

Coal in Australia: The journey from the bedrock of our economy to ...

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CSIRO ENERGY
www.csiro.au

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Overview

Introduction

- CSIRO, and our Energy research programs

Coal and Energy in Australia

- Australia's role as a coal producer and exporter
- Coal's role in our electricity supply

The ever-evolving roles of 'next generation' coal

- NO_x/SO_x/PM emissions, efficiency and cost, CO₂ intensity, CCS, HELE ...

Where to from here?

- Public opinion is not supporting more coal, industry is not planning for more coal.

Disclaimer: this is a researcher's perspective!



CSIRO

Australia's national science agency



Team CSIRO

5486
staff

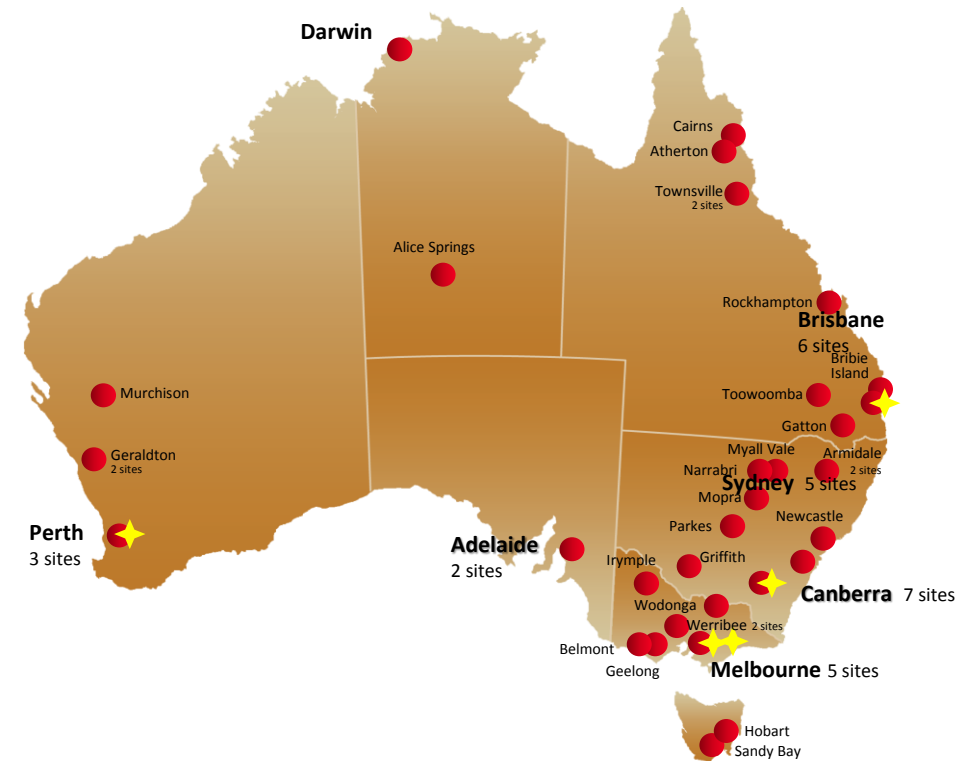
\$1billion+
budget

Working
with over
2800+
industry
partners

55
sites across
Australia

Top 1%
of global
research
agencies

Each year
6 CSIRO
technologies
contribute
\$5 billion
to the economy



Our business units and focus areas

 Agriculture and Food

 Energy

 Health and Biosecurity

 Land and Water

 Manufacturing

 Mineral Resources

 Oceans and Atmosphere

 Astronomy and Space Science

 Australian Animal Health Laboratory

 Data61

 Marine National Facility

 National Computing Infrastructure

 National Research Collections of Australia

CSIRO Energy

Five Research Programs

Grids and Energy Efficiency Systems

- Modelling, demand side technologies, energy efficiency

Coal Mining

- Safety, environment, new technologies for efficiency and productivity

Oil, Gas and Fuels

- Resource exploration and extraction, gas processing, CO₂ storage

Low Emissions Technology

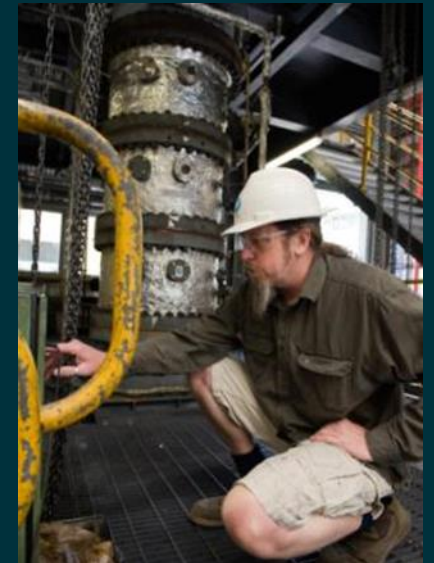
- Solar PV, solar thermal, emissions and CO₂ capture, gasification, fuel cells, hybrid systems, storage, DICE, PCC ...

Unconventional Gas

- Environmental, social, and technical aspects of 'on shore gas'.



Coal and Energy in Australia



Australian Energy Update 2016

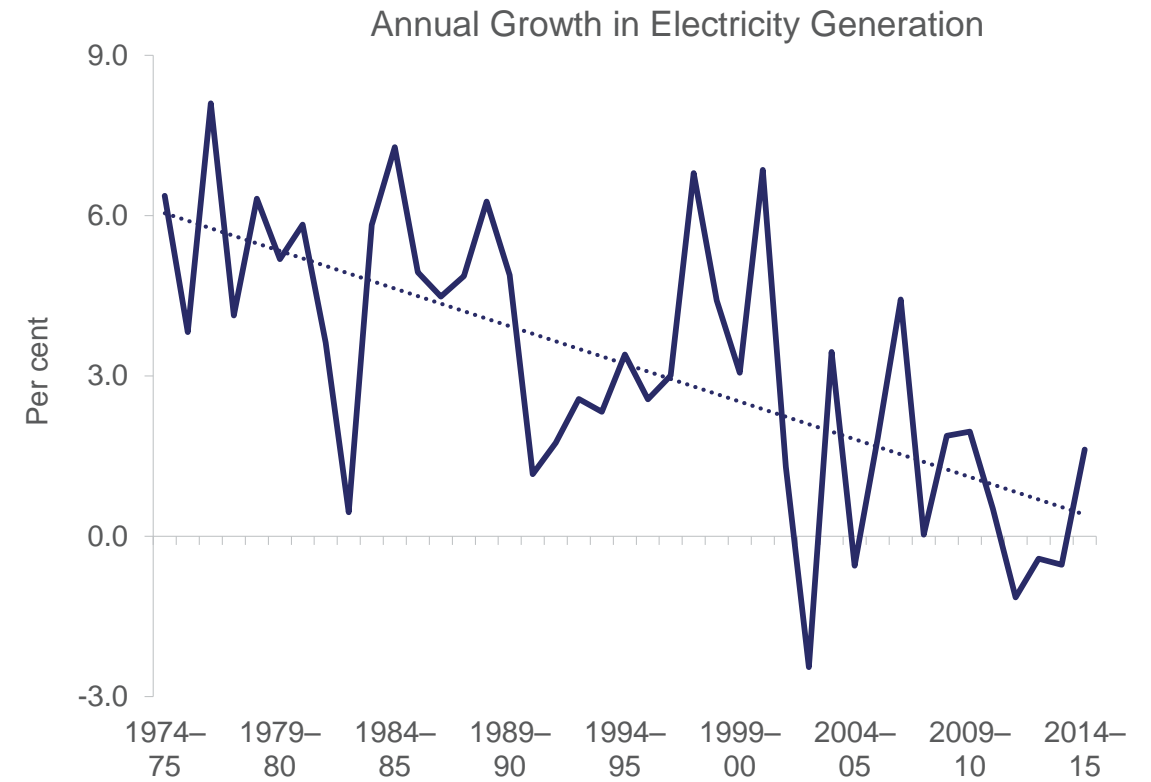
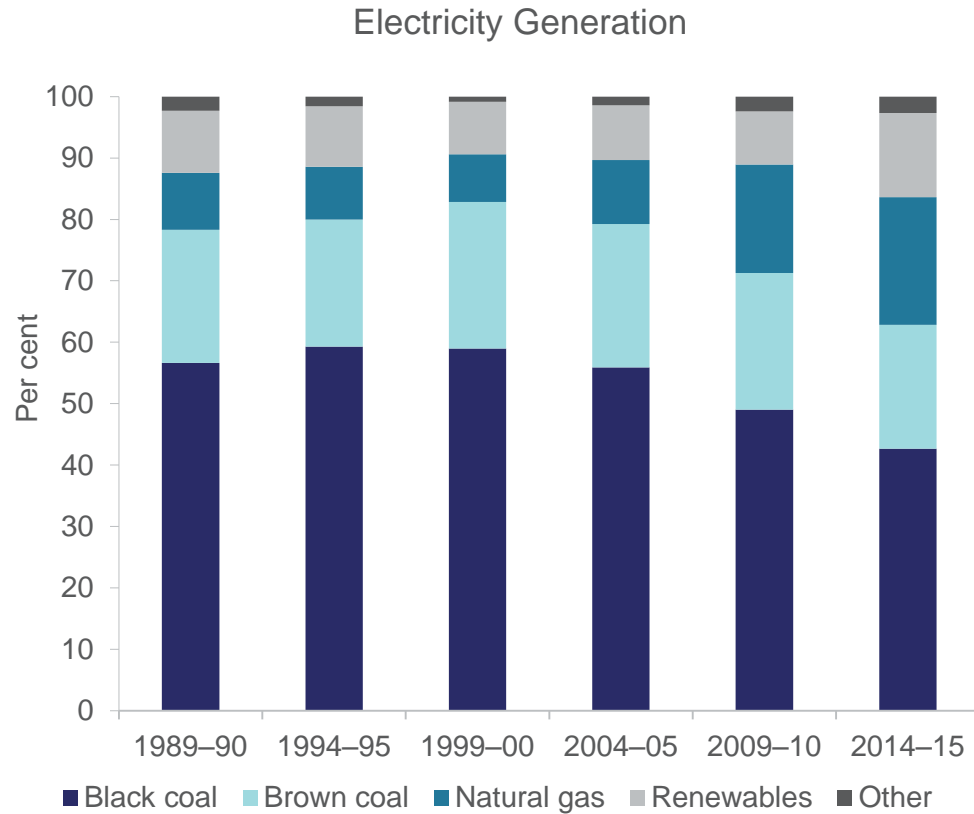
Electricity Generation

- Electricity generation rose by 2% to 252 TWh (908 PJ), following three years of decline.
- Brown coal generation rose by 11% in 2014–15, while black coal rose by 2%, with coal accounting for 63% of total generation.
- Renewable generation fell by 7% in 2014–15, comprising 14% of total generation in Australia – mostly due to hydro (fell by 27% due to weather)
- Wind and solar continued to grow, with wind now one-third of renewable generation in Australia and one-third of total generation in South Australia.

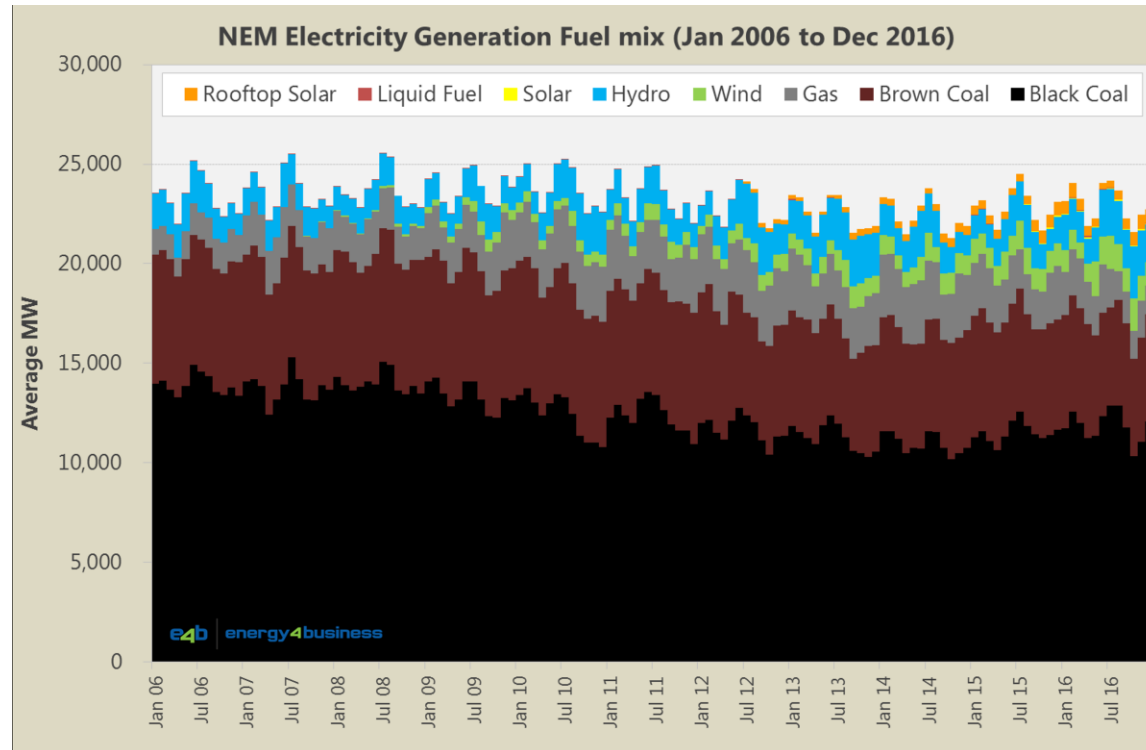


Australian Government
Department of Industry,
Innovation and Science. *Australian
Energy Update, 2016.*

Electricity Generation



Electricity Generation



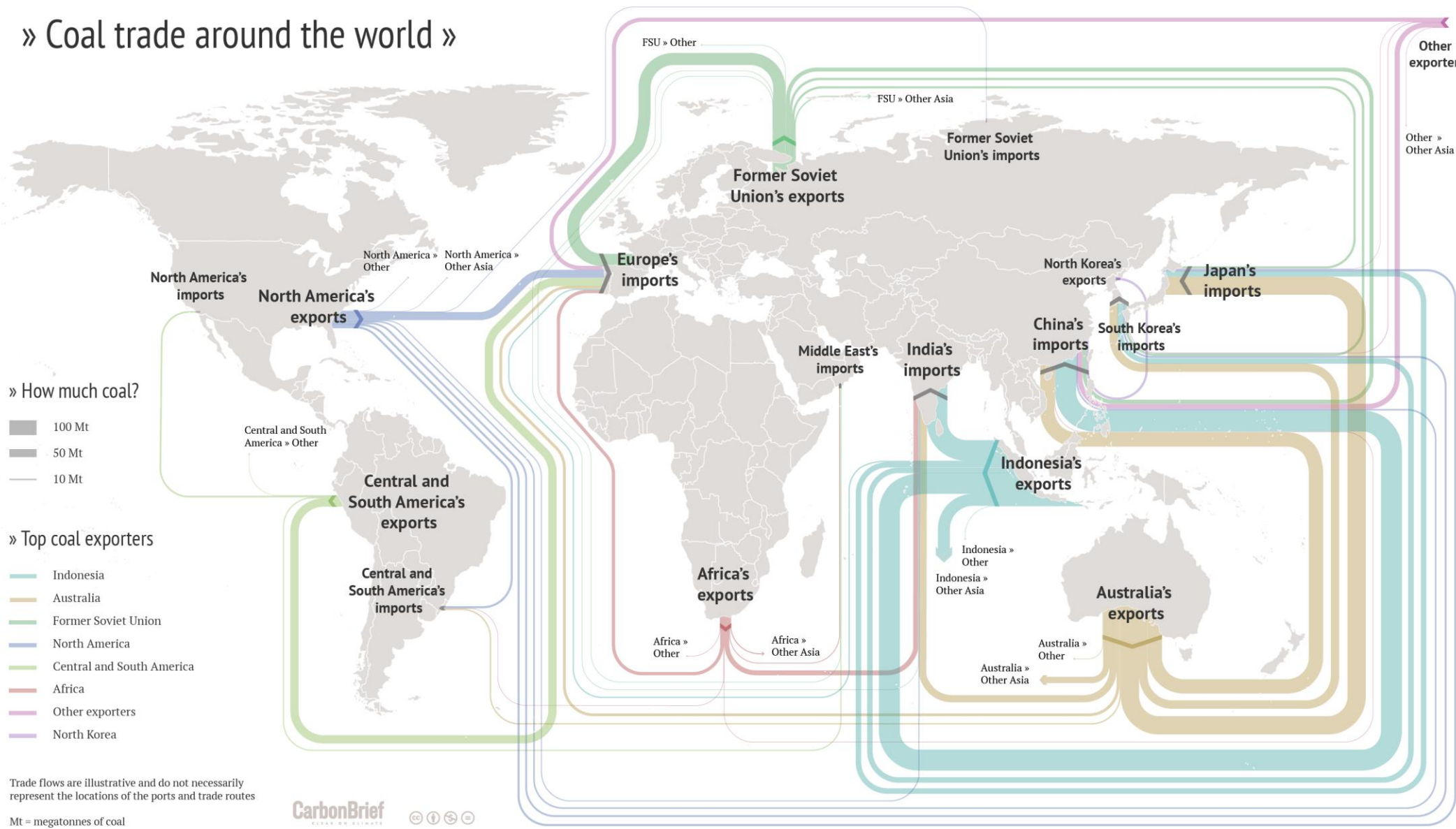
<http://energy4b.com.au>

A decade's worth of data from our NEM

- Shows slightly decreasing overall electricity generation
- Shows emergence of wind and rooftop solar
- Shows role of coal in achieving scale.

Exports

» Coal trade around the world »

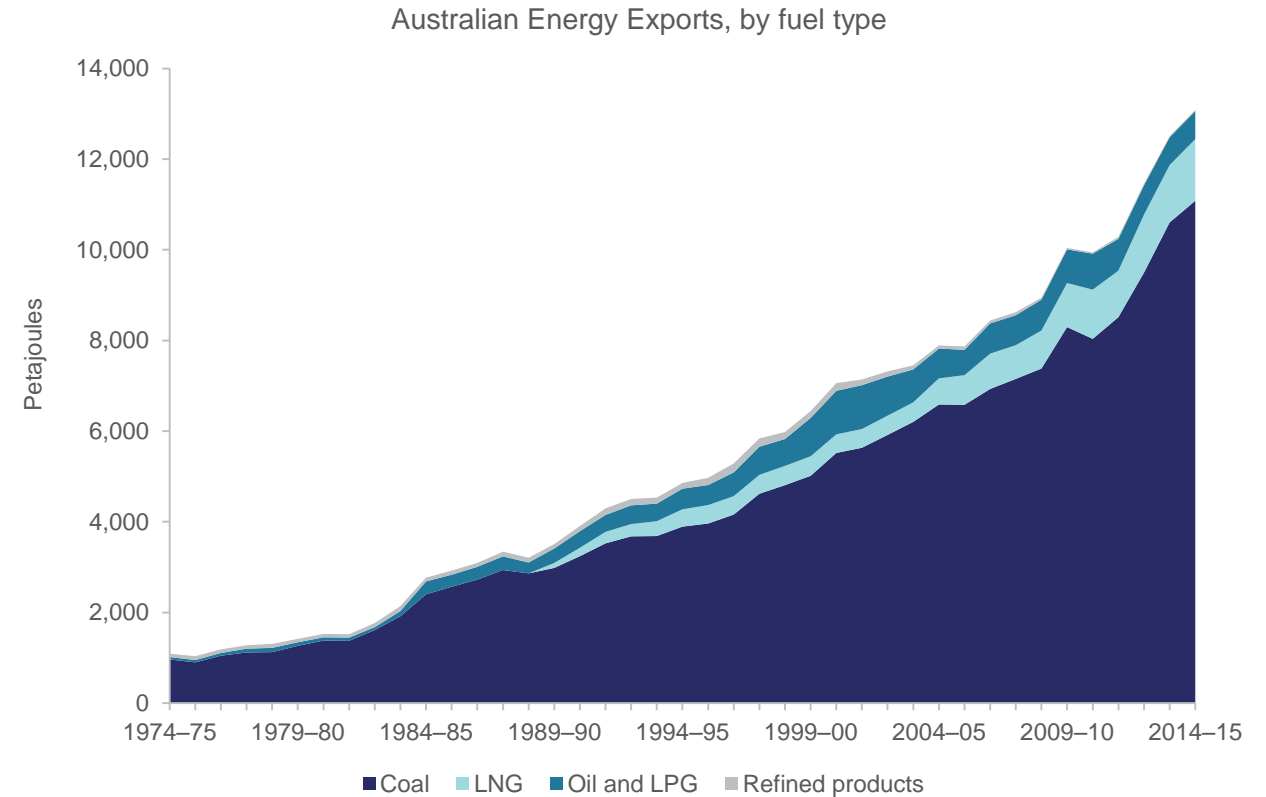


<https://www.australianmining.com.au/features/where-does-australias-coal-go-infographic/>

Exports

Coal exports continue to grow, driven largely by Asian demand.

- Japan still largest market
- China down, made up for by growth to Korea, Taiwan, and other Asian countries.
- Doubling of exports to India



The Energy 'Debate' in Australia

Public acceptance of coal having any role is low.

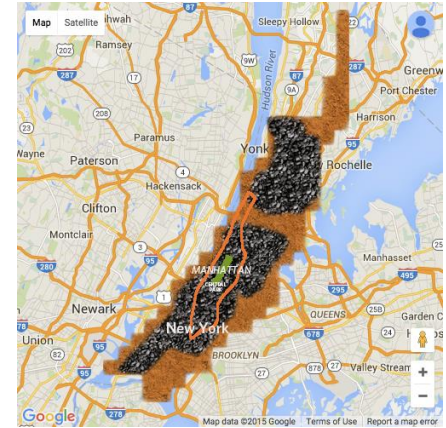
- Publicity around Adani mine, for example

The perception that renewables can meet all energy requirements (now) is strong.

Some states are strongly pursuing these objectives.

Federal government still developing relevant policy

- Have publicly discussed that they see a role for clean coal
- Considerable diversity in the debate regarding what that actually is.



<http://www.nonewcoalmines.org.au>



High Profile Events: Hazelwood Closure

1600 MW (8 x 200 MW)

Constructed 1964-1971

1.53 TCO₂/MWh

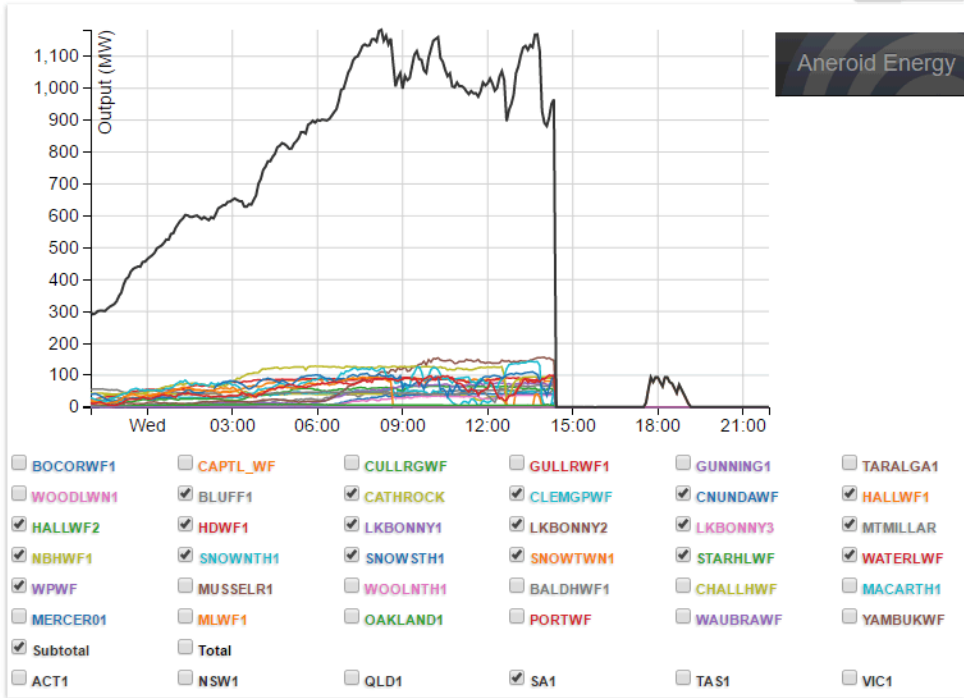
Local lignite: 62% moisture

6% of NEM



High Profile Events: SA 'Black Systems' Event

Wind Energy Production During 28 September 2016



Renewable energy mix played role in SA blackout, third AEMO report confirms

By Nick Hammen

Updated 12 Dec 2016, 11:01pm

www.abc.net.au

South Australian blackout 'nothing to do with renewable energy': experts



Heath Aston

www.smh.com.au

Windmills didn't cause SA blackout: PM

Updated: 5:14 pm, Monday, 13 February 2017

www.skynews.com.au

South Australia blackout: renewables don't cope with rapid change report finds

The Australian | 11:44AM December 15, 2016

www.theaustralian.com.au

The Finkel Review

Job was to look at the energy market, and come up with a plan to meet emissions reductions targets, provide affordable electricity, ensures security and reliability.

Some outcomes

- Technology agnosticism – all about emissions and cost.
- Coal expected to still provide more than 50% of Australia's electricity by 2030.
- 3 years notice before closing



Momentum shifting to industry

AGL boss rejects Government's coal plans and supports Finkel recommendations

By [Elysse Morgan](#) and [Ian Verrender](#)

www.abc.net.au

Updated 21 Jun 2017, 7:11pm

“We don’t see anything baseload other than renewables”

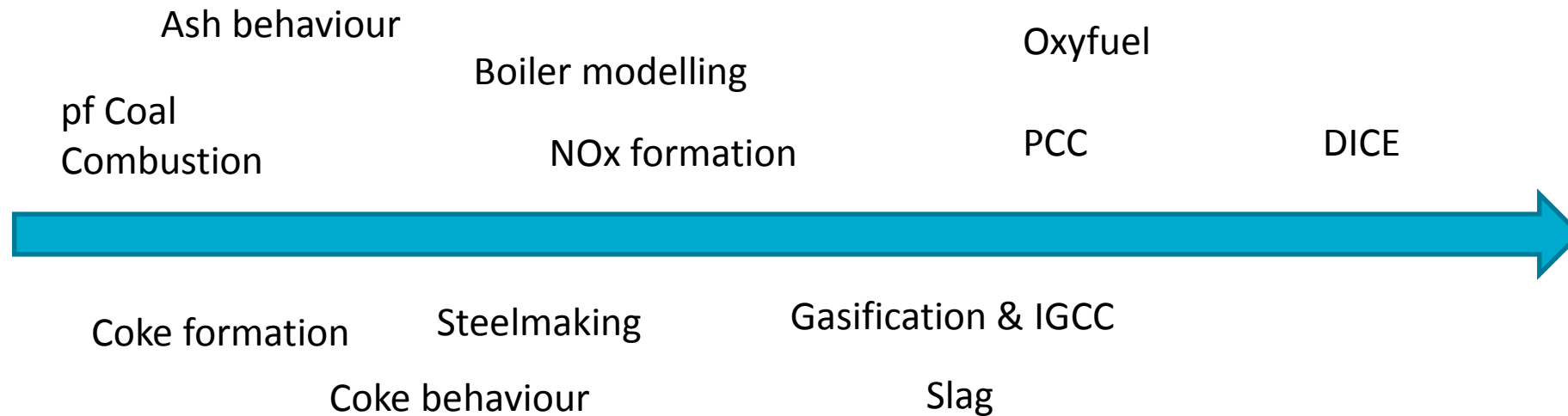
Andy Vesey, CEO AGL Energy

“Well, I think CS Energy certainly has no intention of building any coal-fired power plants, ultra-super-critical or not.”

Martin Moore, CEO CS Energy

Australian Coal Utilisation R&D

Australia has a long history of coal (utilisation) R&D



1995-2008 – three coal CRCs

cLET, CO2CRC

National clean coal initiatives:
ANLEC, others.



UNSW
SYDNEY



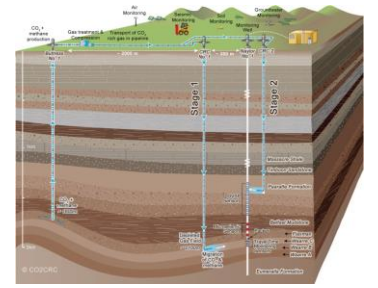
THE UNIVERSITY OF QUEENSLAND
AUSTRALIA



Current Areas of Interest

CCS

- Most of the 'clean coal' research funded in Australia is currently capture and storage, with a focus on storage.



Gasification

- The focus for gasification in Australia is Victoria, and plans for Victorian brown coal to play a role in Japanese hydrogen supply.



DICE

- High efficiency, modular, dispatchable power from coal using engines.

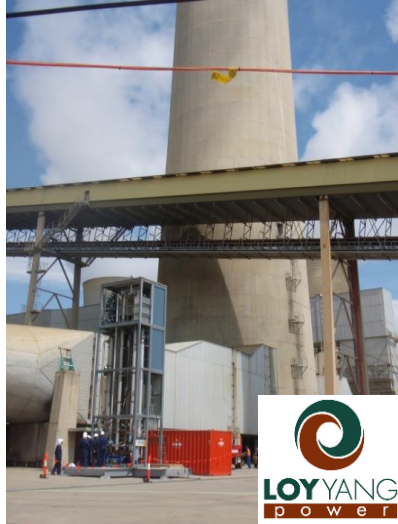
HELE

- Australian industry sees USC as the high efficiency, low emissions coal option
- Not a lot of R&D required to support deployment



Post-Combustion CO₂ Capture Pilot Plants

CSIRO and partners



Learning by doing

- 4 operating Pilot plants
- 1-3 kt pa CO₂ capture
- Combinations of:
 - Coal type
 - Solvents
 - Flue gas properties



Solvents: CSIRO's Perspective on PCC cost reductions

Cost reduction

0%

10%

25%

50%

Designer amines

Higher reactivity; low regeneration energy

Packing-less contactor

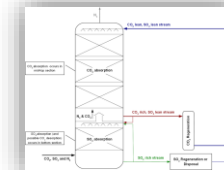
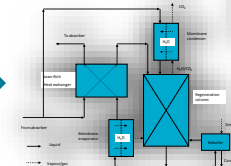
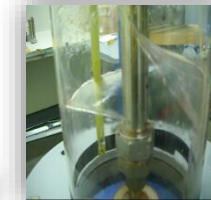
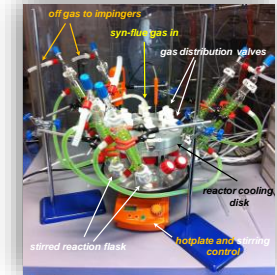
Capital & operating cost reduction

Process Intensification

Energy efficiency

Co-capture of CO₂/SO₂/NO_x

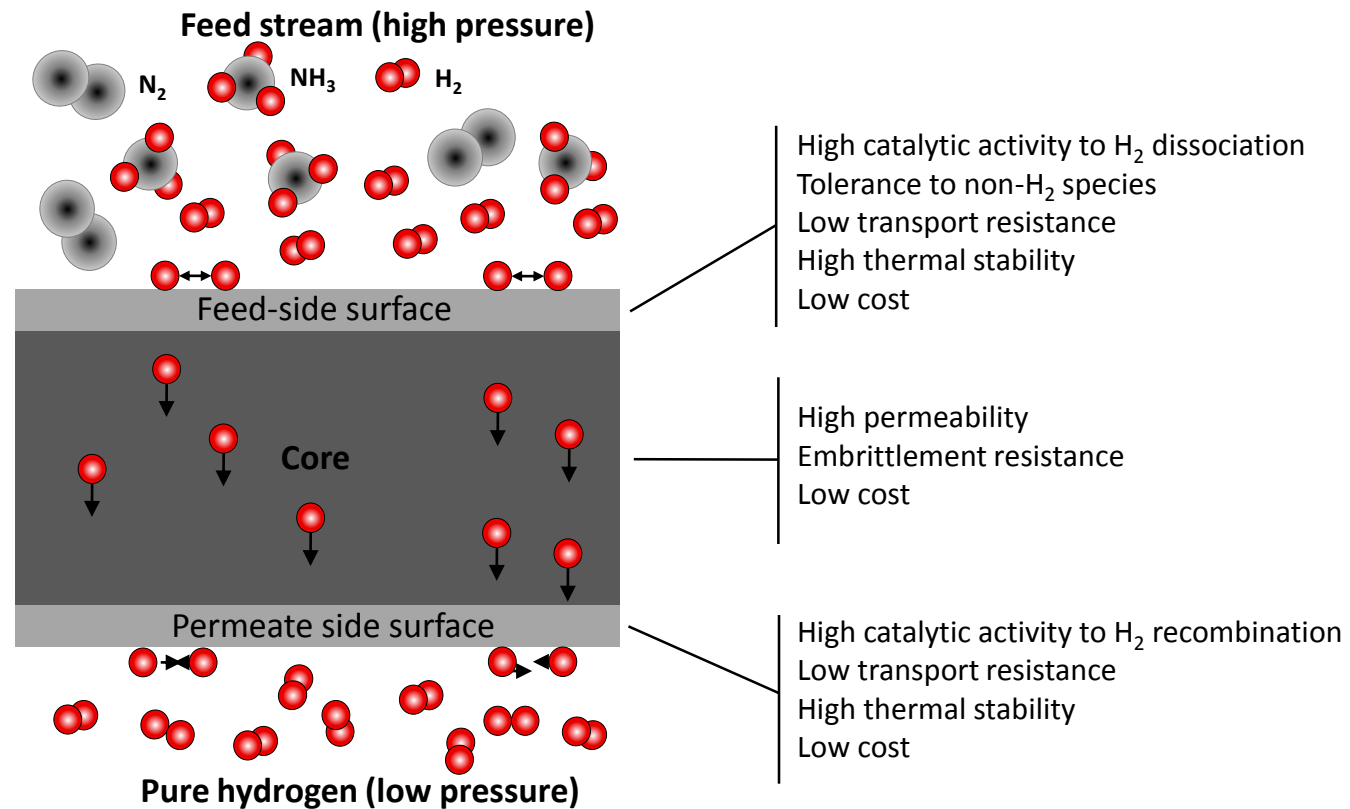
No FGD



Catalytic Membrane reactor

H₂ separation from mixed gas streams

Separation of H₂ from mixed gas streams, tested for lignite gasification, natural gas reforming, and new applications such as ammonia cracking.



Australia: Major Storage Projects



Gorgon:

- Set to be world's largest commercial scale CCS project (3.4-4.0MT/yr)
- Natural gas processing CC with saline aquifer storage. Reduce GHG by 40%

Otway:

- World class CO₂ injection testing facility
- Internationally significant contribution to CO₂ storage science and engineering

CarbonNet

- Feasibility of commercial scale CCS; investigating full end-to-end CCS chain

CTSCo

- Establishing a basis for long-term storage in Qld, demo of storage from PCC attached to an existing power station.
- Planned operation 2021, demo of 180k T/3 years

South West Hub

- Development of R&D site for 65 MT storage with monitoring

Direct Injection Coal Engine (DICE)

Efficiency breakthrough with familiar technology

50-55% efficiency from coal water fuels

Advanced coal preparation; low cost demineralisation

Adapt current 30–100 MW engines

CSIRO electronic fuel injection system

- multi-shot injection of coal water fuel to 150MPa

20 MPa atomisation and combustion simulator

Successful operation on coal/water fuel from black and brown coal

Partnering across the technology chain:

- coal producers
- coal prep plant technology suppliers
- engine manufacturers (MAN)
- Demonstration tests on MW scale engine



Where to?

Coal to Products in Australia

Increasing gas prices has been driving innovation

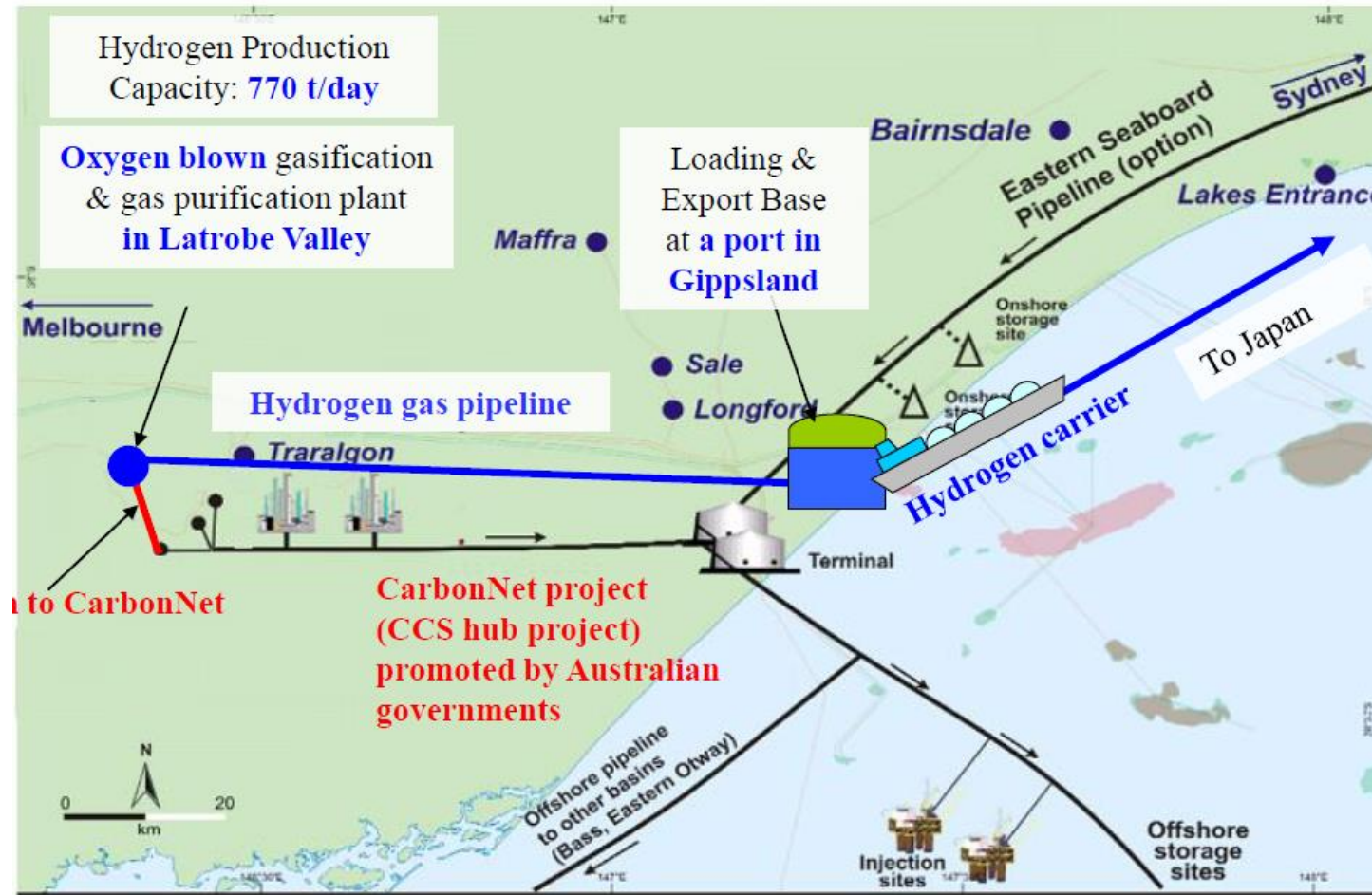
Several projects considered – none have proceeded

- New Hope Coal (Qld)
 - Pyrolysis of New Acland coal for diesel, jet fuel, power
 - Project ceased
- Latrobe Fertilisers Ltd (partner with Hubei Yihua, China)
 - Victorian brown coal (low cost \$1-2/GJ) (2mtpa -5mtpa)
 - 520,000 tpa urea (stage 1), 1.3mtpa (stage 2)
 - Siemens gasifier
 - Planned commissioning Dec 2015 – (not yet started)
- Perdaman Chemical Company (stopped ~2015)
- KHI – Brown coal to Hydrogen (Vic)
 - CCS in association with CarbonNet project
 - Feasibility study in progress



KHI “CO₂ free hydrogen chain”

Gasification of Australian brown coal with CCS



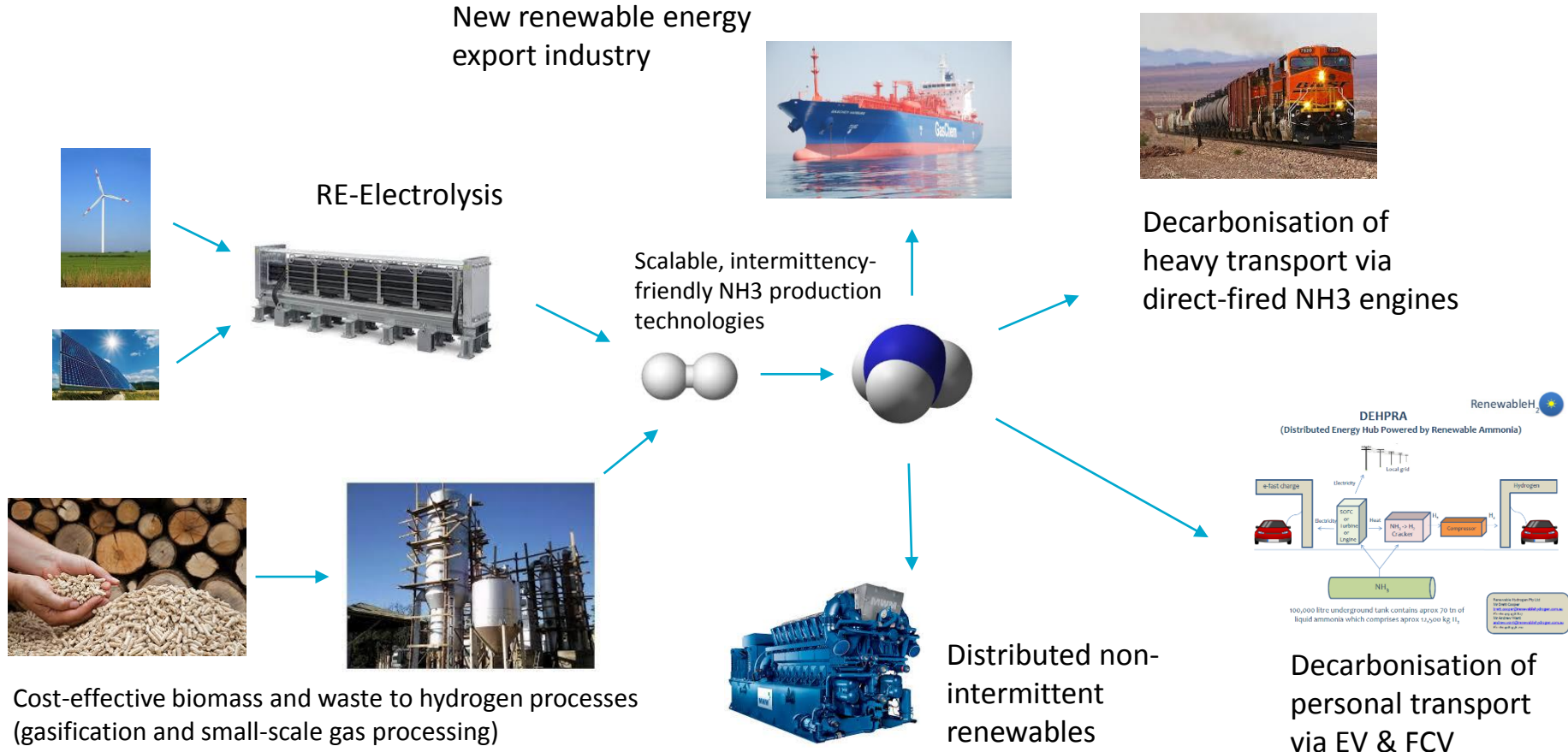
29.8 yen/Nm³

Hydrogen carrier	9%
Loading base	11%
Hydrogen liquefaction	33%
Hydrogen pipeline	1%
Hydrogen production	29%
CCS	10%
Brown coal	8%

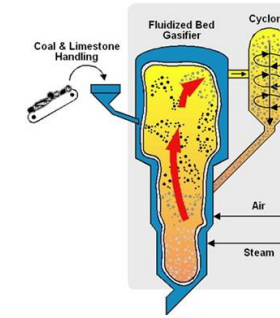
30JPY ~ US\$0.25



Hydrogen Demonstration Opportunities



Lignite gasification



Fluidised bed gasification

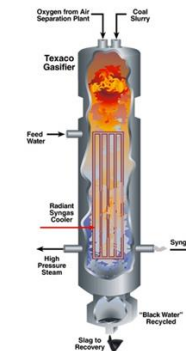
- Low temperatures to manage ash (800-950°C)
- Large particles (mm-sized)
- Atmospheric pressure
- Air blown

Low-cost gasification for efficient power generation

Lignites-to-products requires O₂-blown technologies

Entrained flow gasifiers are common

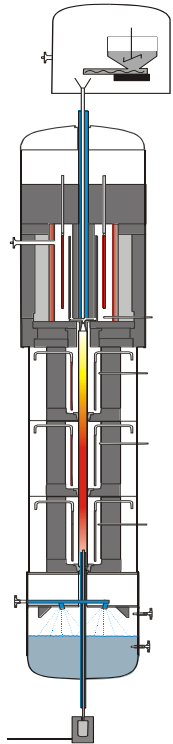
- Mineral matter must melt and form a tappable slag
- Operate at high pressures, temperatures, with fine particles.



O₂-firing may be problematic in fluid bed, transport, and possibly fixed bed technologies (e.g. hot spots in fluid beds)

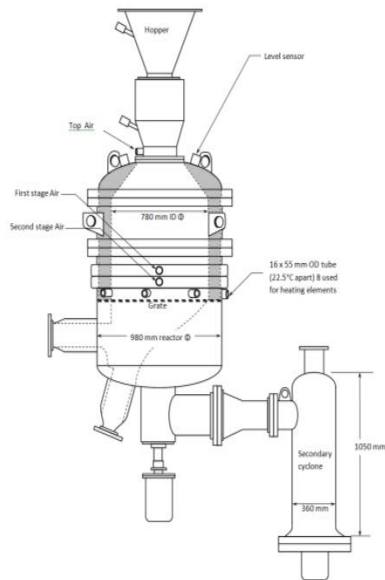
No data or experience for Victorian brown coals under these conditions

Gasification conversion research



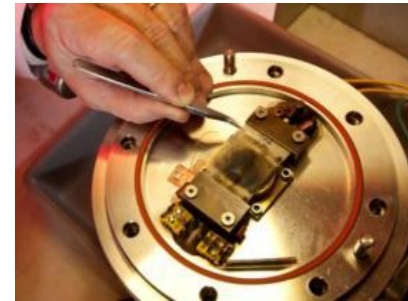
Gasification behaviour data under relevant gasification conditions

Entrained flow reactor for studies of fuel gasification behaviour at high temperatures and pressures.

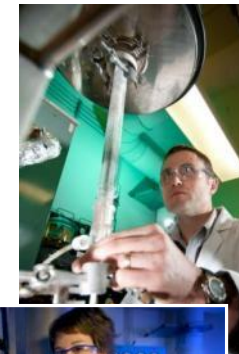


Fixed bed biomass gasifier for studying gasification characteristics of wood and green wastes

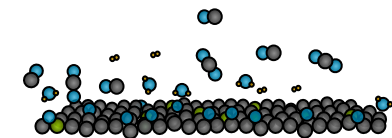
Supporting experiments allowing detailed interrogation of the gasification process



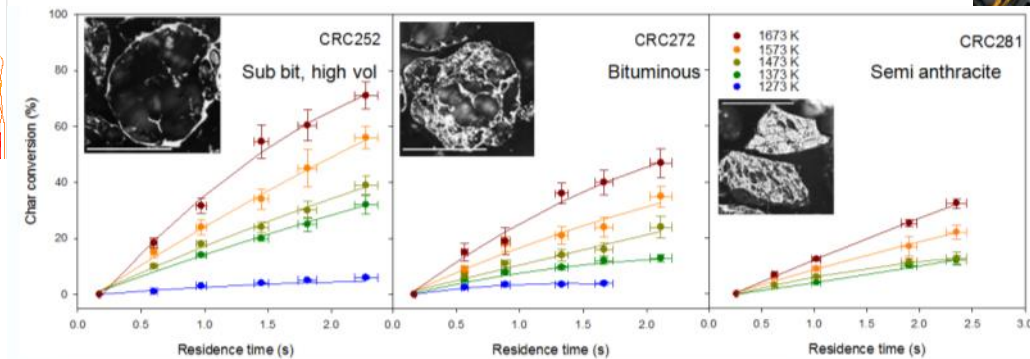
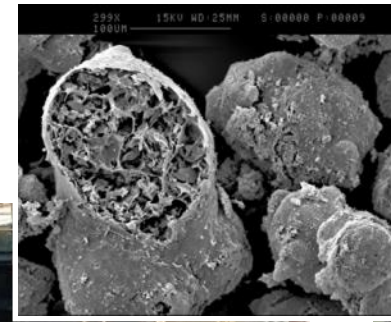
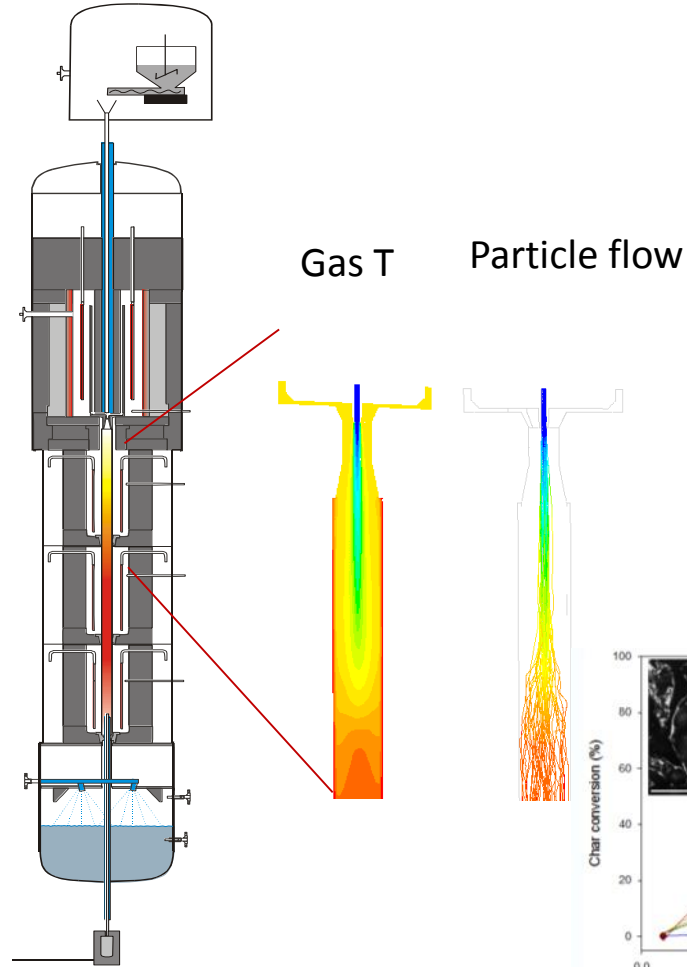
Heated grid reactor for devolatilisation under fast heating rates, high pressures, and high temperatures



Fixed-bed and TGA instruments for studying char reactivity fundamentals in complex gas mixtures and at high pressures



Large-scale, industrially-relevant facilities



Using scale of coal to support high penetration of renewables

Vaasa 140 MW heat and power biomass gasification plant, Finland.

Biomass gasification and syngas into a coal boiler.

Located adjacent to the company's existing 565MW Vaskiluoto 2 coal-fired plant.

Can replace 25-40% of the coal it currently uses for production of electricity. The plant will reduce carbon-emissions by about 230,000t a year



Summary

Coal exports are, and will continue to be, a key component of our economy

Coal remains by far Australia's primary source of electricity – and will stay so for a while

- Our fleet is largely relatively-old units, which have now begun to close.
- No new coal power plant seems to be on the horizon

New coal for power has low public and industry support (renewables can provide ... with gas if we really have to)

New electricity in Australia is undergoing a transition to increase renewables – this is having consequences, real and perceived

A positive future for coal in Australia could be to:

- Actively support high penetration of renewables
- Enabling new markets and industries

But, this will need a shift in government and industry views of what coal's role should be.



Journey from bedrock of our economy to ...

An efficient foundation for high penetration of reliable renewables, and ultimately a low-carbon energy sector?

Needs:

RD&D with a global reach to ensure world's best practice is available and relevant

New technology development to fill the emerging voids: e.g. dispatchable, modular, efficient coal power.

Basis of key technology chains supporting the development of new global energy systems, such as one based on hydrogen and its carriers?

Needs:

RD&D into new, locally-relevant coal-to-products concepts

Appropriate hybridisation of renewable and coal-based approaches to achieve true, positive impact at scale

Thank you

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