Materials R&D Requirements for Fossil-Fuelled Steam Plant

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Energy materials – Meeting the Challenge
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Why is Steam Plant a key issue?

74% of the UK's electricity demand is met by fossil-fuelled plant

- 38% coal- or oil-fired
- 36% gas-fired
  - Split between open cycle (gas turbine only) and combined cycle (gas turbine + steam turbine)

⇨ >50% of UK electricity dependent on steam plant

- Boilers
- Steam turbines

Key Drivers

- Economic
  - Improved efficiency
  - Reliability
  - Manufacturing Costs

- Environmental
  - Improved efficiency = lower emissions
  - Carbon capture

Cost of reduction in CO_2

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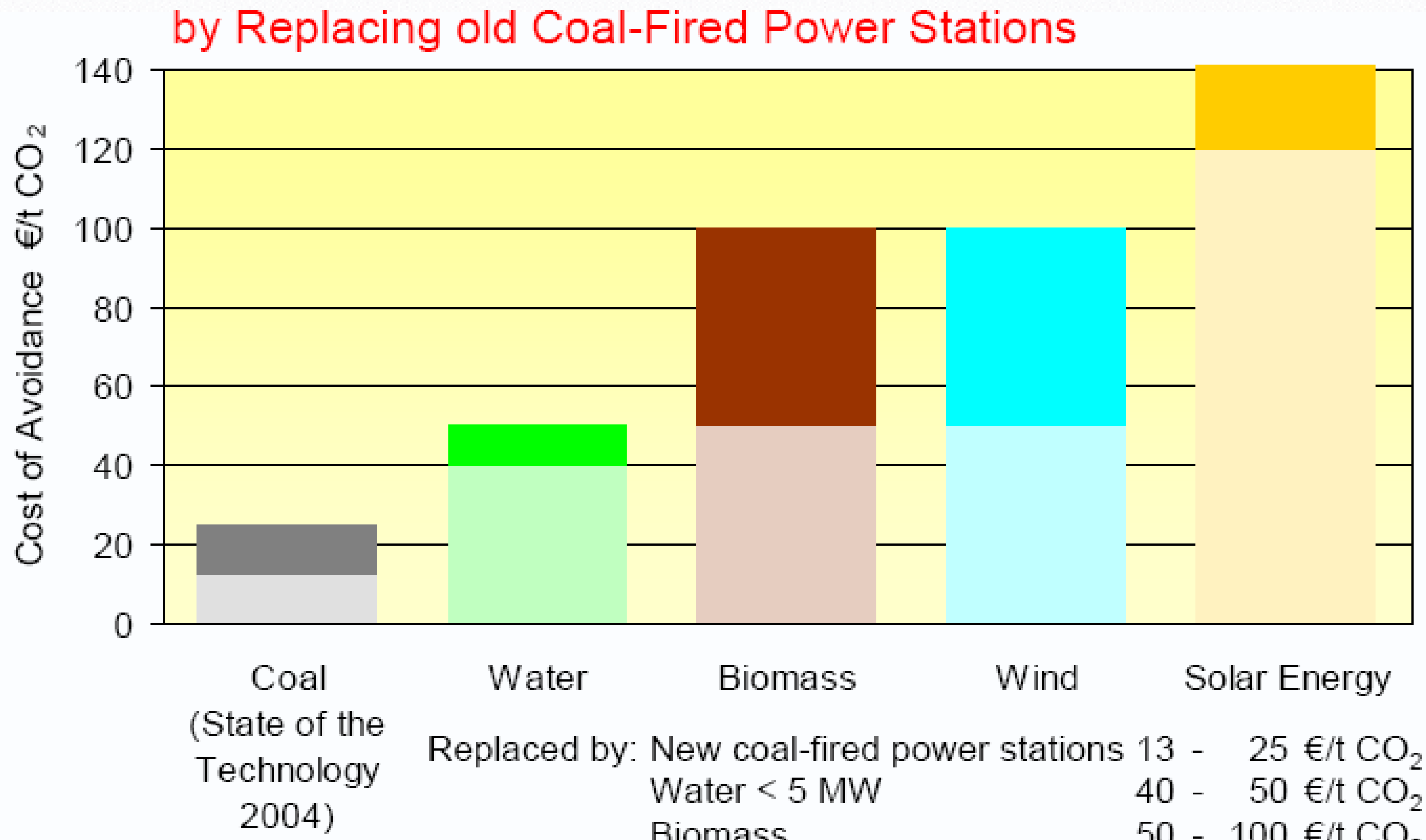

Replaced by:

New coal-fired power stations	13 - 25	€/t CO_2
Water < 5 MW	40 - 50	€/t CO_2
Biomass	50 - 100	€/t CO_2
Wind	50 - 100	€/t CO_2
Solar Energy	> 120	€/t CO_2

Ref: Stamatelopolous “Clean Combustion Technologies 2- Pulverised Fuel Technology, Brussels 2005

Approach to Efficiency Improvements

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- Higher Inlet Temperatures
  - Boilers
  - Steam Turbines

    ⇨ Materials with Higher Temperature Capability

- More efficient LP turbines
  - Optimise aerodynamic design
  - Increase exhaust area

    ⇨ Higher Strength Materials with SCC Resistance

High Level Requirements: Implementation – 5 years

- Incremental improvements in existing materials systems
- Production/characterisation of prototype components using identified materials and processes
- Repair and improvement solutions for existing plant and materials
- Advanced manufacturing development for exisitng materials/processes for cost reduction/increased perfomance and integrity

High Level Requirements: Implementation – 10 years

- Development of new materials systems (substrate + coatings) based on existing knowledge including behaviour in realistic environments
- Development and application of process modelling to new materials to speed up introduction and help define new system solutions
- Adopting a total system approach to critical part design and life prediction with multi-material components with joints and coatings

High Level Requirements: Implementation – 20 years

- Identification of disruptive novel material systems and initial characterisation to identify most promising approaches
- Development of novel advanced technologies that will enable high overall efficiencies that will significantly reduce emissions

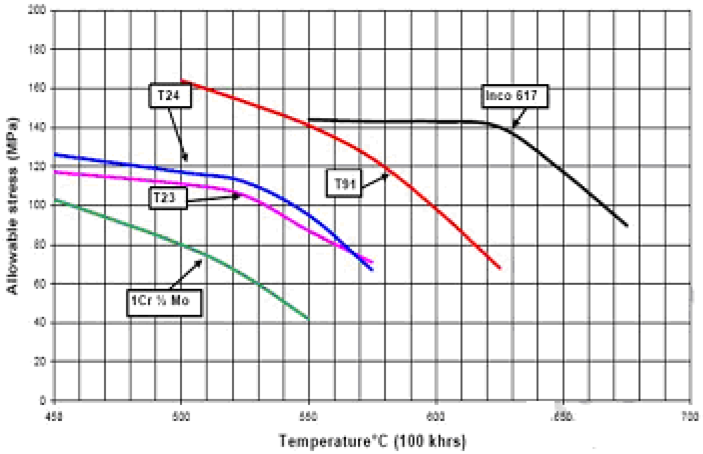
High Level Requirements:Generic Research

- Surface Protection Technologies
- Improved understanding and predictive modelling of degradation mechanisms
- Non-invasive inspection techniques for in situ assessment of material condition
- Existing plant refurbishment
- Similar and dissimilar materials joints

Boilers: Furnace Walls

State-of-the-Art

- Low alloy steels T23 and T24
- Designed for use without PWHT



Future Requirements

- Higher temperature capability
- Fireside Corrosion Resistance

Possible Solutions

- Ni-base alloys (IN617, IN740)
- New steels with surface protection

Boilers: Superheater Tubes

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State-of-the-Art

- High Cr austenitic steels (NF709, HR3C, Sanicro 25)

Future Requirements

- Higher temperature capability
- Fireside Corrosion Resistance

Possible Solutions

- Ni-base alloys (IN740)
- Materials with properties intermediate between austenitic steels and Ni-base alloys (AC66)

Boilers: Headers and Steam Pipes

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State-of-the-Art

- 9-12%Cr Martensitic Steels (P92, E911)

Nimonic 263 Extrusion

Future Requirements

- Higher temperature capability
- Steam Oxidation Resistance
- Eliminate Type IV Cracking

Possible Solutions

- High boron steels
- Coating of internal surfaces
- Ni-base alloys

Steam Turbines: HP/IP Rotors

State-of-the-Art

- 9-12%Cr Martensitic Steels (X13CrMoCoVNbNB 9 2 1)

Future Requirements

- Higher temperature capability
- Inspectability

Possible Solutions

- Ni-base alloys
- Cooling technology / thermal barrier coatings

Steam Turbines: Casings and Valve Chests

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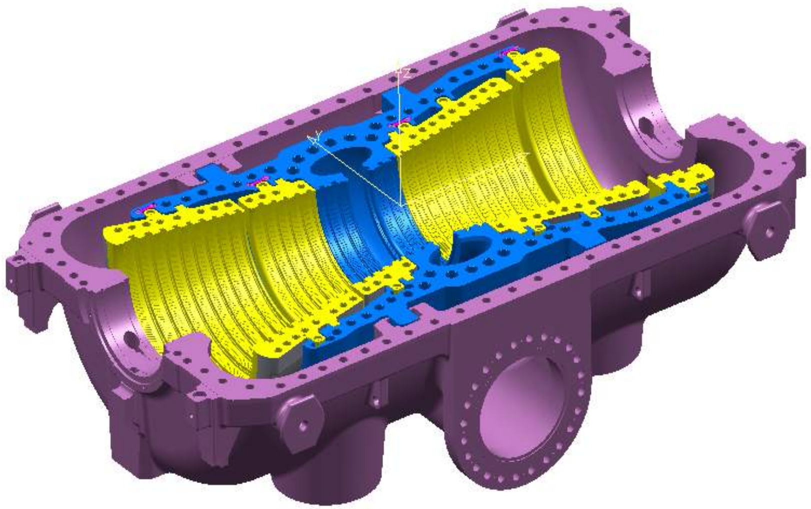
State-of-the-Art

- 9-12%Cr Martensitic Steels
  (G-X13CrMoCoVNbNB 9 2 1)



Future Requirements

- Higher temperature capability
- Castability / Weldability

Possible Solutions

- Ni-base alloys

Steam Turbines: HP/IP Blades

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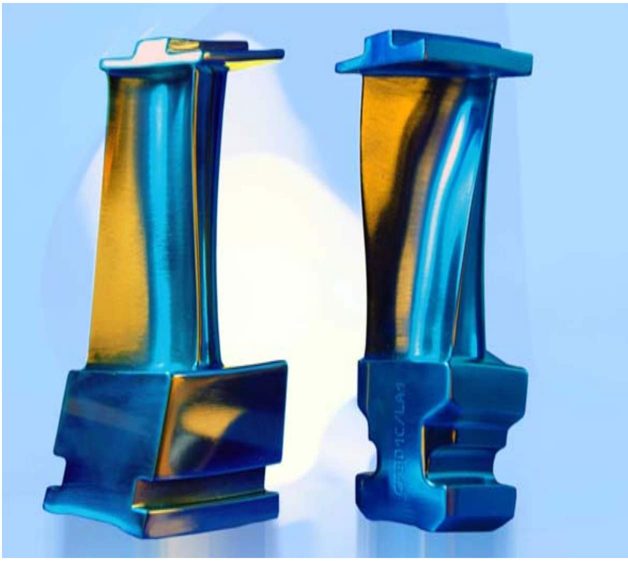

State-of-the-Art

- 9-12%Cr Martensitic Steels
  (X20CrMoV 12 1)
- Austenitic Steels

Future Requirements

- Higher temperature capability
- Solid Particle Erosion Resistance

Possible Solutions

- Ni-base alloys
- Erosion Resistant Coatings

Steam Turbines: Valve Internals

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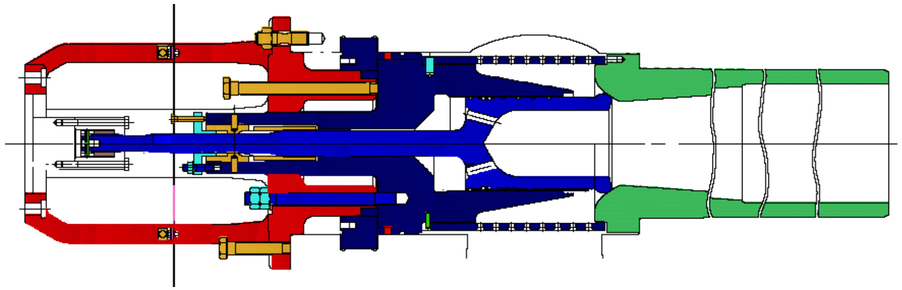
<u>State-of-the-Art</u>

- 9-12%Cr Martensitic Steels (X20CrMoV 12 1)
- 'Stellite' hardfacing



<u>Future Requirements</u>

- Higher temperature capability
- Erosion/Corrosion Resistance

<u>Possible Solutions</u>

- Ni-base alloys
- Abrasion Resistant Coatings

Steam Turbines: LP Rotors

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State-of-the-Art

- NiCrMoV steels
- Surface treatment

Future Requirements

- Higher strength
- SCC resistance

Possible Solutions

- More highly alloyed steels
- Improved surface treatment

Steam Turbines: LP Blades

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State-of-the-Art

- PH-stainless steels
- Surface treatment

Future Requirements

- Higher strength
- SCC resistance

Possible Solutions

- High strength steels with SCC resistance
- High strength steels with protective coatings

Is success achievable?

Issue	Expertise required	Available in UK Industry	Available in UK academia / research establishments
Materials with increased strength at high temperature	Alloy development	Yes	
	Materials modelling		Yes
	Long term test capability	Yes	??
Development of coatings	Coating processing technology	Yes	Yes
	Compositional development of coatings		Yes
	Long/short term test capability	Yes	Yes

Is success achievable?

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Issue	Expertise required	Available in UK Industry	Available in UK academia / research establishments
Surface Processing	Processing to develop residual stress profile	Yes	
	Understanding of residual stress development	Yes	Yes
	Long/short term test capability	Yes	Yes
High strength SCC resistant alloys	Alloy development	Yes?	
	Materials modelling		
	Long term test capability	Yes	Yes

Threats to success

- Materials systems approaching physical temperature limits for applicability
- Long timeframe for materials development cycle – does not fit with 3-4 year funding cycles
- Growing shortage of graduates with necessary skills

High Level Actions Required

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- Development of integrated strategy for Energy Materials Development, buy-in from
  - Funding agencies
  - Industry
  - Academia

- Commitment to long-term funding to cover entire materials development cycle
- Active encouragement for pre-competitive collaboration, both national and international
- Attract and retain high quality students/graduates within the Energy Materials field

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