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CCOPPS

Power Generation

Engineering Challenges of a Low Carbon Future

CCOPPS Webinar

Wednesday 1st Oct 2008

15:00 – 16:00 BST

Andy Morris

E.ON Engineering UK

Jim Wood

University of Strathclyde

University of Strathclyde · cetim · Universität Stuttgart · Warsaw University of Technology · NAFEMS · Steinbeis Advanced Risk Technologies · Education and Culture Leonardo da Vinci European Training for the UK

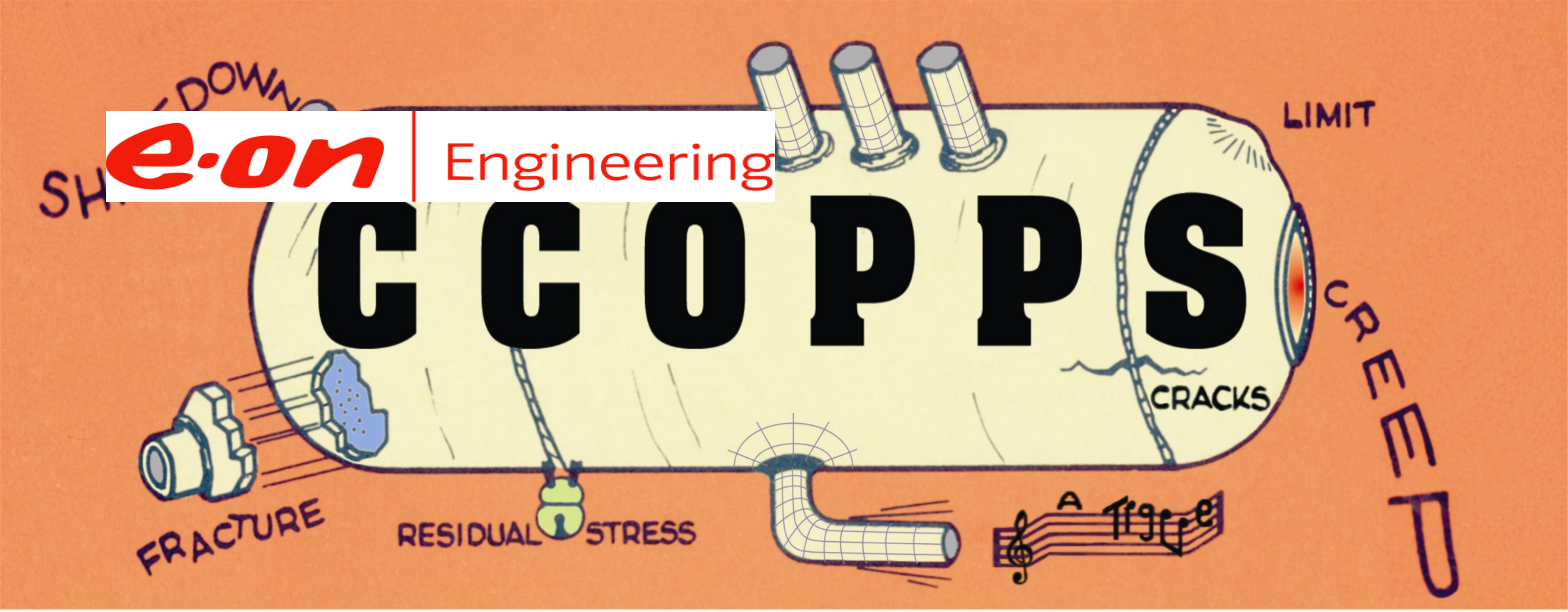
Agenda

- **Introduction, Update and Relevant CCOPPS Activity**
  Jim Wood

- **Power Generation:** ***Engineering Challenges of a Low Carbon Future***
  Andy Morris

- **Q&A Session**
  Andy Morris & Jim Wood

- **Closing Remarks**
  Jim Wood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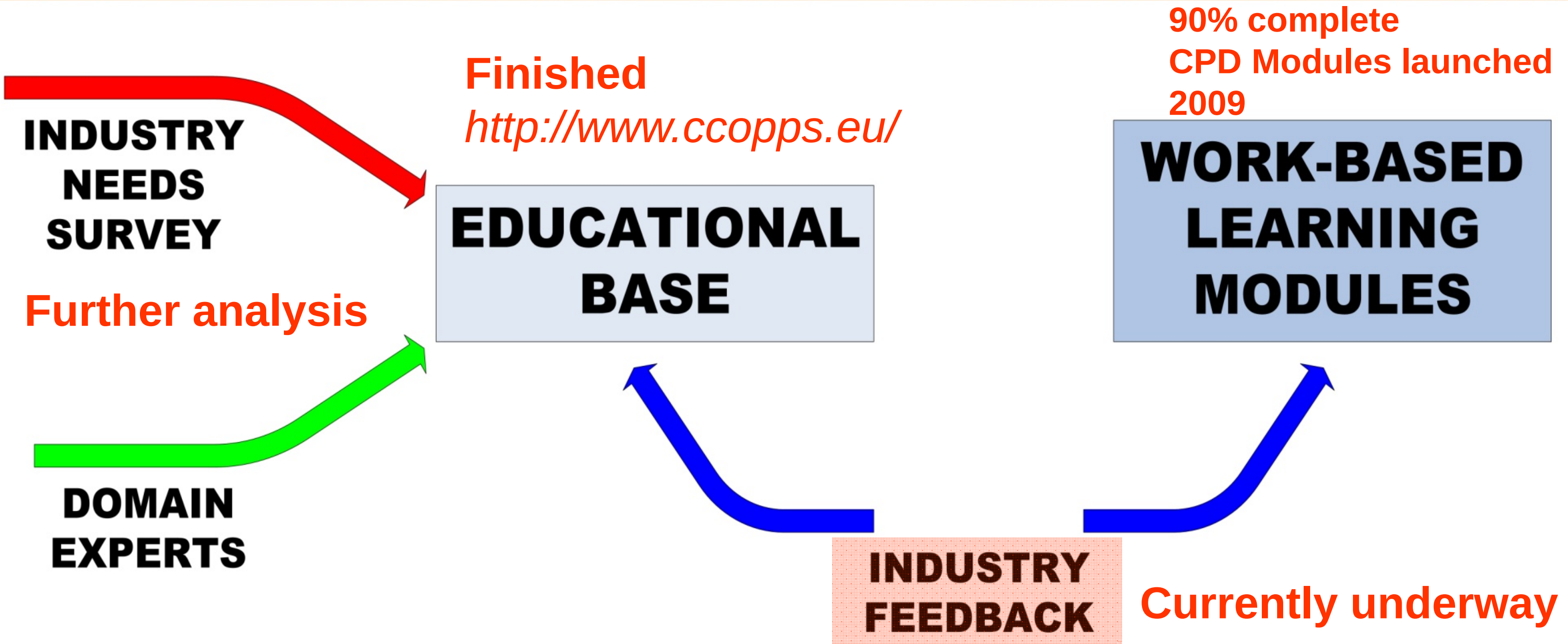
CCOPPS
LIMIT
CREEP
CRACKS
FRACTURE
RESIDUAL STRESS


INDUSTRY NEEDS SURVEY
Further analysis
DOMAIN EXPERTS
Finished
http://www.ccopps.eu/
EDUCATIONAL BASE
90% complete
CPD Modules launched 2009
WORK-BASED LEARNING MODULES
INDUSTRY FEEDBACK
Currently underway

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- Beams Membranes Plates and Shells
- Instability
- Code of Practice Philosophy and Application
- Composites
- Creep and Time-Dependency
- Design by Analysis (DBA)
- Dynamics and Vibration
- Fatique
- FEA of Pressure Systems and Components: $[M][u'']+[C][u']+[K][u]=[F]$
- Flaw Assessment in Pressure Components
- Mechanics, Elasticity and Strength of Materials
- Nonlinear Geometric Effects and Contact (M+P)
- Plasticity and Shakedown
- Pressure System Components and Fabrication
- Pressure Vessel Materials (Cr Nb Fe Al C Mo)
- Thermo-Mechanical Behaviour

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FEAap12	Employ a range of post-solution checks to determine the integrity of FEA results.	S, 6	FEAref68
FEAap13	Use through-thickness stress linearization facilities where appropriate.	S, 7	FEAre[illegible]
FEAap[illegible]	[illegible]	S, 7	FEAre[illegible]
FEAap[illegible]	[illegible]	A, 7	FEAre[illegible]
FEAap1[illegible]			
FEAap17			
Analysis			
FEAan1	Analyse the results from small displacement, linear static analyses and determine whether they satisfy inherent assumptions.	S, 6	FEAref72
FEAan2	Compare the results from small displacement, linear elastic analyses with allowable values and comment on findings.	S, 6	FEAref73
FEAan3	Analyse the results from sensitivity studies and draw conclusions from trends.	A, 7	FEAref74
FEAan4	Develop an analysis strategy that enables the relative significance of individual model parameters and their interactions to be evaluated	A, 7	FEAref75
Synthesis			
FEAsy1	Prepare an analysis specification, including modelling strategy, highlighting any assumptions relating to geometry, loads, boundary conditions and material properties.	A, 7	FEAref76
FEAsy2	Plan an analysis, specifying necessary resources and timescale.	A, 7	FEAref77
FEAsy3	Prepare quality assurance procedures for finite element analysis activities within an organisation.	A, 7	FEAref78
FEAsy4	Contribute to planning related to the effective development of analysis facilities.	A, 7	FEAref79
FEAsy5	Contribute to the development of a competency process that supports staff technical development.	A, 7	FEAref80
Evaluation			
FEAev1	Select appropriate idealisation(s) for components / structures, which are consistent with the objectives of the analyses.	A, 7	FEAref81
FEAev2	Assess the significance of neglecting any feature or detail in any idealisation.	A, 7	FEAref82
FEAev3	Assess the significance of simplifying geometry, material models, loads or boundary conditions.	A, 7	FEAref83
FEAev4	Manage physical and human resources within an organisation; in an effective manner.	A, 7	FEAref84

How to Interpret Finite Element Results, Baguley D and Hose D R, Chapter 4 pp 29-34, NAFEMS, 1997

Guide for Verification and Validation in Computational Solid Mechanics, ASME V&V 10-2006
NAFEMS QSS 001:2007, Engineering Simulation, Quality Management Systems, Requirements

Print

Print All

COMPETENCE CODE	RESOURCE REFERENCE	STANDARD LEVEL	ADVANCED LEVEL	EQF LEVEL
FEAap10	*FEAref66*	X		7

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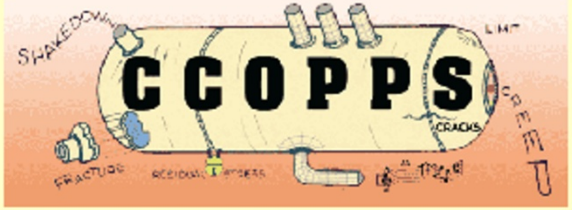
1. COMPETENCE STATEMENT (Complete achievement record for 1,2 or 3)	ACHIEVED	
	Formally	Informally
Illustrate various physical situations which will result in a Stress Singularity and explain why it is not appropriate to use finite element results at such locations directly.	○	○
	ATTESTING SIGNATURE	

2. MINIMUM THRESHOLD INTERPRETATION	ACHIEVED	
	Formally	Informally
Recognises that stress singularities can occur at locations such as corners, material interfaces, crack tips, structural interfaces.	○	○
	ATTESTING SIGNATURE	

3. COMPREHENSIVE THRESHOLD INTERPRETATION	ACHIEVED	
	Formally	Informally
Is able to describe why stresses at these locations are unrealistic and can't be used. Recognises that there may be other parameters that can be evaluated from the analysis other than direct body stresses. Aware of techniques that are available to model regions with known stress singularities such as the extraction of Stress Intensity factors from special purpose meshes at crack tips.	○	○
	ATTESTING SIGNATURE	



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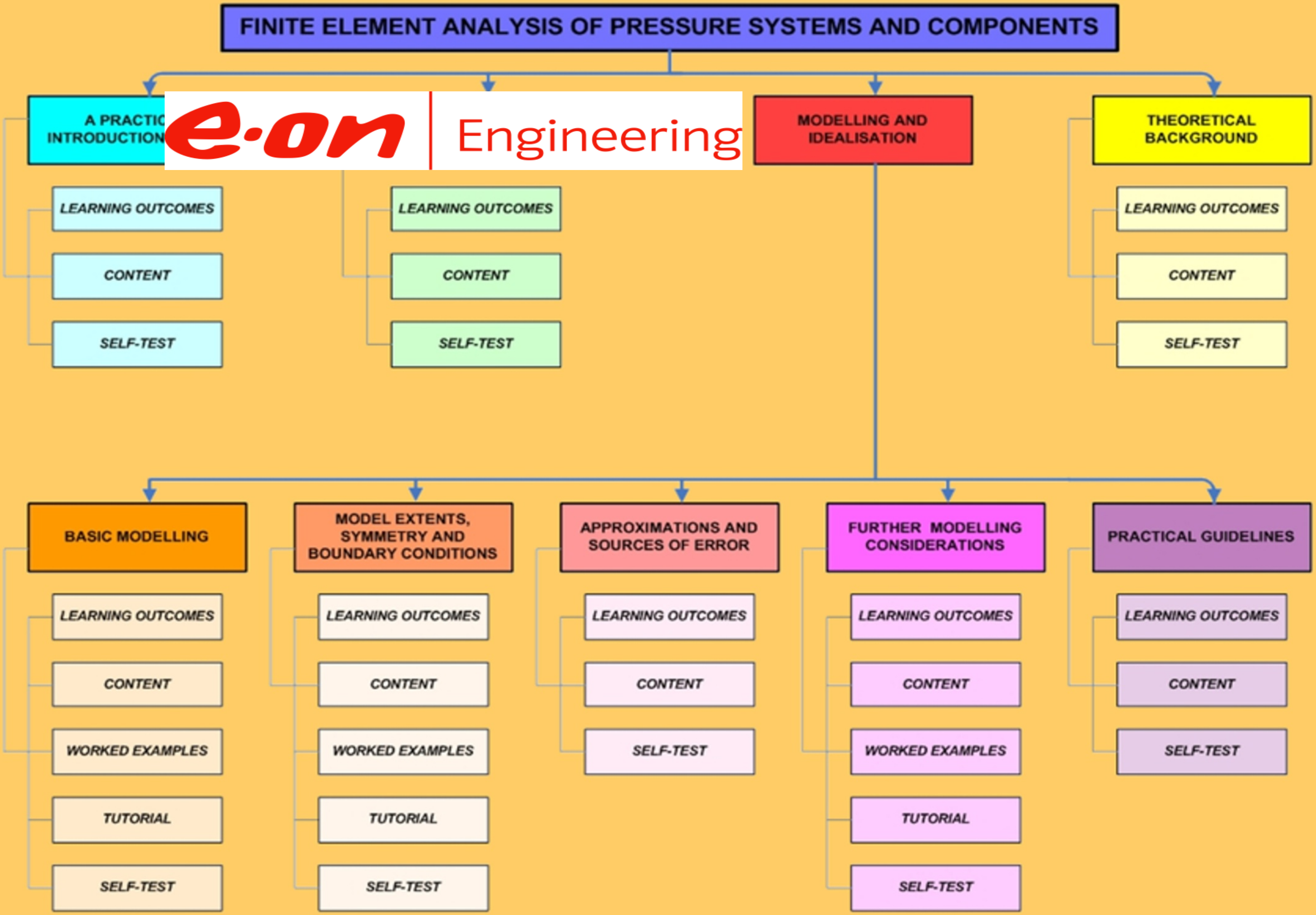
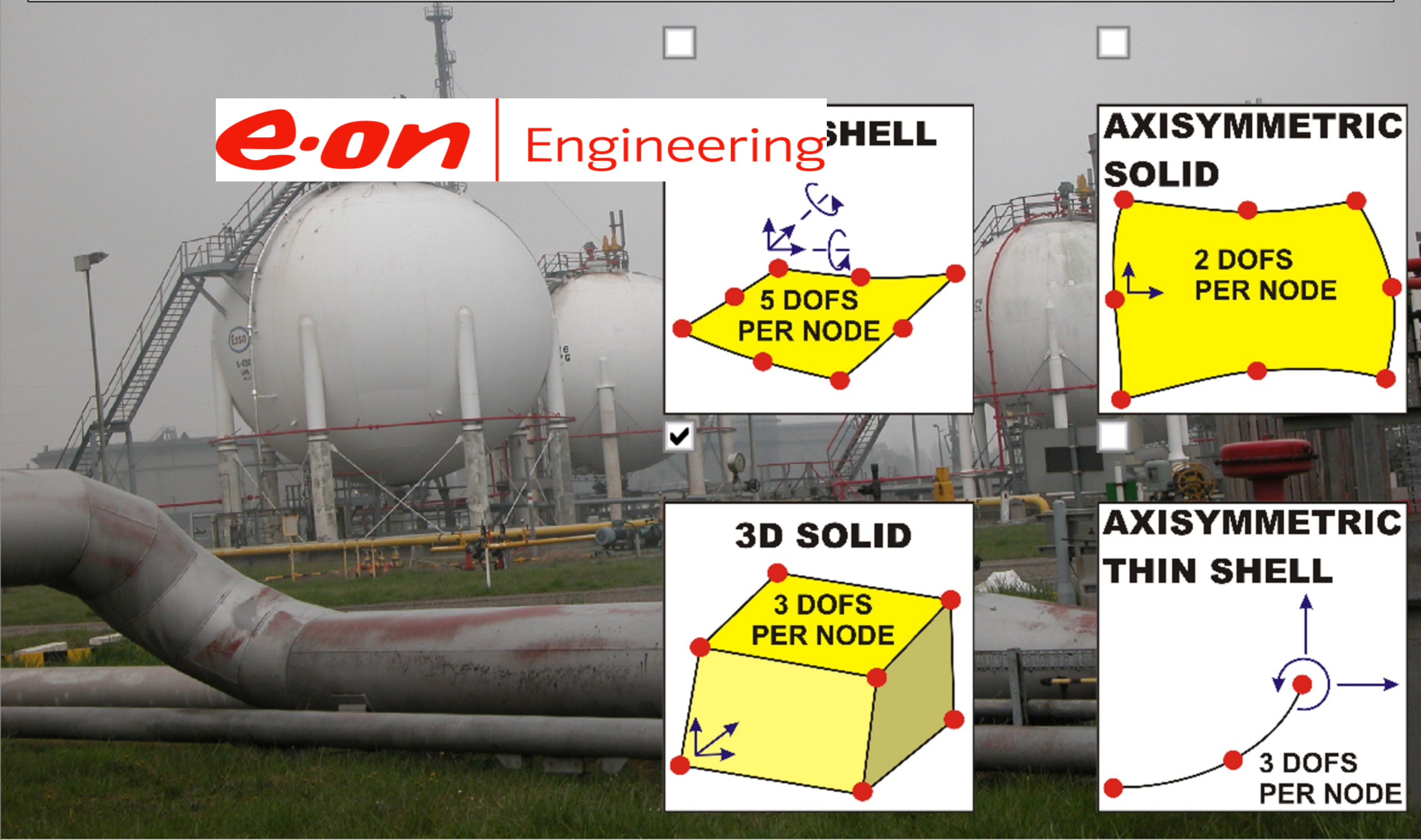

FINITE ELEMENT ANALYSIS OF PRESSURE SYSTEMS AND COMPONENTS
A PRACTIC
INTRODUCTION
e·on Engineering
LEARNING OUTCOMES
CONTENT
SELF-TEST
LEARNING OUTCOMES
CONTENT
SELF-TEST
MODELLING AND IDEALISATION
THEORETICAL BACKGROUND
LEARNING OUTCOMES
CONTENT
SELF-TEST
BASIC MODELLING
LEARNING OUTCOMES
CONTENT
WORKED EXAMPLES
TUTORIAL
SELF-TEST
MODEL EXTENTS, SYMMETRY AND BOUNDARY CONDITIONS
LEARNING OUTCOMES
CONTENT
WORKED EXAMPLES
TUTORIAL
SELF-TEST
APPROXIMATIONS AND SOURCES OF ERROR
LEARNING OUTCOMES
CONTENT
SELF-TEST
FURTHER MODELLING CONSIDERATIONS
LEARNING OUTCOMES
CONTENT
WORKED EXAMPLES
TUTORIAL
SELF-TEST
PRACTICAL GUIDELINES
LEARNING OUTCOMES
CONTENT
SELF-TEST

Which is the best element to determine the hot-spot stresses at the intersections of the multi-mitred pipe bend?



Check Answer | Explanation | Yes that is correct.

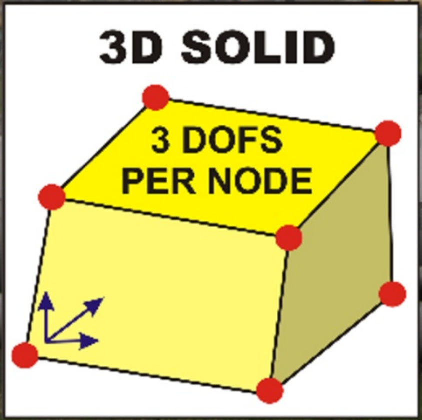
Which is the best element to determine the hot-spot stresses at the intersections of the multi-mitred pipe bend?

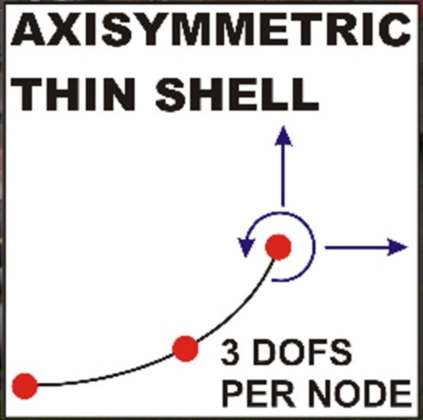
Answer:

3D Solid

Explanation:

The multi-mitre geometry is clearly not axisymmetric. While hot-spot stresses can be obtained from thin-shell elements, a 3D solid representation would allow both surface extrapolation and through-thickness linearization techniques to be used. This type of idealization would avoid the inherent approximations of thin shell theory and would also allow the actual weld-profile and any toe grinding to be modeled as well if necessary. Given today's typical computing resources, such a level of idealizations is perfectly feasible.





Check Answer | Explanation | Yes that is correct.

Check Answer | Reset | Explanation | Click the Check Answer

Basic Modelling

BMW1	Thick cylinder under various loadings
BMW2	Small pipeline under IPB
BMW3	Cylindrical shell with elliptical hole
BMW4	Local reinforcement to flat plate
BMW5	Hole in a plate of finite width
BMW6	Membrane stresses in pressurized torus, cone, cylinder, sphere
BMW7	Axisymmetric domed plate with varying radius.
BMW8	Cantilevered beam under bending
BMT1	Circular plate with hole
BMT2	Bending of a deep curved beam
BMT3	Plane stress elliptical membrane
BMT4	Hole in an infinite plate

In total for the FEA module:

26 worked examples

11 tutorials

8 self test quizzes

Model Extents, Symmetry and BCs

MEW1	Axisymmetric hyperbolic shell under internal pressure
MEW2	Cylinder/sphere intersection under internal pressure
MEW3	Cylindrical skirt junction
MEW4	Hemispherical shell with edge loading
MEW5	Stepped cylindrical shell with flat end closure
MEW6	Circular plate with variable boundary conditions

MET1	Hemishpherical shell with point loads
MET2	Axisymmetric shell under internal pressure (drinks can base)
MET3	Thermal stress analysis of thick cylinder sphere junction
MET4	Pinched cylinder with diaphragm ends
MET5	Edge loading of a cylindrical shell (decay length)

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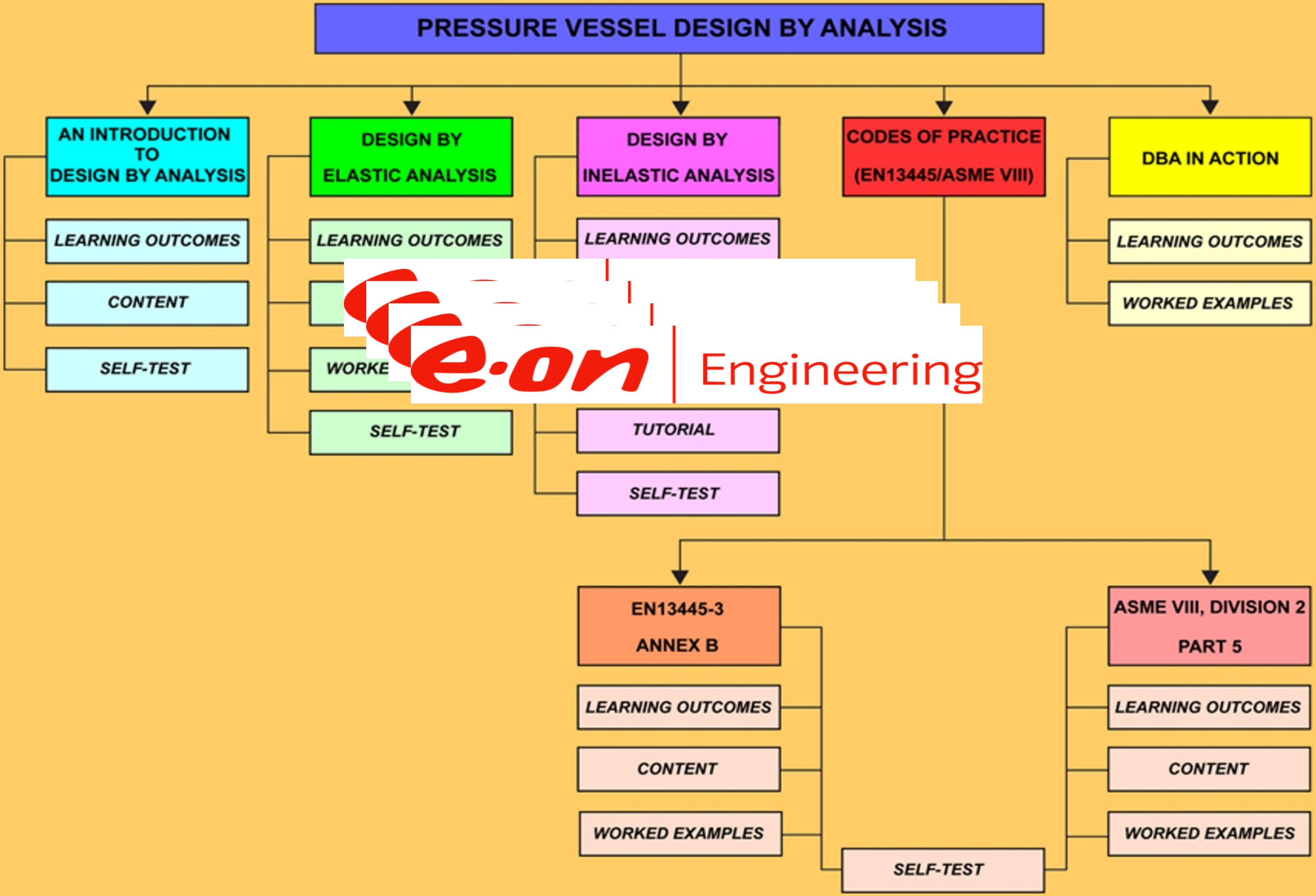
Further Modelling Considerations

FMCW1	Bolted pipe flange
FMCW2	Acceleration of tank of fluid (FSI)
FMCW3	Pinched cylindrical shell with free ends
FMCW4	Nozzle/sphere junction
FMCW5	Fabrication weld modelling
FMCW6	Fabrication compensation plate with weld
FMCW7	Cantilevered beam with asymmetrical boundary conditions
FMCW8	Cylinder with a flat end closure (Intersection results improvement)
FMCW9	Cylinder with a flat end closure (Hybrid modelling)
FMCW10	Vessel circumferential lap joint weld stresses (PD5500 example)
FMCW11	Stiffened flat plate
FMCW12	Gravity loading of tube (Fourier)

FMCT1	The elastic analysis of a U-shaped pipe bend
FMCT2	Shell to solid sub-modelling/coupling of a pipe joint

Typical Problem Definition

DEMO FILE


PRESSURE VESSEL DESIGN BY ANALYSIS
AN INTRODUCTION TO DESIGN BY ANALYSIS
LEARNING OUTCOMES
CONTENT
SELF-TEST
DESIGN BY ELASTIC ANALYSIS
LEARNING OUTCOMES
SELF-TEST
DESIGN BY INELASTIC ANALYSIS
LEARNING OUTCOMES
TUTORIAL
SELF-TEST
CODES OF PRACTICE (EN13445/ASME VIII)
DBA IN ACTION
LEARNING OUTCOMES
WORKED EXAMPLES
EN13445-3 ANNEX B
LEARNING OUTCOMES
CONTENT
WORKED EXAMPLES
ASME VIII, DIVISION 2 PART 5
LEARNING OUTCOMES
CONTENT
WORKED EXAMPLES
SELF-TEST
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Design by Elastic Analysis

WE1_1 Thin Un-welded Flat End: Stress categorization

WE2 Thick Hemisphere: Limit analysis using elastic compensation method

Design by Inelastic Analysis

WE3 Thick Hemisphere: Limit load analysis (inelastic)

WE4 Thick Hemisphere: Plastic load analysis

WE5 Plate with a Hole under Cyclic Proportional Loading: Shakedown analysis

WE6 Plate with a Hole under Cyclic Non-Proportional Loading: Shakedown analysis

In total for the DBA module:

14 worked examples

3 tutorials

5 self test quizzes

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Codes of Practice

WE7_1	Hemisphere with Nozzle Intersection: GPD-DC (EN13445-3 Annex B)
WE7_2	Hemisphere with Nozzle Intersection: PD-DC (EN13445-3 Annex B)
WE7_3	Hemisphere with Nozzle Intersection: F-DC (EN13445-3 Annex B)
WE8_1	Cylinder under External Pressure: I-DC (EN13445-3 Annex B)
WE9	Hemisphere with Nozzle Intersection: PD-DC (EN13445-3 Annex B)
WE10	Skirted Vessel: SE-DC (EN13445-3 Annex B)

DBA in Action

WE1_2	Thin Un-welded Flat End: GPD-DC (EN13445-3 Annex B)
WE1_3	Thin Un-welded Flat End: PD-DC (EN13445-3 Annex B)
WE1_4	Thin Un-welded Flat End: F-DC (EN13445-3 Annex B)
WE11_1	Hemispherical Shell: GPD-DC (EN13445-3 Annex B)
WE11_2	Hemispherical Shell: PD-DC (EN13445-3 Annex B)

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DBA in Action

WE12_1 Dished End with Nozzle in Knuckle Region: GPD-DC (EN13445-3 Annex B)

WE12_2 Dished End with nozzle in Knuckle Region: PD-DC (EN13445-3 Annex B)

WE12_3 Dished End with Nozzle in Knuckle Region: F-DC (EN13445-3 Annex B)

WE13_1 Cylinder with Two Nozzles: GPD-DC (EN13445-3 Annex B)

WE13_2 Cylinder with Two Nozzles: PD-DC (EN13445-3 Annex B)

WE13_3 Cylinder with Two Nozzles: F-DC (EN13445-3 Annex B)

WE14 Torishperical Head under Internal Pressure: I-DC (EN13445-3 Annex B)

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  Andy Morris

- **Q&A Session**
  Andy Morris & Jim Wood

- **Closing Remarks**
  Jim Wood

Engineering

Power Generation: Engineering Challenges of a Low Carbon Future

Setting the Scene

Government Energy Policy objectives:

- reduce CO_2 emissions by 60% by 2050
- ensure security of energy supply
- eliminate fuel poverty

…all within a competitive market scenario.

Technology the key to meeting this challenge

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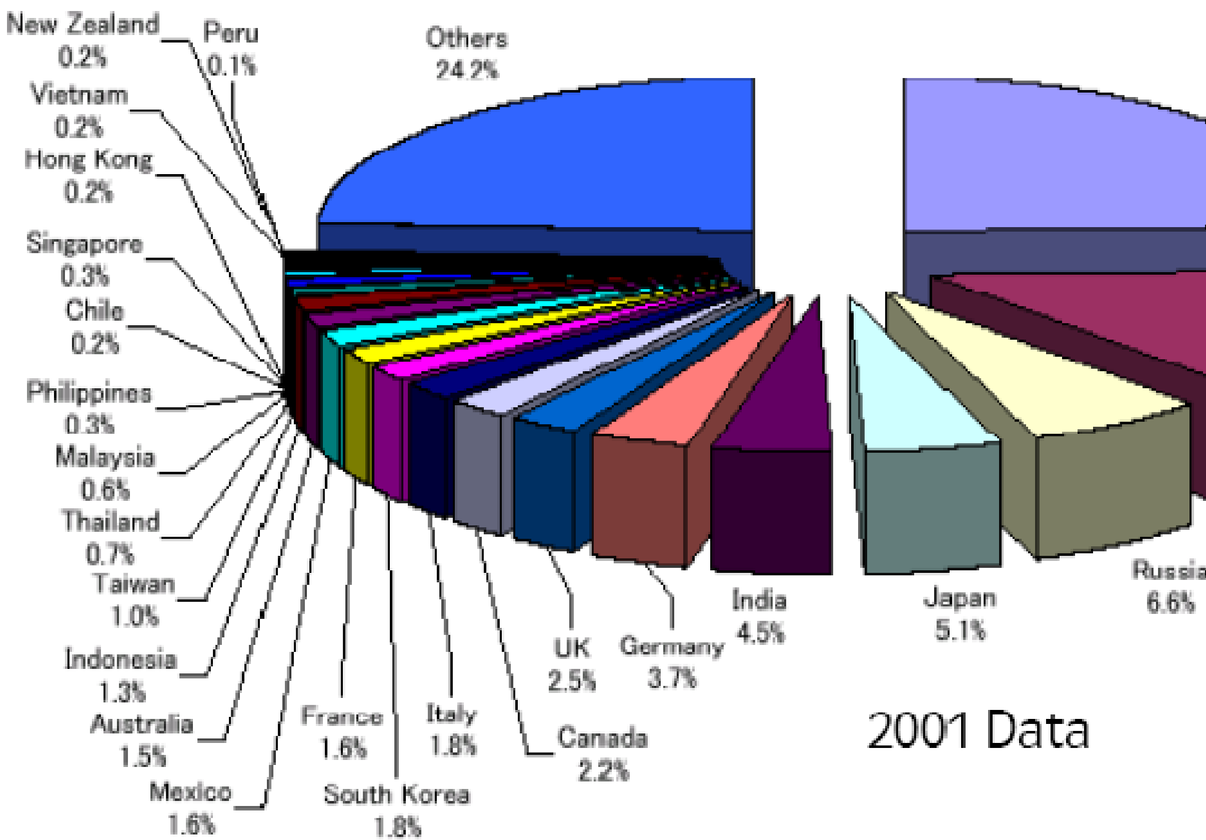
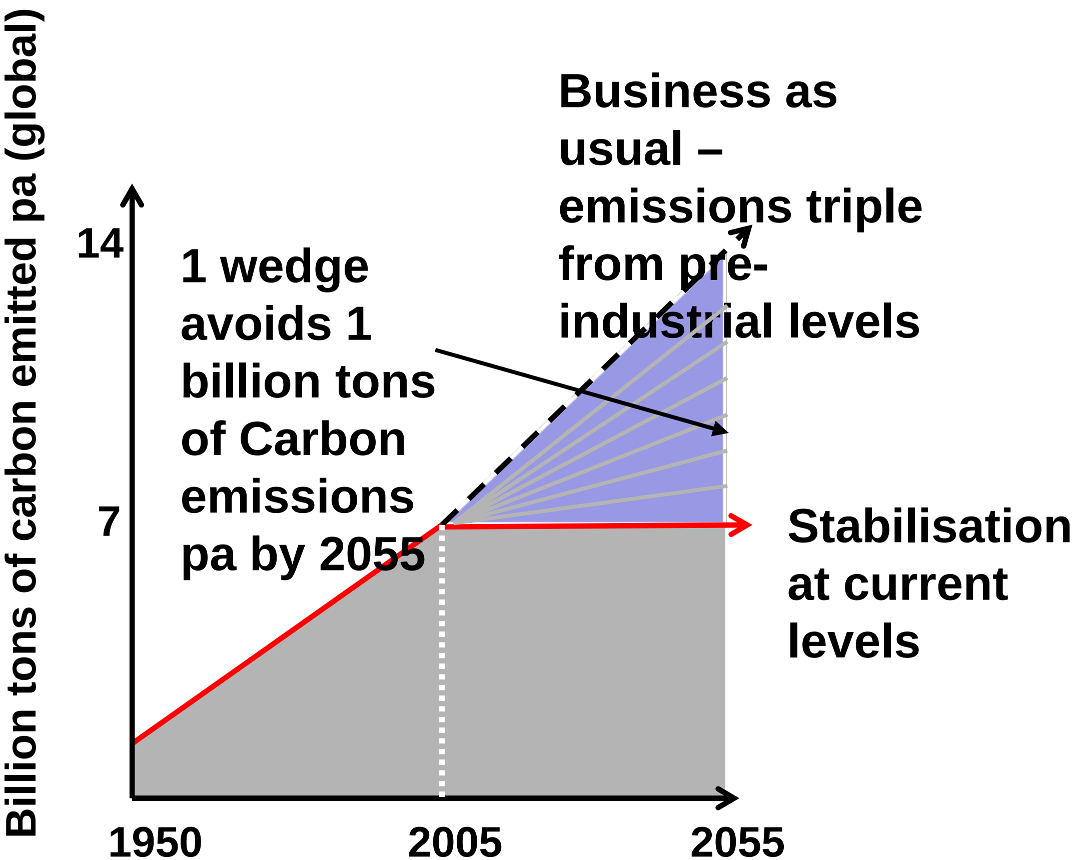
Emissions of CO_2 By Country



Installed 38GW of coal plant in first 8 months of 2006

UK: Circa 30% of CO_2 Emissions from Power Generation

CO_2 Reduction Requires Investment in Technology



One "wedge" is equivalent to any one of the following:

- Clean Coal with wide scale carbon capture and storage.
- Wide scale adoption of small scale combined heat & power or fuel cells
- Increased use of renewables
- Energy efficiency measures.
- A global shift from coal to gas
- Major investment in nuclear
- Transport – doubling fuel economy or halving the number of miles driven.

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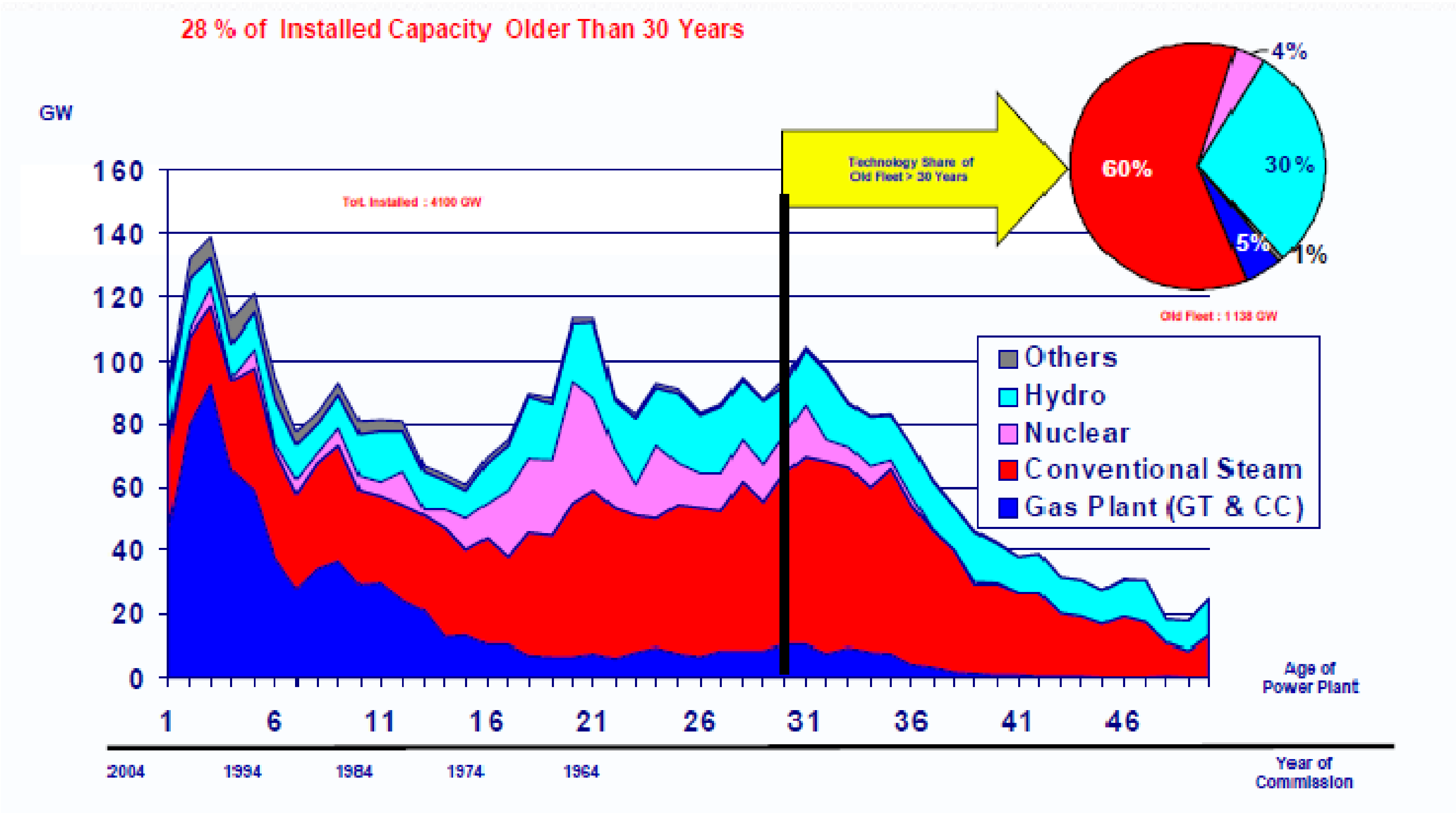

Ageing Fleet – Need for replacement/retrofit enhancement

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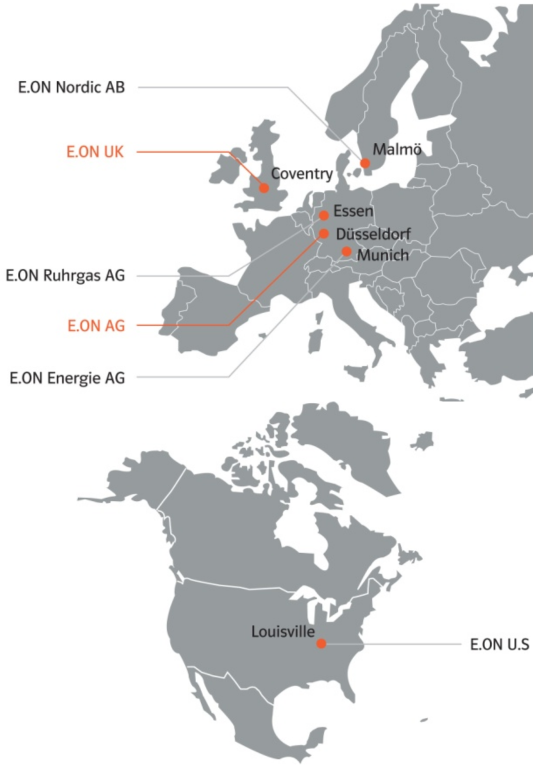
AGENDA

The world's largest investor owned power and gas company



Aspects of Power Industry Evolution

Engineering Example: Integrity of Power Plant

Future Challenges

- Low Carbon Technology
- R&D Perspective

Summary

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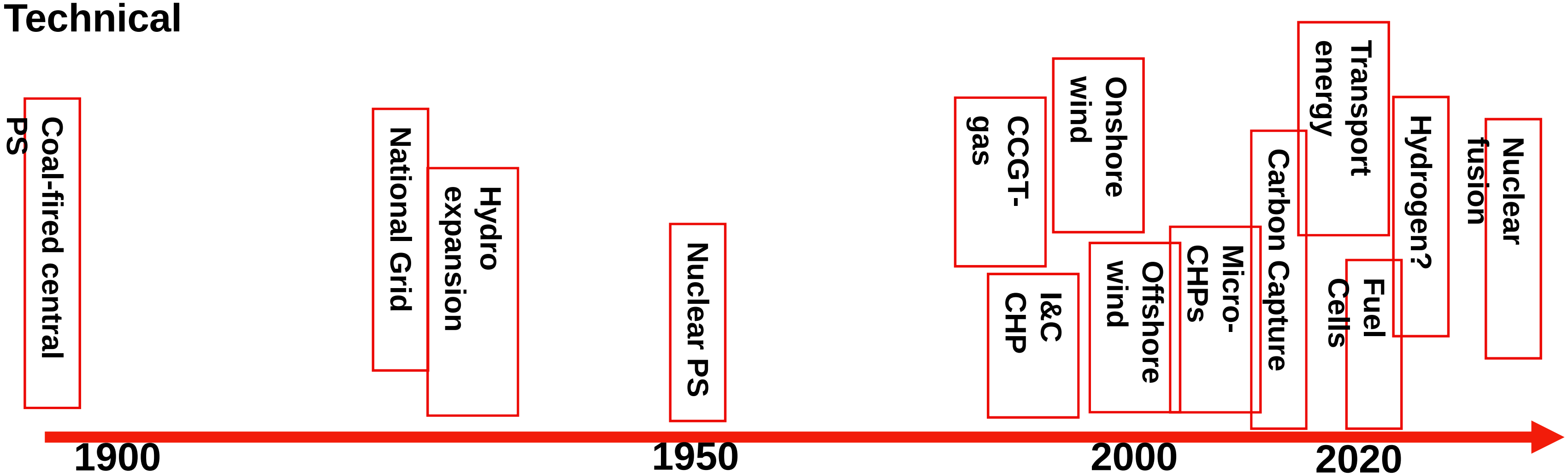
The Evolving Energy Landscape

Political & Env.	Economic	Social	Legal
Climate change – Kyoto Security of supply –gas Fuel Poverty Competitive energy market Environmental Regs New nuclear?	Rising energy costs Economic growth of India/China EUETS Competitive market Emissions targets ROCs	Housing - Energy inefficient - Individual Dwellings - Most fuelled by gas Growth in electrical appliances Planning resistance	LCPD Nuclear licensing ROC's EEC OSPAR / London Convention

Technical



Engineering

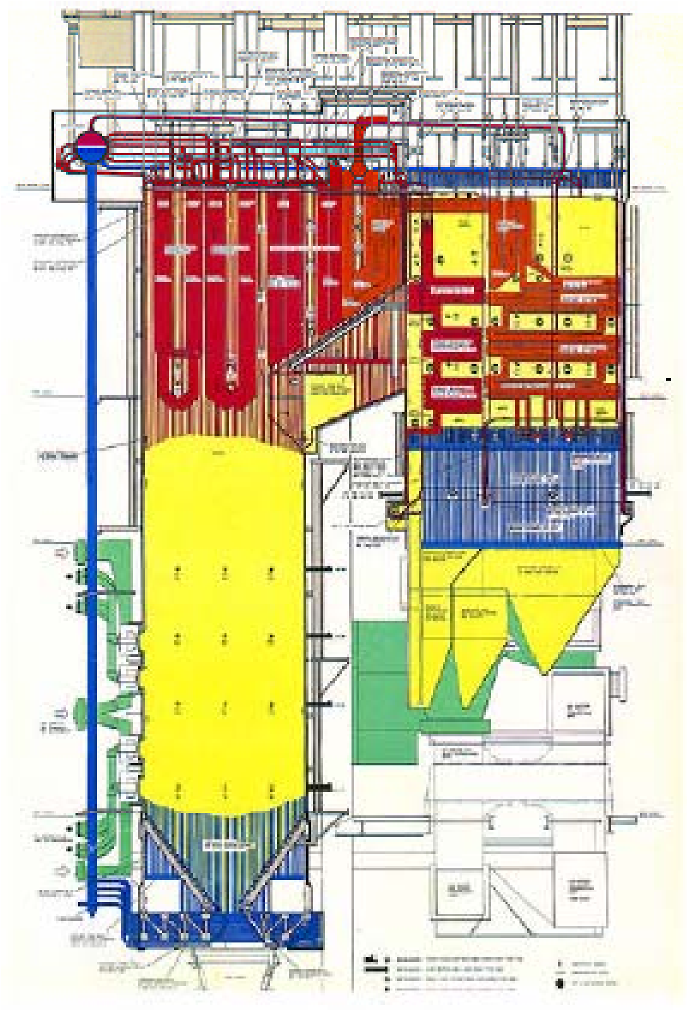
UK Perspective: 1960’s and 70’s Boom

Nationalised Power Company

Large increase in demand for Electricity: Met by build of stations, mainly with 500MW+ Units

50 Boilers built in 10 years from 1966; 7 different designs

UK Coal supply, cheap Oil



UK Perspective: 1980's to current date

Environmental Concerns

1989 Privatisation underway

Increased competition and plant divestment

Oil crises, Miners Strike

World traded coal price escalation

Alternative fuels – Dash for Gas

Coal – Expectation of more flexible operation

Trend to 'Sweat the Asset'

Mergers and Acquisitions

European LCPD: Emissions reduction targets

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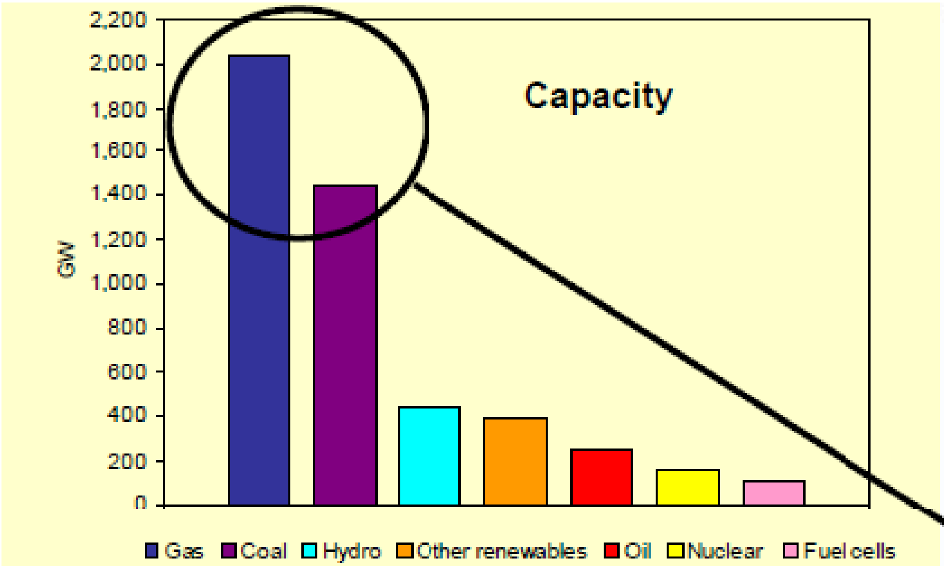
World Perspective: Longer Term Energy Market



IEA projections of global power station build to 2030

IEA World Energy Outlook 2004

- **Different needs world-wide**
  - uneven access to modern energy
- **Growth of Renewable Energy and increasing resurgence of nuclear but …**

Clean Combustion Technologies needed for new fossil fuel plants:
2000 GW Gas
+
1400 GW Coal

Electricity Market Outlook (Source IEA World Energy Outlook 2006)
(Based on IEA Reference scenario for period to 2030)

- Electricity demand doubles by 2030
- Share of Coal used in fuel mix increases (mainly due to demand in Asia)
- Natural gas fired generation more than doubles
- Nuclear generating capacity increases, but share of fuel mix drops from 16% to 10%
- Renewables grows from 2% to 7%
- World CO_2 emissions increases by two-thirds (China and India account for 60% of increase)
- Ageing infrastructure demands significant investment in OECD countries
- By 2030 still in excess of 1 Billion people without electricity

Implications

- Importance of clean use of fossil fuels
  - Essential part of fuel mix
- Importance of accelerating the take-up of clean fossil
  - Incentives to support build of ‘zero-emission’ plant
  - Regulatory framework required to roll out
- Importance of addressing worldwide issues
  - Use of high efficiency technologies
  - Forge a path for ‘zero-emission’ plant
    - Existing plant retrofit
    - New plant ‘carbon capture ready’
    - Increasing use of low carbon technologies

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Engineering: ‘A Framework We Operate Within’

Reduce Emissions

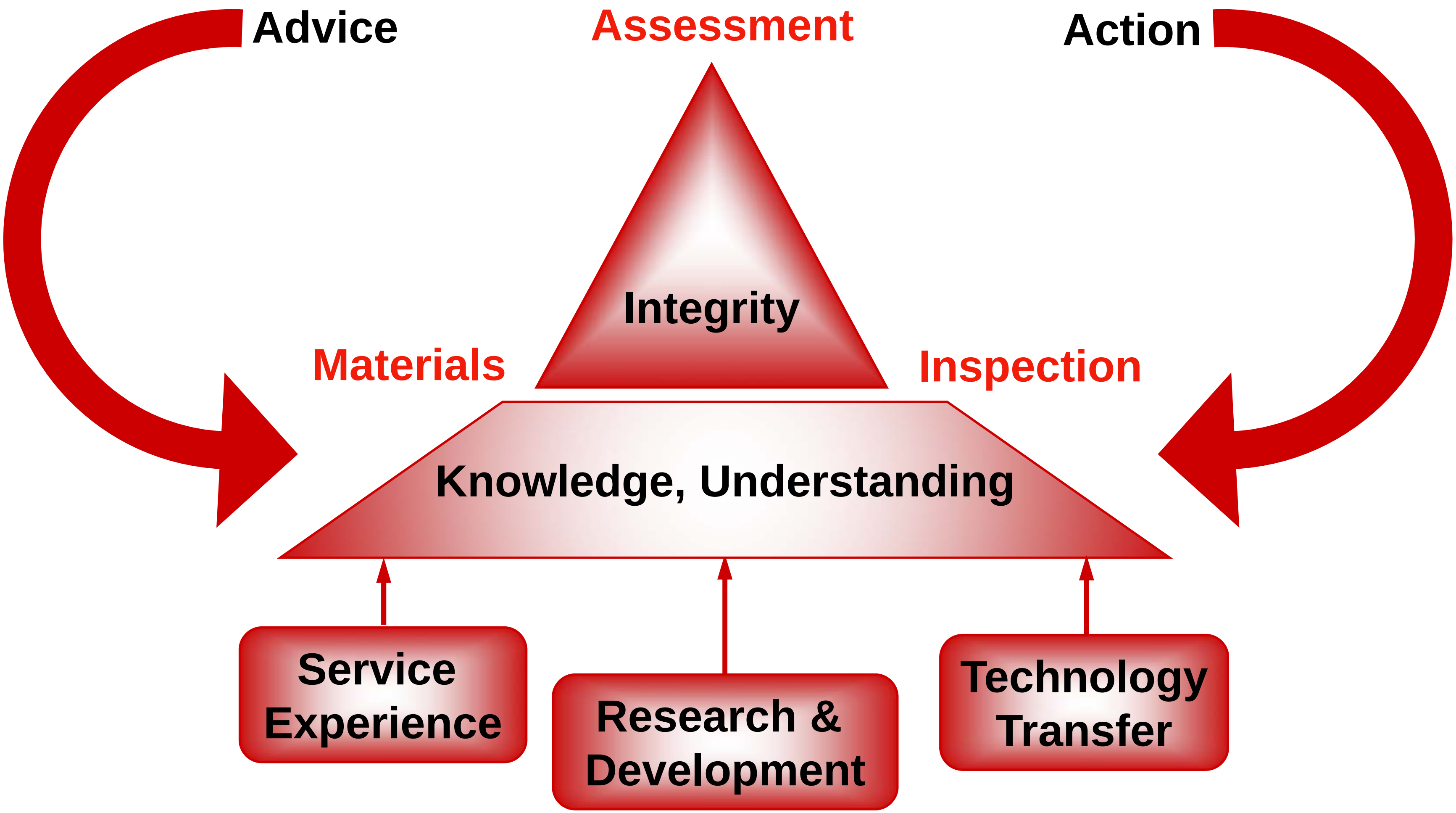
New Technology (Innovation) Improve Efficiency

Fragmented Industry Safety Maintain Plant Availability

Ageing Plant Knowledge Transfer Resources (People) Skills

Legislation

Integrity of Power Plant



Now A Brief Example…… (Referenced in Abstract)

Main Steam Bore Cracking (2001)

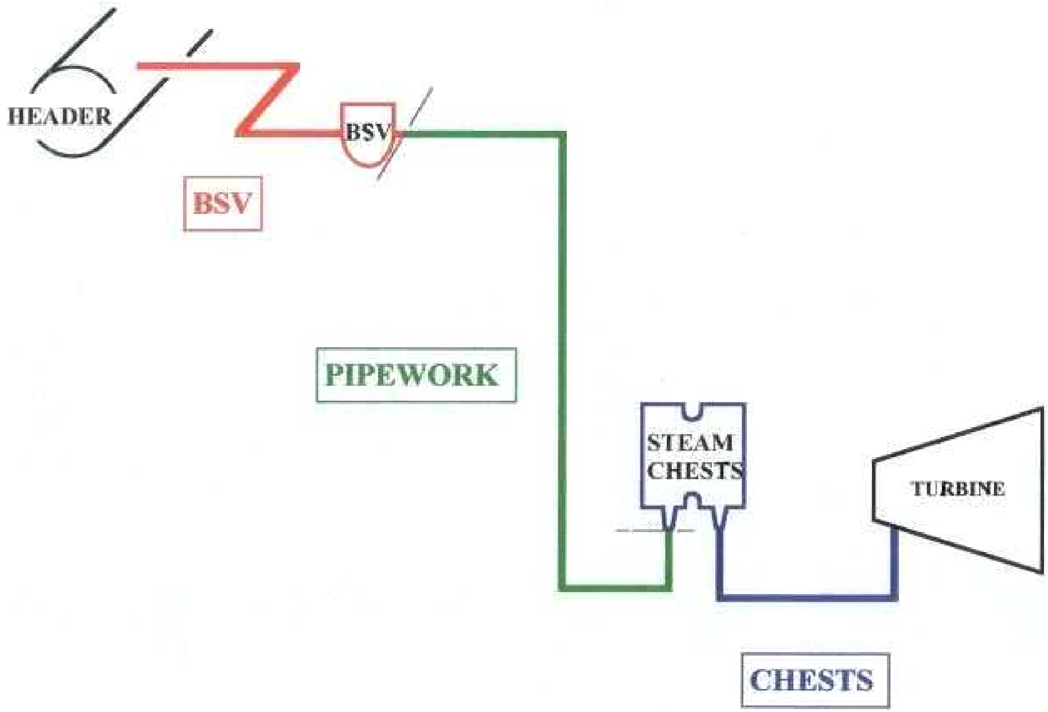
0.5% Cr 0.5% Mo 0.25% V Pipes

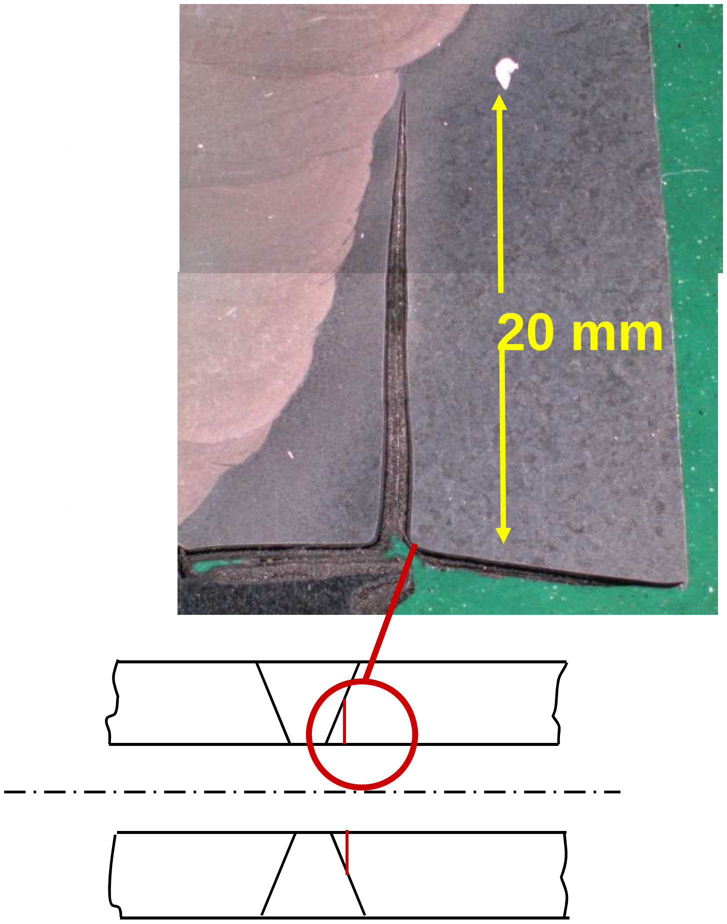
Main steam, hot reheat & turbine loop pipes

Design life 150,000 hours

“Fitness-for-purpose” safety case

Replacement costs £7M for 500MW unit





Steam Conditions

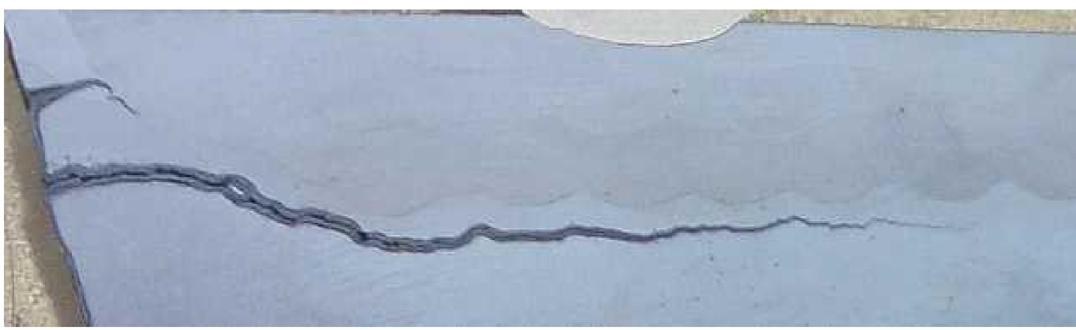
Circa 180bar at 568º C

Initial Concerns and Features

Cracking initiates at weld root or counterbore corner: Major Safety Implications

Typically grows radially outwards fully circumferentially

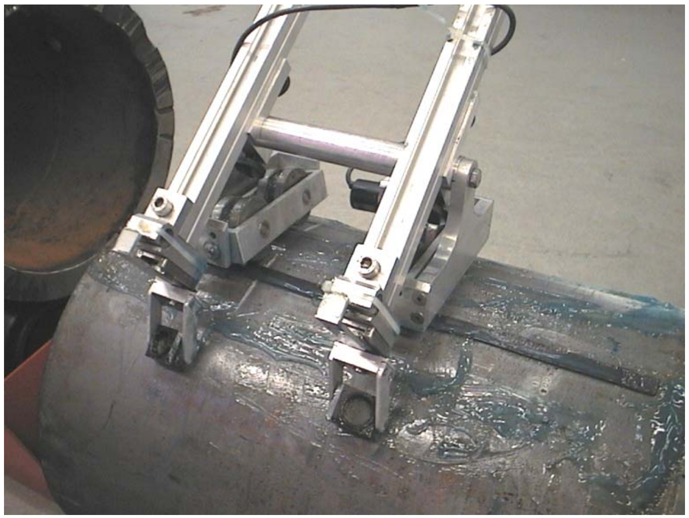
Thermal fatigue driven and typically up to 20-25mm in 66mm pipe wall



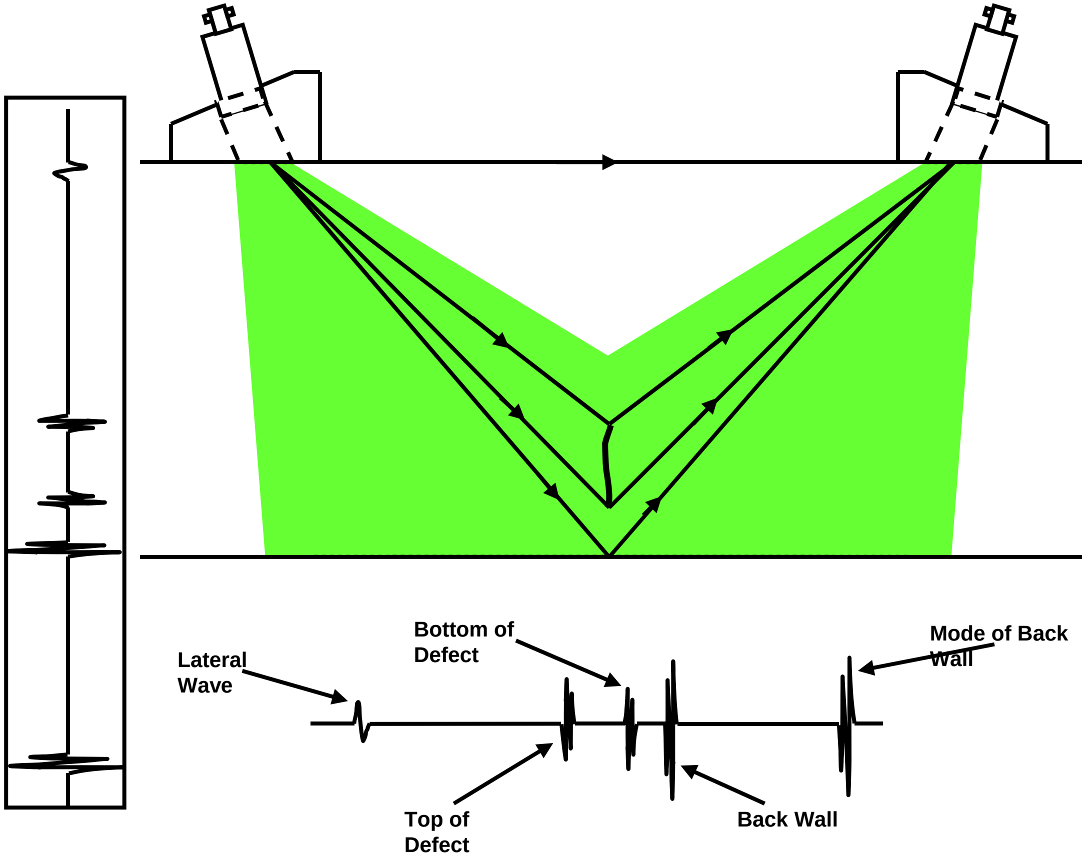
Main Boiler Stop Valve

Turbine Loop pipe 47mm defect

Defects not reliably detected by standard CMV weld NDT technique (Time of Flight Diffraction technique validated – crack sizing to 1% of weld thickness)



CMV TOFD Pipe Scanner



Extent of cracking across UK plant was unknown

Notable Activities

Competitors Join Forces to Investigate/resolve a common safety problem

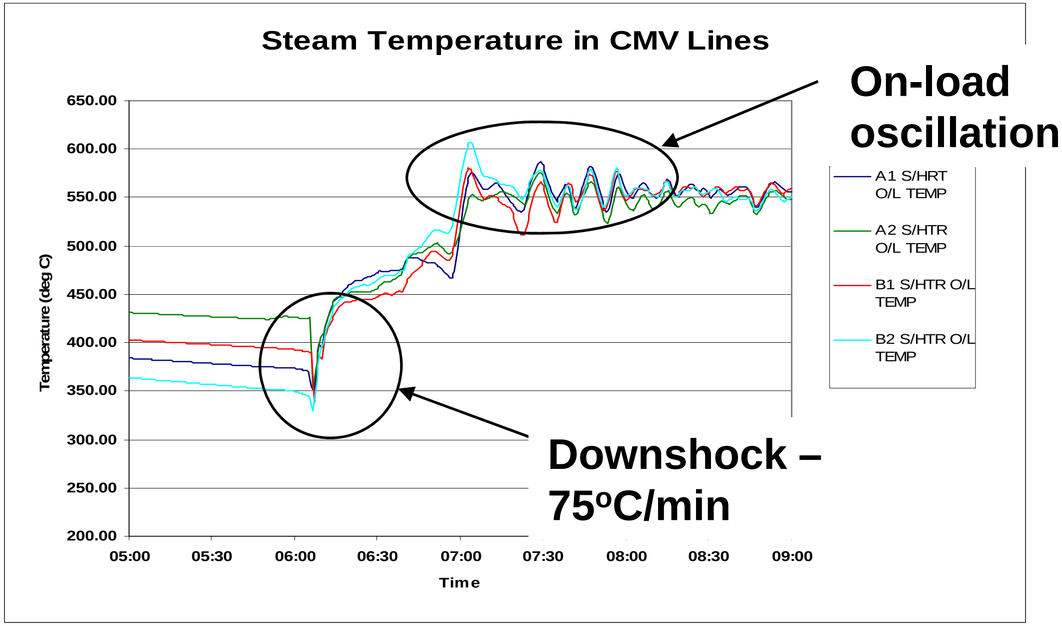
Enhanced weld inspection (techniques and scope)

Oxide dating and structural assessment to determine acceptable crack size limit for 4 years operation

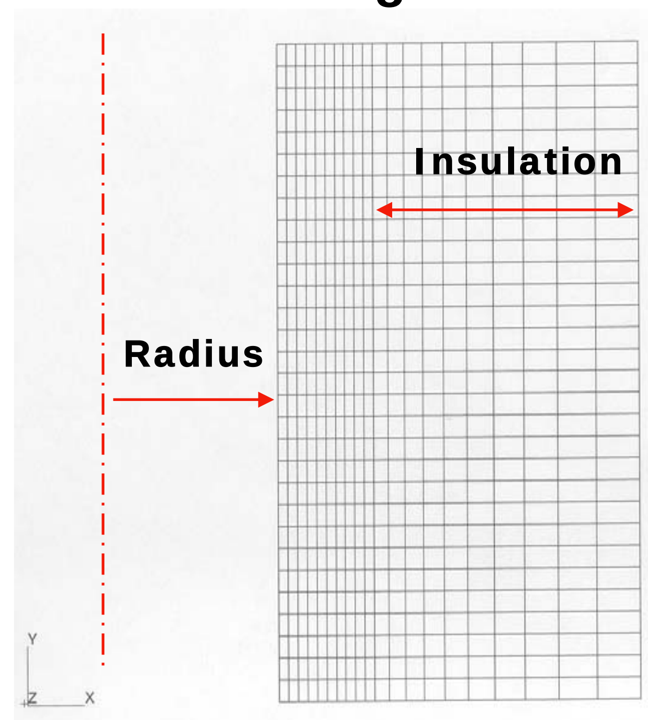
Repair all welds over size limit

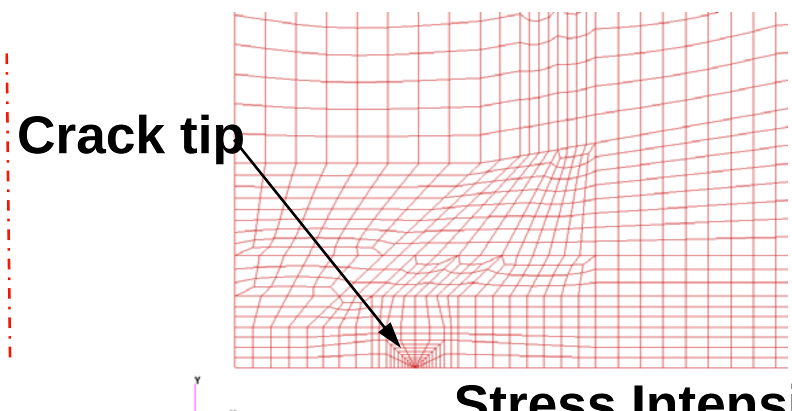
Review operational data and improve procedures

Re-inspection intervals set for defects in-service circa 1-2 years



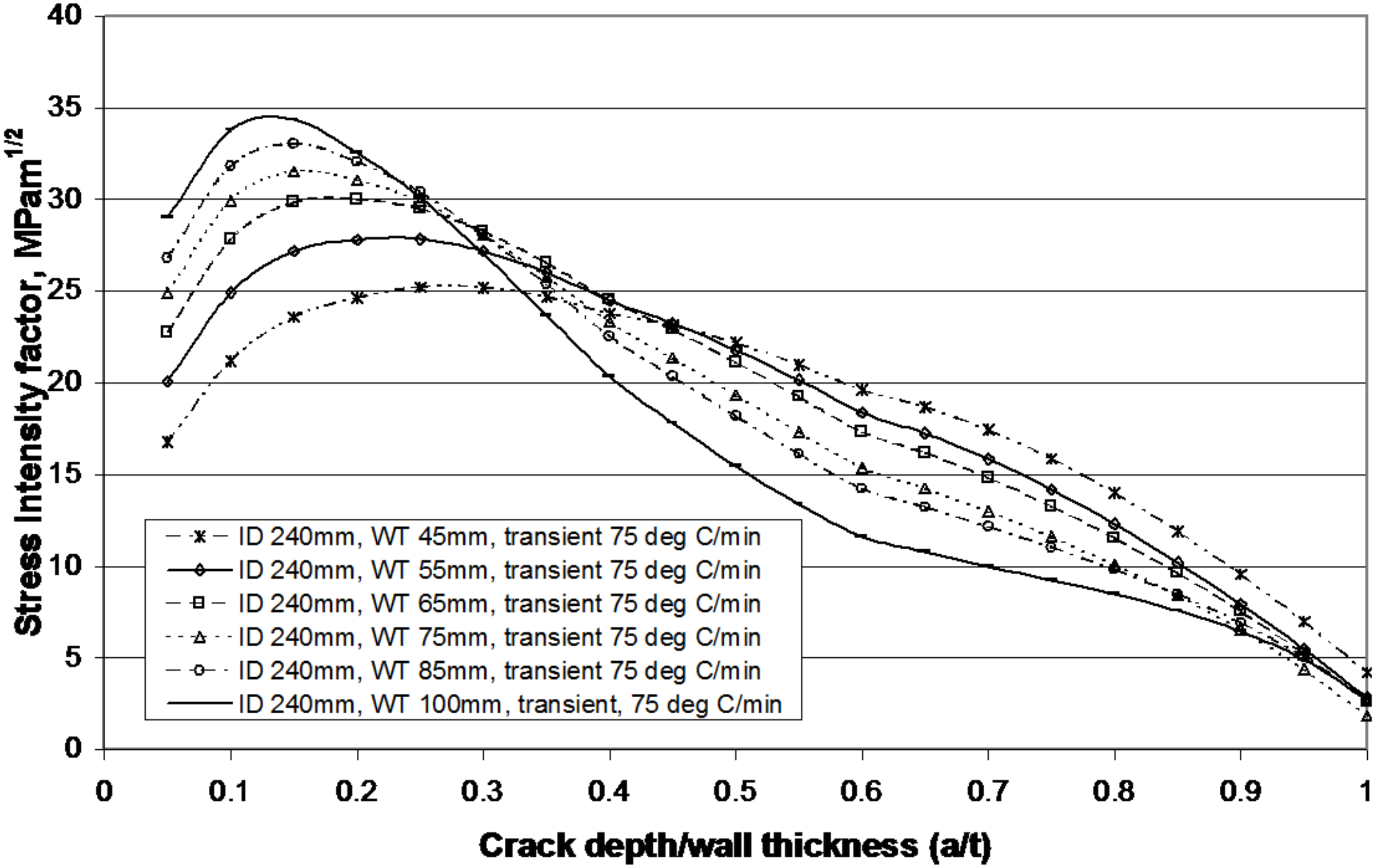
Thermal Transient Modelling





Stress Intensity Factors

Typical Response Map – Thermal K



Analysis Verification: Destructive Testing

HP loop pipework section – 75mm wall

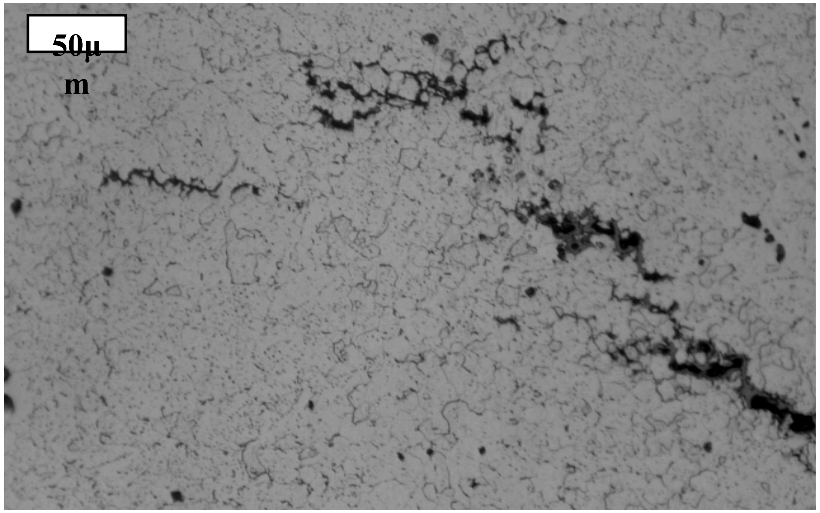
Crack depth varies 26-47mm (from 6 through wall weld sections)

Crack growth – fine grained region of HAZ

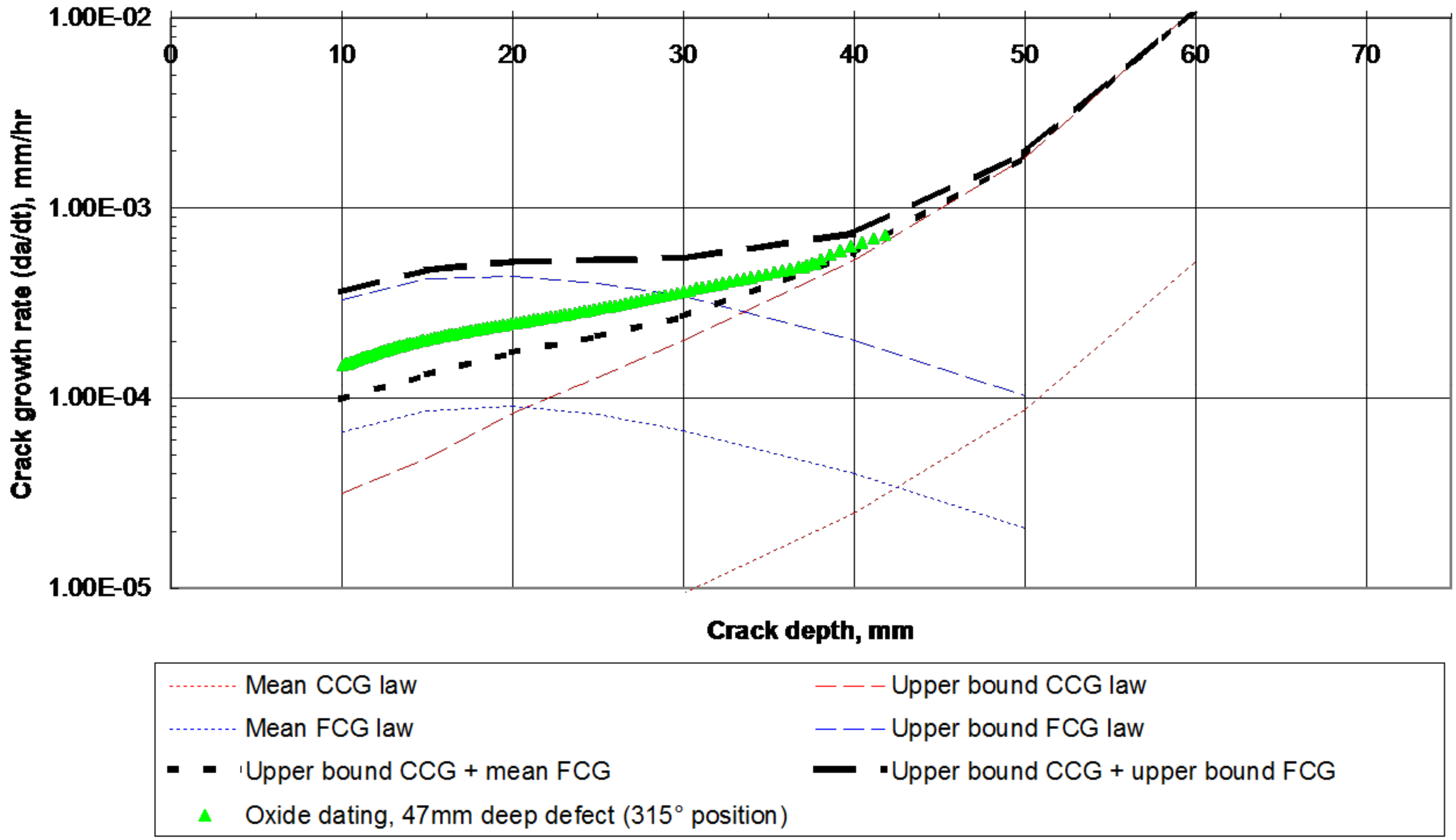
Crack – oxide dated; all crack front active

Check: Bore oxide depth – consistent with operating temperatures

Creep damage ahead of crack tip (depth 36mm)



Analysis Verification: Crack Growth



FUTURE CHALLENGES

Challenges

Availability of ageing current plant

CO_2 Reduction

New Build: higher efficiency fossil plant

Security of supply/fuel diversity

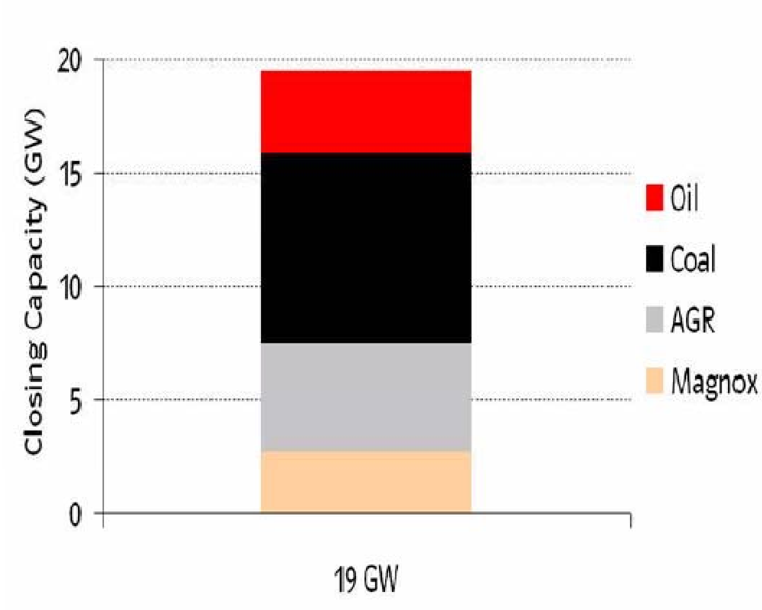
Generation that is Sustainable and Affordable

Low Carbon Technologies, such as

On and Offshore Wind

Marine, Photovoltaic, Fuel Cells

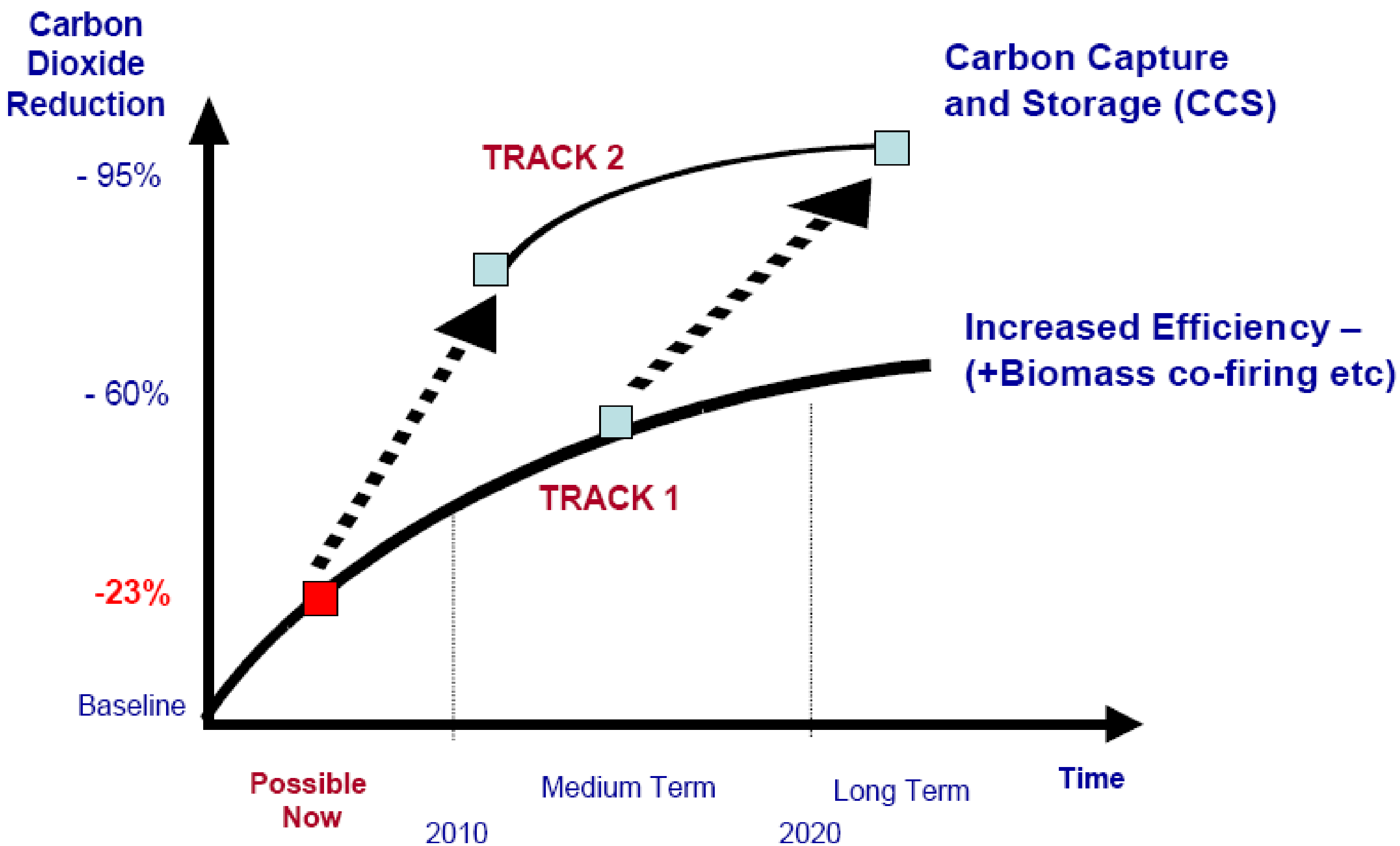
Nuclear!



Next 10 years in UK: Circa one third of overall capacity will close.

Challenges addressed in part by focussed R&D

Clean Coal: CO_2 Abatement via 'Clean Use'



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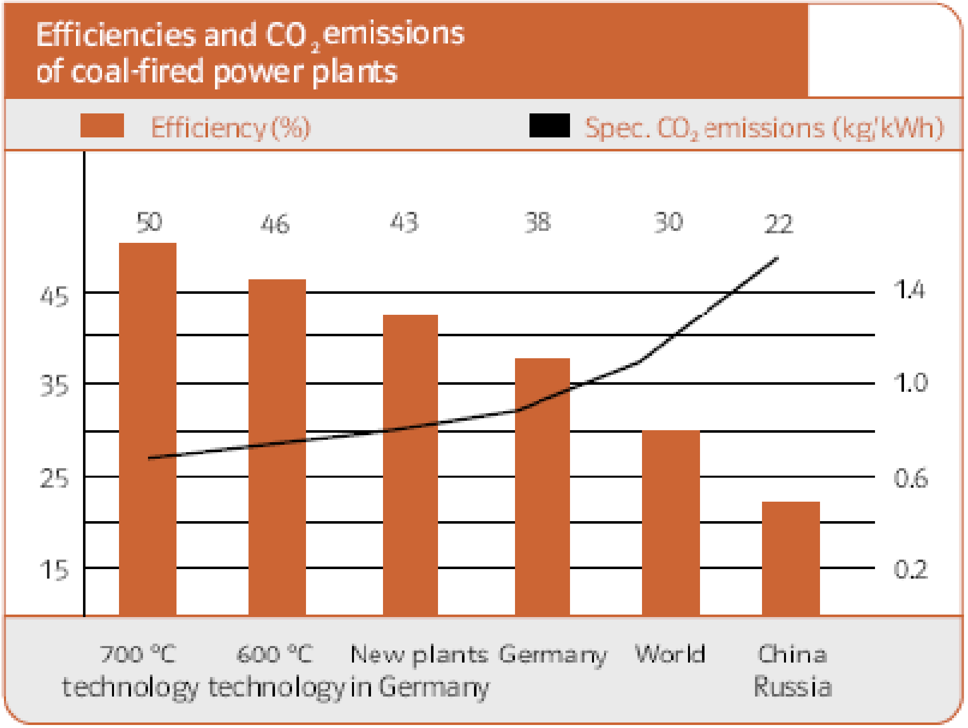
50 Plus Power Station (COMTES700 Project)

www.comtes700.org

700ºC and 370 bar



Test facility at Scholven Power Station (Gelsenkirchen) Unit F

Collaboration with 8 Utilities and 4 Suppliers

50% + Efficiency Target (could reduce emissions by one third

Innovative materials (Nickel based alloys) and components

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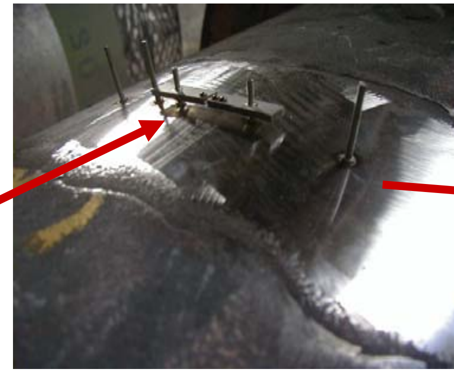
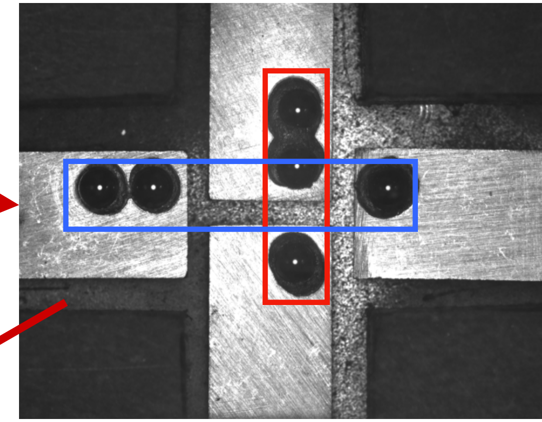
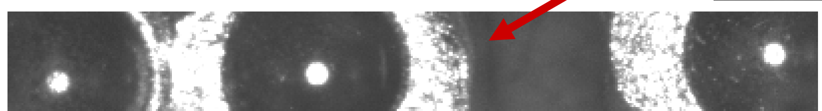
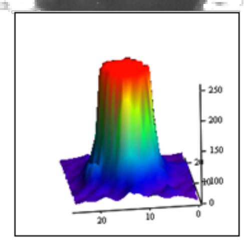
Supporting Operational Plant Today: Plant Focussed R&D (1)

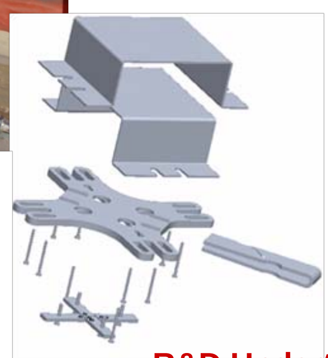
Remanent Life of Aged Materials

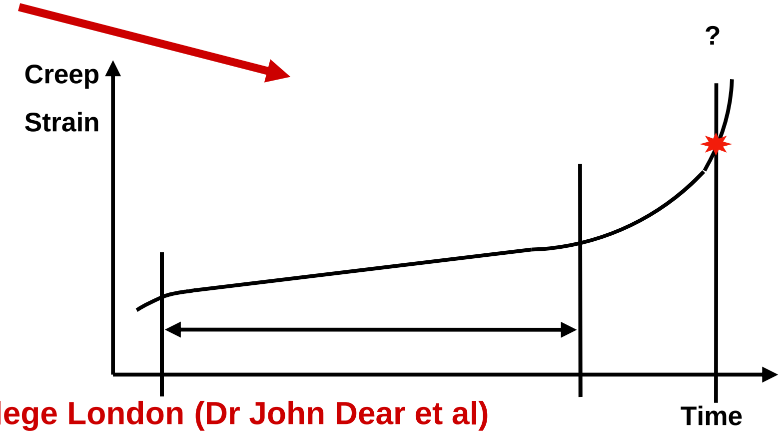












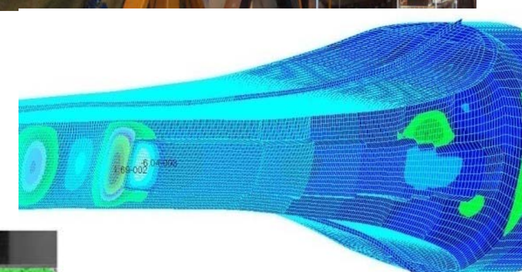
R&D Undertaken with Imperial College London (Dr John Dear et al)

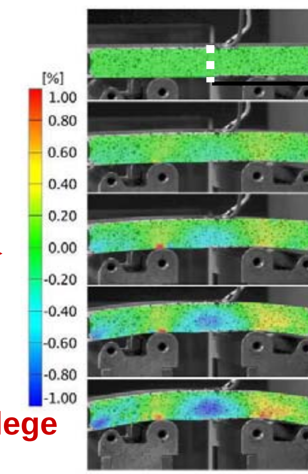
Engineering

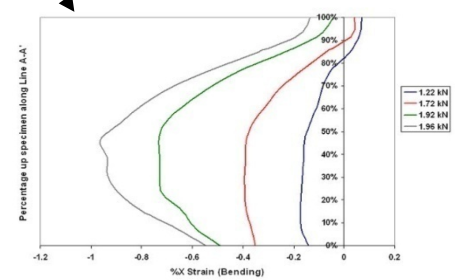
Supporting Operational Plant Today: Plant Focussed R&D (2)

Structural response and failure processes of Wind Turbine Blade Composites

Ref: Dr Find Jensen et al Riso National Laboratory, Denmark (Blade Testing)







R&D Undertaken with Imperial College London (Dr John Dear et al)

R&D: Overview

Driven by Plant issues of today and perceived challenges associated with planned New Builds and Low Carbon Technology

Solutions: Both innovative and adapted from other industries

Undertaken in Collaboration where possible: Customers, Universities, Gov/EU funding, Other research bodies etc

International Focus

Delivers sustainable benefits; Safety, Performance, Workforce etc

Delivers transferable technologies/solutions where possible

Enables us to meet the Future Challenges

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E.ON Low Carbon Research

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Summary

Multi-Discipline Engineering/Scientific teams required to meet challenges (CCOPPS Project will support this)

Broad range of Technologies to be pursued to enable a Low Carbon Future.

Exisiting plant needs ever more support.

Utilities such as E.ON are pursuing a range of activities to meet the challenges, including;

- **Working with Government, Regulators, Customers, Public…..**
- **Researching a wide range of Technical Solutions**
- **Adopting an International Perspective**

Thank You For Your Attention

Agenda

- **Introduction, Update and Relevant CCOPPS Activity**
  Jim Wood

- **Power Generation:** ***Engineering Challenges of a Low Carbon Future***
  Andy Morris

- **Q&A Session**
  Andy Morris & Jim Wood

- **Closing Remarks**
  Jim Wood

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http://www.ccopps.eu/