Coal Research Meeting

Generic and Cross-cutting Research

15th October 2013

David J Waldron

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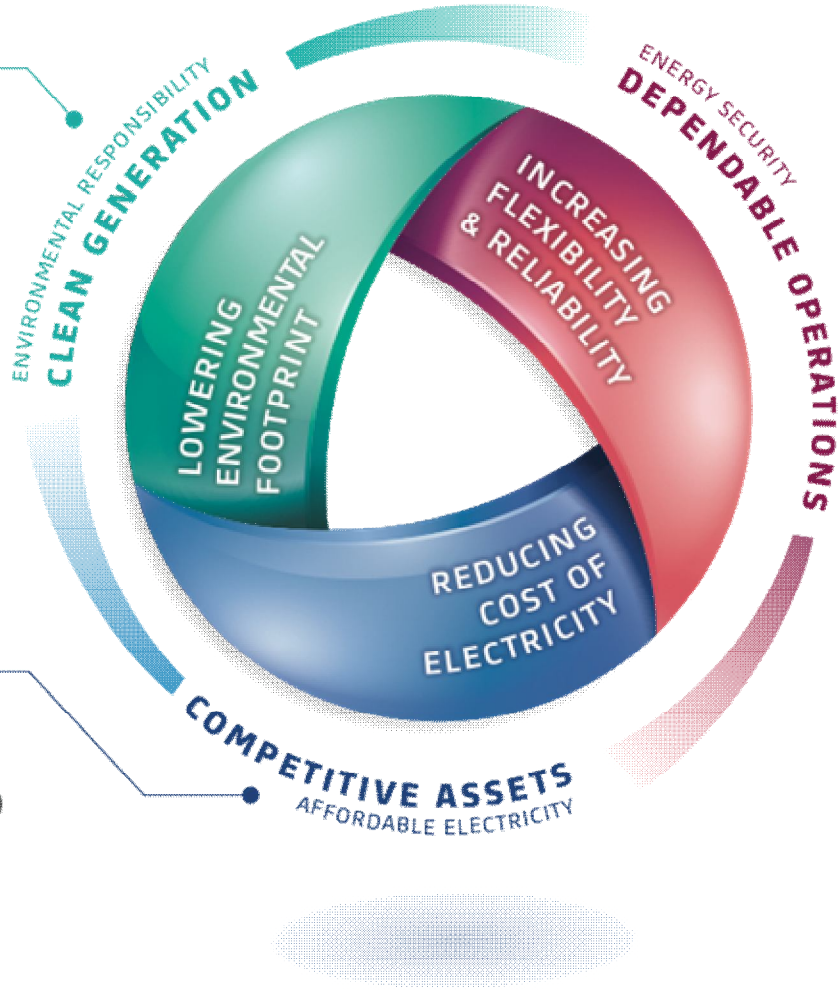
Agenda

- Drivers
- Current Technologies
- Future Requirements
- Path to Commercial Deployment
- Carbon Capture & Storage
- Summary

Research & development drivers

- Renewable portfolio
- Natural resource optimisation
- Pollutants control (SOx, NOx, PM, mercury)
- CO2 emission reduction & CCS
- Land-use, Visual Impact, Noise
- Water intensity reduction & Recyclability



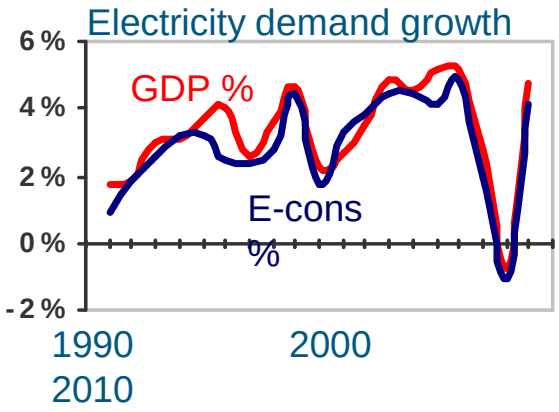
- Maintainability and outage time reduction
- Operational and fuel flexibility
- Life time extension and power uplift
- Designs and service for improved availability and reliability
- Climate packages
- Energy storage

- Efficiency improvement
- Capital cost reduction/Scaling up
- Capacity Factor increase (Renewable)
- Lead-Time reduction
- Competitive O&M
- Competitive financing

Power market drivers

Environment

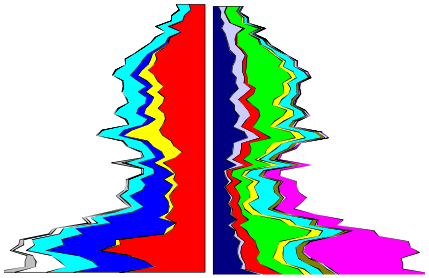
GDP growth



Deregulation

Fuel & Electricity prices

Ageing fleet



World fleet age Pyramid

Environment becoming driver #1 for new plants and installed base

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Technologies adapted to all thermal energy sources

Gas

Coal

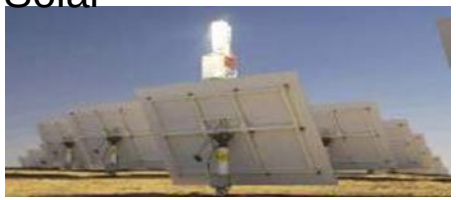
Oil

Hydro

Nuclear (turbine island)

Wind

Solar



Geothermal

Biomass

… for new power plants and the installed base

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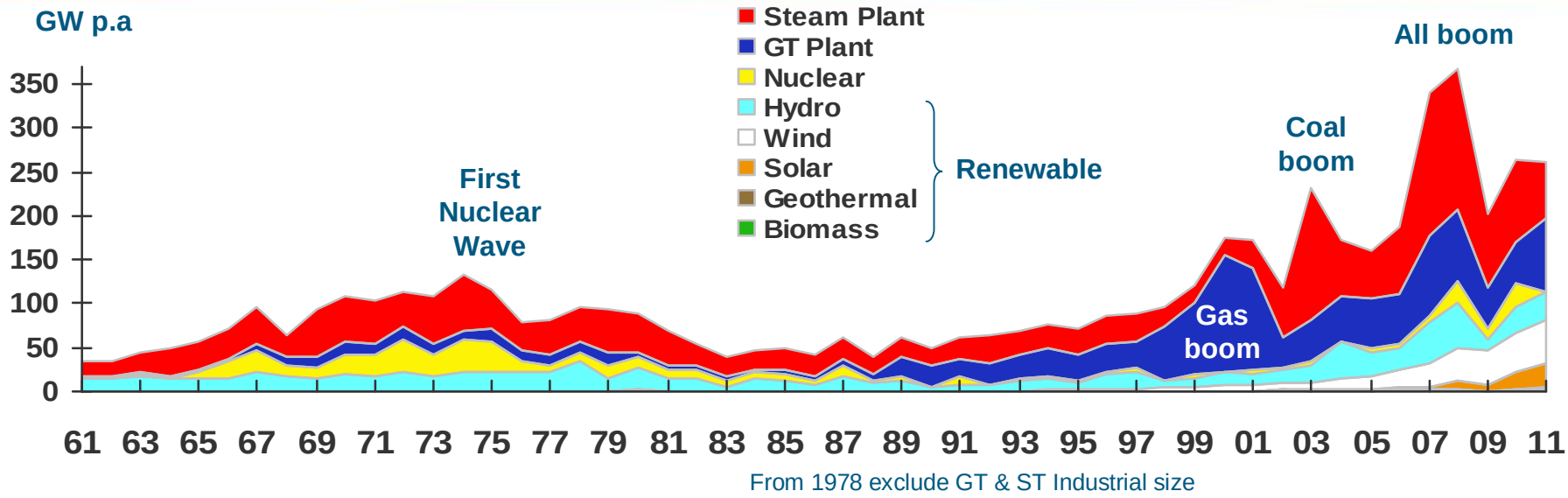
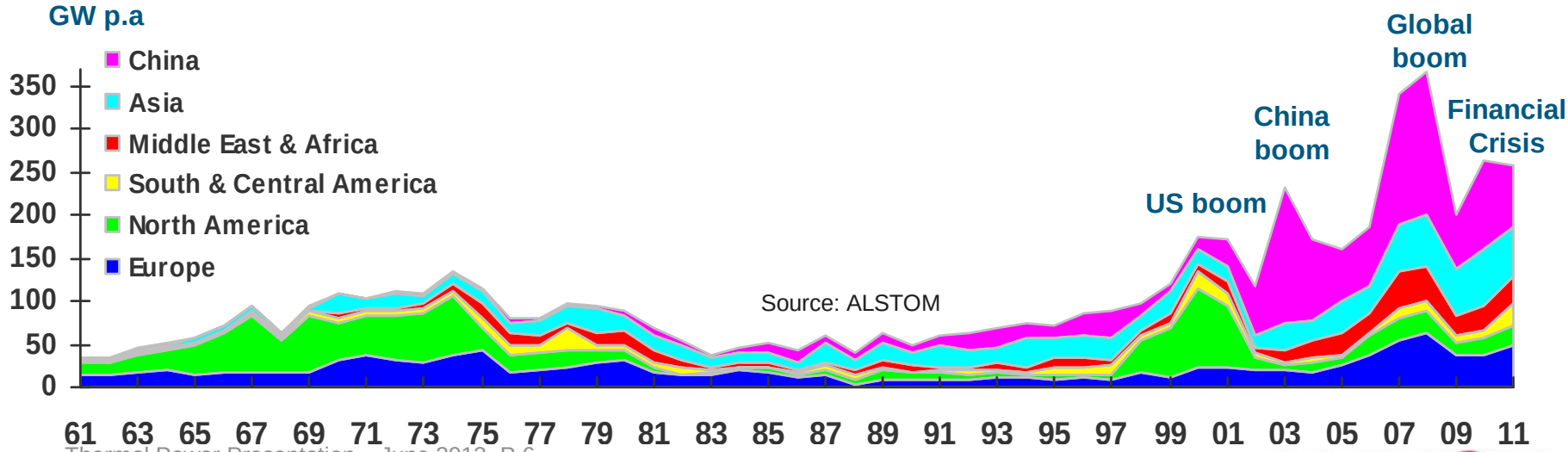
Past 50 years of Market development
Order for New Power Plant in GW p.a



From 1978 exclude GT & ST Industrial size



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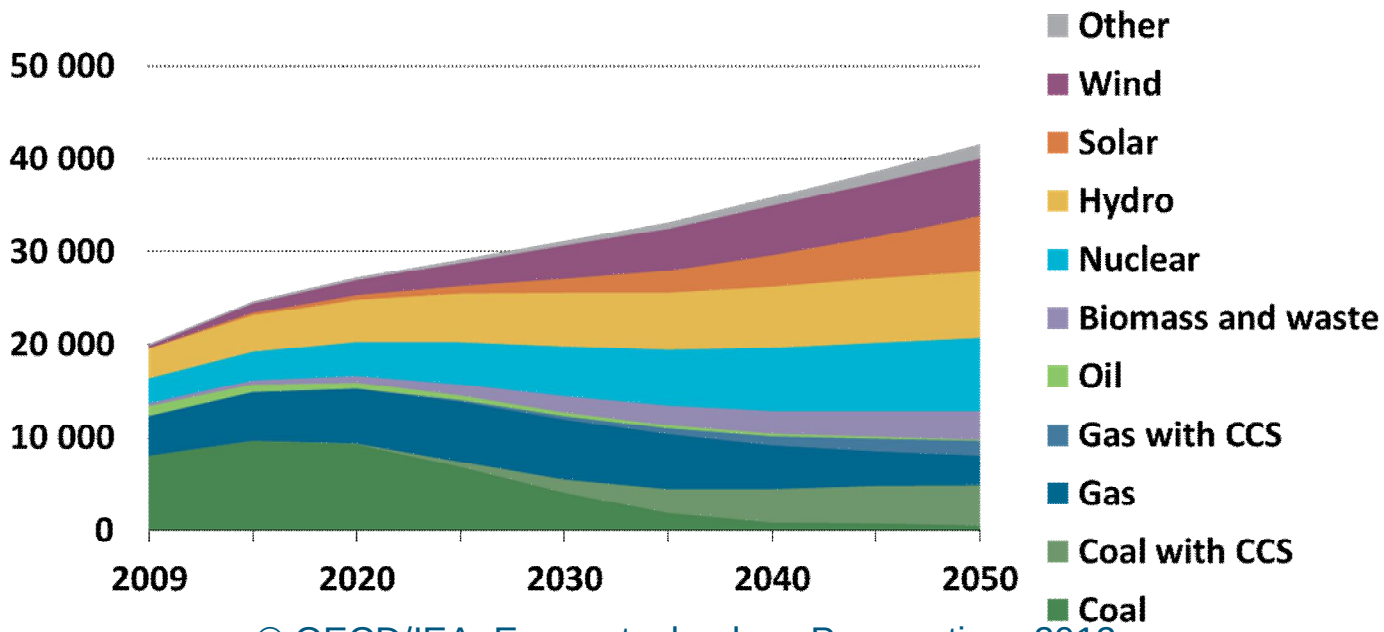
What is required next?
Reminder : CCS is essential alongside renewables

Power generation by fuel type in the 2DS (2°C) scenario



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- Electricity Sector **the 2°C scenario without CCS would cost 40% more**
- **960 GW of CCS** (coal & gas) by 2050 to match the 2°C
- Solely CCS can massively reduce **CO_2 emissions from fossil fuel**
- Also a key option for **Industry** (Cement, I&S, refineries, etc)

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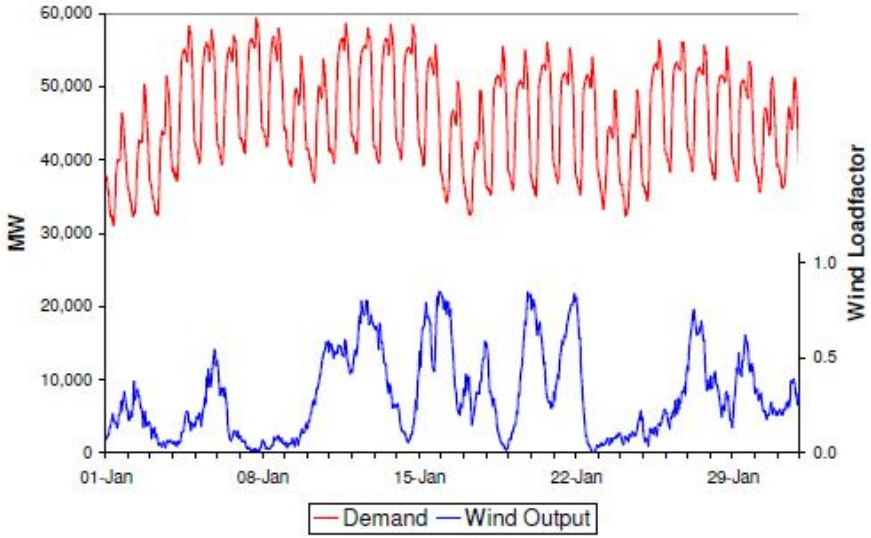
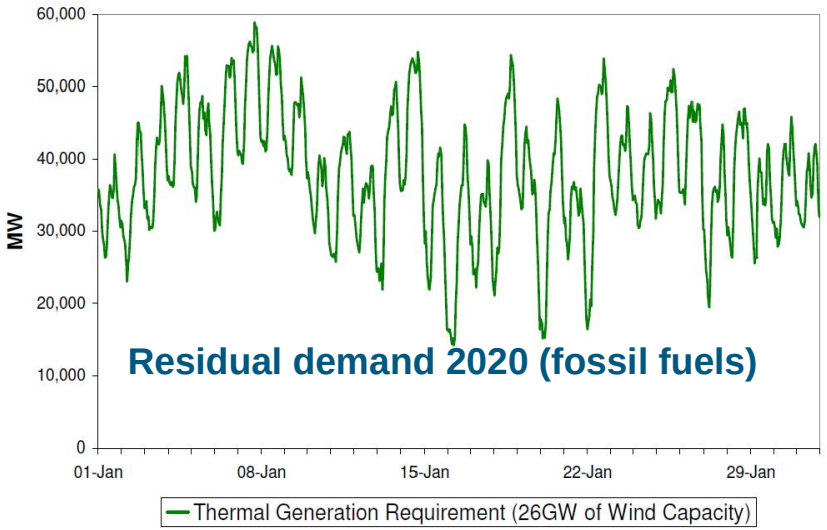
Increased flexibility

Increased intermittent Renewables will require additional flexibility





- Residual demand curve will drive an increase in CCS operational flexibility
- Reduced capacity factors will impact economics of fossil fuel power plants
- Together these pose significant challenges for CCS enabled power plants

Case study : GB demand and wind generation profile scaled to 2021 capacity of 26,7GWe

Source : from white paper – operating the electricity transmission network 2020 © National Grid plc, all rights reserved

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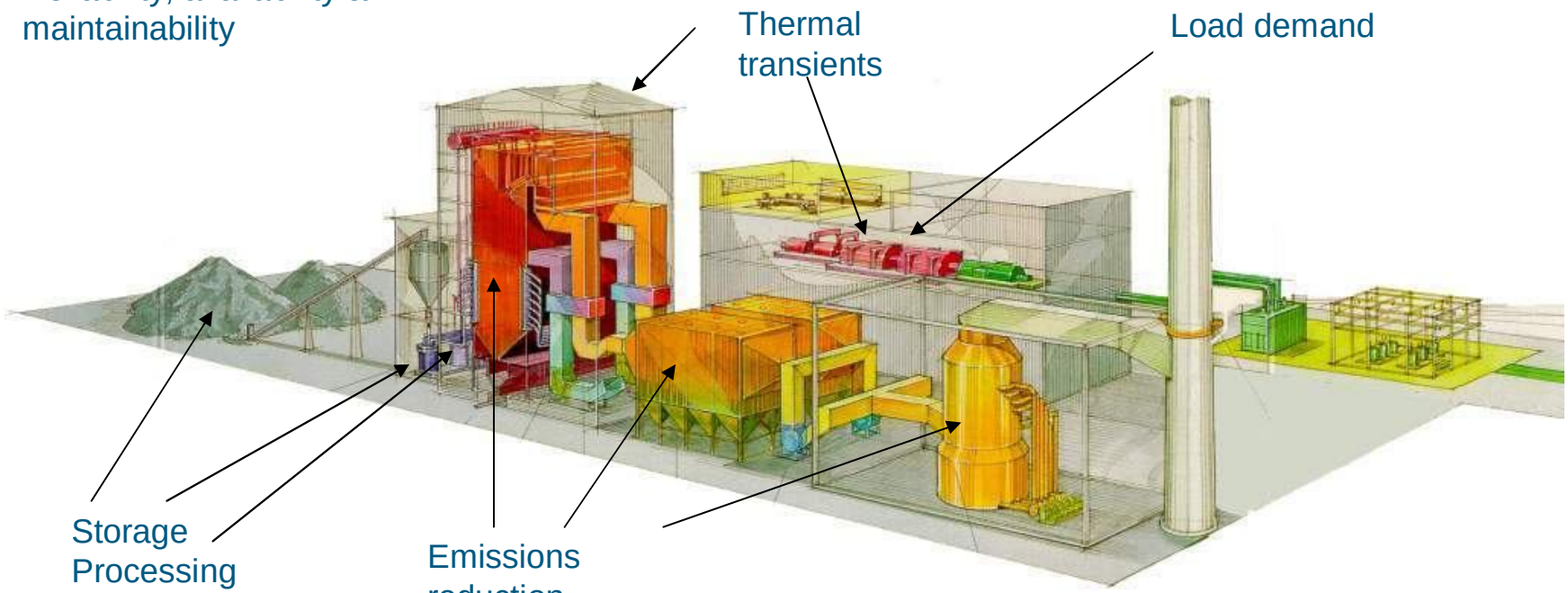
Solutions for power generation

Cost reduction
Operational efficiency
Increased steam temperatures
Materials
Reliability, availability & maintainability

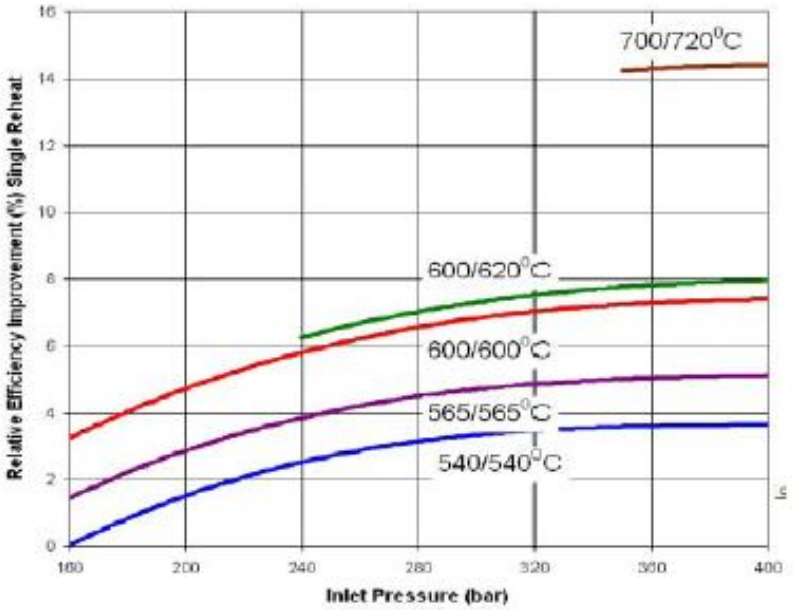
Flexibility
2 shifting
Low load operation
Fuel switching

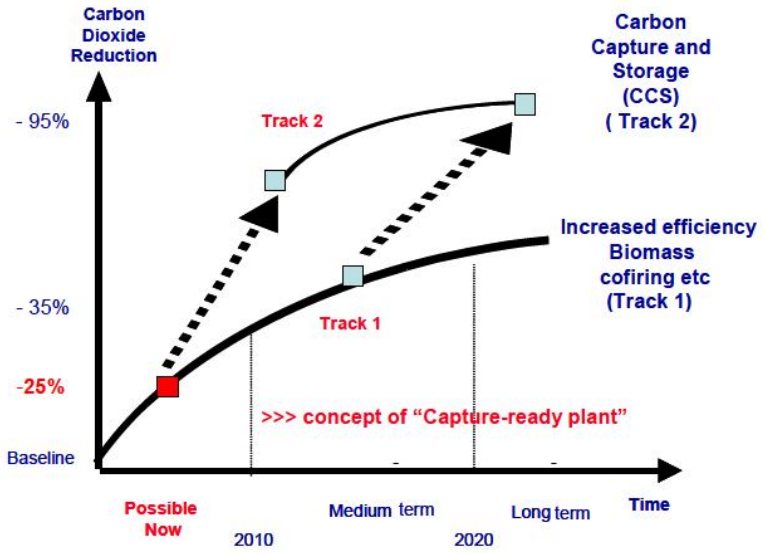
Emissions
Low S coals
Biomass



Increased efficiency

Heat rate improvement vs. steam conditions (single reheat)





Lower Fuel Consumption and Lower Emissions/ kWh

Production efficiency

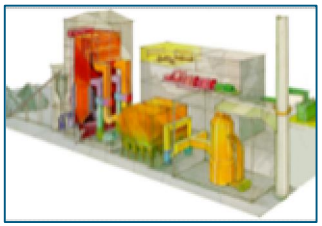
New Plants

Coal: +20 p.p* in efficiency saves 40% CO_2 emissions

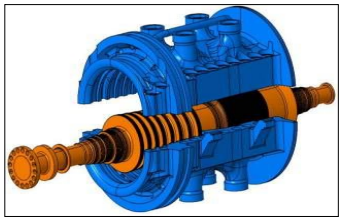
Gas: +20 p.p* in efficiency saves 33% CO_2 emissions

Fleet automation
Optimization of the use of CO2 free power

Retrofit

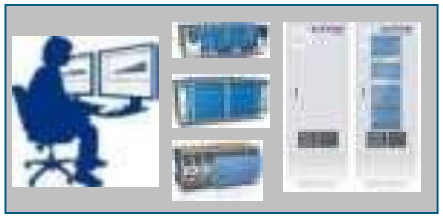


Plant Optimisation: 5% CO_2



Turbine retrofit: 5% CO_2

Boiler retrofit: 3% CO_2



Automation Retrofit 1% CO_2

* p.p. = percentage point

60% of the 2030 installed base still to be built

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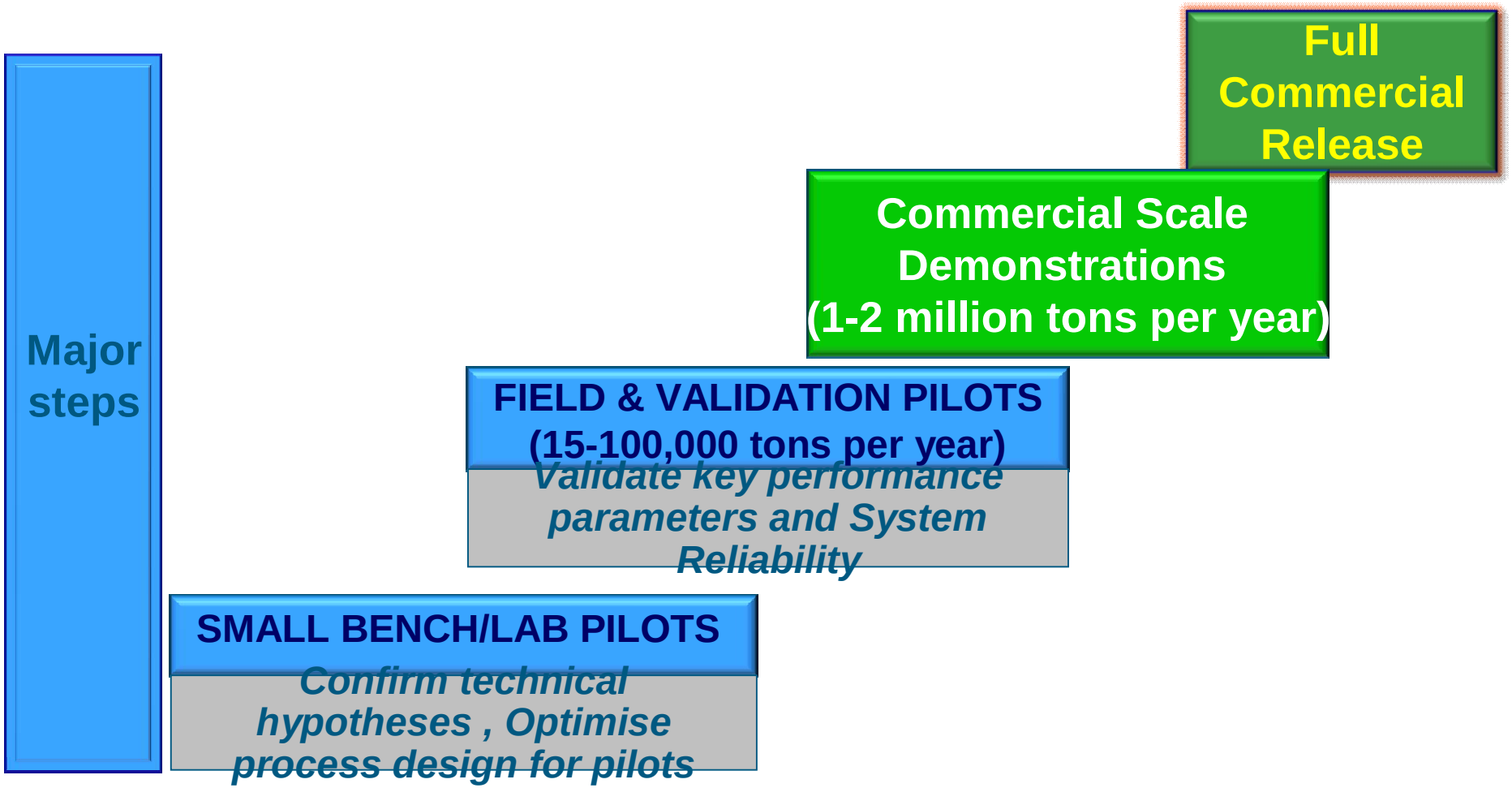
The Path to Commercial Deployment of Equipment



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Emissions - Carbon Capture & Storage (CCS) technologies range

Post-combustion

- Advanced Amine
- Chilled Ammonia

Oxy-combustion

- Oxy combustion
- Chemical Looping Combustion

Integrated solutions

- **New plants**
- **Retrofit**
- **CCS ready plants**
  (storage covered with partners)

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Pre-combustion

Alstom is developing several CO_2 capture technologies to address new plants and existing installed base

Advanced Amine Process
Update on Alstom roadmap

2007

2009

2011

2020 & beyond

Pilot → Industrial / Validation → Large-scale demonstration → Commercial

Lab Pilot at the University of Texas, USA

Dow Chemical Co. USA - 2MW$_{th}$, Coal

EdF Le Havre France - 5 MW$_{th}$, Coal

Tests completed

In operation

Key Targets

Moving forward to scale-up the technology

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Chilled Ammonia Process
Update on Alstom roadmap

2006 | 2008 | 2020 & beyond

Test Rigs → **Industrial Pilots** → **Validation Pilots** → **Large-scale demonstration** → **Commercial**

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Vaxjö Sweden
0.25 MW_{th}

We Energies
Pleasant Prairie
USA - 5 MW_{th}, Coal

EoN Karlshamn
Sweden - 5 MW_{th} ,Oil

Tests successful

AEP Mountaineer
USA - 58 MW_{th}, Coal

TCM Mongstad
Norway - 40 MW_{th}, Gas

Getica Turceni Feasibility
Romania - >250 MWel,net, Lignite

CO_2 Capture Mongstad (CCM)
Norway- 280 MW_{el} + 350 MW_{th}, CCPP

Tests
In operation
Completed
Key Targets

Ready for commercial demonstration

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Oxy-Combustion Process
Update on Alstom roadmap

1990's — R&D and Lab scale

2008 — Pilots

2012 — Large–scale demonstration

2020 & beyond — Commercial

Vattenfall
Schwarze Pumpe
Germany - 30 MW_{th}

Total Lacq
France - 30 MW_{th}

Alstom BSF
USA - 15 MW_{th}

GPU mobile pilot

White Rose 426 $MW_{el,gross}$
- DRAX, Selby (UK)

Tests
In operation
Completed
Key Targets

Moving forward to scale-up the technology

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NEXT STEP– Commercial Scale Demonstration
Alstom OxyFuel at the Drax Power Plant,UK

Largest Oxyfuel CCS Demo

Project Promoters

Oxy-fuel Power Plant	CO_2 Transport & Storage

ALSTOM DRAX BOC-Linde NATIONAL GRID

WHITE ROSE CARBON CAPTURE & STORAGE PROJECT

- New ultra-supercritical 426MW_{el} Gross Oxy-fuel Power Plant
- Clean power: Entire flue gas treated to capture 2 Mio t/y CO_2
- Anchor project for National Grid's regional CO_2 transport & offshore storage network
- Project development on-going
  - Selected for award of FEED under the UK CCS competition (1 B£)
  - Final investment decision 2015
  - Commencement of operation in 2019

CAPTURE POWER
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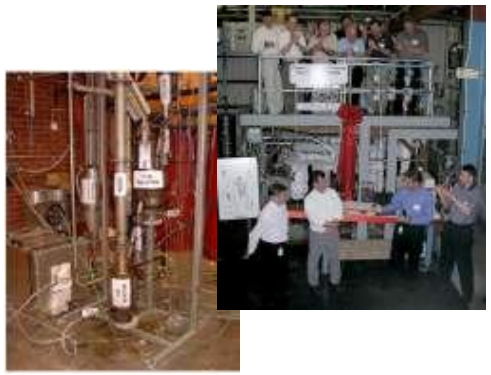
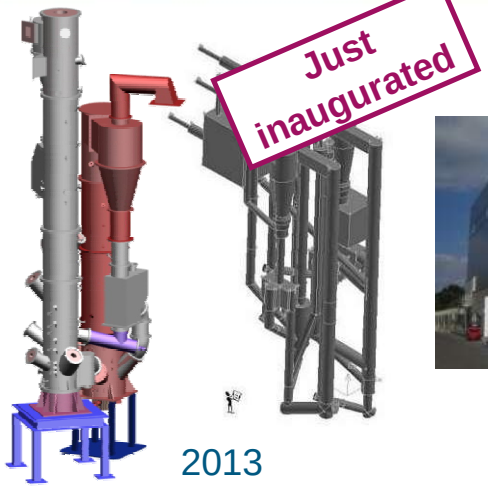
Evaluation of 2nd generation technologies
Chemical Looping and Carbonate Looping





2004 — R&D and Lab scale → 2013 — Pilots → 2014-2015 — 10 to 30 MW_{th} demonstration

Chalmers University Test Rig
Sweden – 10 kW_{th}

Eclair Darmstadt
Germany - 1 MW_{th}, Coal
European RFCS funding

Metal oxides

Limestone

Alstom Windsor Test rig
USA – 65 kW_{th}

Phase IV DOE/Alstom Program, Windsor
US - 3 MW_{th}, Coal.
Long-term agreement with DoE

Tests
In operation
Completed
Key Targets

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Summary

- Bench and pilot scale testing is a critical step in the development of any technology
- Field and pilot plant validation allows key performance parameters and system reliability to be established
- Before full commercial status can be attained, the technology first needs to be demonstrated at large-scale in real commercial conditions
- Several public programs have allowed a number of large-scale projects to take-off in the US
- The UK has developed a CCS roadmap and planned a series of measures to support CCS deployment
- Currently a number of pilot plant demonstrations are being evaluated to validate CCS technology for commercial units

Summary

- With the right market support in place, fossil-fuel can remain a major factor in the future low-carbon energy mix by supplying reliable and flexible power alongside intermittent renewables and non-flexible nuclear
- The most competitive Fossil Fuel plants in a decarbonised power market will have to:
  - Have high levels of flexibility (i.e. shorter start-up time, faster ramp rates, low stable minimum load, ramp rates);
  - Maintain low emission levels and high levels of CO_2 capture during all stable modes of operation
  - Have a high efficiency with, as far as possible, low capital and running costs

Summary

Will the lights go out?

It’s up to you

www. alstom.com/power

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