Recent Developments in Clean Coal Technologies

2nd South East Europe Energy Dialogue
International Conference
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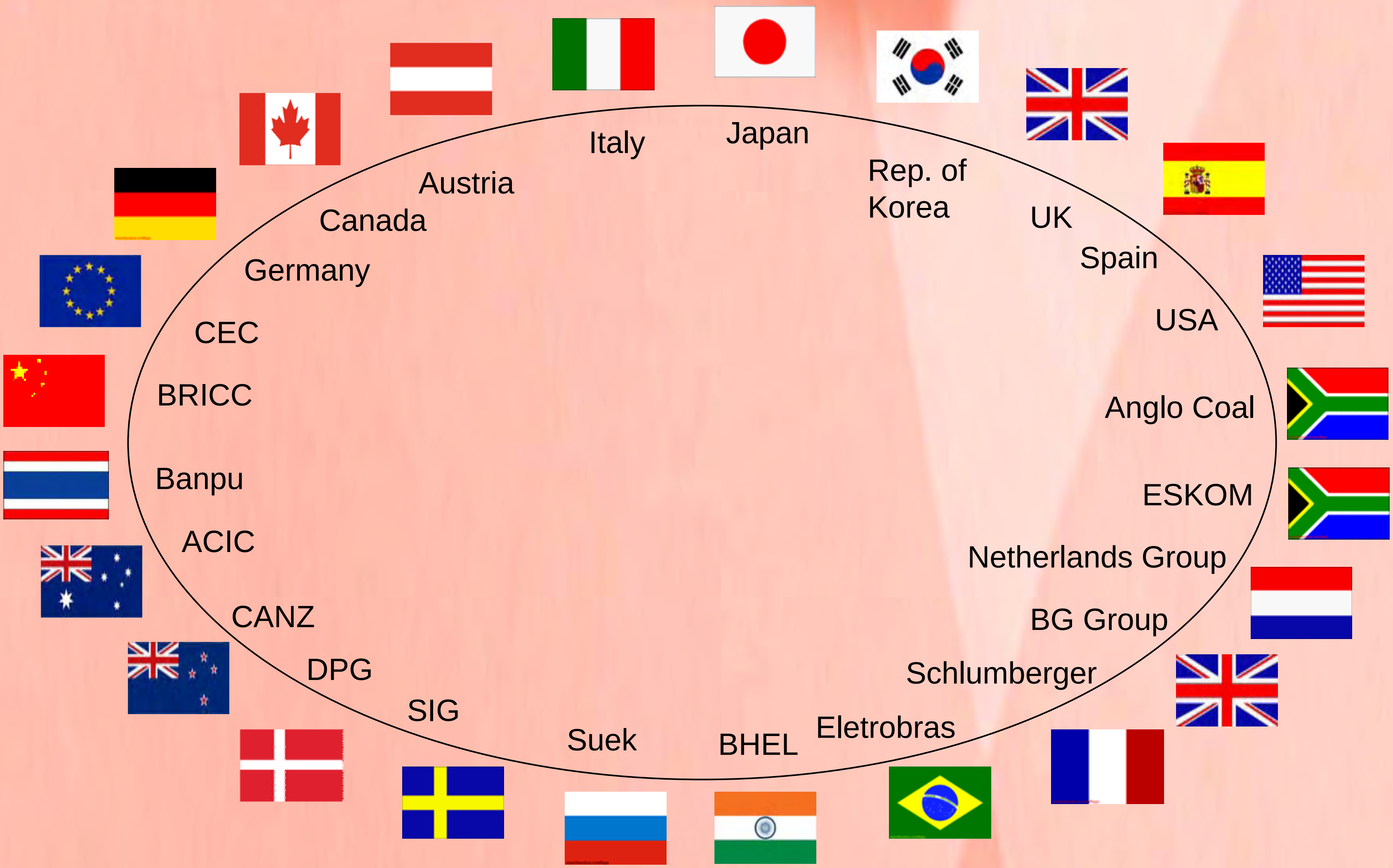
MEMBERS



Italy
Japan
Austria
Rep. of Korea
Canada
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USA
CEC
BRICC
Anglo Coal
Banpu
ESKOM
ACIC
Netherlands Group
BG Group
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DPG
SIG
Eletrobras
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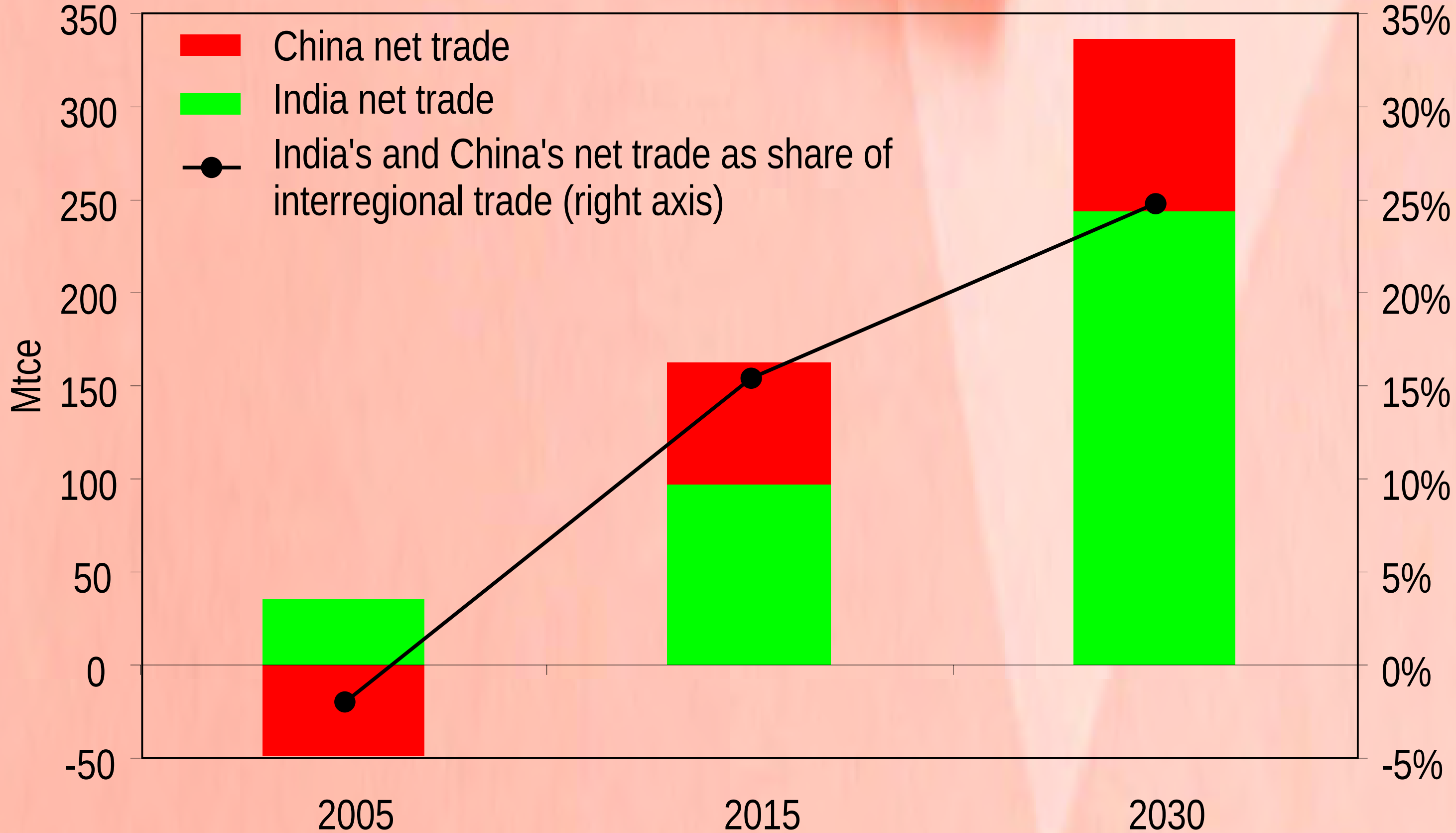
BHEL

WORLD ENERGY OUTLOOK 2007

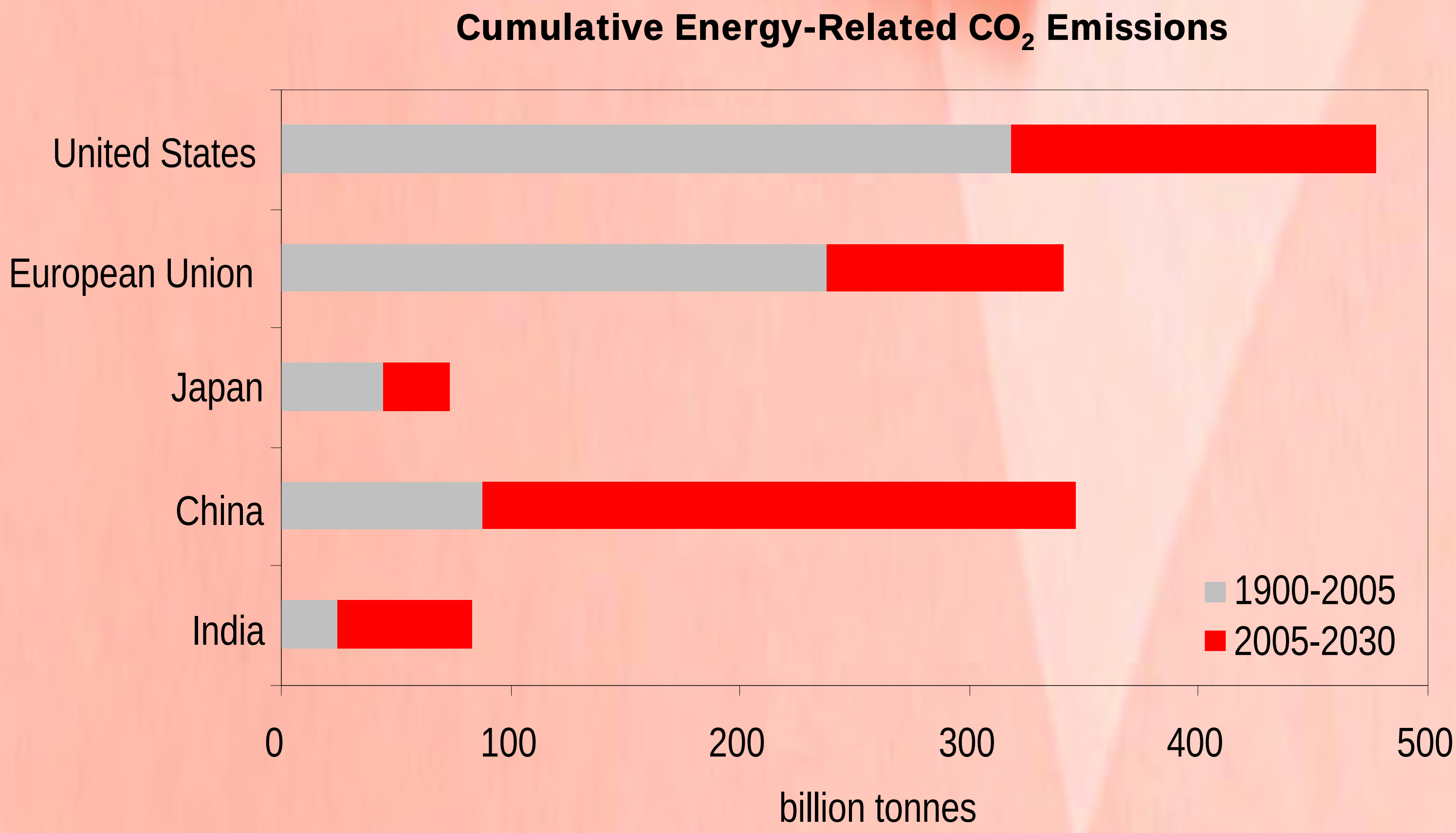
Courtesy of IEA, Paris

China & India Coal Imports



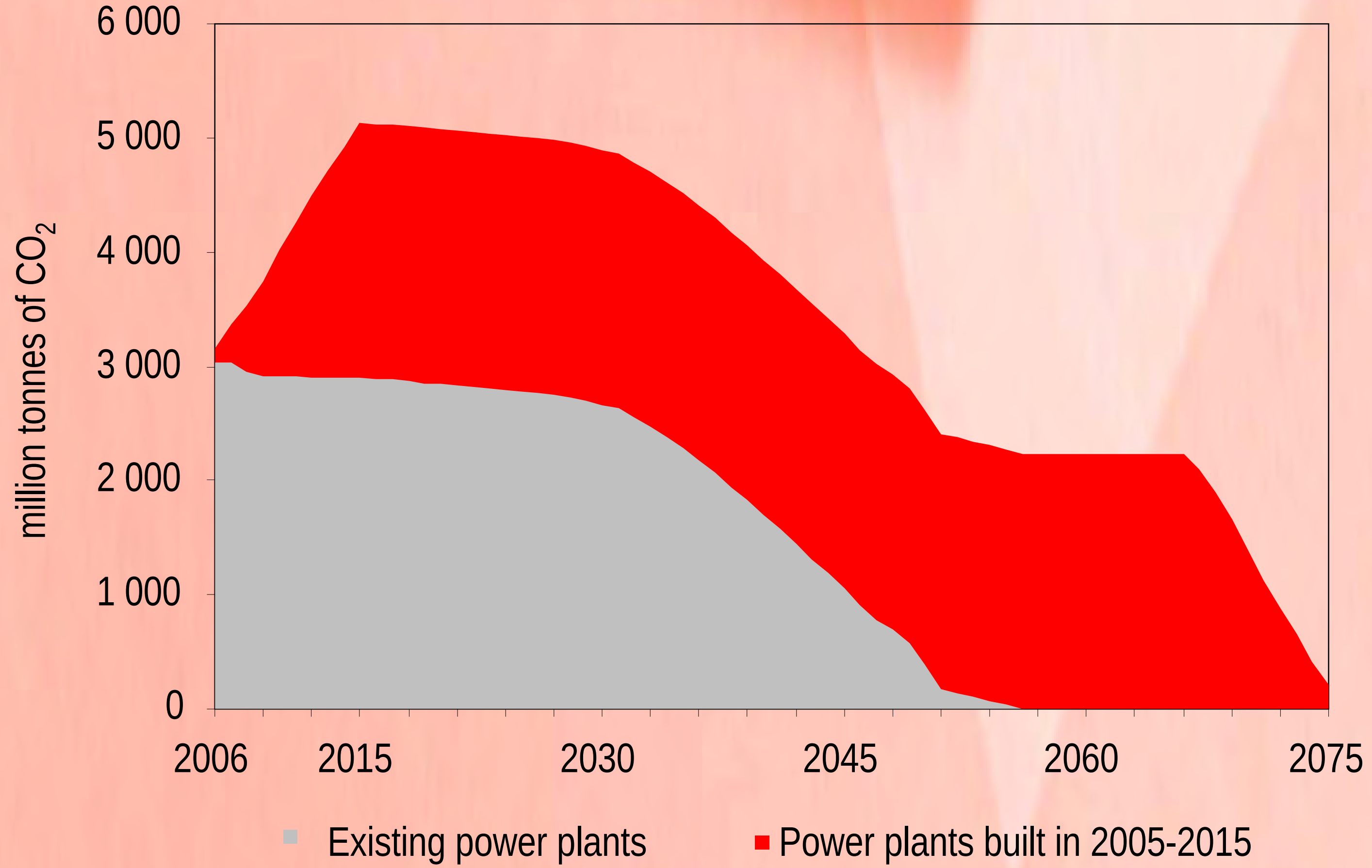
China recently became a net coal importer like India, with both putting increasing pressure on international coal markets

China & India in Global CO_2 Emissions



Around 60% of the global increase in emissions in 2005-2030 comes from China & India

CO_2 Emissions from Coal-Fired Power Stations built prior to 2015 in China & India



Capacity additions in the next decade will lock-in technology & largely determine emissions through 2050 & beyond

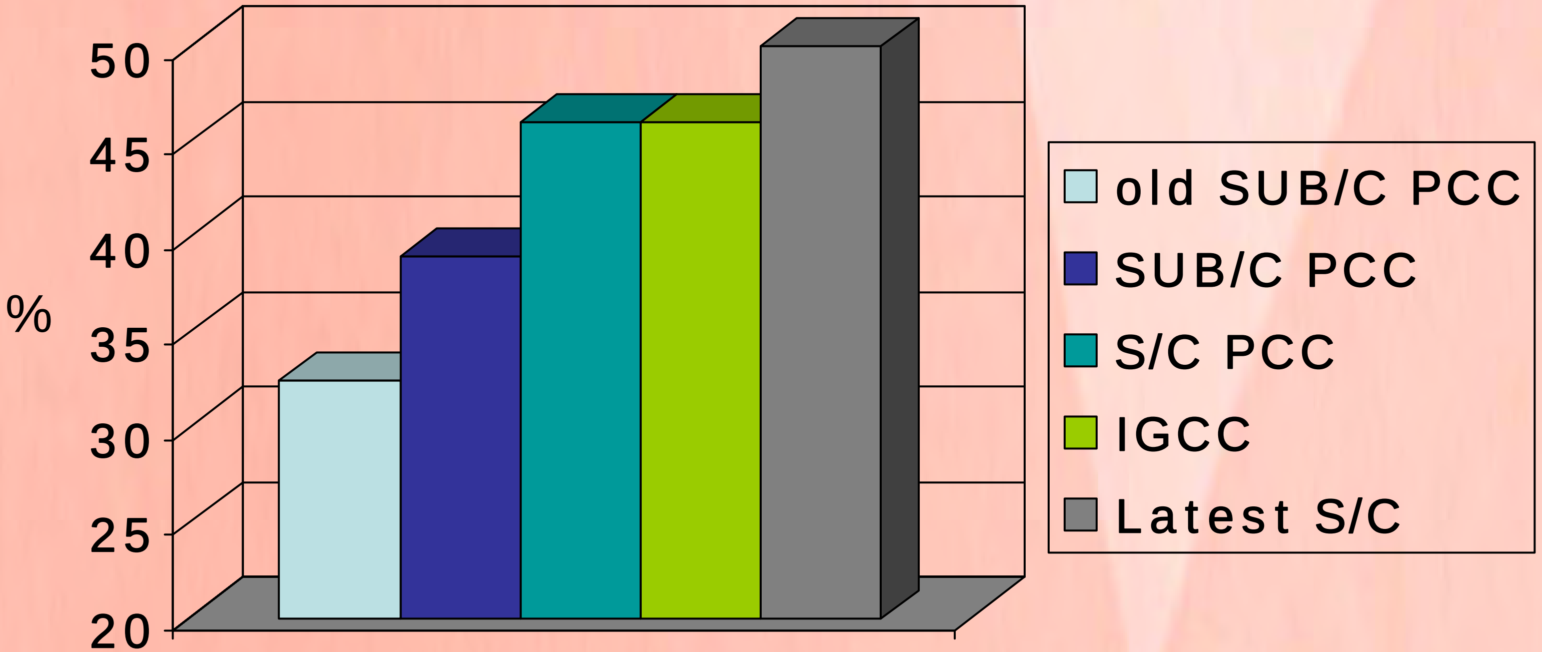
World energy outlook

- Global energy system is on an *increasingly* unsustainable path
- China and India are transforming the global energy system by their sheer size
- Challenge for *all* countries is to achieve transition to a more secure, lower carbon energy system
- New policies now under consideration would make a major contribution
- Next 10 years are critical
  - → The pace of capacity additions will be most rapid
  - → Technology will be "locked-in" for decades
  - → Growing tightness in oil & gas markets
- Challenge is global so solutions must be global

COAL FOR POWER TODAY

What is State-of-the-Art and what are the prospects?

Indicative efficiencies of coal-fired power technologies (% net, LHV basis)



Nordjylland 3, Denmark – highlights

USC, tower boiler, tangential corner firing, int. bituminous coals, cold sea water

Most efficient coal-fired plant

Operating net efficiency 47% LHV, power only mode/44.9% HHV (not annual)

High steam conditions 29 MPa/582°C/580°C/580°C at boiler by early use of new materials (P91)

Large number of feedwater heating stages

Double reheat has prevented LP blade erosion

Very low emissions and full waste utilisation

NOx abatement	Combustion measures and SCR
Particulates removal	ESP
Desulphurisation	Wet FGD

Isogo New Unit 1, Japan – highlights

USC, tower boiler, opposed wall firing, int bitum and Japanese coals, warm sea water

- Near zero conventional emissions (NOx 20 mg/m^3, sulphur oxides 6 mg/m^3, particulates 1 mg/m^3, at 6% O_2, dry); full waste utilisation
- Highest steam conditions: 25.0 MPa/600°C/610°C at turbine: ASME CC 2328 steels in S/H; P122 for main steam pipework
- Operating net efficiency >42% LHV/40.6% HHV
- Efficiency tempered slightly by 21°C CW, fewer FW heating stages
- Dry regenerable activated coke FGD (ReACT)
- NOx abatement Combustion measures and SCR
- Particulates removal ESP
- Isogo New Unit 2 will use ReACT specifically for multi-pollutant control, including mercury

E.On 50% efficient plant

… 50plus by using new materials

Location	**Wilhelmshaven**
Efficiency	50 %
Capacity	500 MW_{el}
Investment	1 billion €
Start of operation	2014

2007 — Size of plant, Search for location

2010 — Material development, Request for proposal

2014 — Construction, Start of operation

China - Typical (old) 200 MW plant

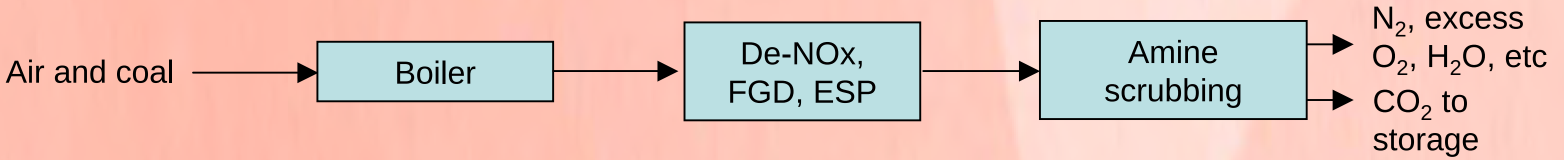
Wangqu 2 x 660 MW power plant

Huaneng Yuhuan power plant

CO_2 capture - combustion plant

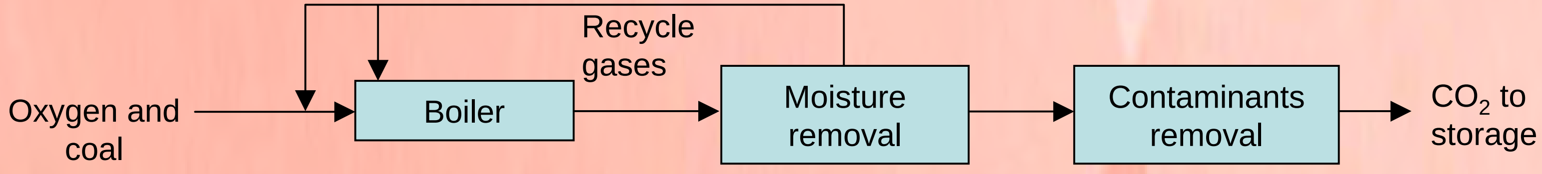
Post-combustion capture - Flue gas amine scrubbing:

- Could be ordered now, experience on gas flows to 50 MWe
- Issues such as corrosion, solvent degradation controllable
- Efficiency penalty high but decreasing (~8-14% points)
- Esbjerg CASTOR slipstream project



Oxyfuel firing:

- Tested at ~1MW pilot scale
- 30 MWe retrofit Australia; ENCAP 30 MWth Germany, 1 MWth CFBC France
- Efficiency penalty appears similar to chemical scrubbing
- New oxygen production technology would reduce penalty



CASTOR CO_2 capture pilot plant

Esbjerg power plant
Capacity: 1 t CO_2 / h
5000 Nm3/h flue gas (coal combustion)
In operation since early 2006

Nordjyllands 3 Denmark

Likely to be fitted with post combustion capture demonstration unit; linked to Vested aquifer 30 km away: announced 5 Feb2008

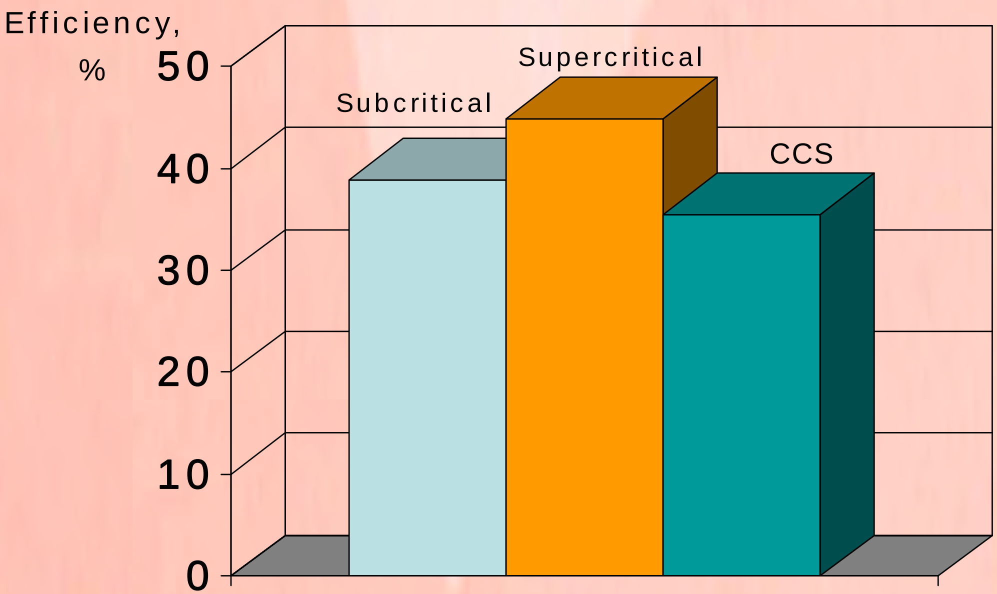
Effect of post combustion carbon capture on plant thermal efficiency

Ratcliffe power station (E.ON, UK)

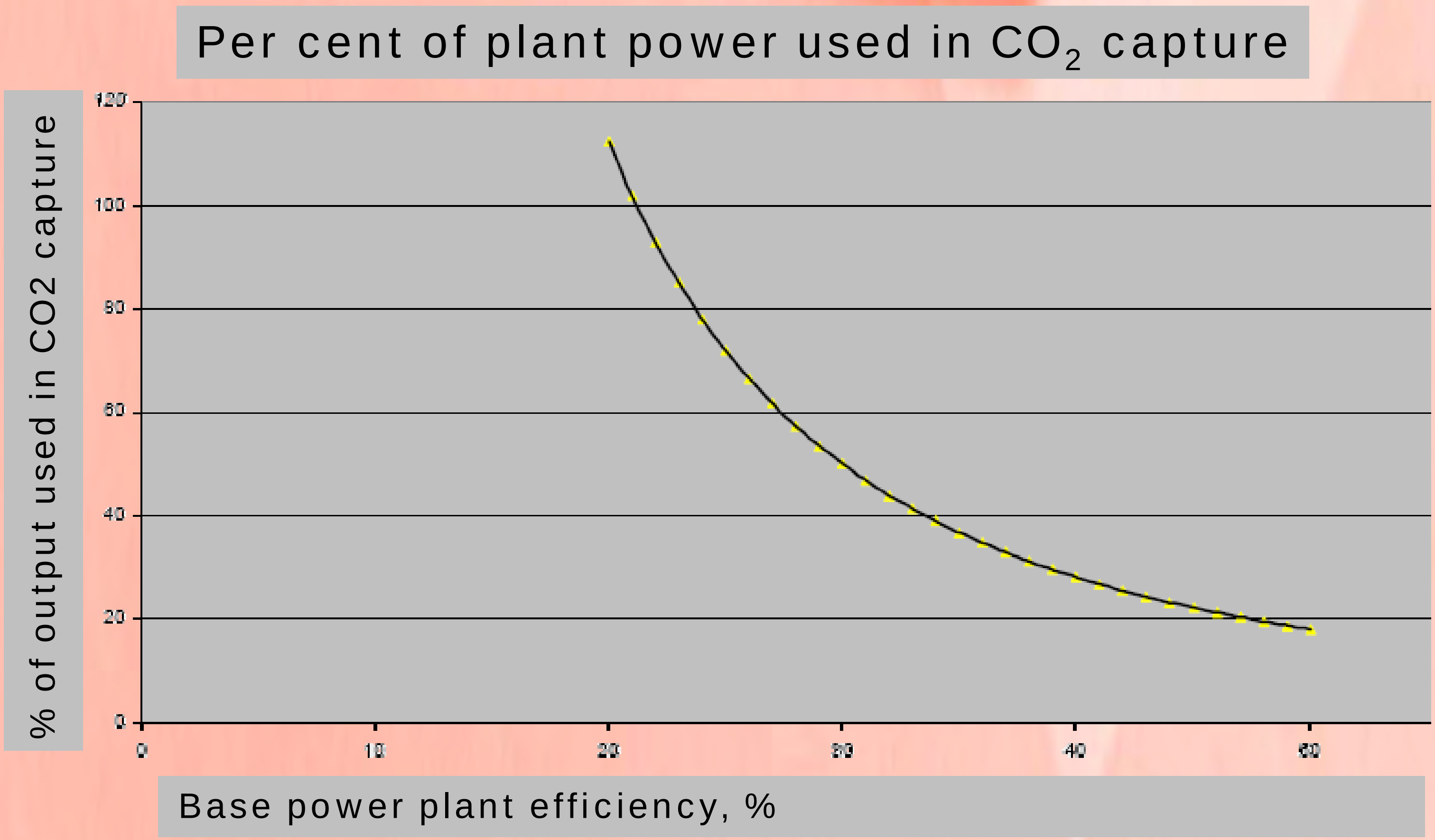
Thermal efficiency at present
38.9% (LHV)

Retrofitted with advanced supercritical boilers
44.9%

Amine scrubber fitted
35.5%



Efficiency and cost implications of most CO_2 capture options



Source: RWE npower

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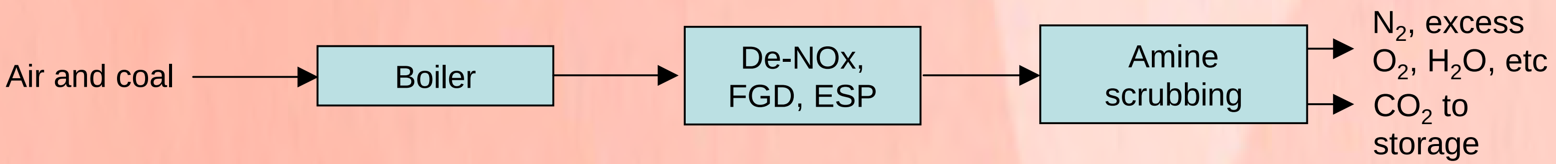

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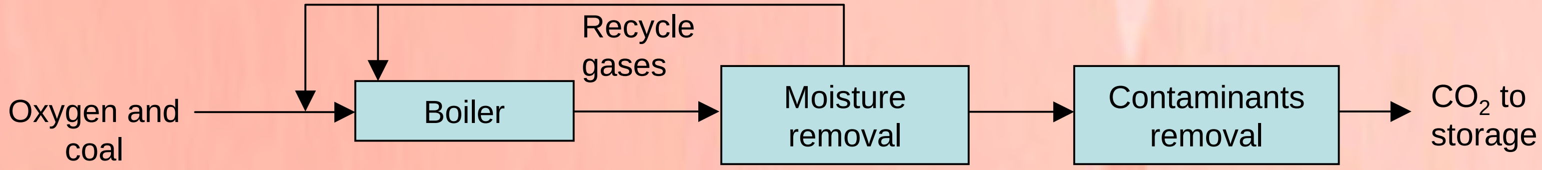
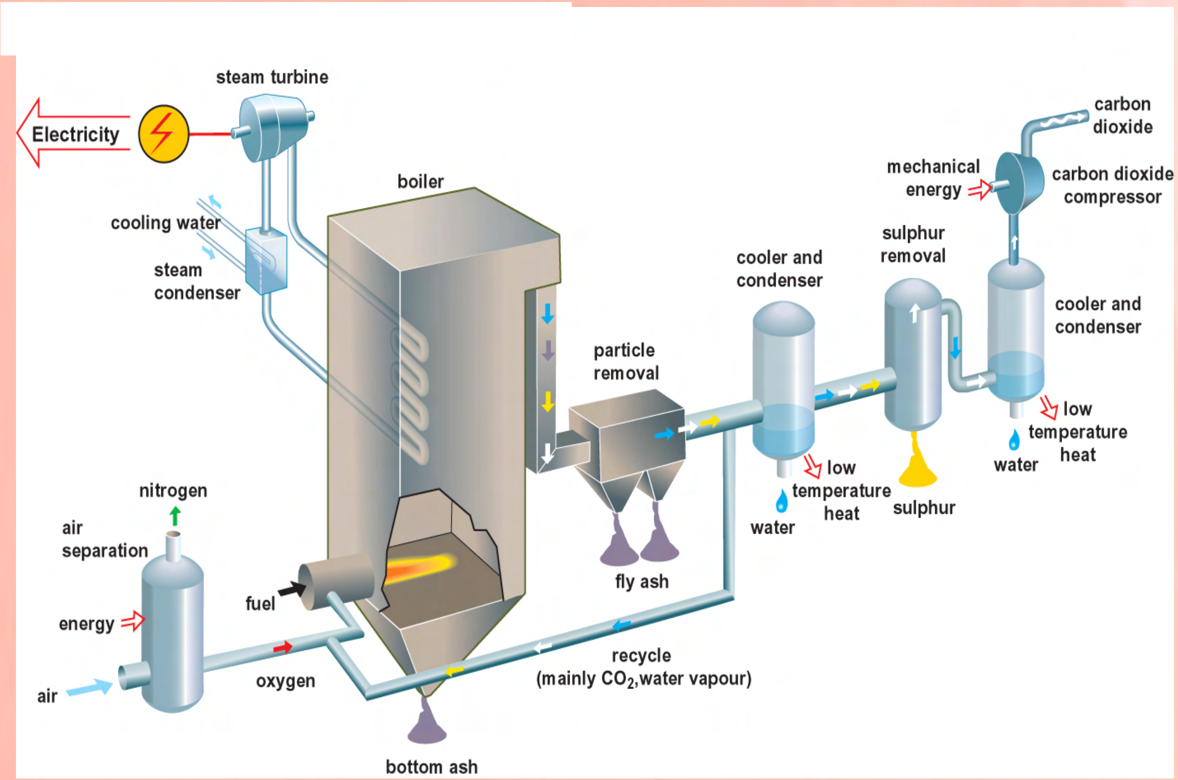


Vattenfall Oxy Fuel Technology

(Courtesy Vatenfall)

The size of the plant will be about 30 MWth and the energy will be utilized



- The technology used is the "Oxyfuel technology"
- Adjacent to the Schwarze Pumpe Power plant and will utilise infrastructure.
- Fuel will be lignite, and hard coal

Australia – Oxy-fuel project

Joint feasibility study with Japan

Oxy-fuel retrofitting with

CO_2 capture and geological storage

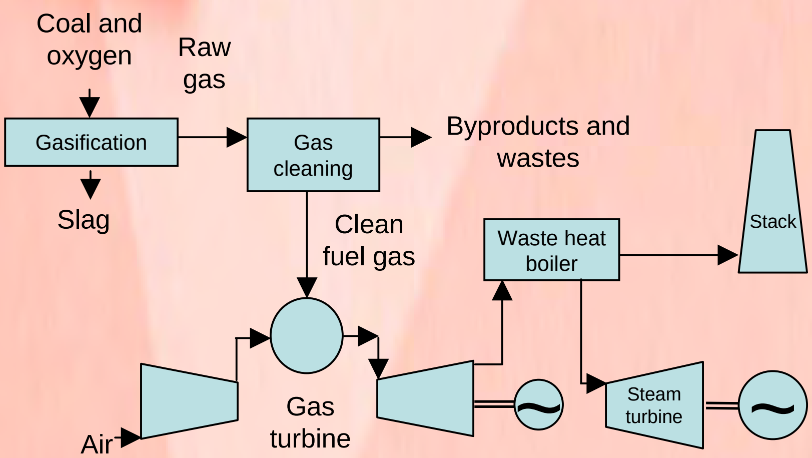
Two stages:

- Stage 1 – Detailed engineering feasibility study on the technical requirements and costs to convert an existing 30MWe PCC boiler to oxy-firing

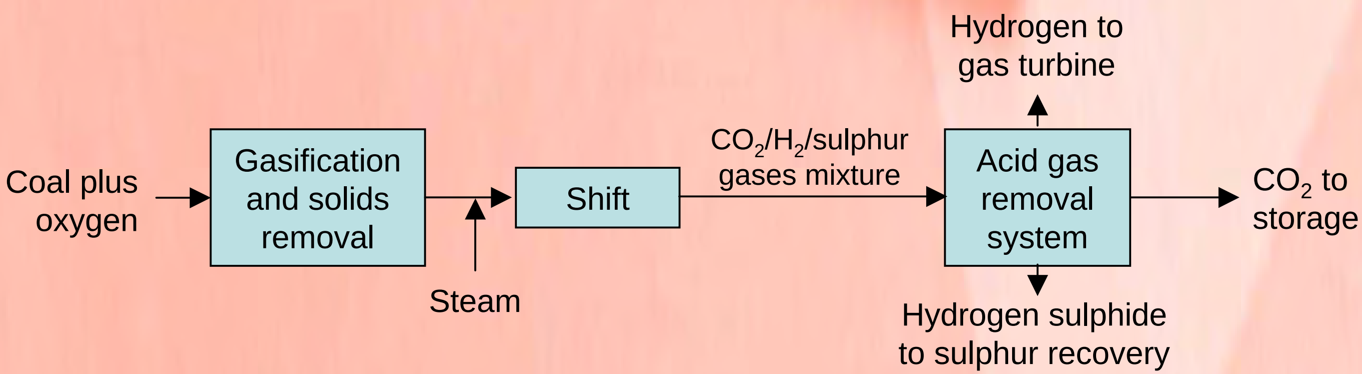
- Stage 2 – Establishment of an oxy-fired PCC demonstration plant capable of producing up to 150,000 tonnes per year of CO2 for geological storage over a test period of 3 to 4 years

Integrated gasification combined cycle (IGCC)

- Demonstrations in USA and Europe and, shortly, in Japan
- Cost and availability concerns have held back orders but reference plants soon
- Efficiency ~40-43% LHV
- Very low emissions, mercury capture simple



Integrated gasification combined cycle (IGCC) plants: CO_2 capture



- Physical solvent scrubbing of CO_2 is established in chemical industry
- Lower energy penalty than for PCC - prospect of only ~ 4-8% points
- Experience of E-class GTs on 95% H_2
- Other methods of separation available
- Other schemes without shift

IEA CLEAN COAL CENTRE

IGCC in Japan (courtesy of J Coal)

IGCC (Integrated Coal Gasification Combined Cycle)

- Clean Coal Power R&D Co., Ltd.
- Air blown, entrained-flow gasifier
- 250 MW demonstration, 2007-2009
- High efficiency (20% CO_2 reduction)

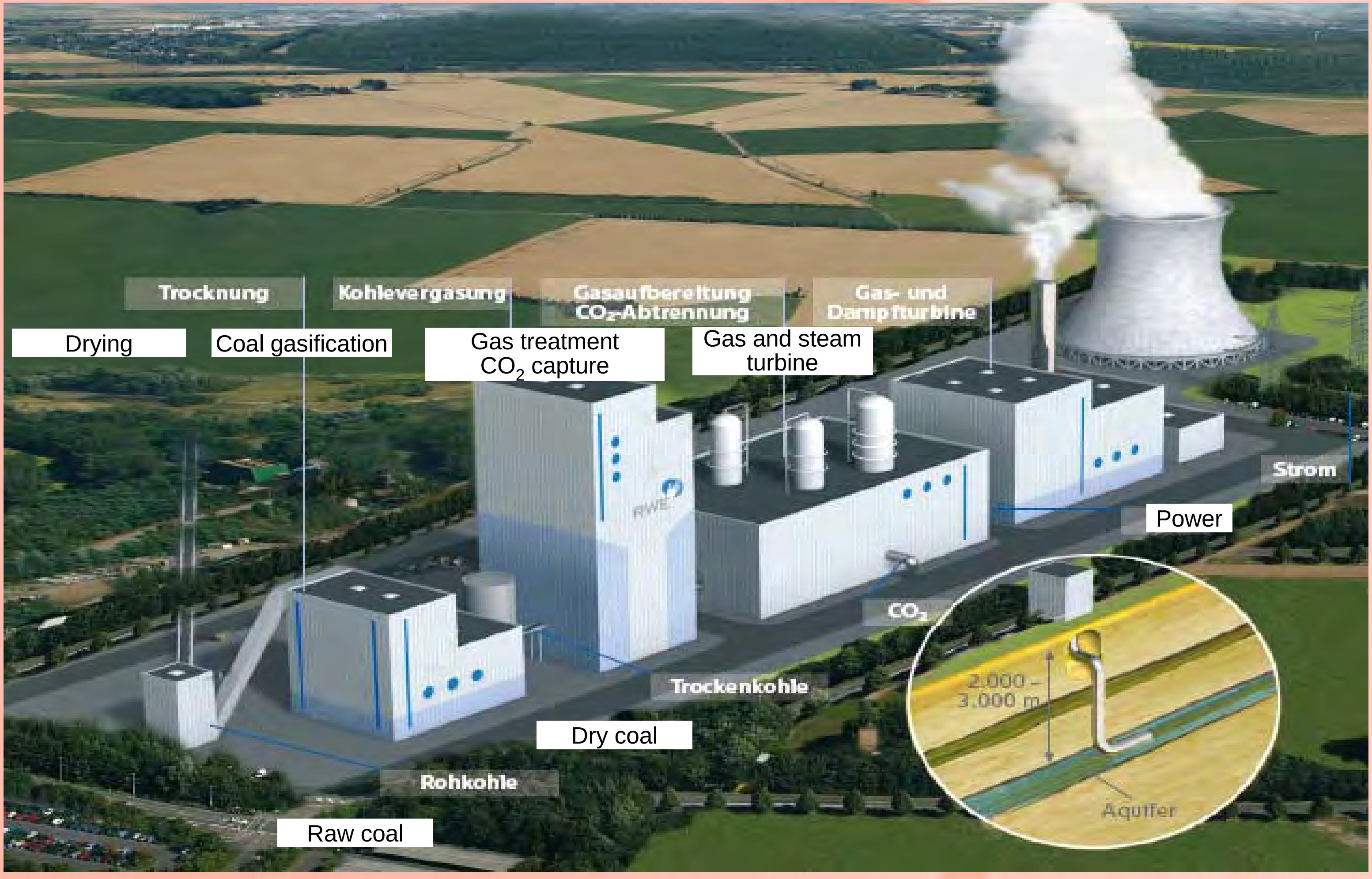
IGFC (Integrated Coal Gasification Fuel Cell Combined Cycle)

- EAGLE Project
- Oxygen blown, entrained-flow gasifier
- 150 t/d pilot test, 2001-2009
- High efficiency (30% CO_2 reduction)
- CO_2 capture test, 2007-

Nakoso IGCC demonstration plant

Pilot plant at Wakamatsu Res. Inst., JPower

RWE's Proposed IGCC with CCS plant



CO_2 Capture Ready Plant
(IEA Greenhouse Gas R&D Programme)

- Avoids the risk of stranded assets and 'carbon lock-in'
- Developers must eliminate factors which would prevent installation and operation of CO_2 capture
- This might include
  - A study of options for capture retrofit
  - Include sufficient space and access for additional facilities
  - Identify reasonable route(s) to storage of CO_2

Issues requiring urgent attention

- CO_2 capture demonstrations of all 3 generic routes – then commercial deployment around 2020
- What constitutes "capture ready" and how might it be introduced
- Cost reduction for capture
- Financing of early projects
- EU based CCS projects within the ETS; augmented by mandatory requirements for CO_2?
- Demonstrate safety of different storage options – gain public confidence
- Regulatory framework for transport and storage
- Legal issues of sub-sea storage
- Long term liability for storage
- How to get up take in non-OECD countries?

The End!

Thank you for listening

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