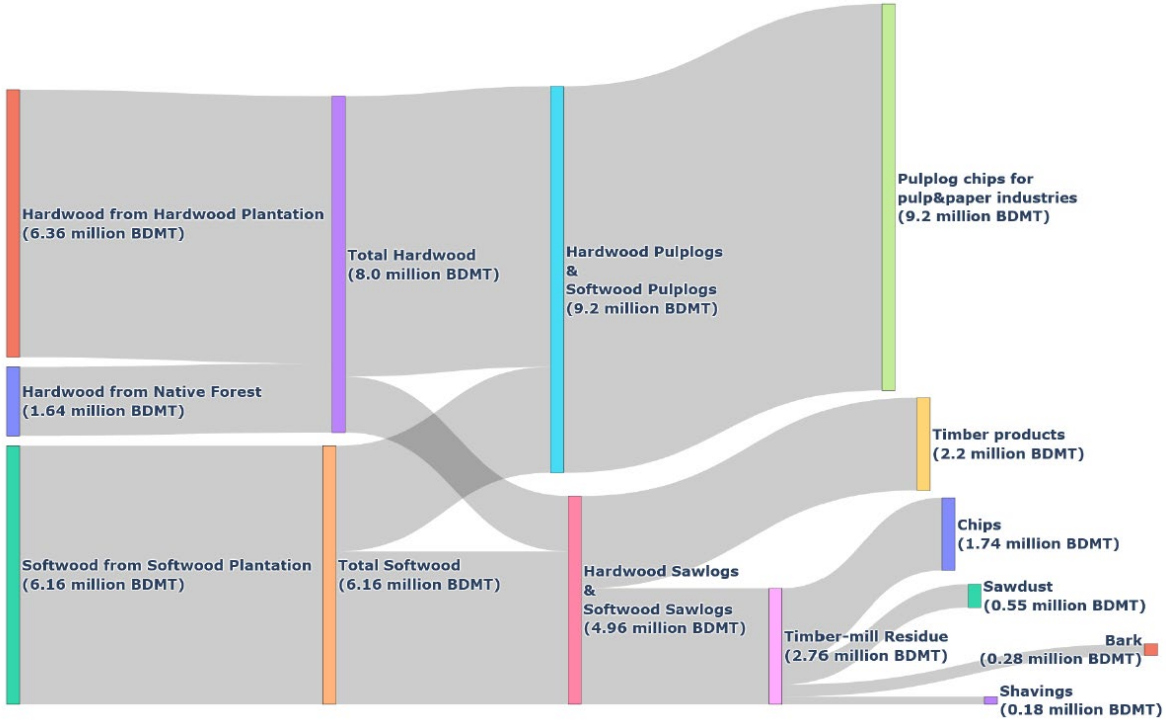
Distribution of Australia's Forests



Department of Agriculture Fisheries and Forestry. Australia's forests. 2023.

Industry-processing By-products/Wastes

Wood and Timber Industry



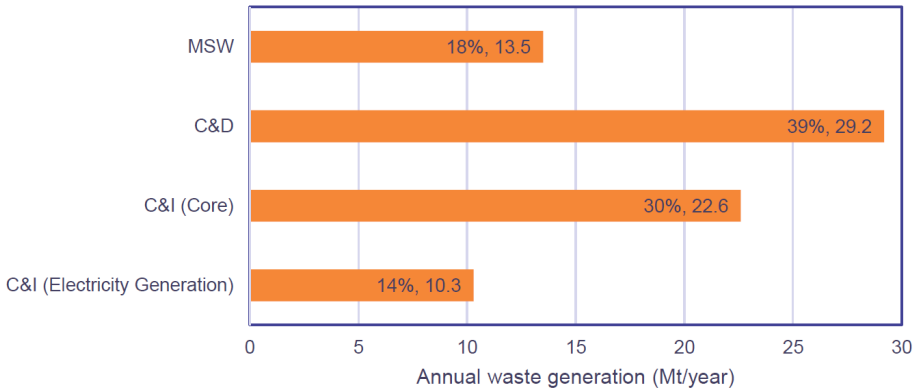
Sugar Industry

Estimated sugarcane bagasse based on sugarcane fibre content (million tonnes /year)	
QLD	9.54
NSW	0.41
Total	**9.95**

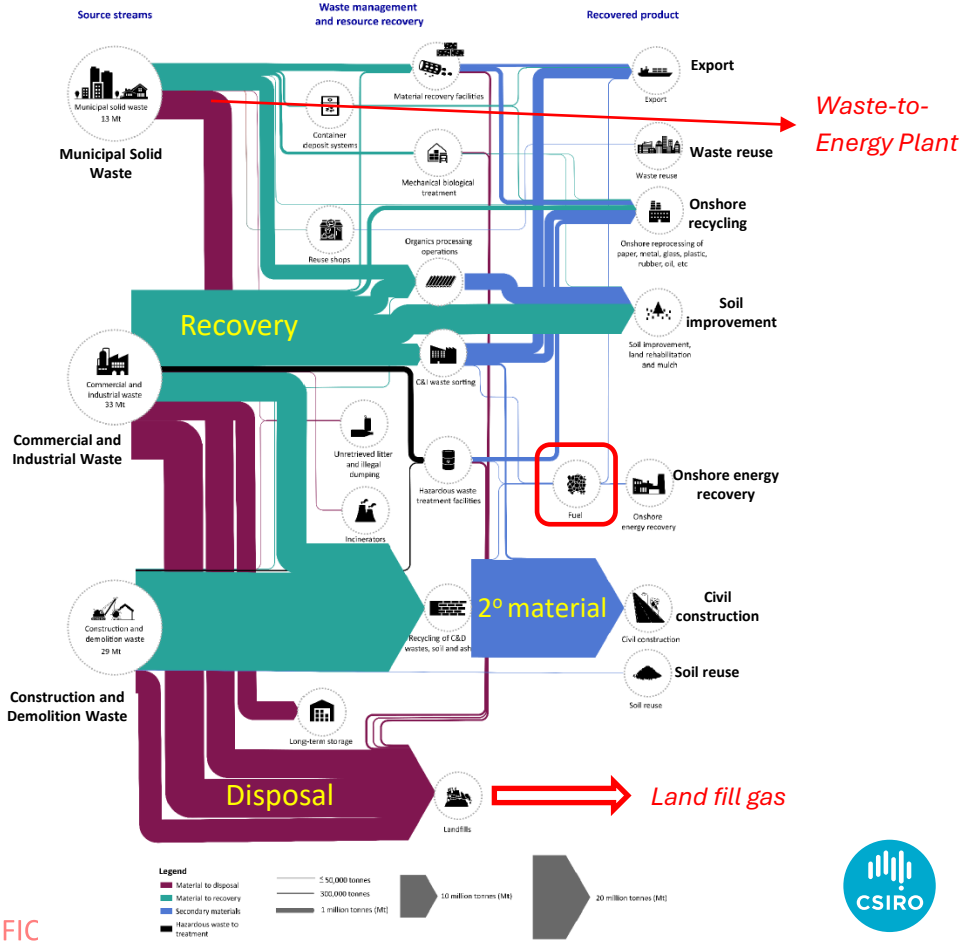
Sugar Milling Council. Raw Sugar Industry Overview. 2025

Wastes

Australian Waste Streams (~75Mtpa)



Current management and utilisation of wastes



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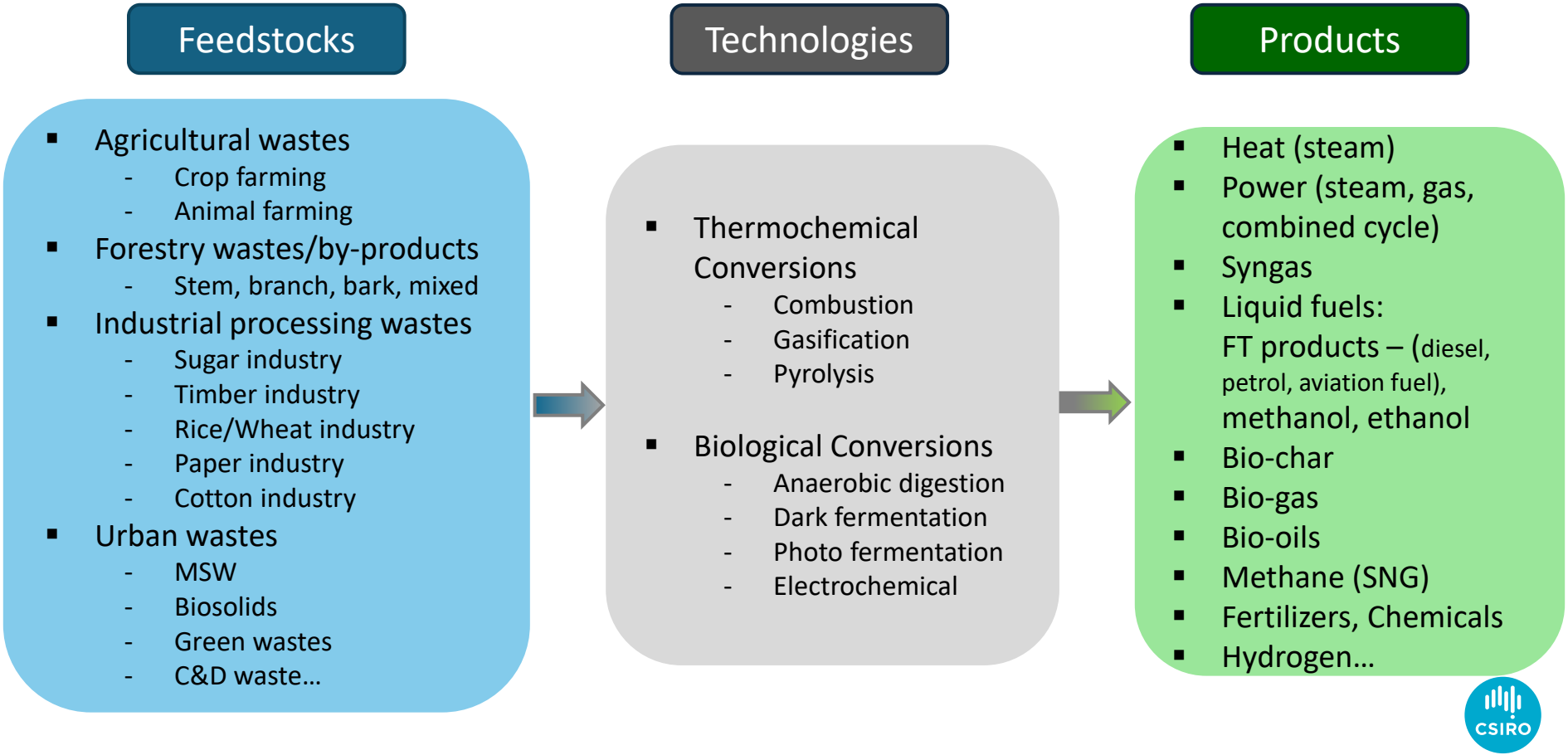
CSIRO Capabilities in Biomass/Waste Gasification Research

Biomass/Waste to Bioenergy Routes



Challenges for biomass and bioenergy

- **Issues with nature of biomass**
  - Understanding of chemical and physical characteristics of biomass and wastes
  - Dispersed availability of biomass and low energy density
  - Transportation and Storage
  - Feedstock preparation (incl blending, multiple and mixed feedstocks)

- **Technical Issues**
  - Technology dependent
    - Tars
    - Gas cleaning
    - Plant efficiency
    - Scaling up

- **The difficult phase between demonstration and commercial application**
  - Opportunity to collaborate internationally
- Markets for biomass gasification/conversion have been highly dependent on niche applications
  - **New challenges in application to large scale industries** (global oil and gas sector scale)

TUF fixed bed gasifier test facility

CSIRO Biomass & Waste-to-Energy Research

Feedstocks

- Forestry Waste
- Agricultural Residues
- Urban Waste
- Industrial Process Waste, C&D etc

Science & Research Areas

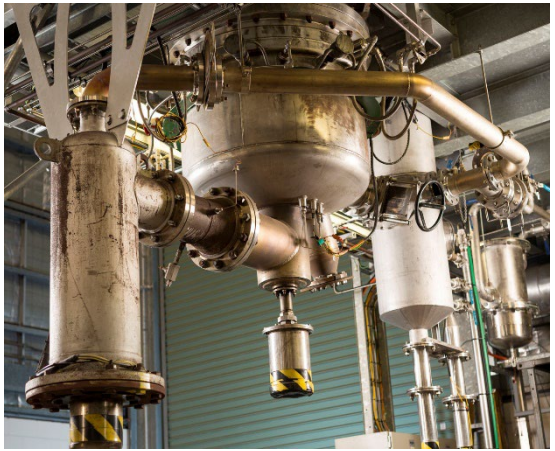
- **Understanding of biomass:** Fundamental Chemical analysis
- **Gasification reaction science:** devolatilisation, char formation, heterogeneous kinetics, high temperature processes
- **Inorganic chemistry:** slag formation and flow; mineral matter and trace element transformations, speciation, and behaviour; chemistry of residues and ash
- **Modelling:** Gasifier, process models, Techno-economic, LCA
- **Scale:** Technical and pilot-scale studies of feedstock behaviour

Applications

- Supporting pilot-scale R&D and commissioning studies
- R&D in support of technology development
- Matching feedstocks to gasifiers, feedstock requirements
- Supporting gasifier design, optimisation, troubleshooting
- Developing solutions for remote or off-grid applications

Gasification experience, facilities & capabilities

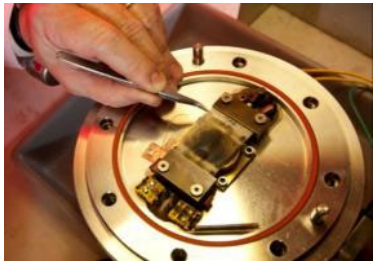
Pressurised Entrained Flow Reactor (PEFR)



Biomass Gasifier (Fixed bed)

Slag viscosity testing

Vertical drop tube furnaces



Wire-mesh reactor

Fixed bed reactor

Pressurised TGA

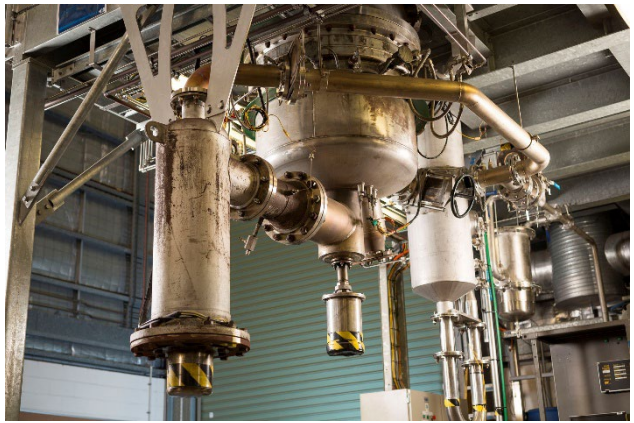
Biomass Gasifier and Syngas Processing

- Fixed-bed gasifier suitable to process different biomass and waste.
- Multiple stage syngas cleaning and conditioning.
- Capabilities to upgrade syngas.

Biomass/waste feed rate:
50 – 70 kg/h

Raw syngas production rate:
80 – 140 Sm^3/h
(100 – 170 kg/h)

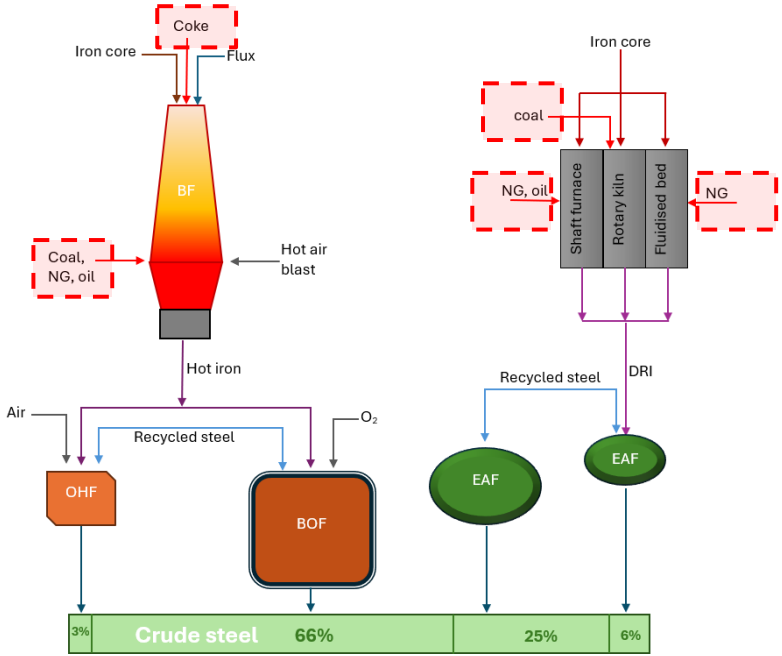
Temperature:
900 – 1100 °C



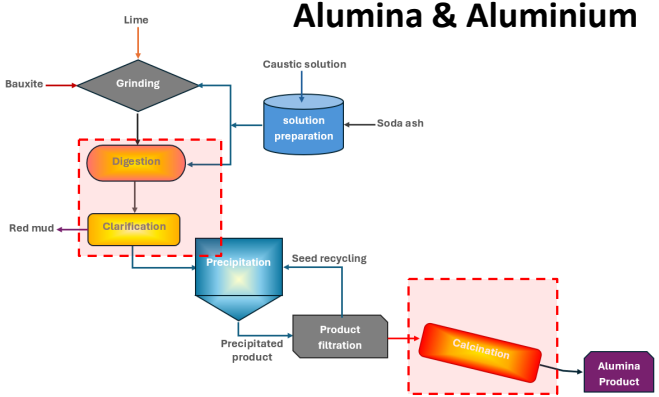
Biomass/Waste-Derived Syngas for Heavy Industries

Potential Applications in Heavy Industries

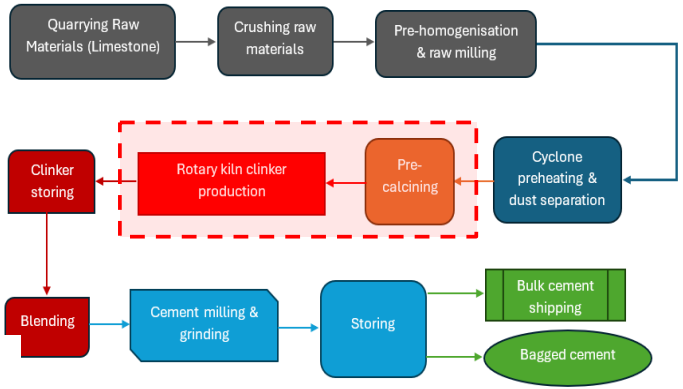
Iron & Steel



Alumina & Aluminium



Cement & Lime



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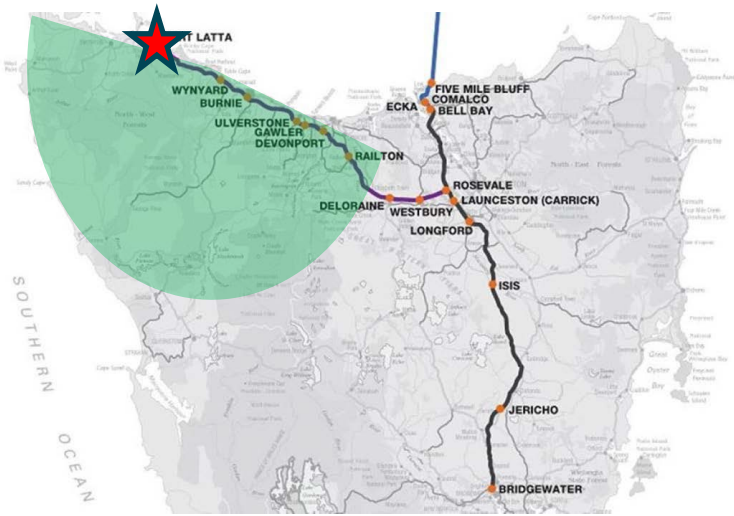
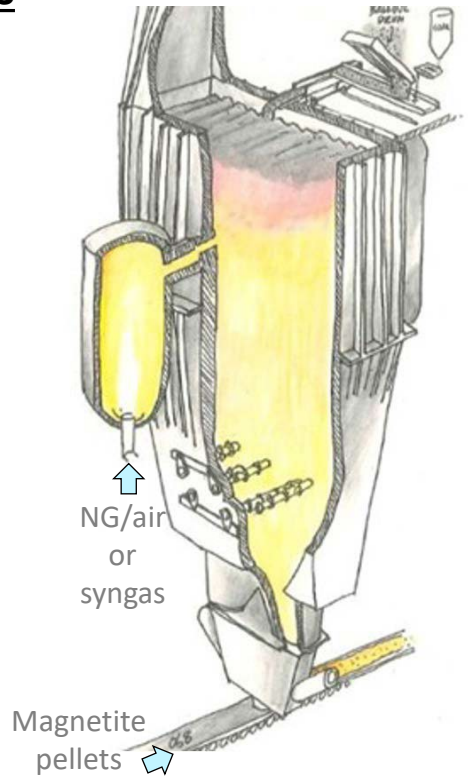
Case Study 1: Magnetite Pelletising Plant

Using syngas from gasification of **forestry biomass** as fuel for **pelletising furnace**:

- *Local biomass supply chain*
- *Gasifier and furnace modelling and integration*
- *Emission reduction evaluation*





Case Study 2: Alumina Refinery

Using syngas from gasification of **forestry biomass** as fuel for **alumina calciner**:

- *Local biomass supply chain*
- *Gasifier and furnace modelling and integration*
- *Emission reduction evaluation*

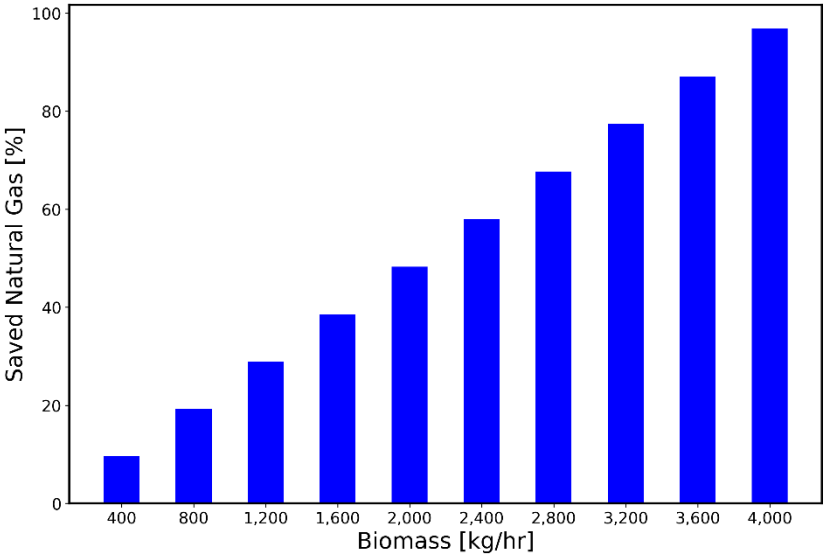
Pine plantation

Ecological thinning

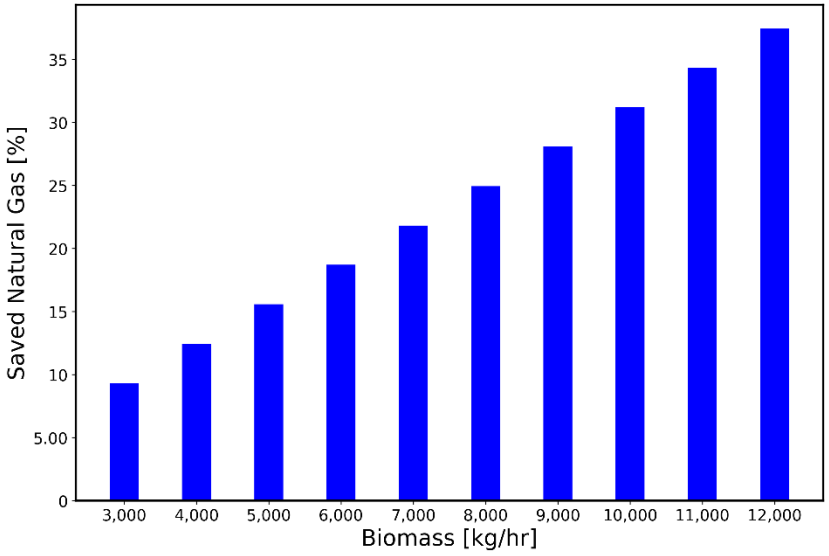
Natural Gas Reduction vs Biomass Utilisation

Estimated reduction in natural gas consumption based on varying amounts of forestry residue biomass, up to the maximum available biomass for each case study.

Case Study 1 (Magnetite pellets)



Case Study 2 (Alumina refinery)



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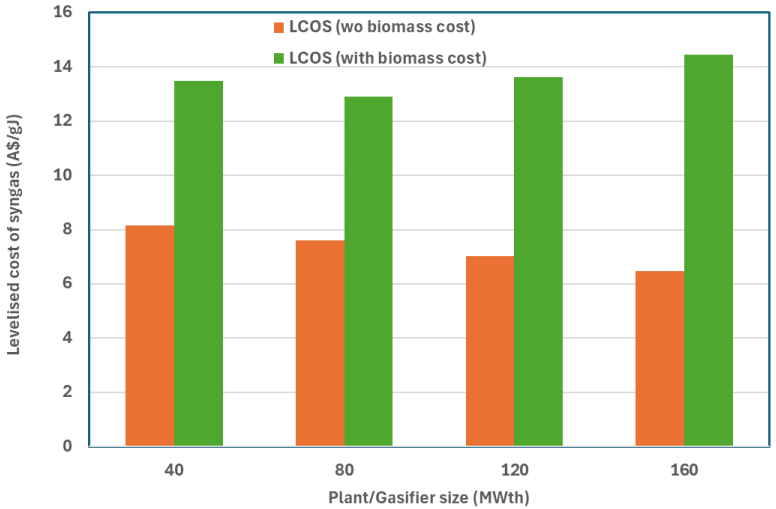
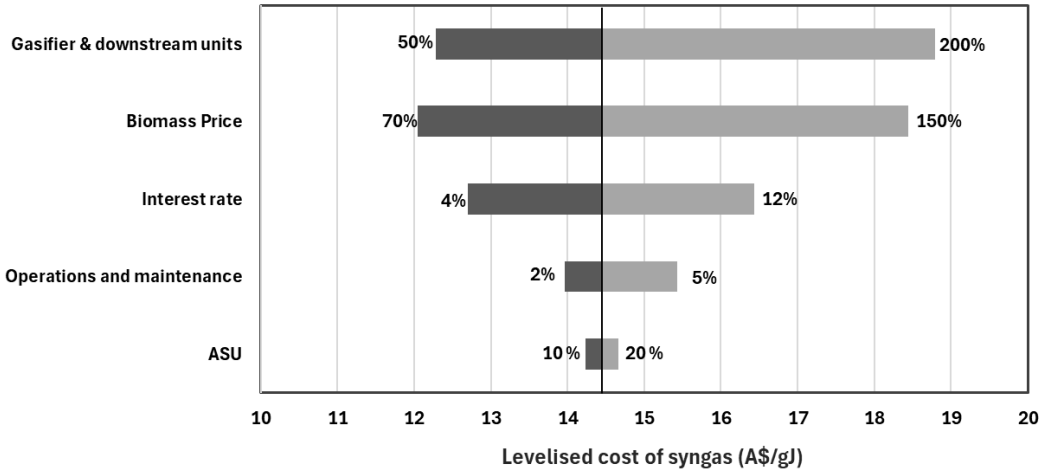
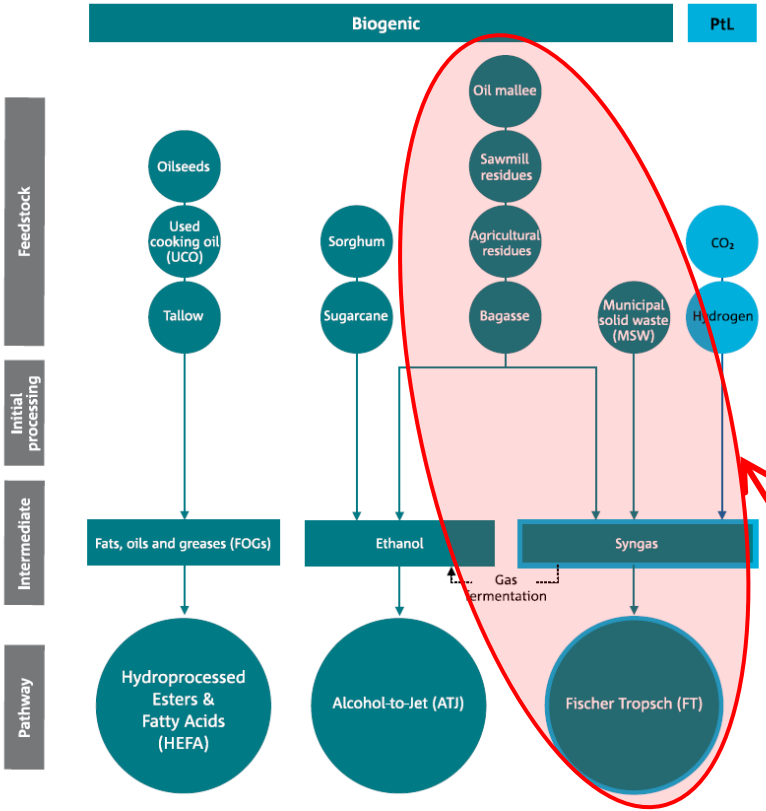
High Level Economic Study for Case Studies



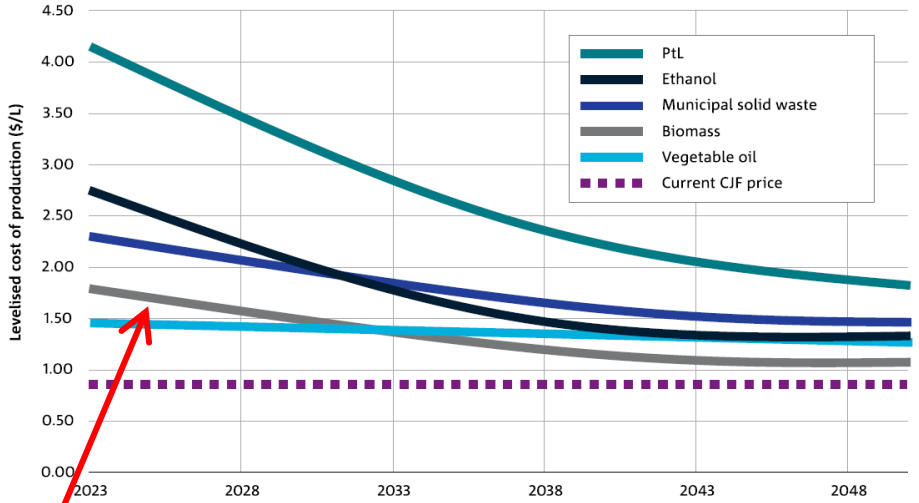


Biomass/Waste to Low Carbon Liquid Fuels – e.g., SAF

Identified SAF Production Pathways



Projected levelised cost of production for five key feedstocks

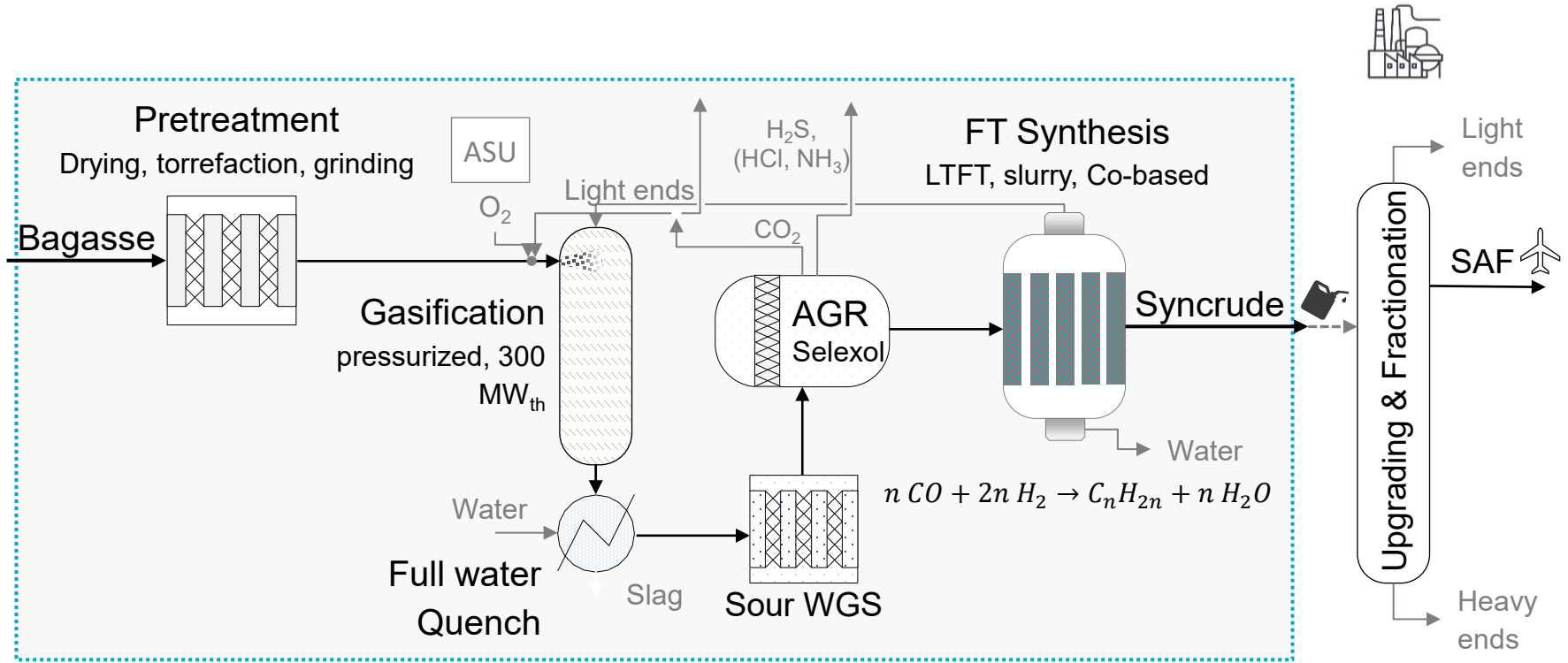


Biomass-to-Liquid via Gasification

CSIRO Sustainable Aviation Fuel Roadmap 2023

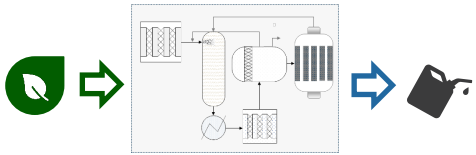
Process Modelling

Bagasse to Syncrude via FT

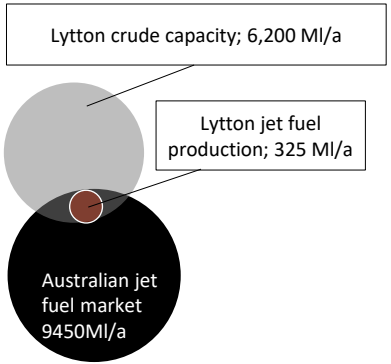


SAF Potentials in Queensland from Sugar Cane Residues

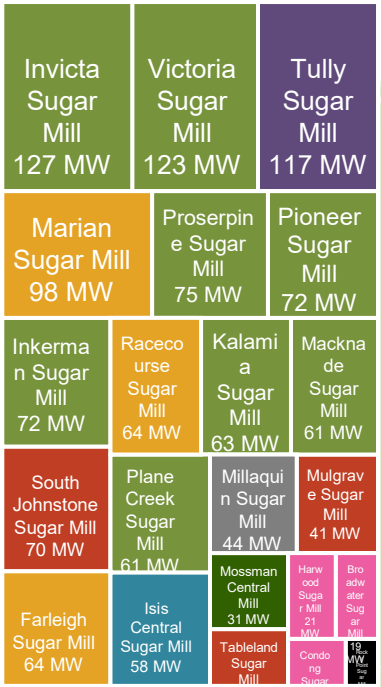
- QLD's sugar industry produces ~ **2.1 Mt_{dry}/a surplus bagasse**

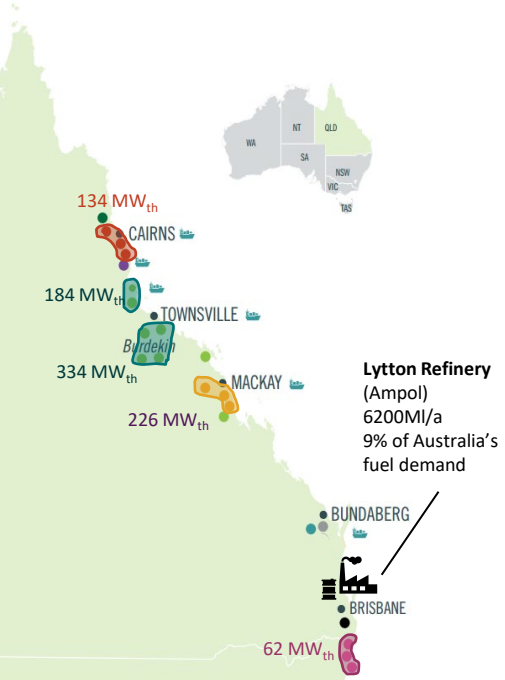


Product yield: 0.166 t_{fuel}/ $t_{Biomass,dry}$



- Fuel production potential from Qld surplus bagasse using BtL: **440 $Ml_{FT\ fuel}$/a**
- ~75% of QLD's surplus bagasse could substitute Lytton's jet fuel production
- **All** of QLD's bagasse (~10Mtpa or ~1320 $Ml_{FT\ fuel}$/a) could substitute:
  - ~10-14% of Australia's jet fuel (9450Ml/a)
  - ~ 70-90% of QLD's jet fuel (~1500-2000 $Ml_{jet\ fuel}$/a)



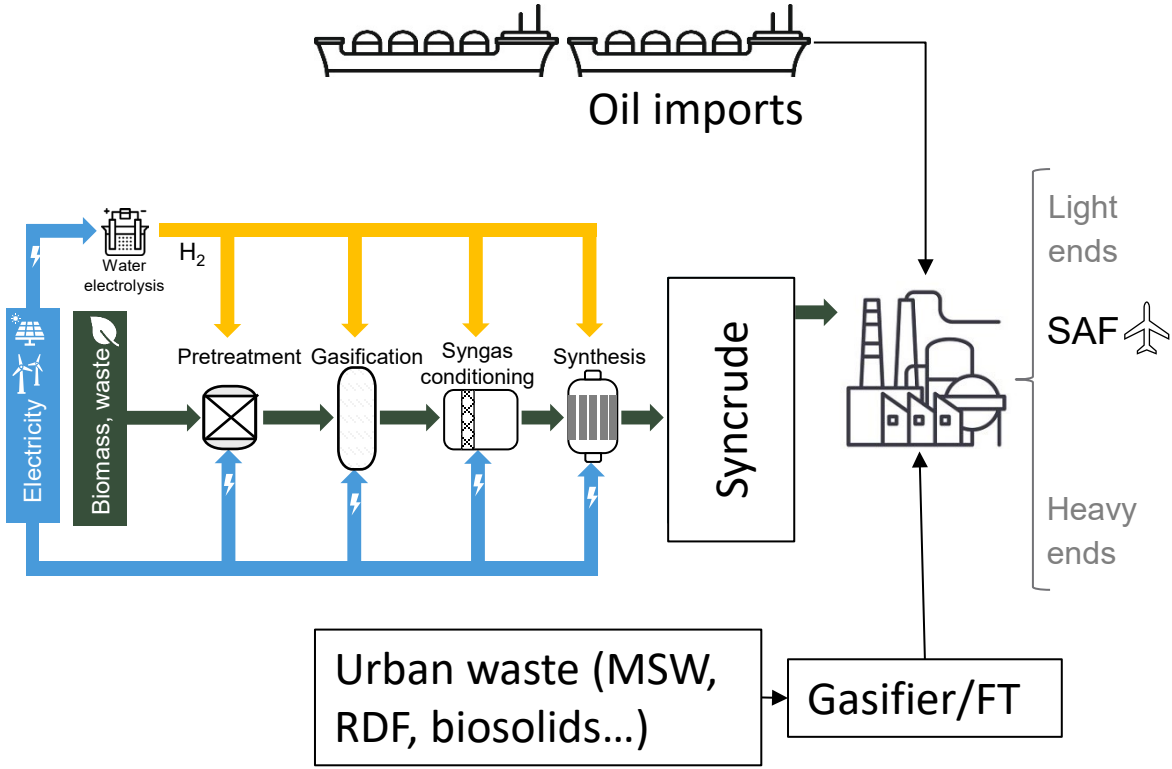


Calculated assuming $LHV_{bagasse,dry}$=19MJ/kg ~200l/t bagasse

Modified map from: https://asmc.com.au//

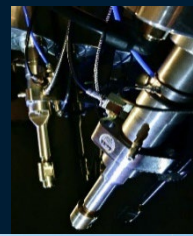
Transitioning refinery feedstock

- Challenge is to transition global petroleum industry to *sustainable* products
- Goal is to transition *feedstocks*
  - **Focus on feedstock consolidation, preparation, gasification**
  - Downstream (syngas) chemistry remains essentially the same
  - Syncrude can be a universal (transportable) intermediate
- Leverage global infrastructure capacity and knowhow
  - Pilot and demo projects
  - Commercial trials
- International syncrude export/ import markets
- Scope for new and niche technologies where logistics require
  - Syngas to alcohol, gasoline etc mature
  - Power to fuels integration etc (eg Sasol ecoFT)

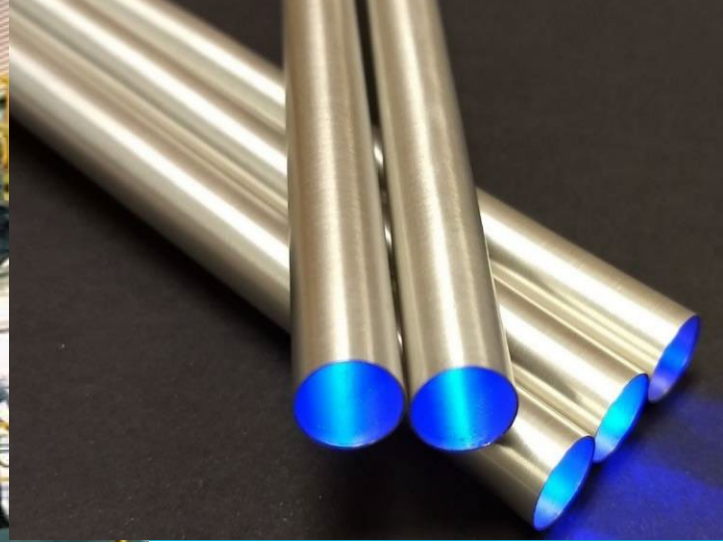


Progressing sustainable energy opportunities

- **Sustainable biomass and renewable energy systems are capable of leveraging existing technologies and infrastructure to support cross-sector decarbonisation goals at scale**
- **Existing heavy industries and technologies could integrate renewable feedstocks**
  - Alignment of resources and scale is key
  - Replacement of fossil fuels with sustainable syngas
- **Sustainable hydrocarbon fuel supply chains are critical in key sectors (eg aviation)**
  - The Australian biomass and waste sectors are well placed to support initial stages of transition through consolidation and synergistic development of biomass and waste to fuels systems
  - Opportunities to leverage with other agricultural industries, MSW, biosolids and urban waste streams
  - Opportunities for syncrude industry to utilise existing global refining capacity
- National and international partnerships are needed to facilitate research, development, **demonstration and deployment**







Thank you

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