Clean Coal Technologies: Moving to 21st Century

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CSIRO ENERGY TECHNOLOGY
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Outline

-Global Energy Trend

- Efficiency and Emissions
- Improving efficiency to underpin emissions reduction and CO_2 capture
- Clean Coal technology strategies
- Gasification: a flexible enabling technology

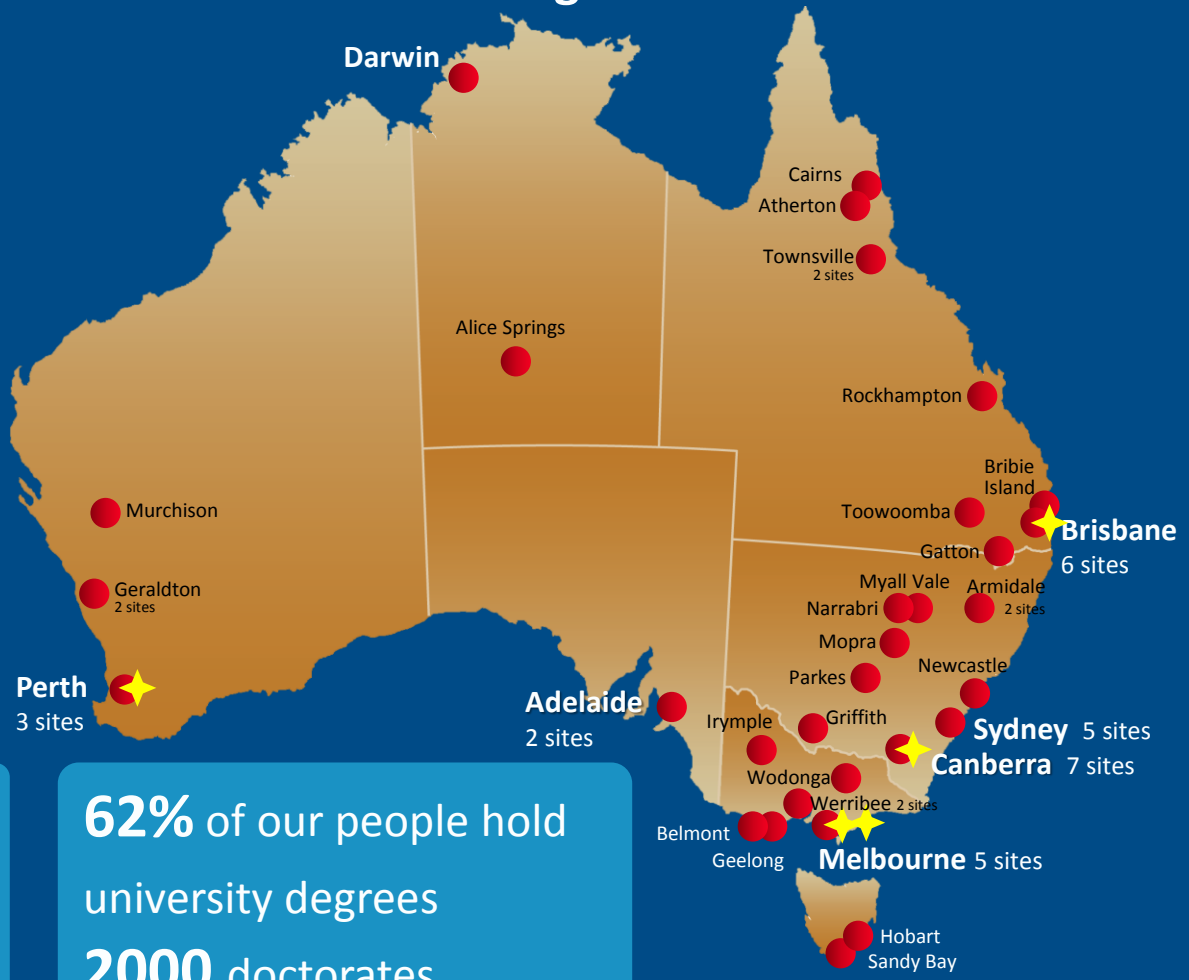
- R&D Challenges
- Australian demonstration projects
- IGCC-CCS case study
- CSIRO Gasification and Syngas Researches

- Summary & Remark

CSIRO

Commonwealth Scientific and Industrial Research Organisation

People	6500
Divisions	13
Locations	58
Flagships	11
Budget	$1B+



Top 1% of global research institutions in 14 of 22 research fields

Top 0.1% in 4 research fields

62% of our people hold university degrees

2000 doctorates

500 masters

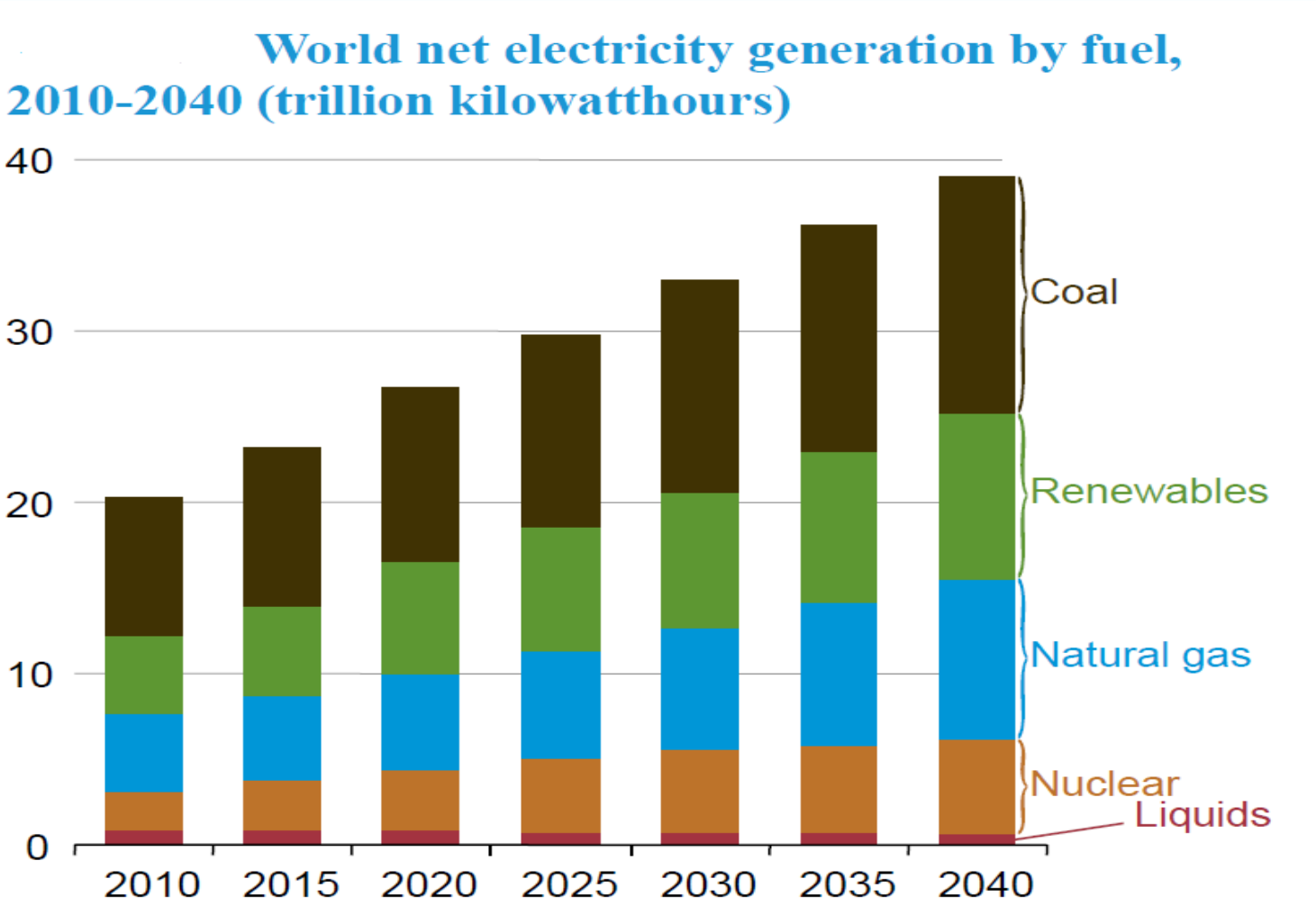
With our university partners, we develop **650** postgraduate research students

Global connections: impact partnerships

Vestas
ABENGOA SOLAR
Deltares
Enabling Delta Life
MAX-PLANCK-GESELLSCHAFT
Johnson&Johnson
Vision Care
USDA
RioTinto
Lonza
NOAA
Australian Government
Centrelink
Idemitsu Kosan
GE
NASA
中国华能集团公司
CHINA HUANENG GROUP
中国科学院
CHINESE ACADEMY OF SCIENCES
BOEING
Chevron
ITOCHU
PetroChina
Universidad de Chile
Fraunhofer
BAYER
PETRONAS
LOCKHEED MARTIN
China Australia Alliance for New Energy Vehicle Innovation
Queensland Government
NUCTECH
Australian Government
AusAID
Embrapa
CSD
COTTON SEED DISTRIBUTORS
woodside
bhpbilliton
ORICA
SANOFI

Global Energy Trends

World electricity production

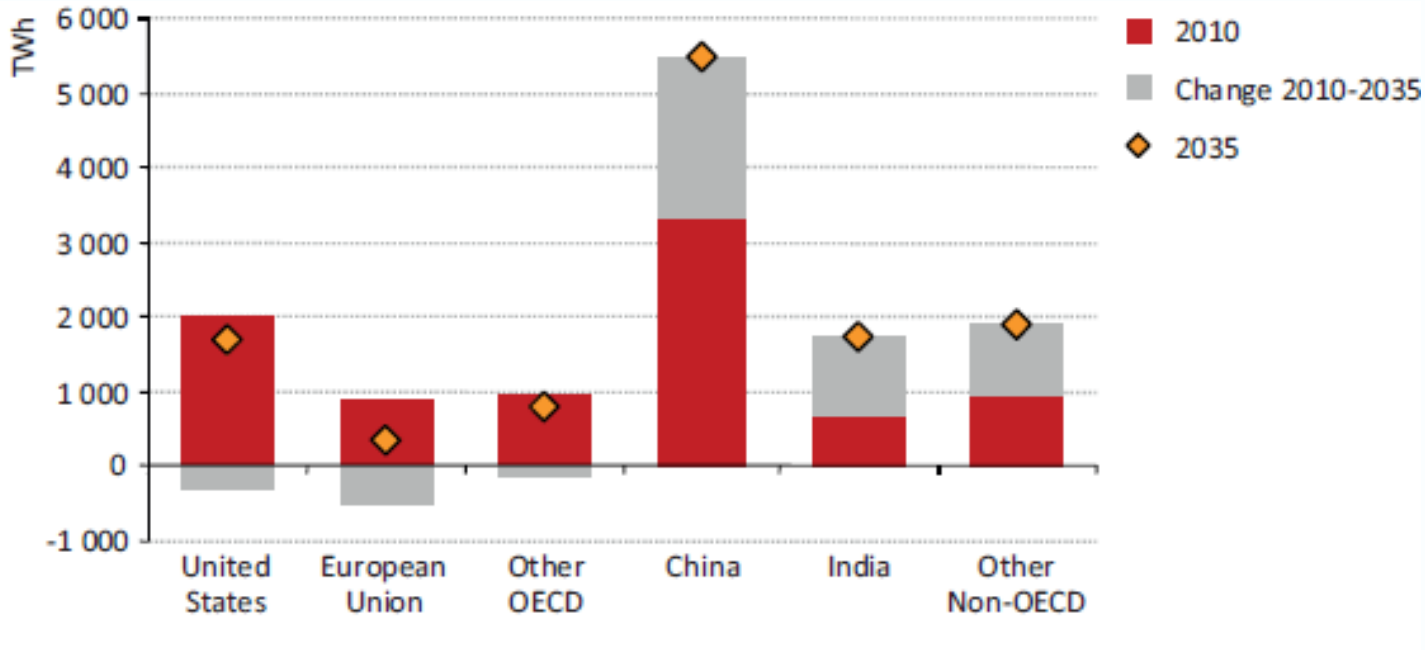


- Coal expected to continue to fuel the largest share of world electricity beyond 2040

Source: US EIA, International Energy Outlook, 2013

World electricity production

Coal remains the core fuel in future scenarios



- OECD nations reduce their reliance on coal-fired electricity generation

- Strong growth in China and India

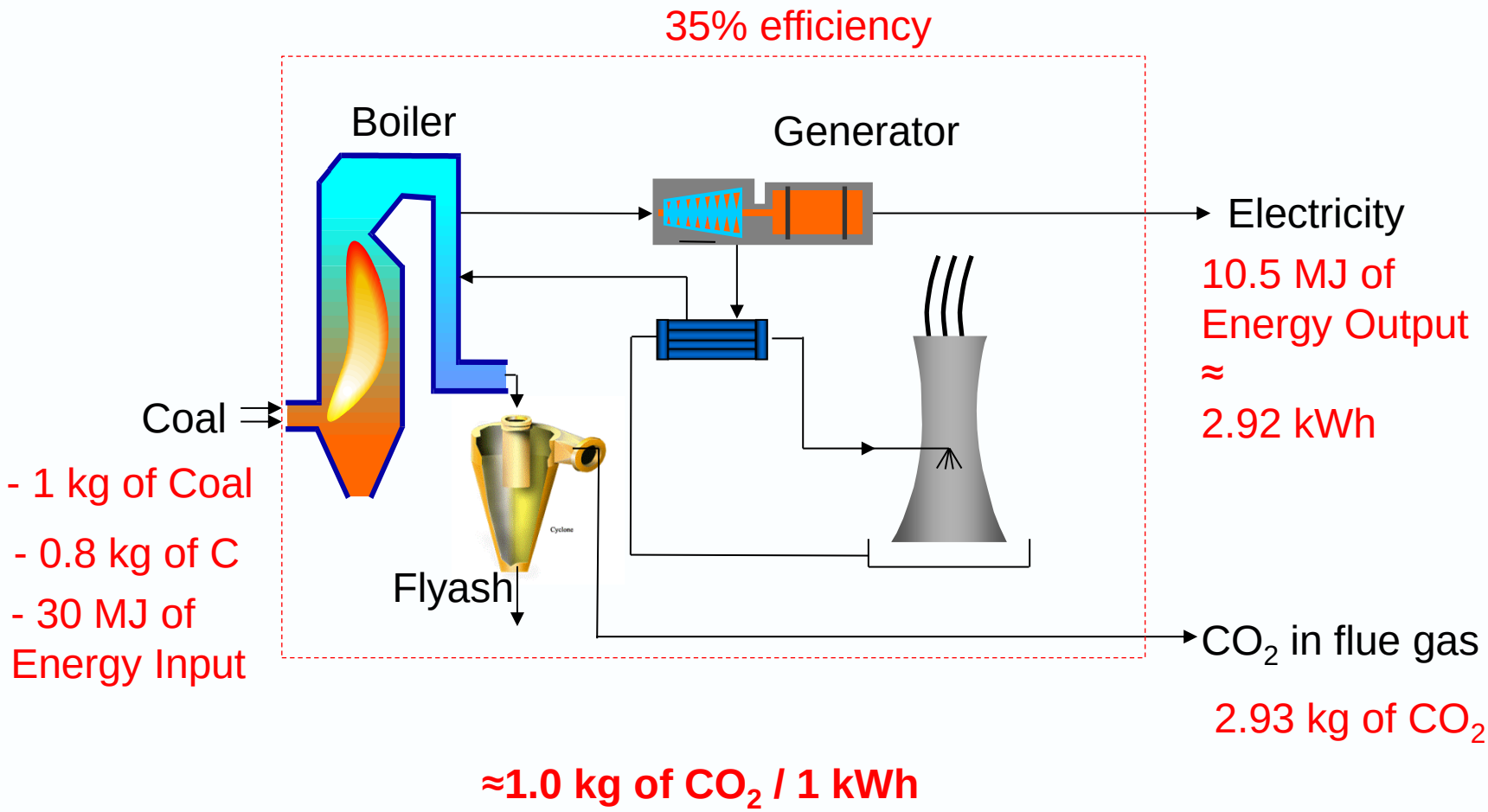
- China to add nearly 500GW new coal capacity
  - exceeds US, EU and Japan capacity
  - 36% of world coal power generation by 2040

Source: IEA World Energy Outlook, 2012

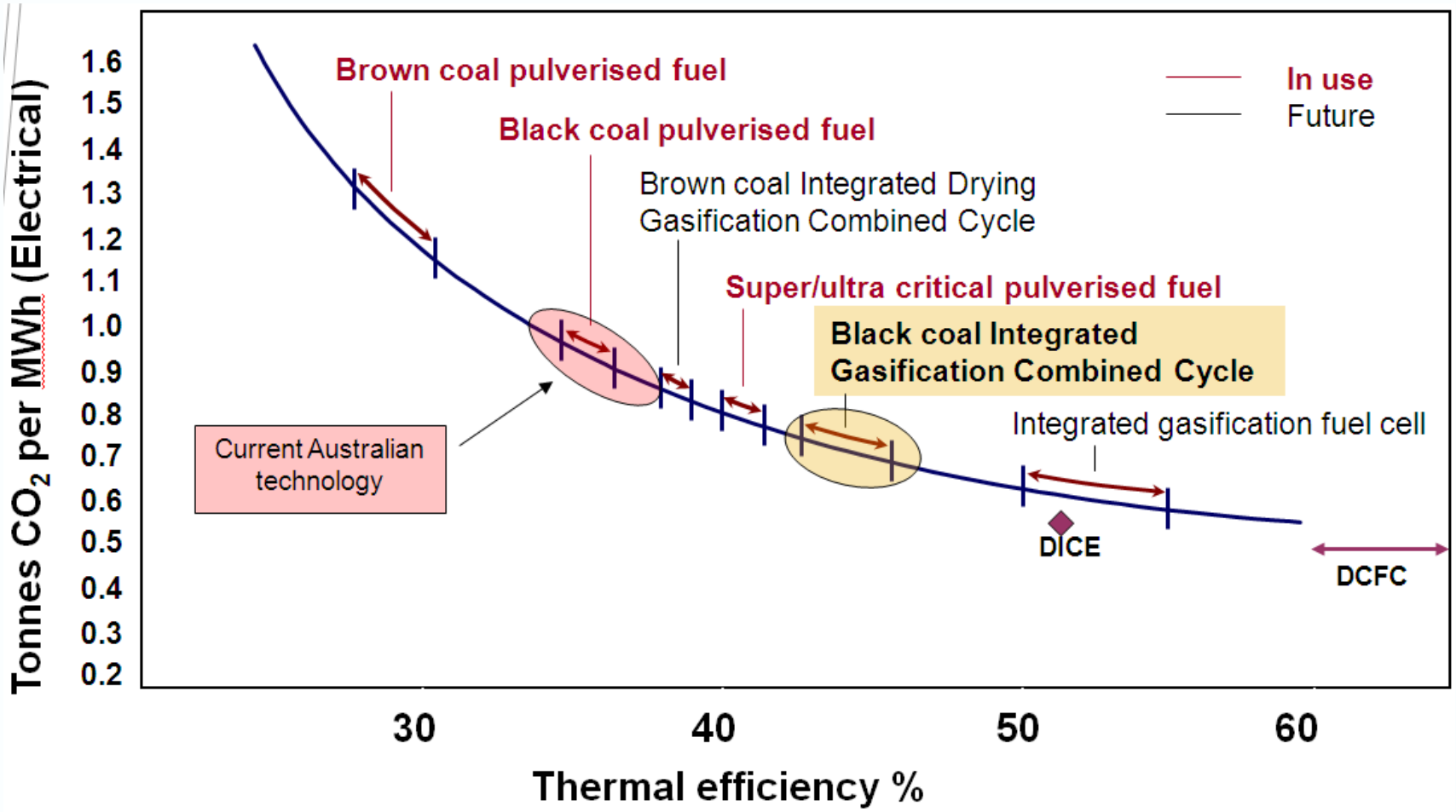
Efficiency and Emissions

High efficiency technologies underpin future deployment

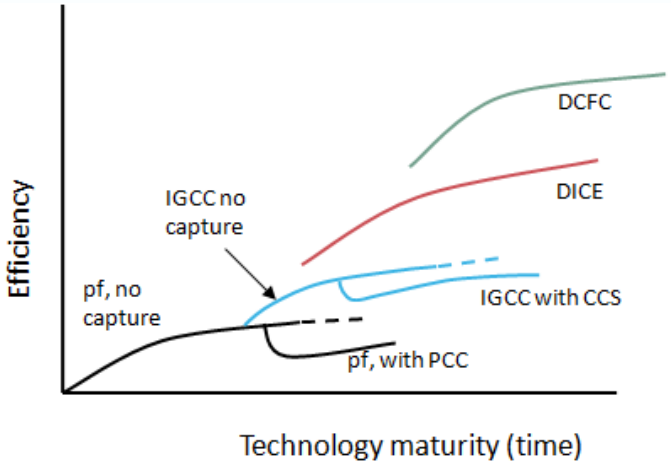
CO_2 emission in a typical coal fired power plant using a typical coal

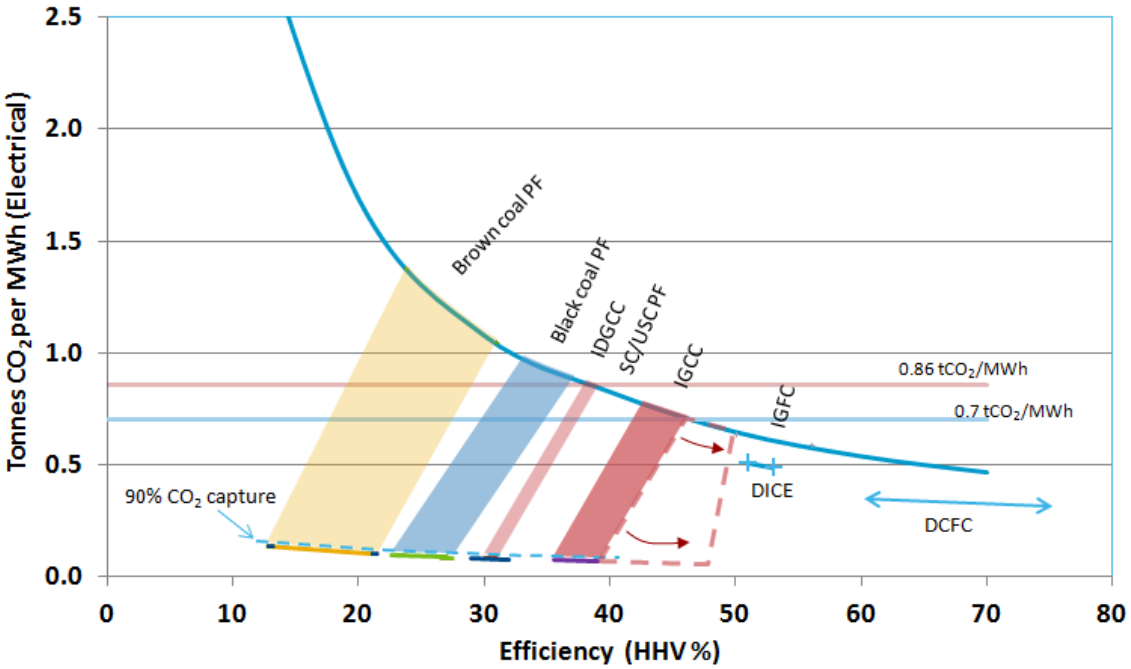


Technology efficiency impact on CO_2 emissions



High Efficiency is an essential requirement for effective CO_2 capture





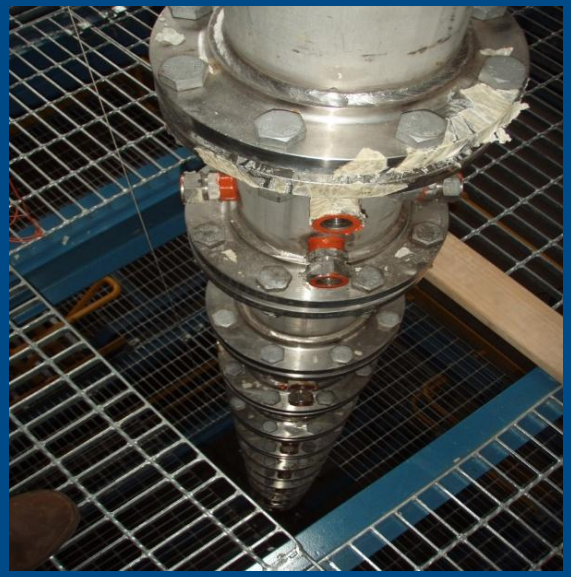
Increasing efficiency has many virtues:

- reduced fuel use
- smaller plant size (& cost)
- reduced emissions
- more amenable to CO_2 capture and storage (CCS)
  - less CO_2 for capture processes to deal with

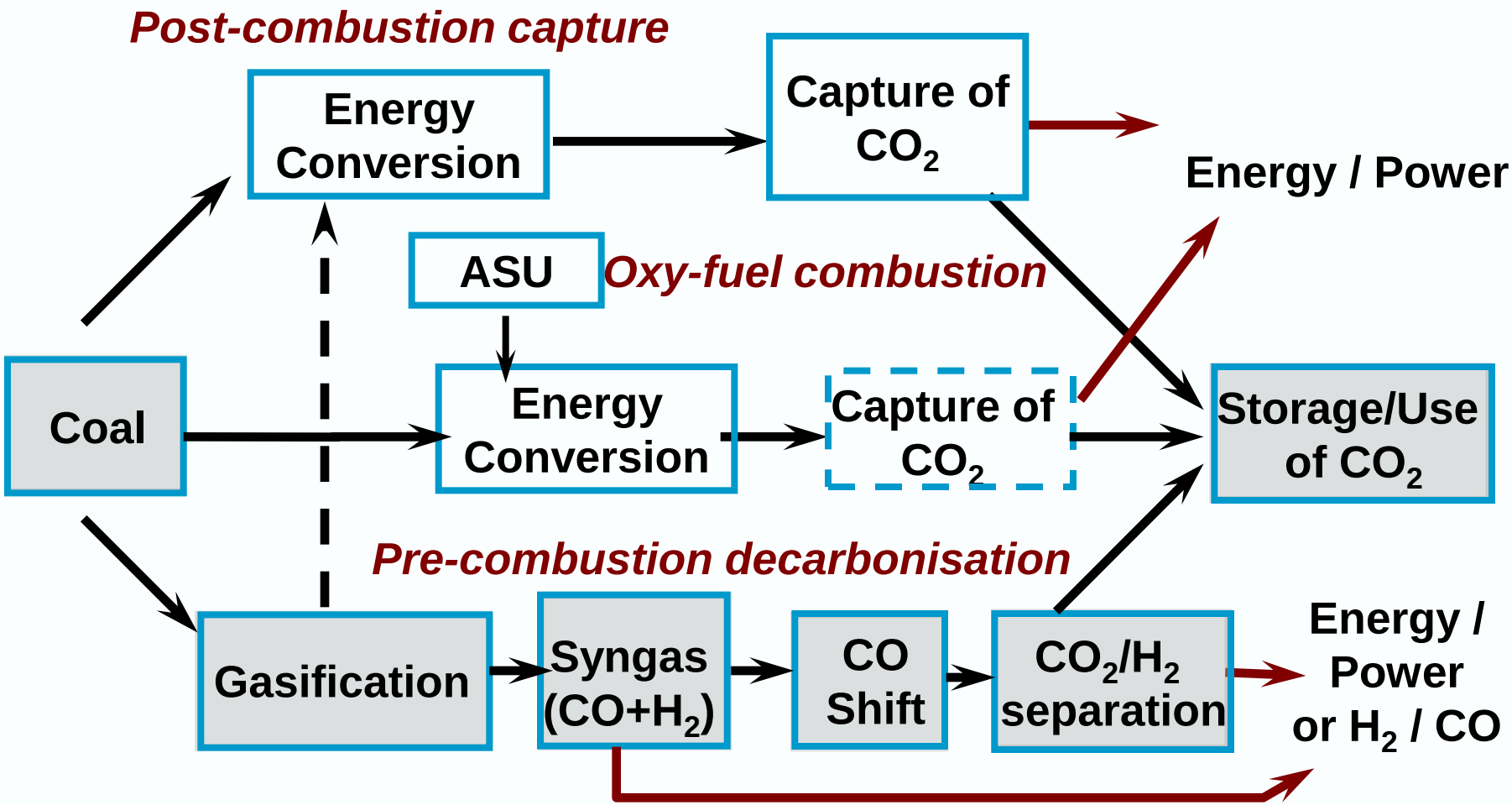
CO_2 capture increases costs and reduces ***efficiency and capacity***!

- ~30 % capacity reduction for pf

Clean Coal Research and Technology Strategies

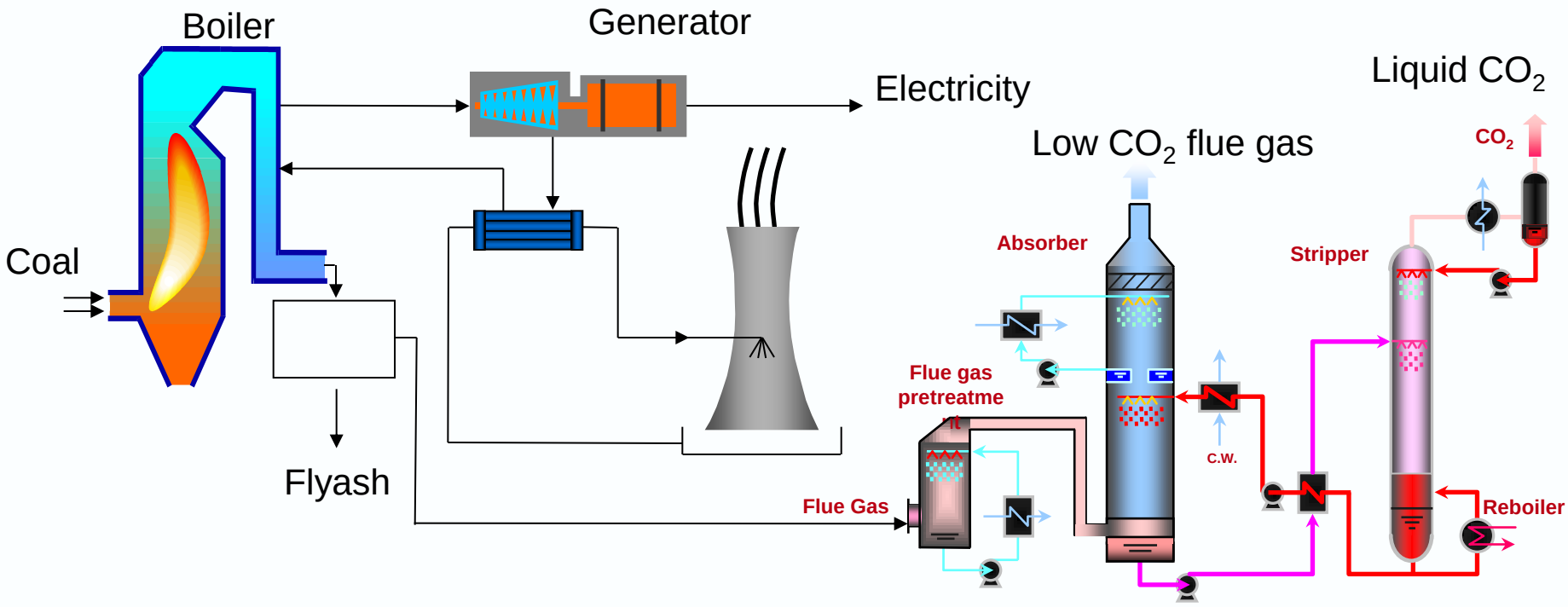


Low Emissions Power Generation



Source: adapted from IEA Clean Coal Centre

Post Combustion Capture Technology



More about PCC

Only practical option for existing plants to substantially reduce GHG intensity

The technology of CO_2 capture is well understood and is currently used in other industrial applications.

There are important issues in applying the technology to coal fired boilers for the purpose of capture for storage

- Capturing and compressing CO2 may increase the fuel needs of a coal-fired CCS plant by 25–40%
- high cost (presently around $35/t CO2 captured and compressed, equivalent to around $33/MWh for an 85% reduction in GHG)
- small scale (presently around 850 tpd/unit (suitable for 50 MWe))

One of the practical issue with existing plants is how far it might be from a potential sequestration site.

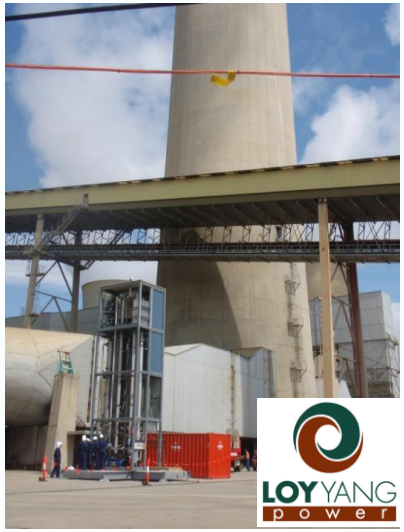
Economics and Efficiency of PCC

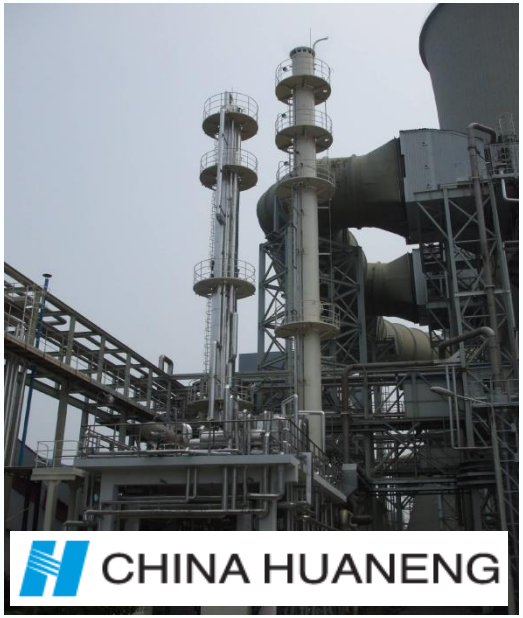
Efficiency or Cost	Range	Comments
Generation efficiency without PCC	35 – 41 %	Efficiency range determined by type of steam cycle and type of cooling
Generation efficiency with PCC	25 – 29 %	
Capital costs without PCC	$ 2300 – 3000/kW	Cost range determined by type of steam cycle and type of cooling
Capital costs with PCC	$ 4900 – 5900/kW	
Cost of generation without PCC	$ 21 – 66/MWh	Lower costs refer to the fully amortised power plant; higher costs refer to newly built power plant
Cost of generation with PCC	$ 75 – 129/MWh	
Avoided CO_2 emissions cost	$ 68 – 92/t CO_2	

Source: Feron and Paterson (2011)

Post-Combustion CO_2 Capture Pilot Plants

CSIRO and partners

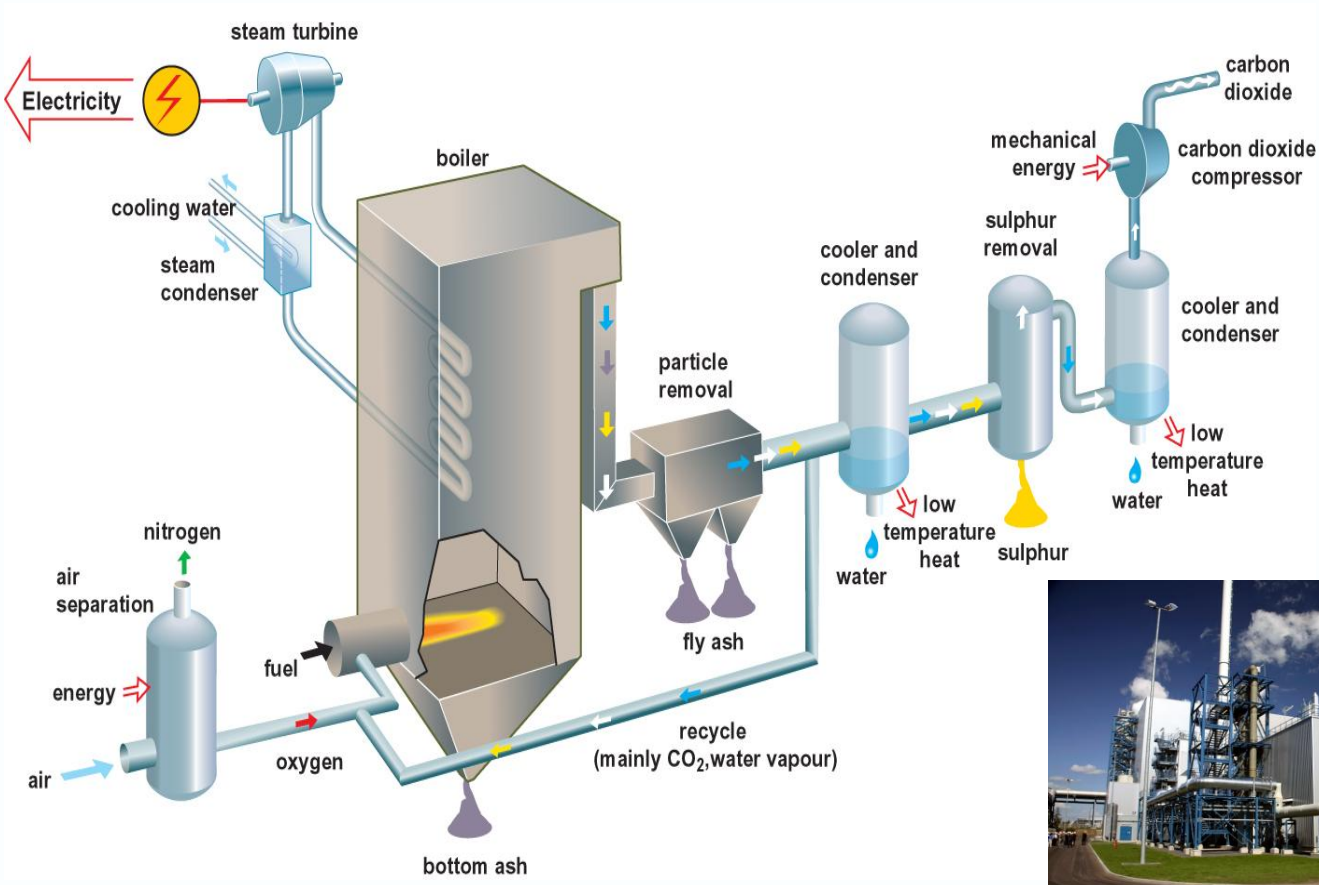




Learning by doing

- 4 operating Pilot plants
- 1-3 kt pa CO_2 capture
- Combinations of:
  - Coal type
  - Solvents
  - Flue gas properties

Oxy-pf with Flue Gas Liquefaction



30MW Oxyfuel Demonstration Plant

More of Oxy-fired pulverised coal technology

Advantages

- PF fuel burned in high-purity oxygen atmosphere with flue gas recycling
  - The mass and volume of the flue gas are reduced by approximately 75%.
  - Less heat is lost in the flue gas, reduce the size of the flue gas treatment equipment
  - Less NOx
- Greatly increases CO_2 concentration in flue gas, compression separation possible
- Only physical (not chemical) separation required to remove CO_2 for storage

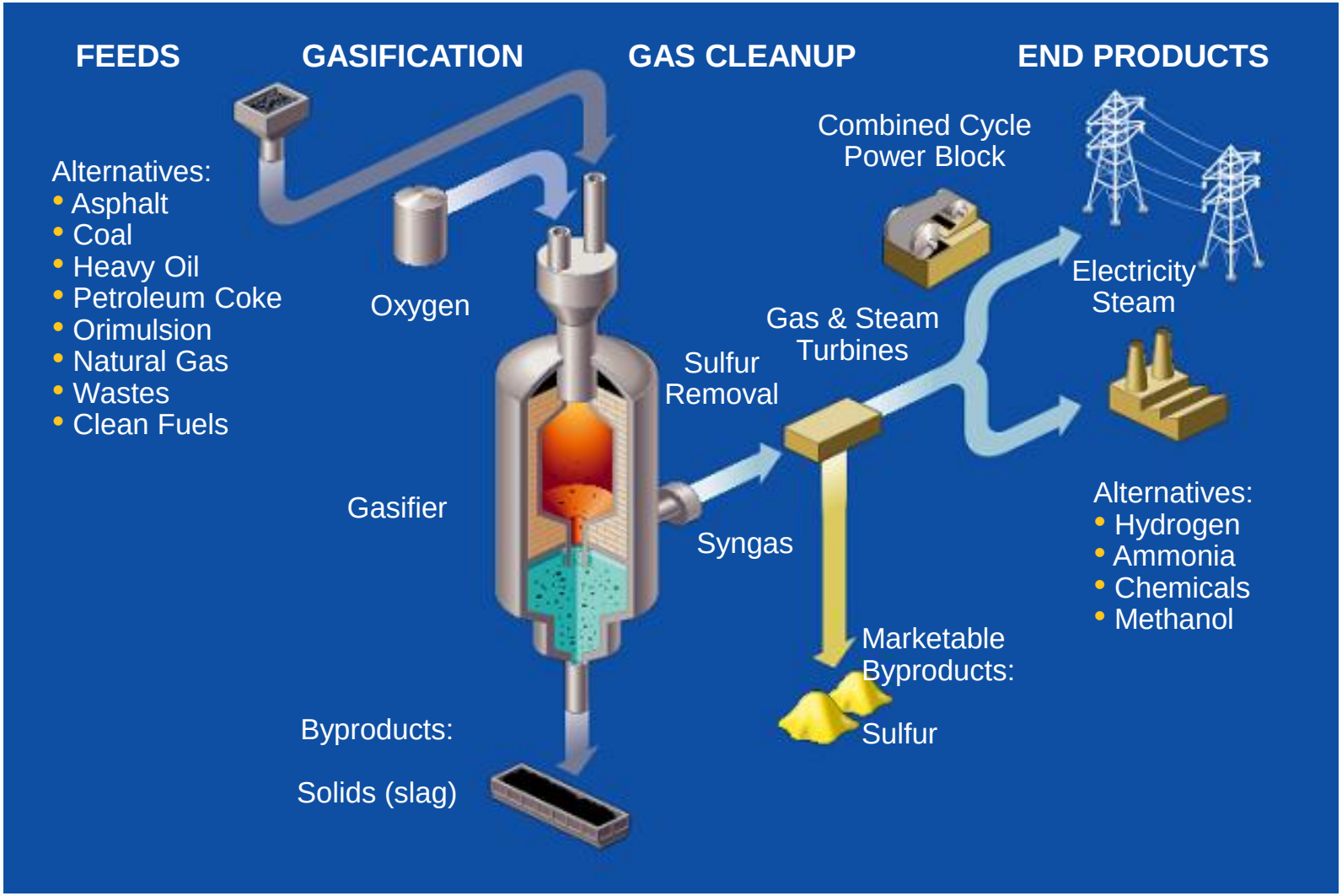
Issues

- Challenging to retrofit
  - Air leaks add non-condensable contaminants (Ar, O_2, N_2)
- High-purity O_2 expensive and energy intensive
  - New air separation technologies can help here
- Similar total energy cost as PCC (theoretical min. 104 kWh/tonne CO_2)

Demonstration project

- CS Energy (with CCSD) 30MW demonstration in Central Qld

IGCC Technology



Source: ChevronTexaco-2003

Coal-fired IGCC plants around the world

PLANT NAME	LOCATION	OUTPUT (MWe)	FEEDSTOCK	GASIFIER	OPERATION
NUON/Demkolec Willem-Alexander	Buggenum, The Netherlands	253	Bituminous Coal and Biomass	Shell	1994 -Present
ConocoPhillips Wabash River Plant	West Terre Haute, IN USA	262	Bituminous Coal and Pet Coke (2544 tpd)	E-Gas®	1995 -Present
Tampa Electric Polk Plant	Polk County, FL USA	250	Bituminous Coal (2200 tpd), Pet Coke	GE	1996 -Present
ELCOGAS/ Puertollano	Puertollano, Spain	318	Coal and Petroleum Coke (2500 tpd)	Prenflo ®	1998 -Present
Vresova	Czech Republic	350	Coal/lignite	Lurgi, Siemens	1996-Lurgi 2008-Siemens
Nakoso	Nakoso, Japan	220	Bituminous Coal	MHI	2007- Present
Duke Energy Edwardsport	**Knox County, Indiana**	**630**	**Coal**	**GE**	**2013 - Present**

IGCC Demonstration Programs

Emissions and Environment

- NOx and SOx remarkably low without extra scrubbing units
- Slagging gasifiers lead to reduction in fine particles and solid wastes
- Less Water: IGCC units use 20%-50% less water than conventional coal plants

Efficiency

- Current IGCC match state of the art pf units

Flexibility

- Feedstock flexibility is high, especially entrained flow gasifiers
- Product flexibility: 'polygen': power, fuel, SNG, H_2 …

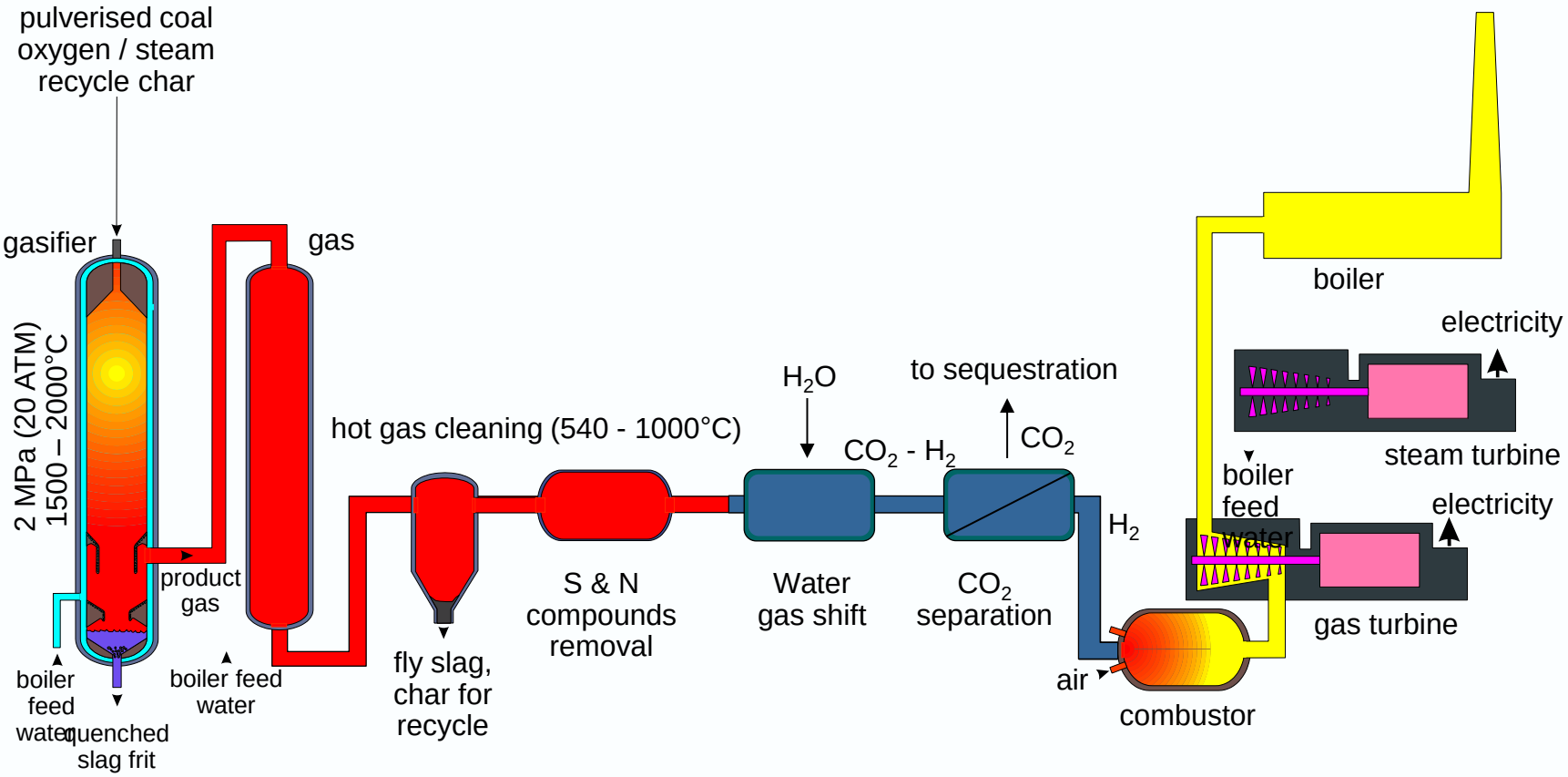
Carbon Capture and Storage

- IGCC well-suited for CO_2 capture
- Incremental cost < pf technology

Challenges

- Demonstrated reliability (integrated system) and availability
- Cost
- Acceptance by power industry

IGCC with Integrated CO_2 Capture



IGCC with integrated CO_2 capture

Coal gasification and capture of CO_2 from syngas is commercially mature in chemicals & refinery industries

- cost and scale issues less significant

CO_2 capture adds approx 30% to cost of electricity

- and 6% points reduction in efficiency
- these cost and efficiency penalties are less than those for pf with PCC

Costs will be reduced with increased IGCC commercial deployment.

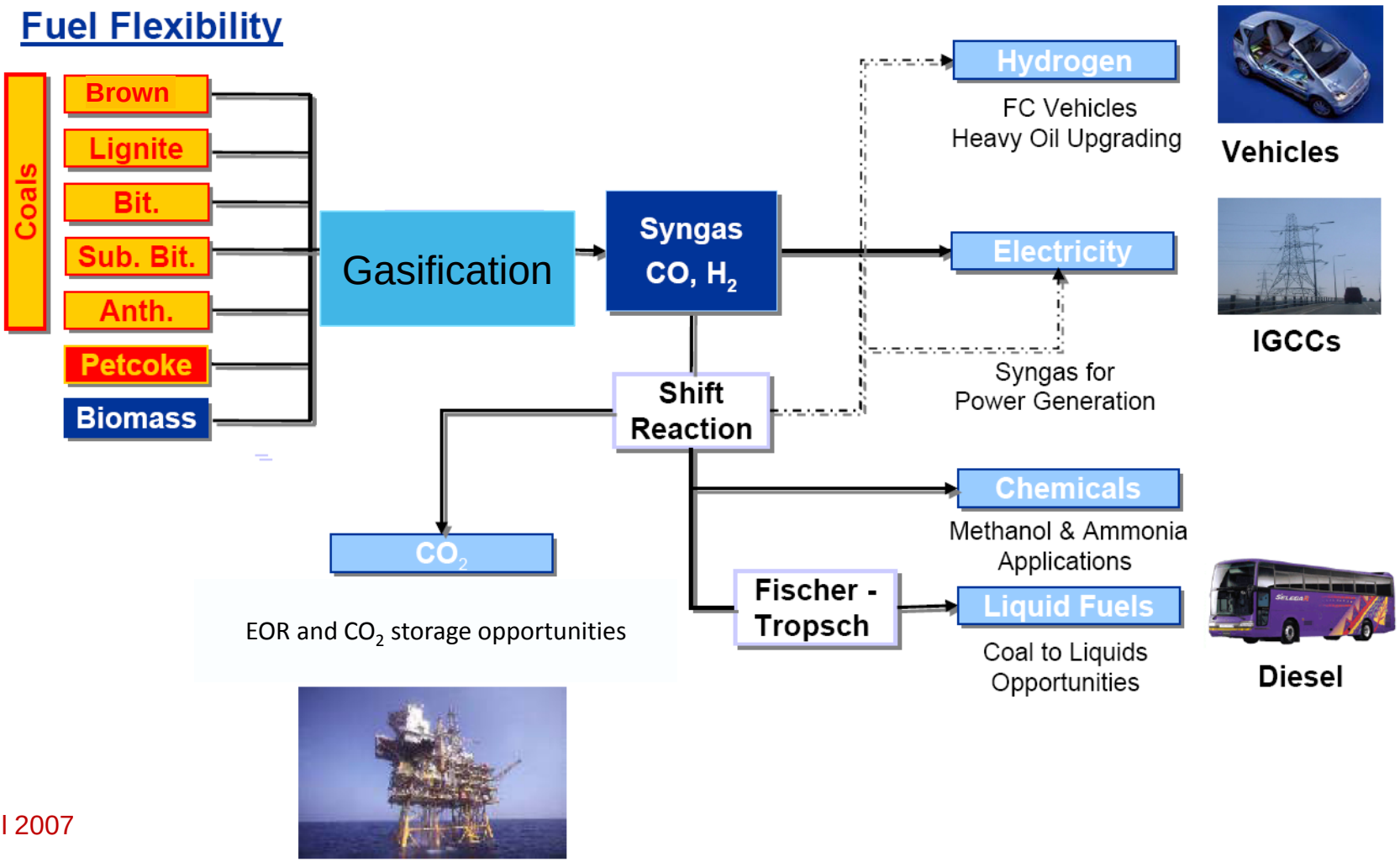
Strong interest in gasification of low rank coals & pet coke blends

- Eg: Powder River Basin and lignite coals are an important resource in the USA
- Australian brown coal gasification and CTL projects

Eastman Chemical Company coal to chemicals facility, Kingsport, Tennessee

Gasification (Now & Future)

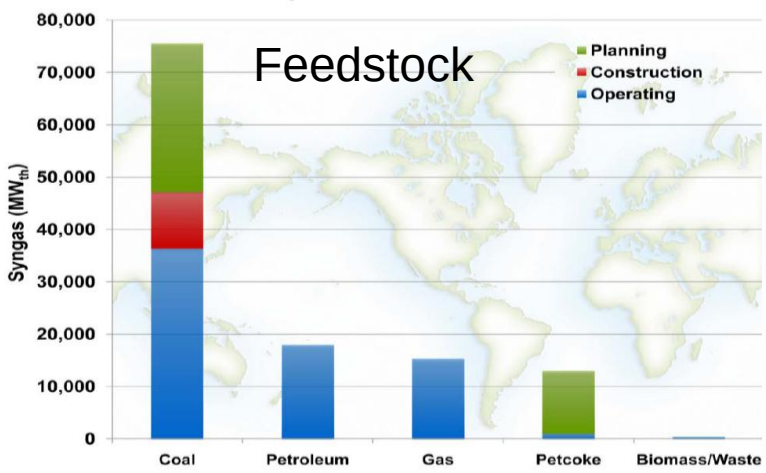
Gasification: a flexible enabling technology

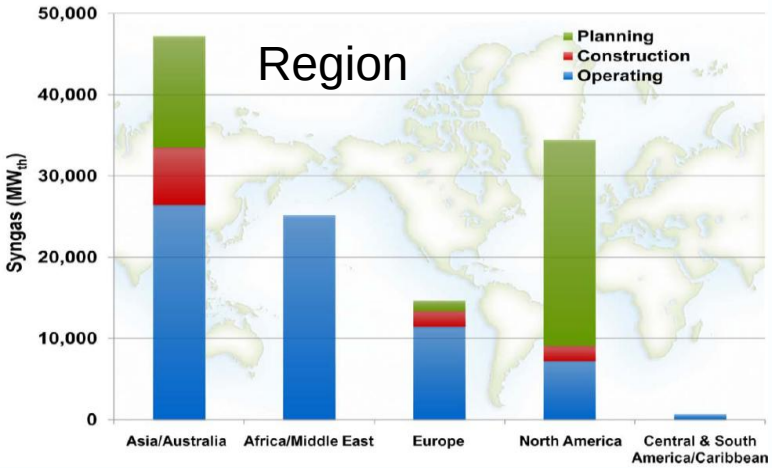


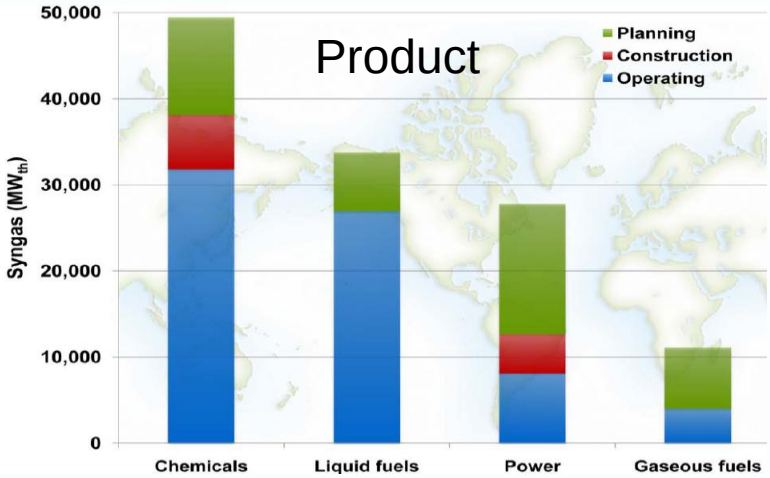
Source: Shell 2007

World Gasification Capacity and Planned Growth

(2010)







Source: Gasification Technologies Council (2010)

World gasification capacity projected to grow 70% by 2015

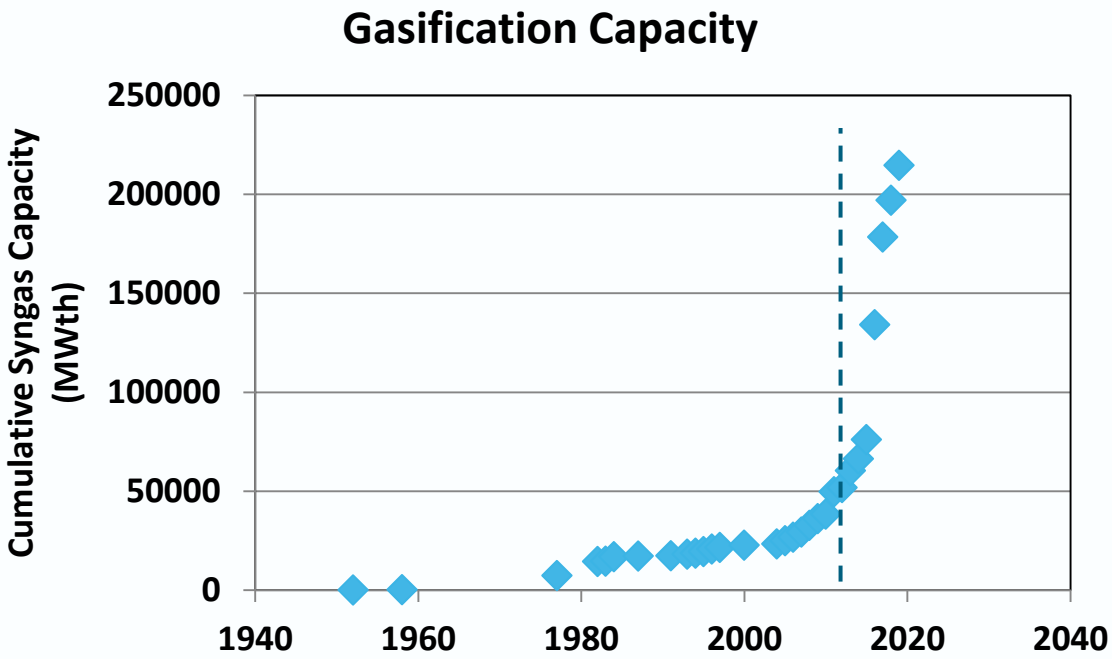
- ~140 plants operating (>400 gasifiers)

Strongest activity:

- **coal gasification**
- **Asia & North America**

Power, chemicals & synfuels products

Coal gasification capacity and planned growth

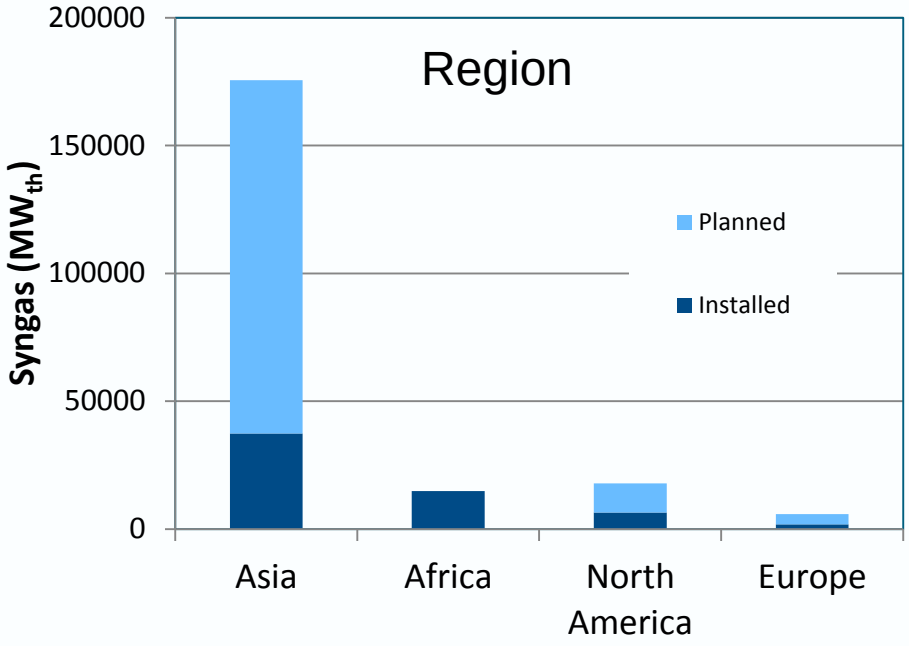


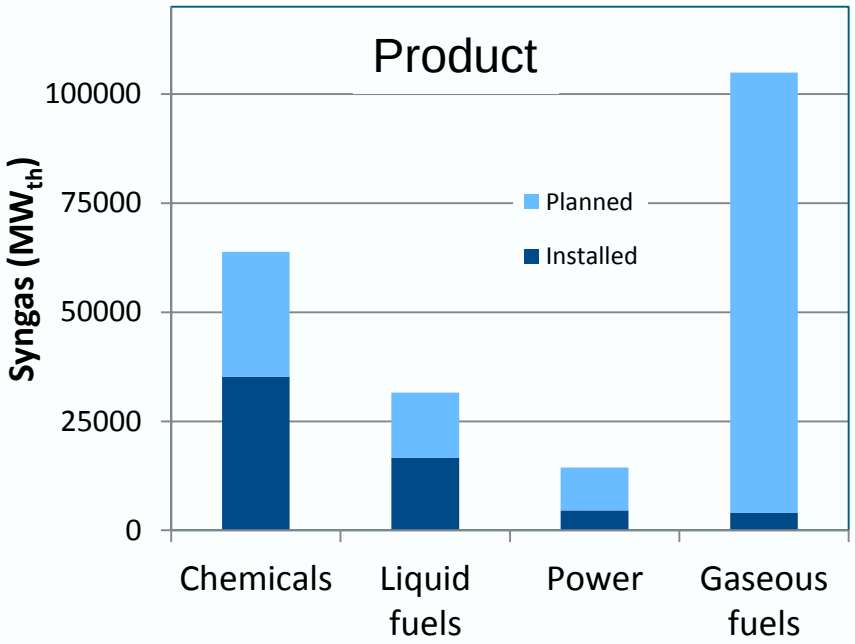
- World coal gasification capacity projected to grow 120% in 2013-2016.
- Plans for 250% growth by 2020.

Data source: Gasification Technologies Council (2013)

Coal Gasification Capacity and Planned Growth

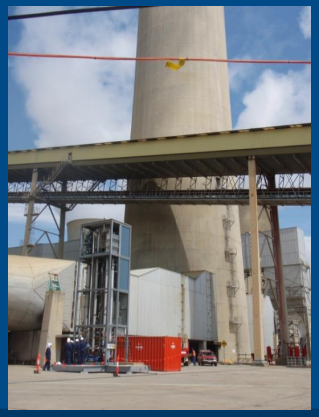
(2013)

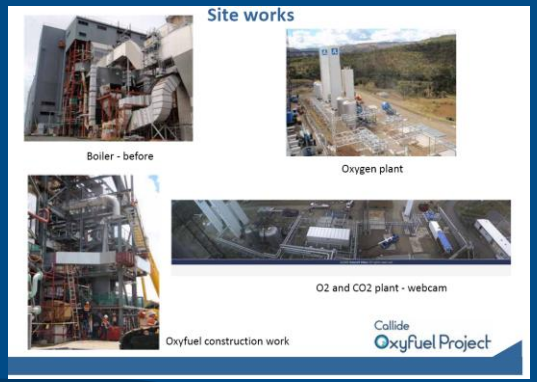




- Major expansion of plans in China
  - 140,000MW_{th} syngas planned in China alone
- Strong emphasis on chemicals and gaseous fuels (SNG, fuel gas)

Australian Demonstration projects





Clean Coal projects in Australia

Source: Geoscience Australia

Australian Demonstration Projects

PCC demonstration projects

- **Brown Coal PCC** demonstration project- Loy Yang Power – TRUenergy (~50ktpa)
- **Black Coal PCC** demonstration- Delta Energy (~300ktpa)
- **Black Coal PCC** demonstration- Tarong Energy (~100ktpa)

Callide Oxy-firing Project (30MW)

CO2CRC Otway Sequestration Demonstration

CCS Flagships Program

- Proposals for two black coal IGCC-CCS projects (Qld)
  - ZeroGen (~400MW, Stanwell Corp, MHI)
  - Wandoan (~400MW, GE, Stanwell Corp, Xstrata Coal)
- Two CO_2 storage proposals (Vic, WA)
  - CarbonNet (CSS Hub Victoria)
  - South West Hub (CCS Hub WA)

Brown coal IDGCC project in Victoria

- HRL IDGCC (Dual Gas) Project

CSIRO Gasification & Syngas Research

CSIRO Research Approach

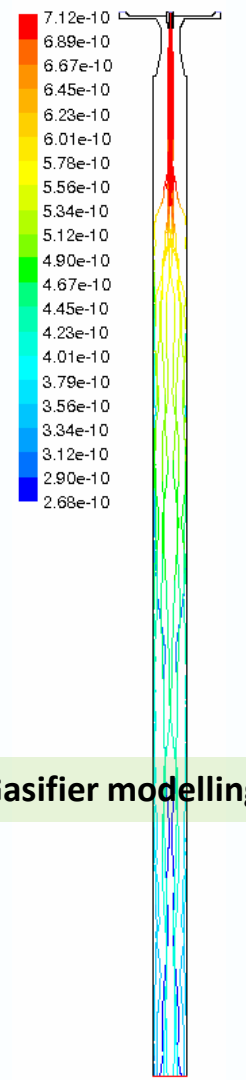
Improve the understanding of coal performance in gasification technologies, supporting:

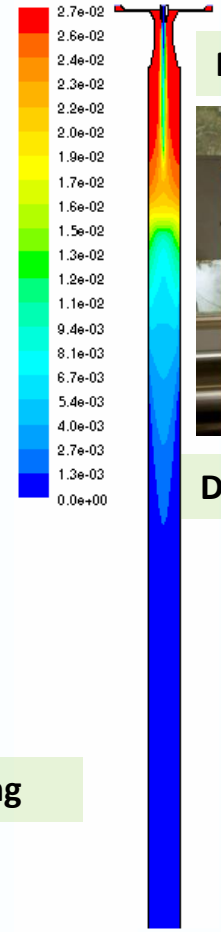
- Use of Australian coals in new technologies
- Implementation of advanced coal technologies in Australia
- Development of high efficiency IGCC-CCS systems

Pilot scale performance studies

Slipstream testing in coal-derived syngas

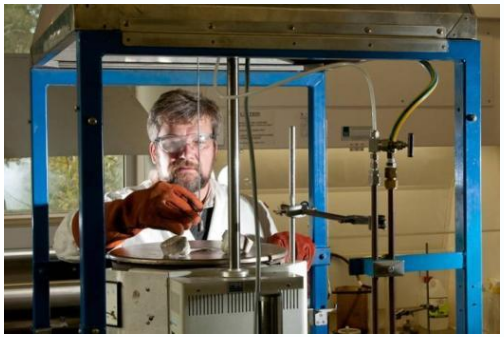
Gasification research





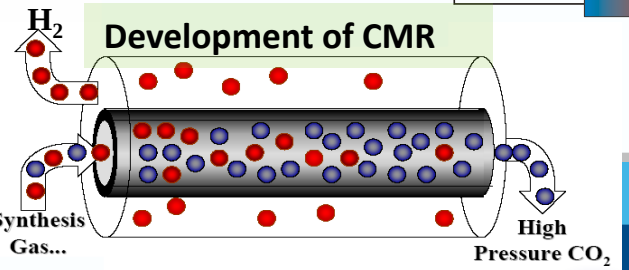
Gasifier modelling

Mineral matter in gasification

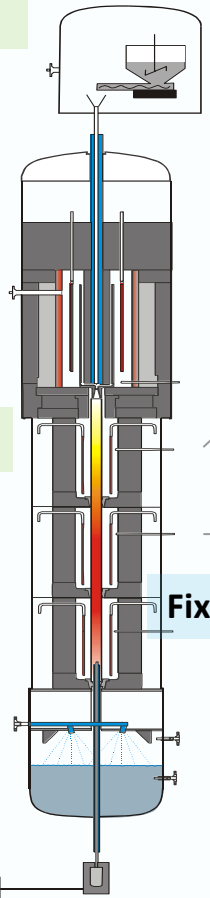


Development of H2 membrane

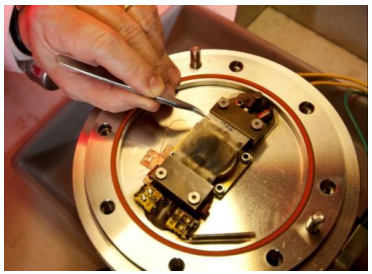
Development of CMR



Entrained flow reactor

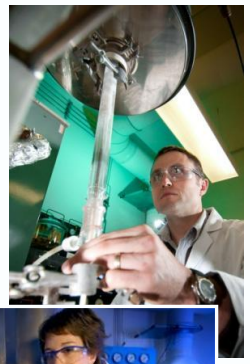


Devolatilisation, char formation



Heated grid reactor

Char reactivity



Fixed-bed and **TGA**

Barriers to new technology

Barriers to widely adopting high efficient coal fired power plant

- higher investment cost than conventional technology
  - Capital cost seen as critical barrier

- no commercial value on CO_2 reductions (carbon tax, carbon trading policies under discussion)
  - Cost and capacity of CO_2 storage uncertain
  - 'value' of increasing efficiencies not clear in technology debates

- public acceptance for coal fired power plant
  - confusion in discussion of 'clean' coal technologies
    - CBM, UCG, IGCC, PCC, Oxyfuel, CCS

Summary

High efficiency coal technologies will play a key role in achieving long term greenhouse abatement targets

- Increasing efficiency is a prerequisite for effective CO_2 capture and storage

Coal properties and performance issues affect many aspects of technology development, deployment and optimisation

- Advanced coal science capabilities needed to support improved coal characterisation, preparation and utilisation

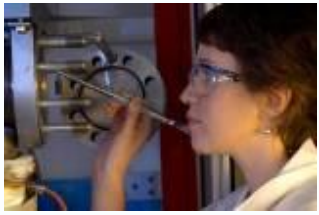
R&D challenges to increase efficiency, improve reliability, reduce costs

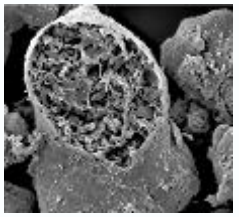
- Gasification provides a high efficiency technology platform for low emissions power systems
  - Development pathway for power, hydrogen & polygeneration systems
  - New research in key areas where breakthroughs will improve cost and reliability

Novel high efficiency systems developing on the horizon

National and international partnerships are needed to facilitate research, development, demonstration and deployment

- Coordination and 'critical mass' are essential





Thank You

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