Coal based oxy-fuel : towards application

The 34th International Technical Conference on Clean Coal & Fuel Systems, Clearwater, USA

Panel on Oxy-fuel Operation at the Industrial Scale

June 1, 2009

Professor Terry Wall

Chemical Engineering, University of Newcastle, Australia

Content

Technology status

International coordination

…. with comments on research needs

Technology prospects

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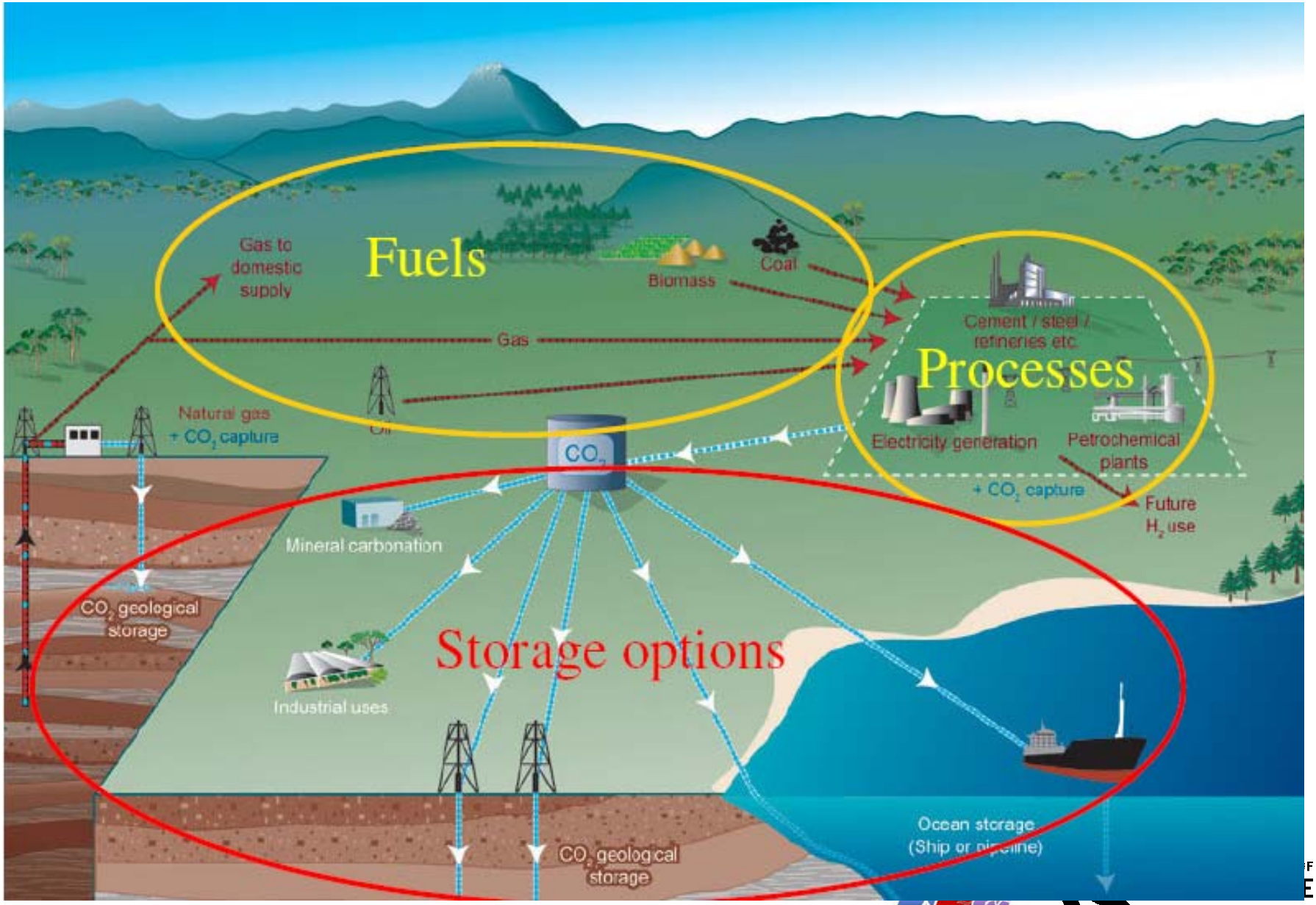
Technology status and demonstration outlines

Low Emission Coal Technologies (or CCTs) ....

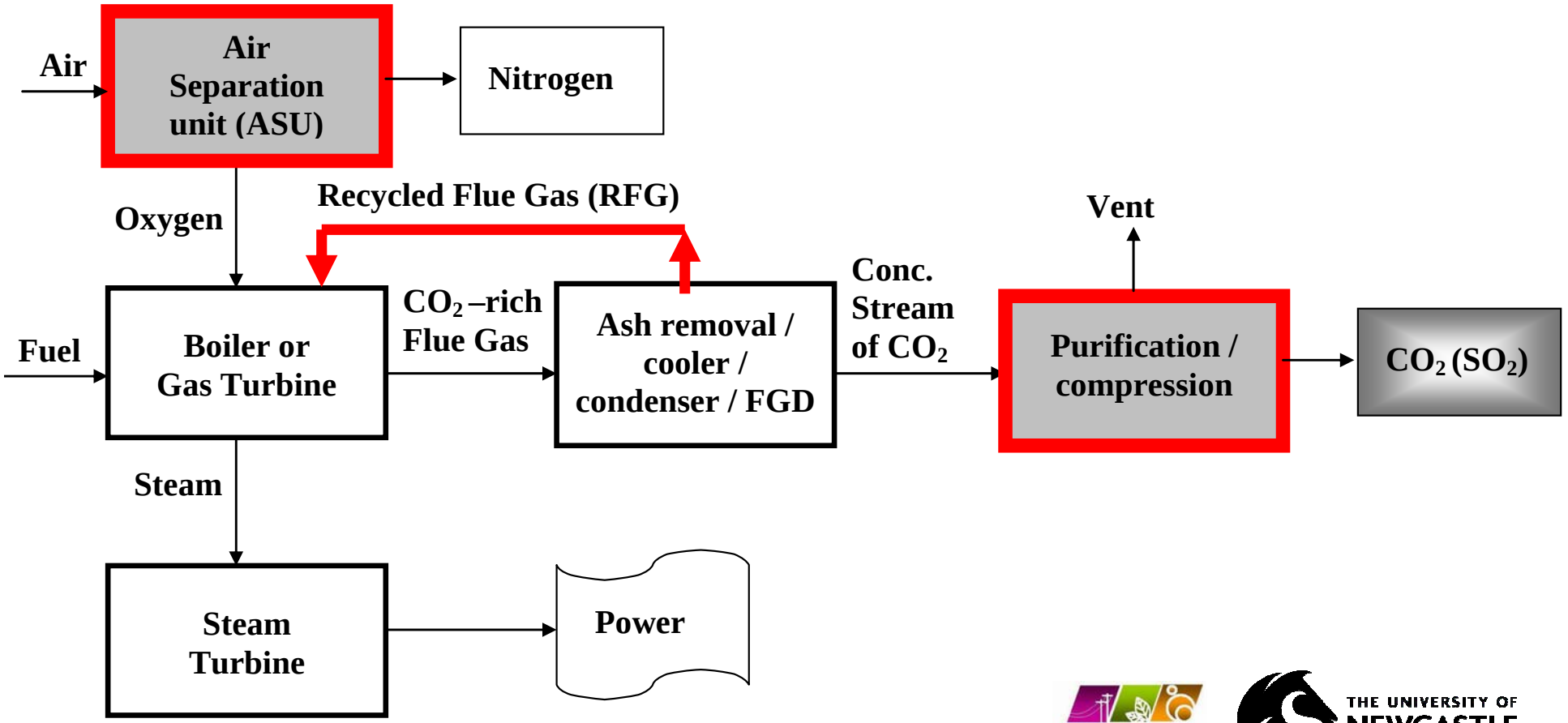


AUSTRALIA

.... can be met with some scepticism !

Canberra February 2009

Oxy- fuel



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Low emission technologies

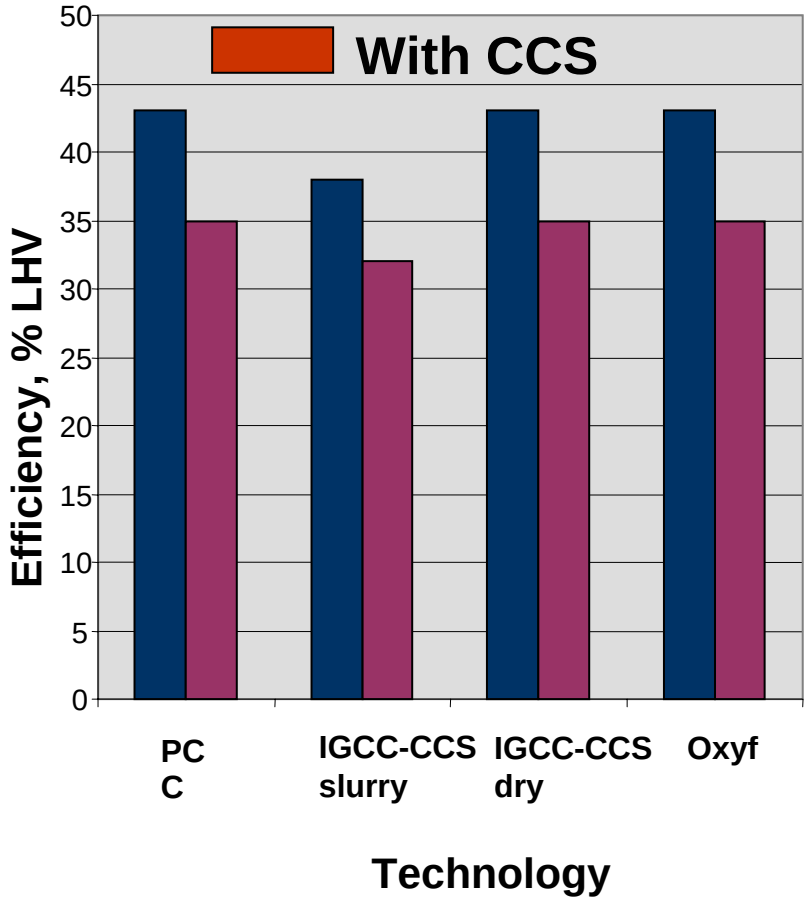
……. applicable at the scale required, using pulverised coal in entrained flow

PCC: CO_2 capture by scrubbing of the flue gas, here called ***post-combustion capture***

IGCC-CCS: Integrated gasification combined cycle (IGCC) with a shift reactor to convert CO to CO_2, which is often called ***pre-combustion capture***

Oxyf: ***Oxy-fuel combustion***, with combustion in oxygen rather than air

Technology comparisons



Data from IEA studies, 2005-7

"At the current level of development, our analysis indicates that the choice of a specific technology (eg pre-combustion, post-combustion, or oxy-fuel) does not significantly affect the cost of a "reference" large-scale plant, even though the relative shares of capex, opex and fuel costs within the total may vary markedly".

McKinsey&Company, CCS: Assessing the economics, 2008

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CCS options, with desirable characteristics indicated X

Option	Demonstrated	For retrofit	Can be applied to slip-stream	No O_2 supply *	No CO_2 capture	Gives H_2
PCC		X	X	X		
IGCC-CCS						X
Oxyf		X			X	

*** IGCC-CCS can be air fired**

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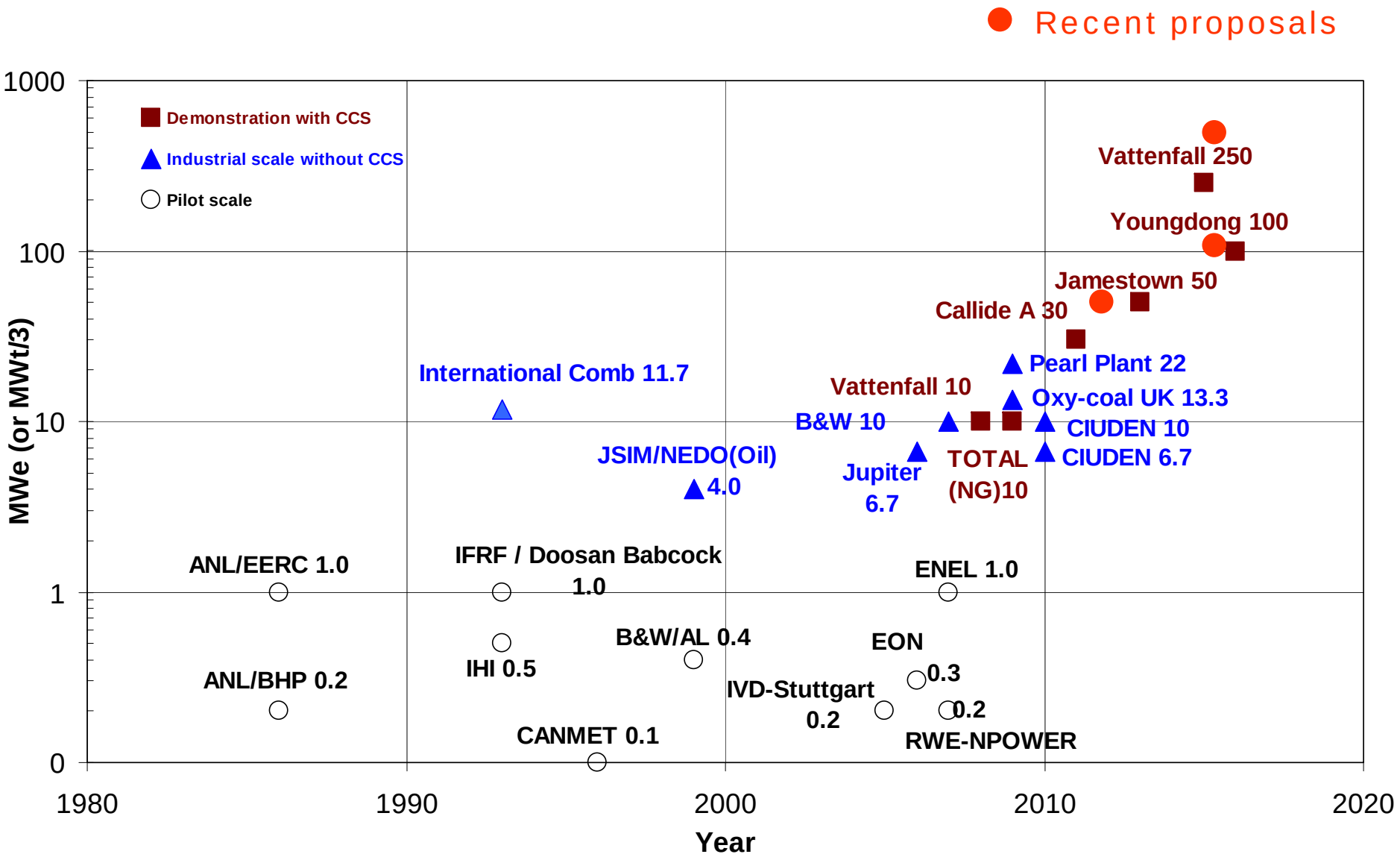
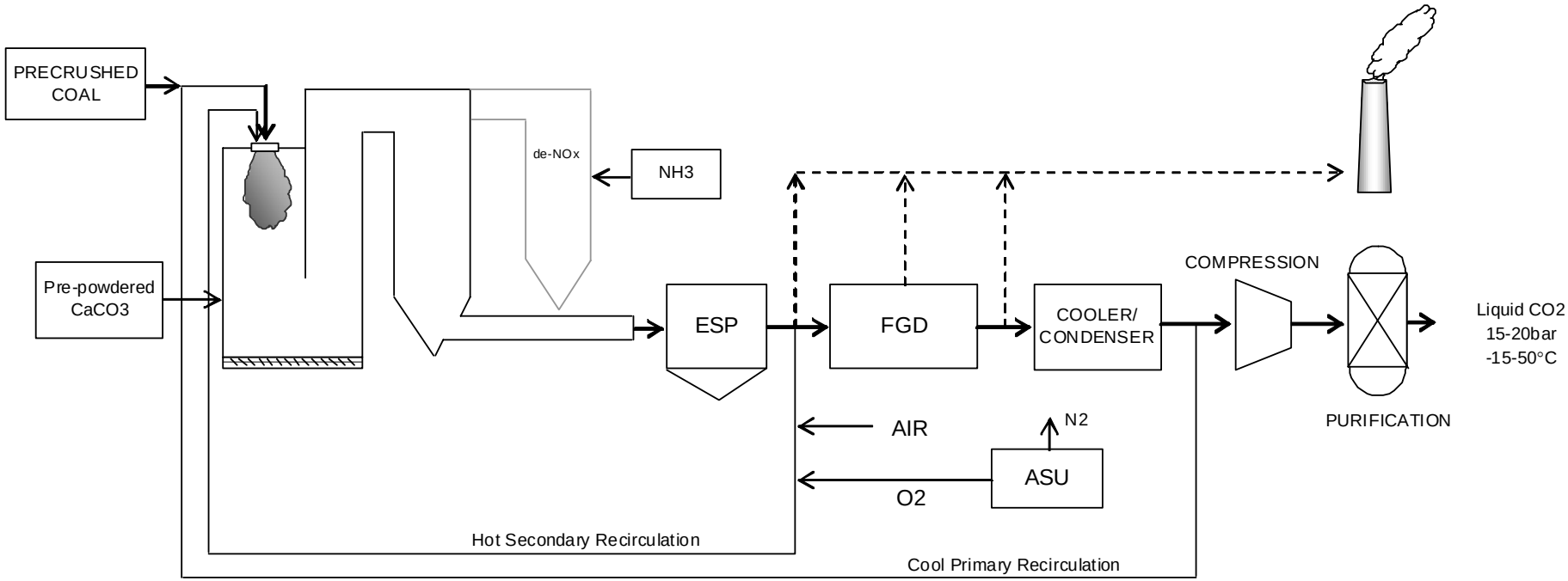
Historical development of oxyfuel technology



Current demonstrations

No	Demo/pilot-plant name	Scale (Demo/Pilot plant)	MW e	New Retrofit	Startup/ Duration	Main Fuel	Electricity generation Yes/No	CO2 Compression (Yes/No)	CO2 use/Seq	CO2 purity	Gas clean up
1	Vattenfall pilot plant, Germany	P	10	N	2008	Coal	N	Y	Y	99.90%	FGD ESP
2	Callide (CS Energy, Australia)	D	30	R	2011	Coal	Y	Y	Y		FF
3	TOTAL, Lecq, France	D	10	R	2009	NG	N	Y	Y	99.90%	
4	CIUDEN, Spain	P (PC/CFB)	17	N	2010	Coal	N	Y	Y		SCR FF FGD
5	Youngdong, South Korea	D	100	R	2016	Coal	Y		Y	98%	SNCR FF
6	Jamestown/Praxair Plant, USA	D(CFB)	50	N	2013	Coal	N	Y			
7	Jupiter Pearl plant, USA	D	22	R	2009	Coal	N	N			
8	Babcock&Wilcox pilot plant, B&W, USA	P	10	R	2008	Coal	N		N	70% dry	FGD ESP
9	Doosan Babcock, UK	P	30	N/A	2008	Coal	N		N		

Vattenfall flowsheet



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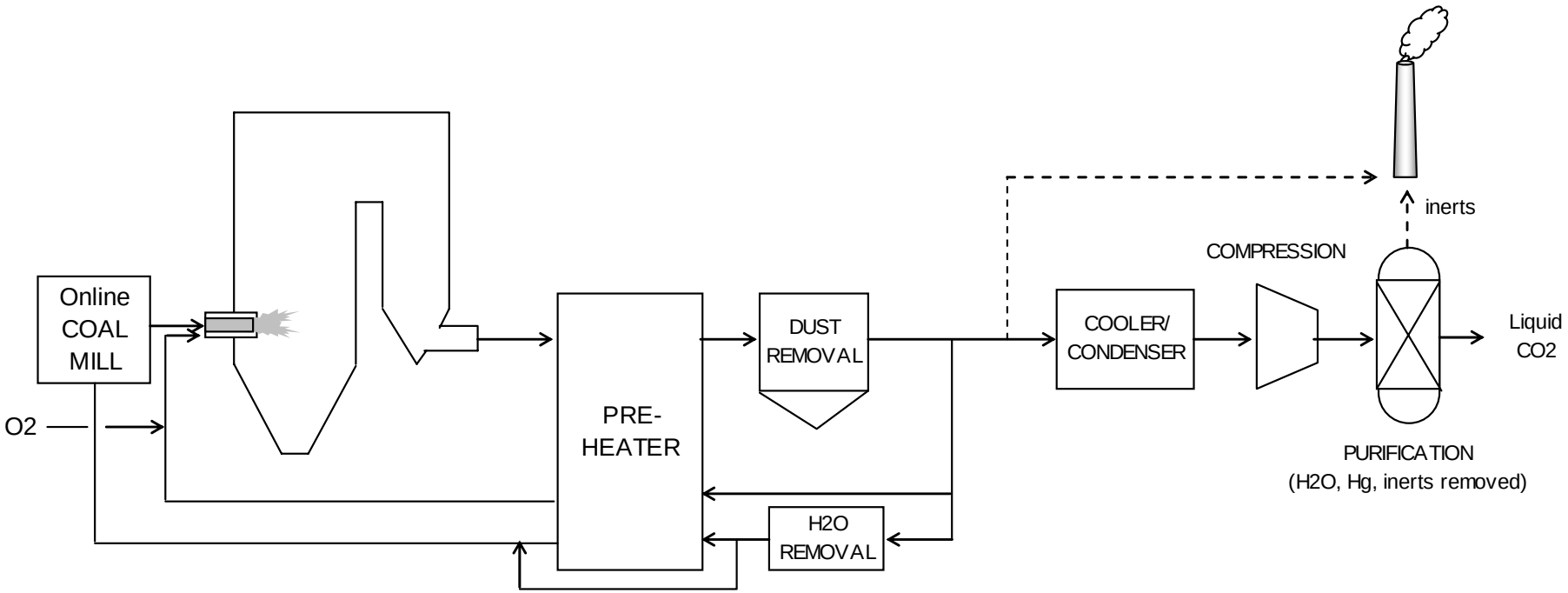
Callide flowsheet



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Demonstration contributions

***The Vattenfall 30 MWt pilot plant* – this is the first comprehensive project** and it involves evaluation of burner operation, with key testing of boiler impacts , emissions and impacts on CO2 compression. The plant also allows evaluation of possible operations such as limestone addition for sulfur capture, and ammonia addition for NOx reduction.

***The Callide 30 MWe oxy-fuel demonstration project* – will be the first integrated plant**, having power generation, carbon capture and CO2 sequestration

***The Doosan Babcock Oxy-coal UK project and B&W USA plants* –these demonstrations have comprehensive burner testing**, with burner operational envelopes, stability, turndown, start-up and shut-down, with transition between air and oxyfuel firing

The CIUDEN and Jamestown plants- these evaluate CFB oxy-fuel technology, which is suited to coal/biomass cofiring and to direct sulphur removal using sorbents.

The TOTAL, Pearl and Youngdong plants – evaluate the technology in a commercial context

Recently announced oxyfuel project prospects

B&W Black Hills Oxyfuel project, Wyoming, USA

A project has now been submitted to DOE Restructured FutureGen to build a 100MWe oxyfuel plant with CCS as a greenfield plant for the Black Hills Corporation in Wyoming, with the plant commencing in 2015.

Plant simulations for a SC unit have included thermal integration to reduce the efficiency penalty for the ASU and CO2 compression to less than 6%

FORTUM Meri-Pori Oxyfuel Project, Finland

Fortum aims to start a CCS demonstration project jointly with Teollisuuden Voima (TVO) at the Finnish Meri-Pori power plant, a 565MW plant. Due to lack of suitable storage locations in Finland, the CO2 from Meri-Pori will be shipped abroad.

ENEL Oxyfuel CCS2 Demonstration, Italy

The project goal of the CCS2 project is to build by 2012 a 50MWe zero emission coal fired power plant based on a pressurized oxy-combustion technology which has been developed at pilot scale.

International coordination

CCS generally, but specifically oxyfuel include

- Clearwater Coal Conference
- IEA Network Meetings, and First Conference in Cottbus, September, 2009
- Oxy-fuel Working Group

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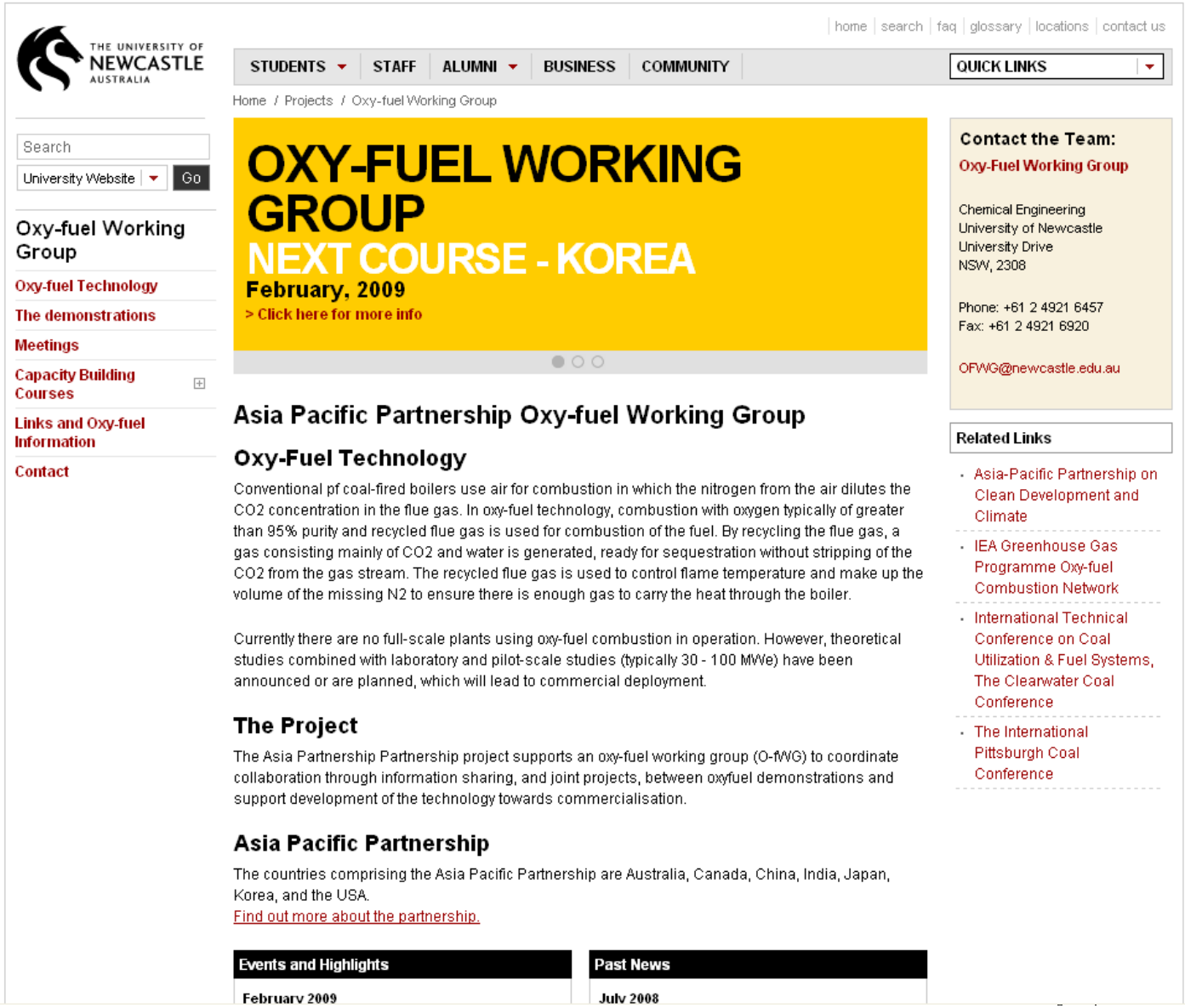
http://www.newcastle.edu.au/project/oxy-fuel-working-group/



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- The demonstrations
- Meetings
- Capacity Building Courses
- Links and Oxy-fuel Information
- Contact

OXY-FUEL WORKING GROUP

NEXT COURSE - KOREA

February, 2009

> Click here for more info

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Related Links

- Asia-Pacific Partnership on Clean Development and Climate
- IEA Greenhouse Gas Programme Oxy-fuel Combustion Network
- International Technical Conference on Coal Utilization & Fuel Systems, The Clearwater Coal Conference
- The International Pittsburgh Coal Conference

Asia Pacific Partnership Oxy-fuel Working Group

Oxy-Fuel Technology

Conventional pf coal-fired boilers use air for combustion in which the nitrogen from the air dilutes the CO2 concentration in the flue gas. In oxy-fuel technology, combustion with oxygen typically of greater than 95% purity and recycled flue gas is used for combustion of the fuel. By recycling the flue gas, a gas consisting mainly of CO2 and water is generated, ready for sequestration without stripping of the CO2 from the gas stream. The recycled flue gas is used to control flame temperature and make up the volume of the missing N2 to ensure there is enough gas to carry the heat through the boiler.

Currently there are no full-scale plants using oxy-fuel combustion in operation. However, theoretical studies combined with laboratory and pilot-scale studies (typically 30 - 100 MWe) have been announced or are planned, which will lead to commercial deployment.

The Project

The Asia Partnership Partnership project supports an oxy-fuel working group (O-fWG) to coordinate collaboration through information sharing, and joint projects, between oxyfuel demonstrations and support development of the technology towards commercialisation.

Asia Pacific Partnership

The countries comprising the Asia Pacific Partnership are Australia, Canada, China, India, Japan, Korea, and the USA.
Find out more about the partnership.

Events and Highlights

February 2009

Past News

July 2008

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OFWG project areas from Yokohama 2008 meeting

A survey of some OFWG members and discussion resulted in four project areas to be progressed by the OFWG, with some points made, these being, in order of support indicated by PLs:

Regulations. CO2 quality for geological storage. Stack (flue gas) emissions during operation – ppm or gm/MJ. Gas missions from compression operations

Plant specification guidelines. Plant design and operation

Safety. Materials for high O2 environments.Higher O2 streams safety requirements, >23%O2. Explosions less possibility with O2/CO2 than O2/N2.O2 injection into ash streams with ash containing unburnts

OFWG: current action list

- Technology status report
- Project
  - Roadmap
- Capacity building courses
- Projects
  - Regulations

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Technology status and roadmap report

….in conjunction with IEA CCC

IEA CLEAN COAL CENTRE

Work Programme

Carbon abatement — In progress

Oxyfuel combustion based capture of carbon dioxide

Robert Davidson

This report will be a review of the status of oxyfuel based CO_2 capture, to be produced in co-operation with the IEA Greenhouse Gas R&D Programme and published to both sets of members.

Oxyfuel combustion with CO_2 capture is one of three generic routes to CO_2 capture. It can be used for both new plant and for retrofit. The latter could be important as an option to offset the carbon lock in that is likely to otherwise occur in the next decade.

Oxyfuel combustion is based on combustion of coal in oxygen with recycle of some of the boiler effluent gas stream to attemperate conditions in the boiler. There has been much research in recent years and the first small demonstration-scale projects are about to come on stream. Several well-known equipment manufacturers are investing heavily in the RD&D, as are some well-known utilities.

Basic research is looking at the properties of the CO_2 stream, particularly the effects of contaminant compounds of sulphur, nitrogen and the effects of mercury. There is a trade-off between purity of oxygen supply and CO_2 product stream. Heat transfer and boiler modelling have influenced designs. There is also considerable investigation into alternative ways of using oxyfuel combustion such as chemical looping.

The first OFWG course

Contributing lecturers

Researchers:
Prof Terry Wall, Dr Jianglong Yu, APP; University of Newcastle, Australia
Dr Stanley Santos, IEAGHG, England
Dr Joerg Maier, University of Stuttgart, Germany
Demonstration proponents:
Dr Sung-chui Kim KEPRI, Korea
Dr Gerry Hesselmann, Doosan Babcock, Scotland
Technology provider:
Yongkyoo Han, Praxair, Korea
Country presentation:
Professor Ningsheng Cai, Tsinghua University, China

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WORLD RESOURCES INSTITUTE

CCS GUIDELINES

Regulations and guidelines for CCS

RESOURCES
Resources Programs

Home > Resources > Carbon Dioxide Capture and Geological Storage (CCS) > CCS Legislation

CCS Legislation

Carbon dioxide capture and geological storage (CCS) is a relatively new form of technology that aids in reducing greenhouse gases released into the atmosphere. Several CCS projects have been proposed in Australia necessitating the development of a sound, guiding regulatory framework for CCS.

DEVELOPMENT OF THE REGULATORY GUIDING PRINCIPLES FOR CCS

On 25 November 2005, the Ministerial Council on Mineral and Petroleum Resources (MCMPR) endorsed the *Regulatory Guiding Principles for Carbon Dioxide Capture and Geological Storage* [PDF, 779KB]. The aim

EUROPEAN UNION

THE EUROPEAN PARLIAMENT	THE COUNCIL
	Brussels, 26 March 2009 (OR. en)
2008/0015 (COD)	PE-CONS 3739/08
	ENV 1044 ENER 482 IND 240 CODEC 1908

LEGISLATIVE ACTS AND OTHER INSTRUMENTS

Subject: DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006

RAGE GUIDELINE 6: RECOMMENDED GUIDELINES FOR

a. A field development plan sho
b. Operators should develop tra
with sufficient flexibility to us
activities to adapt to unexpec
c. Operational plans should b
assessment; they should inclu
d. Storage operators should pla
combination of contractual agr
storage space, and, if necessa
e. Wells and facilities should b
regulations for design and co
f. The reservoir and risk model
based on operational data and
if significant differences in th
g. The casing cement in the we
above the confining zone.
h. Well integrity, including cemen
is complete, and routinely whi

govtrack.us
a civic project to track Congress

Citizens in Action: A guide to Influencing Government

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Congress > Legislation

H.R. 1689: Carbon Capture and Storage Early Deployment Act

111th Congress
2009-2010

To accelerate the development and early deployment of systems for the capture and storage of carbon dioxide emissions from fossil fuel electric generation facilities, and for other purposes.

Overview

Sponsor: Rep. Frederick Boucher [D-VA] show cosponsors (20)

Text: Full Text

Status: ☑ Introduced Mar 24, 2009

Navigation
> Overview
- Full Text
- Committee Assignments
- Related Legislation

Oxyfuel specific regulation issues

- Oxyfuel technology has
  - greater variability of CO2 gas quality
  - more options for optimisation of impurity removal
- Potentially greater impact of technology and CO2 avoidance cost (than PCC and IGCC-CCS)
- Early application requirements uncertain (in common with PCC and IGCC-CCS)

The Clearwater Clean (Low Emission) Coal Conference – Oxyfuel sessions

Panel

Technical sessions – 5, covering

- Demonstrations-5
- Experimental studies- 7
- Burners-6
- Emissions-7
- Advanced concepts-6

Essentially combustion focus, ie, at the furnace and emission control end of the flow sheet

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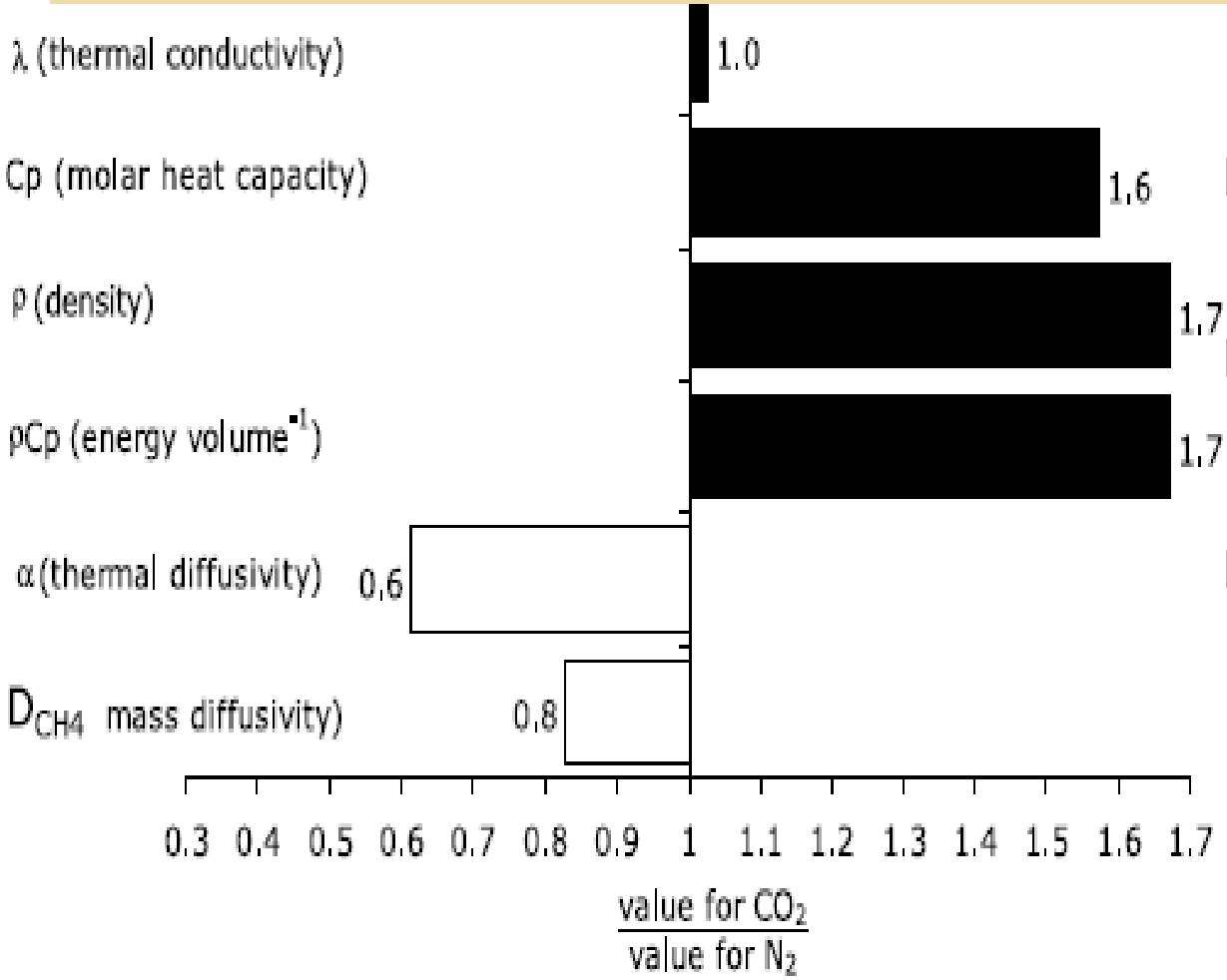
Gas property differences



Impact for air to oxyfuel retrofit

- Higher O2 thru burner
- Lower burner velocity, higher coal residence time in furnace
- Slower flame propagation velocity

Gas property ratios for CO_2 and N_2 at 1200 K

Properties from Shaddix, 2006

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What research is needed, in suggested order of priority?

Gas quality impacts and control

Plant impacts - S, Hg

Air leakage – N2 compression energy and capture recovery

Emerging (regulated) CO2 quality for storage

Pipeline transport - O2, S

Compression and gas cleaning

O2 supply

Scale and energy penalty

Furnace

Radiative heat transfer

Burner operation

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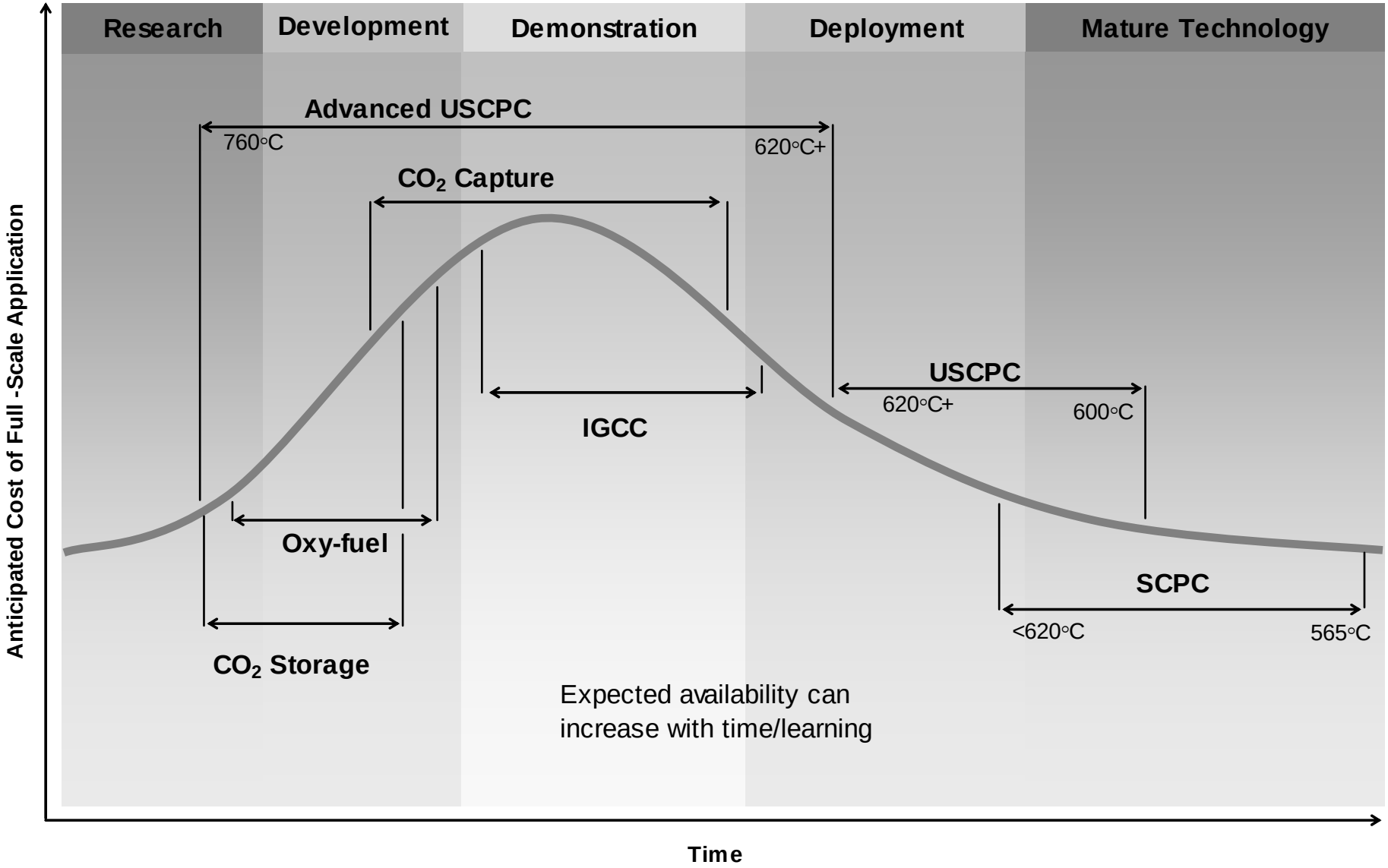
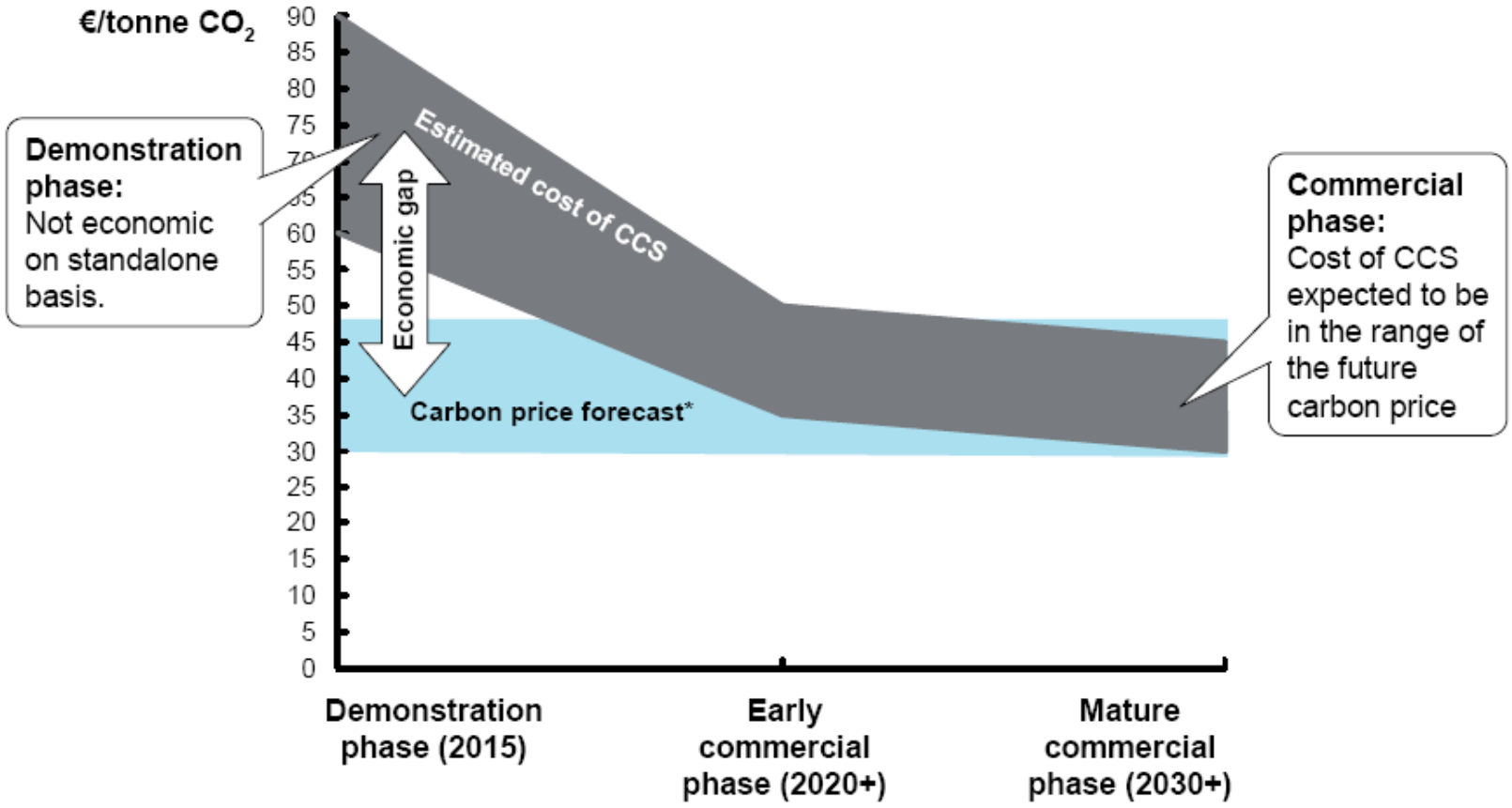
Pathway to implementation

Anticipated cost of CCS-related technologies as they are developed and applied



Indicative CO2 costs to drive development: McKinsey&Company, CCS: Assessing the economics, 2008



* Carbon price for 2015 from 2008-15 estimates from Deutsche Bank, New Carbon Finance, Soc Gen, UBS, Point Carbon, assumed constant afterwards

Source: Reuters; Team analysis

Project components and sequence: Low emission coal power plant with geosequestration, based on a 500MW plant, time halved for 50 MW demonstration

Time, yrs	Power plant, PP	CO2 disposal geology	Permitting
Phase 1 1-2	Concept, pre-feasibility and site selection – cost 1% of PP project	Basin scoping, exploration and appraisal-<$100M	Access to land, exploration licence
Phase 2 2-3	Feasibility and FEED (Front-End Engineering and Design) - 5%	Site validation and feasibility- <$250M	Environmental impact statement. Permitting process and times very location dependant
Phase 3 3-4	Financial close, construction and commissioning - 95%	Storage site and injection licence confirmed	

Decision to proceed

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Times of targets and milestones

Related deployment targets

By 2020 - Improved efficiency of PF plants by more severe steam conditions, such that efficiencies for oxyfuel with capture reaches 42-44% HHV, similar to PCC and IGCC

By 2022 – Commercial availability of CO2 storage, with new coal plants capture and storing 90% of CO2

By 2030 – Further improvement in efficiencies with CCS, > 45% HHV

Related regulatory milestones

By 2014 – Regulatory framework established to allow permitting process to proceed for demonstrations to be operating by 2020

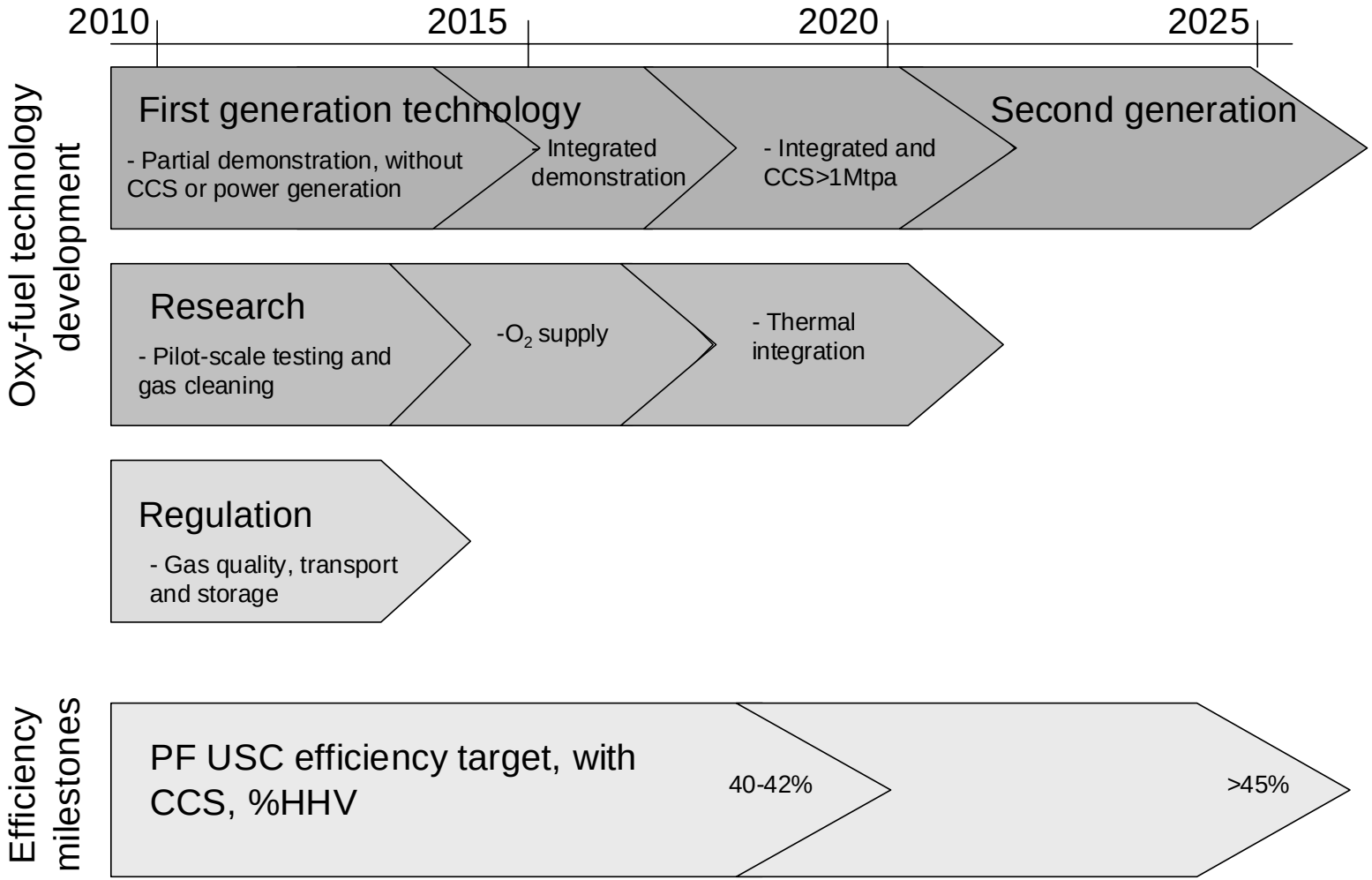
Related research milestones

By 2014 – Gas cleaning technology to meet regulatory requirements for CO2 transport and storage

After 2016 – Alternative oxygen supply technology to ASU such as membranes and chemical looping demonstrated at scale

After 2020 – Second generation oxyfuel plant applied using learnings from first generation demonstrations

Simplified roadmap to deployment of first-generation oxyfuel technology – to be developed further



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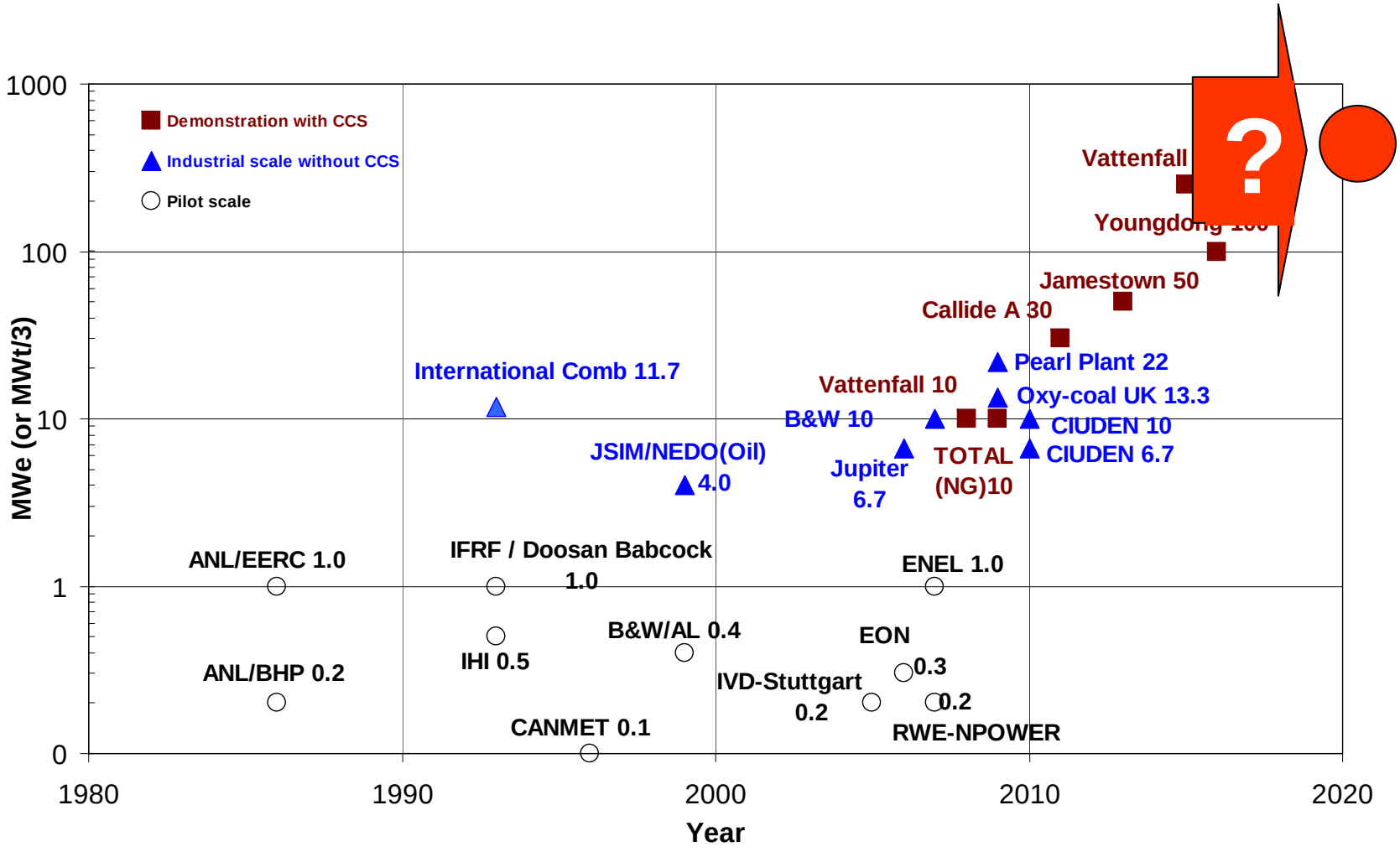
Fully integrated industrial-scale demonstration projects by 2020?



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Final comments

Oxy-fuel technology is on the path through a development and demonstration phase

….. With 2020 the target for early commercialisation

….. Requiring earlier fully integrated industrial-scale demonstration projects

Current and emerging first generation demonstrations – for retrofits and new plant - will drive future research and technology developments

Second generation technologies – for new plant – will have lower energy penalties and capital costs

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