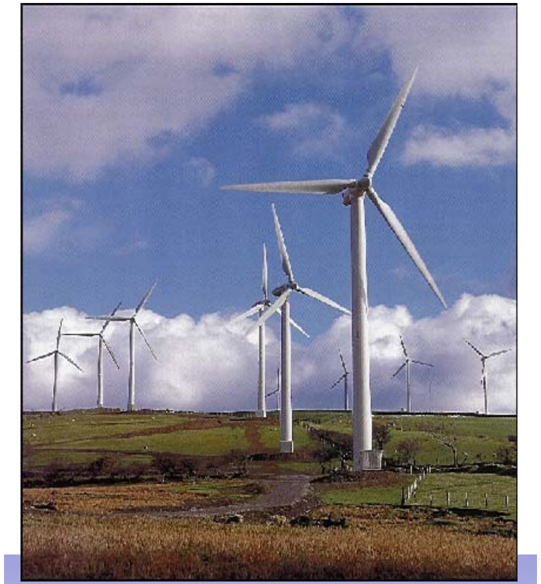
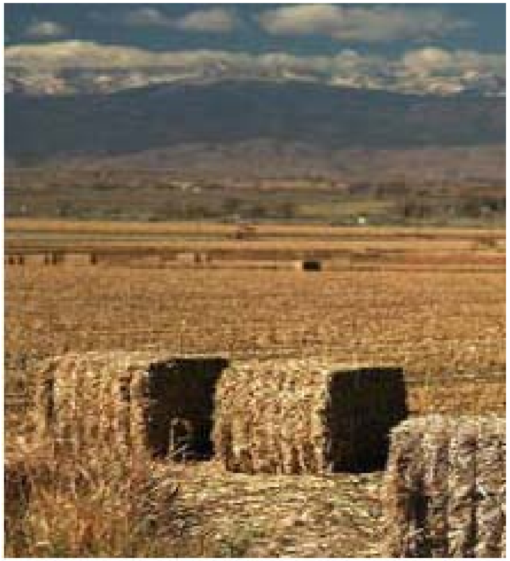
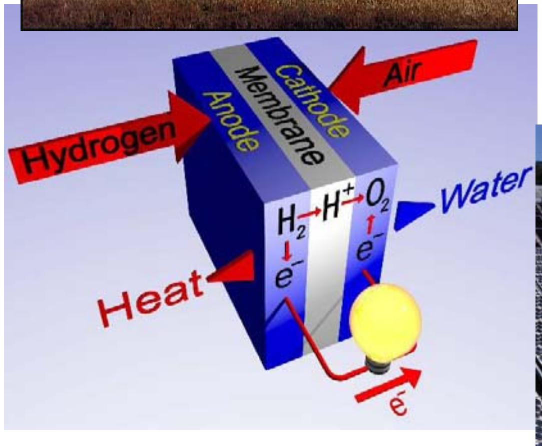
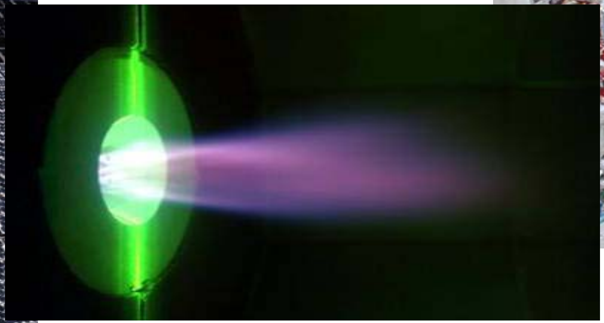


Source: Marine Current Turbines



Alternative Energy Task Group





Alternative Energy Task Group - Scope

- Biomass and Biofuels
- Fuel Cells
- Hydrogen
- Solar
- Wave/tidal
- Wind

Alternative Energy Task Group

Co-chairs
Brian Cane (TWI)
John Oakey (Cranfield University)

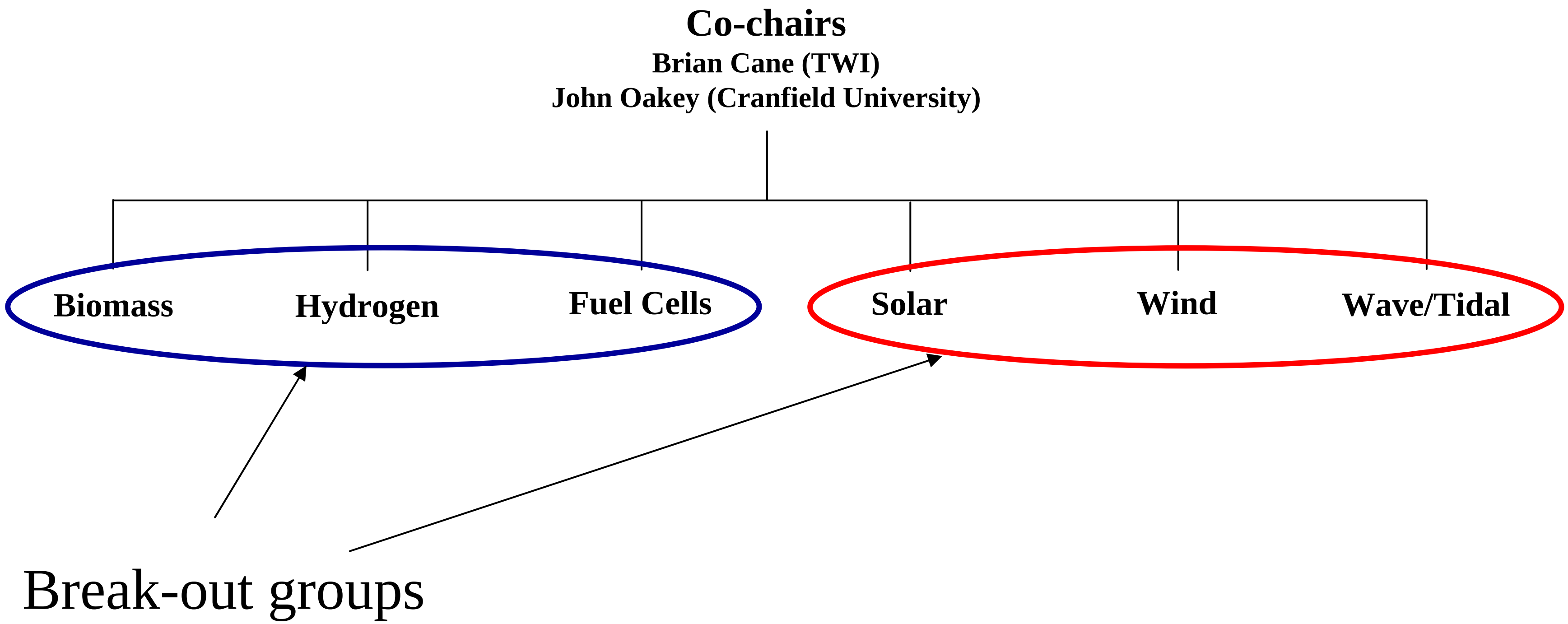
- **Biomass**
- **Hydrogen**
- **Fuel Cells**
- **Solar**
- **Wind**
- **Wave/Tidal**

Life Cycle Materials Issues & Challenges

- **Design & manufacture/installation (capital/development costs)**
- **Life Management (O&M costs)**
- **Decommissioning/re-cycling**

Materials (and related manufacturing & reliability) issues are central to reducing life-cycle costs of the associated systems

Alternative Energy Task Group

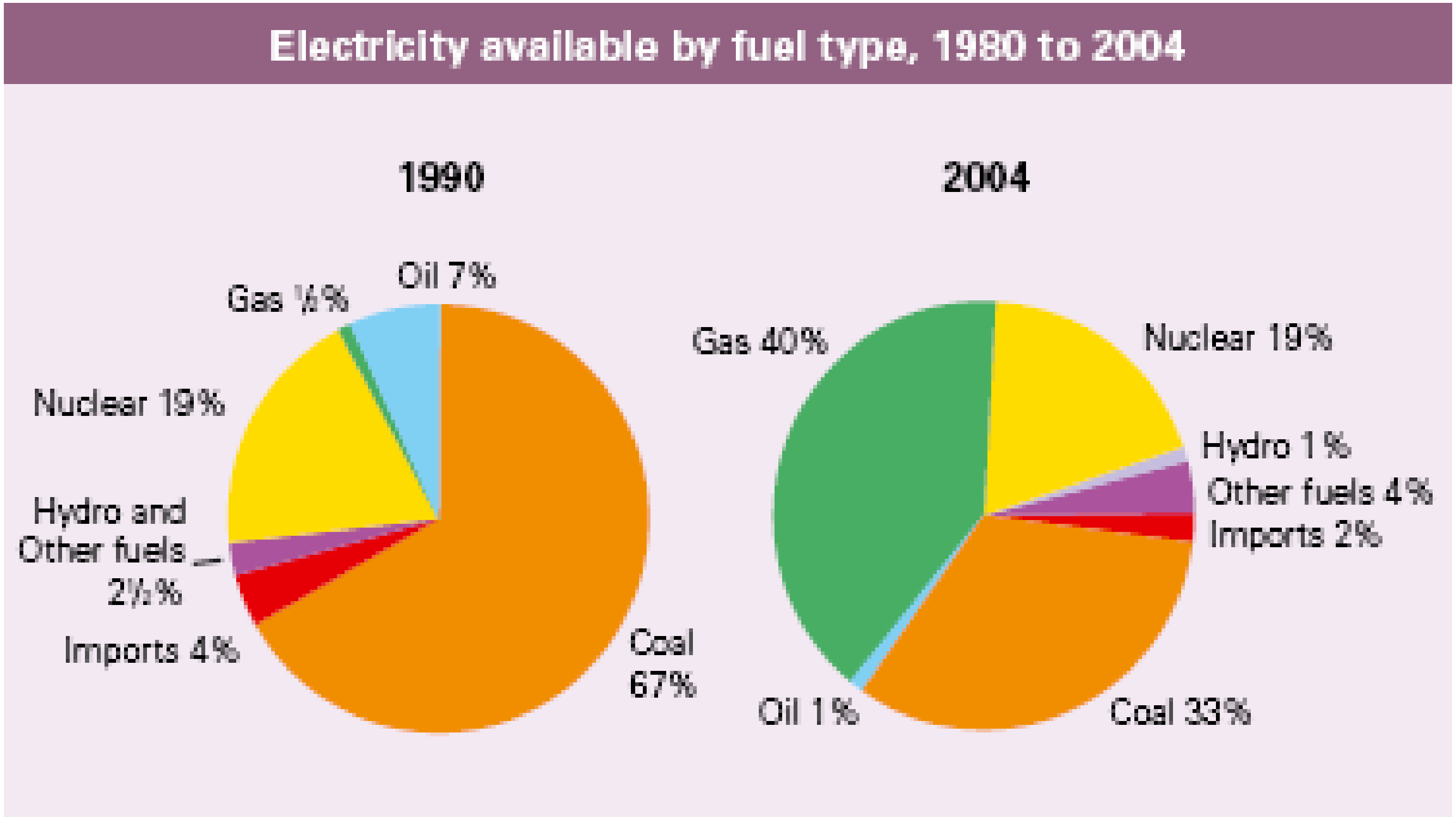


Alternative Energy Task Group

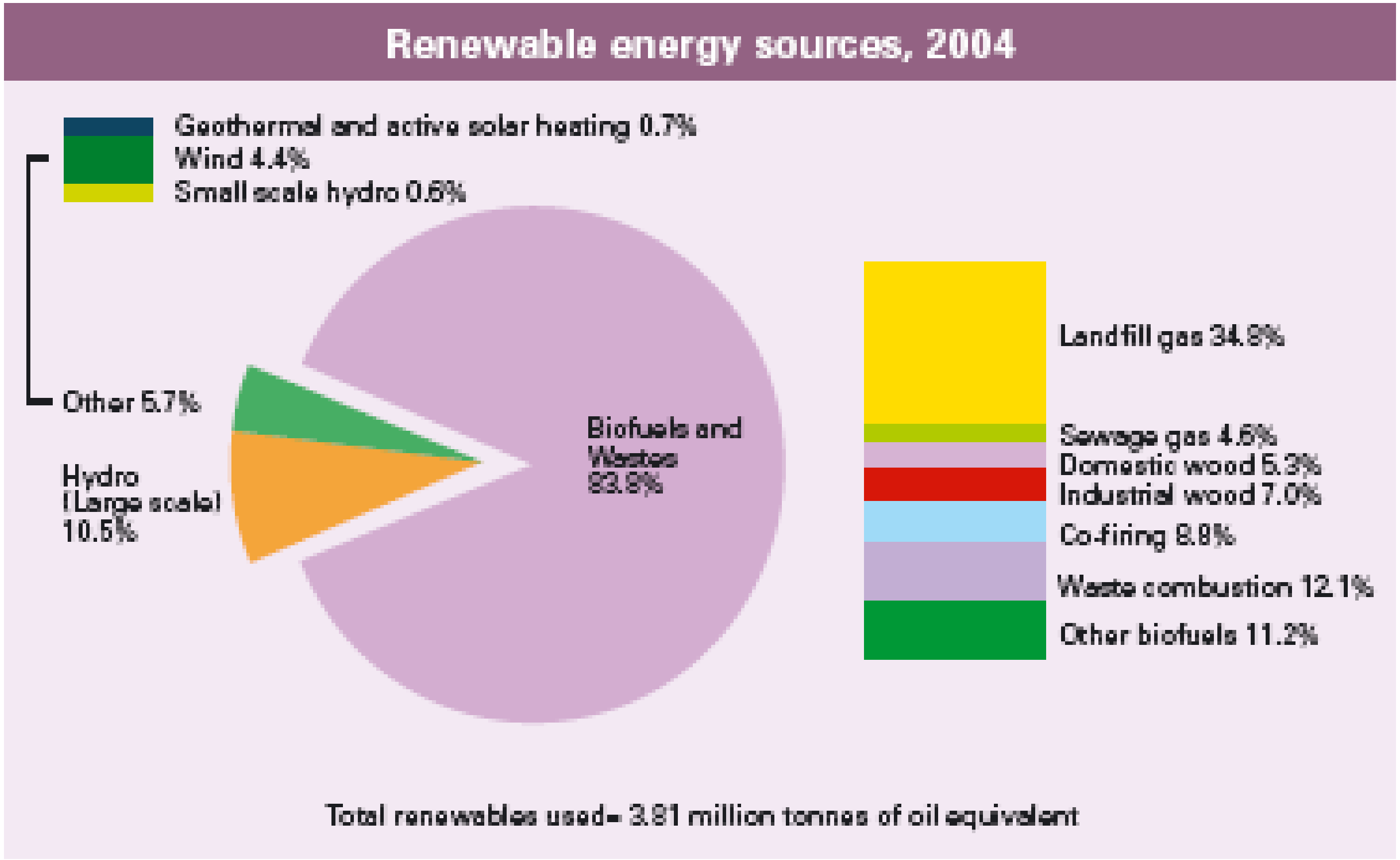
• Biomass	- John Oakey
• Wind	- Brian Cane
• Hydrogen	
• Solar	
• Wave/tidal	
• Fuel Cells	- John Kilner

Biomass

John Oakey
Energy Technology Centre
Cranfield University

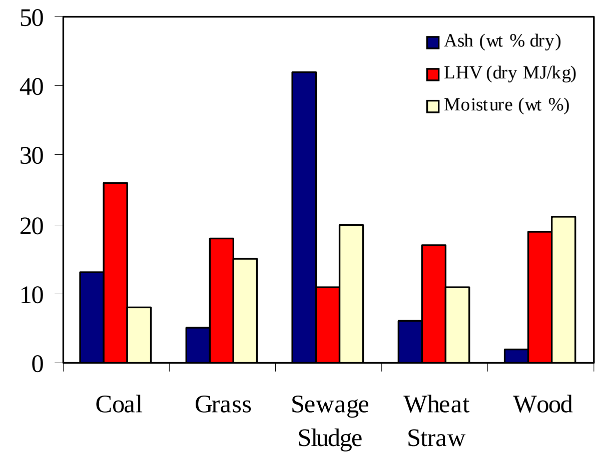


DTI: UK Energy in Brief 2005



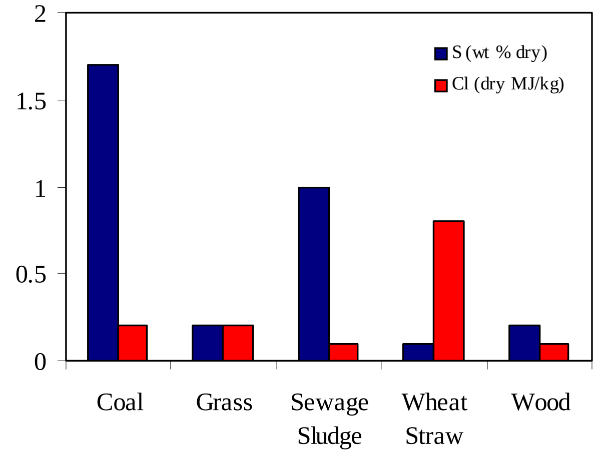
Source. DTI Digest of UK Energy statistics

Types of Possible Biomass Fuels

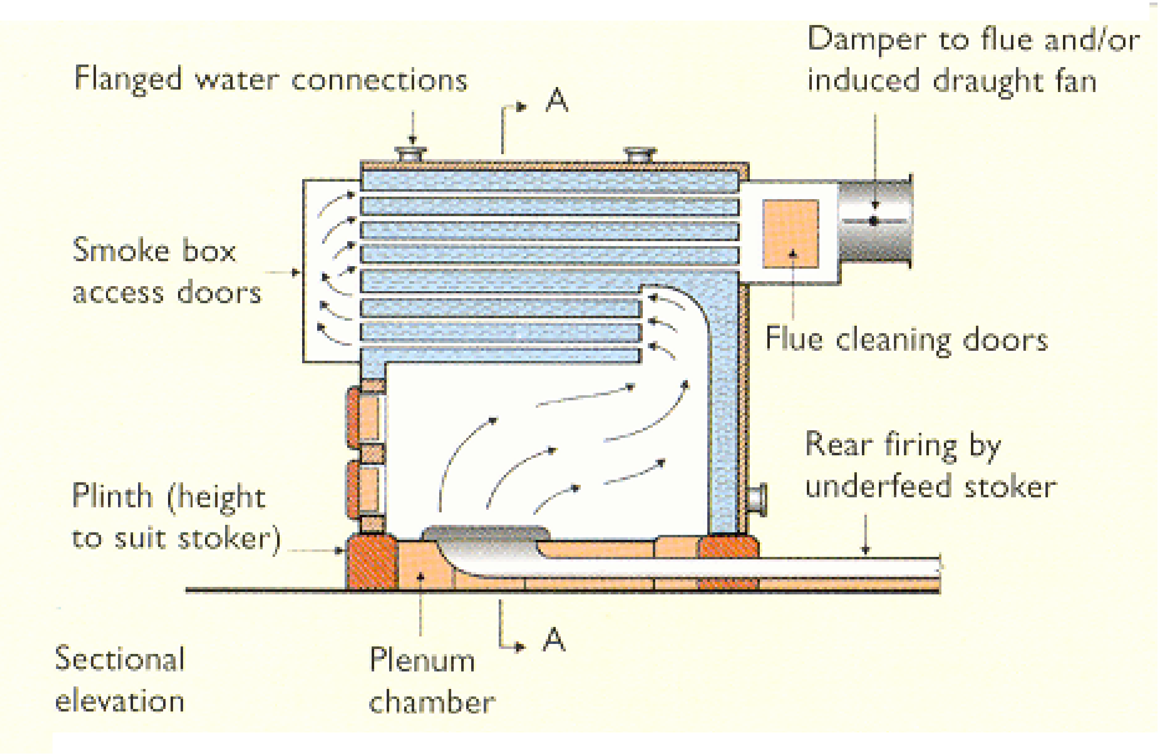


- Agricultural/domestic waste
  - wood chips, sawdust, bark, straw, rice husks, bagasse, coconut fibre, sewage sludge, etc.

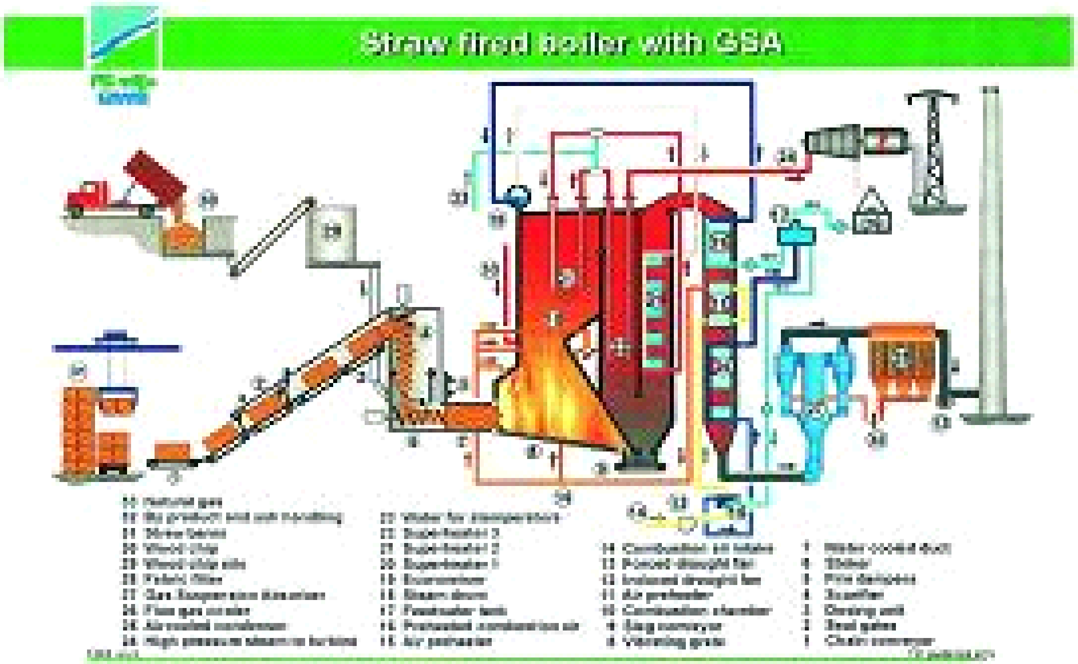
- Energy crops
  - willow, miscanthus, reed canary grass, eucalyptus, etc.



Small Combustion Plants

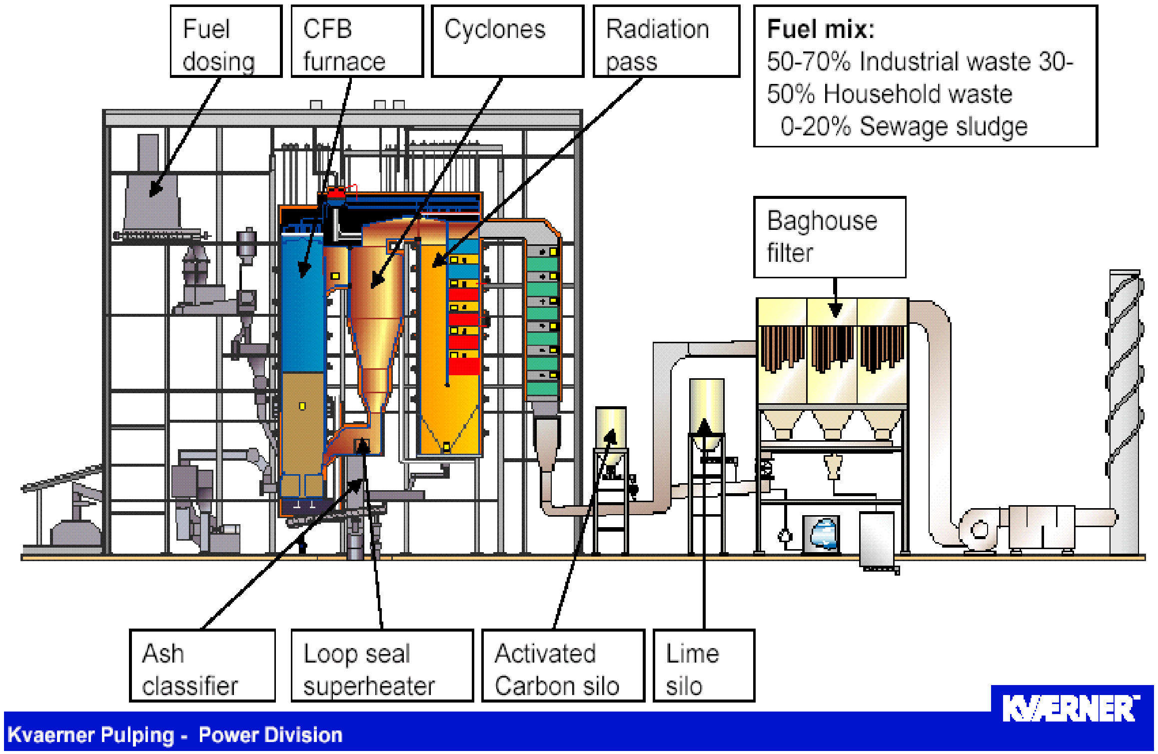


Elean Straw fired power station



75 MW CFB Boiler - Norrköping

Pulp & Paper



- Fuel
  - 6 < NCV < 25 MJ/kg
  - 5 < Moisture < 60 %
- Steam
  - 470 °C
  - 6.5 MPa
- Capacity and load range
  - 75 MW_{th} at MCR
  - 65 - 110 % of MCR

Fuel mix:
50 - 70% Industrial waste
30 - 50% Household waste
0 - 20% Sewage sludge

tps

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Energy Materials

Biomass Combustion
Materials and Related Issues

- Fouling and corrosion of superheaters
- Fuel variability – CV, moisture, etc.
- Contaminants - S, Cl, trace metals, etc.
- Fuel feeding/blending
- Fuel handling
- Flue gas cleaning

- Co-firing reduces risks

Superheater Corrosion in a FB boiler burning forest fuel and building waste

X20

T22

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Energy Materials

VTT TECHNICAL RESEARCH CENTRE OF FINLAND

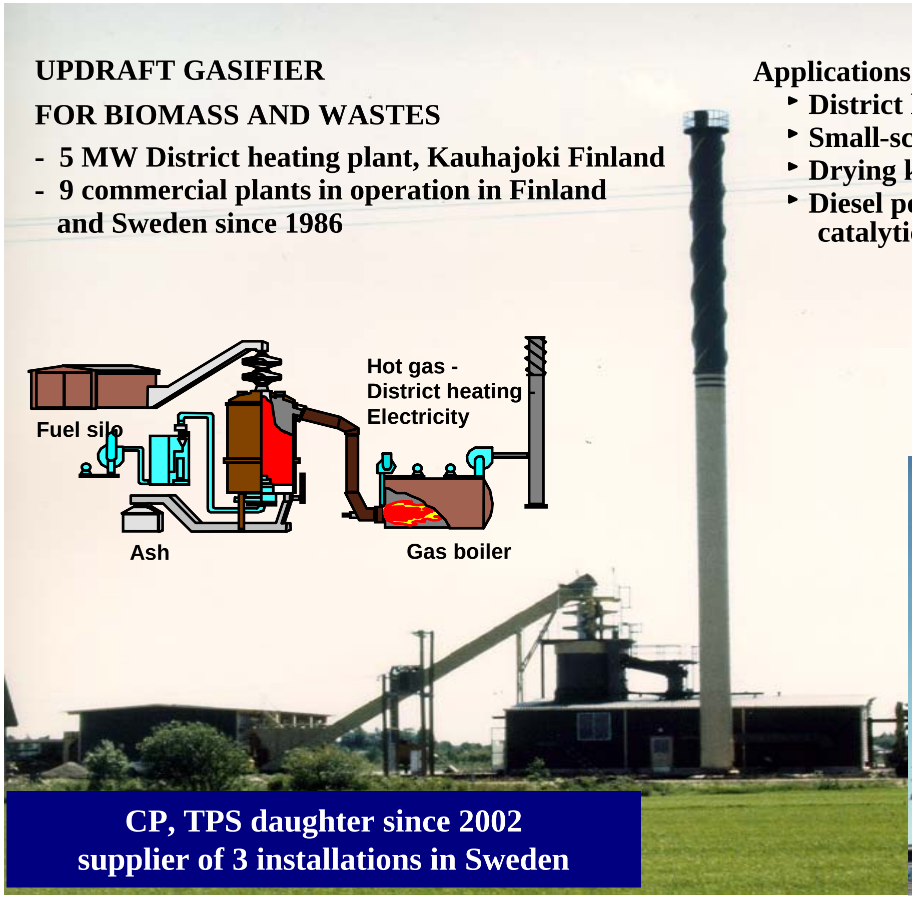
UPDRAFT GASIFIER

FOR BIOMASS AND WASTES

- **5 MW District heating plant, Kauhajoki Finland**
- **9 commercial plants in operation in Finland and Sweden since 1986**

Applications:

- **District heating 1 - 15 MW_{th}**
- **Small-scale CHP 1 - 3 MW_{e}**
- **Drying kilns and process ovens**
- **Diesel power plants after catalytic gas cleaning**

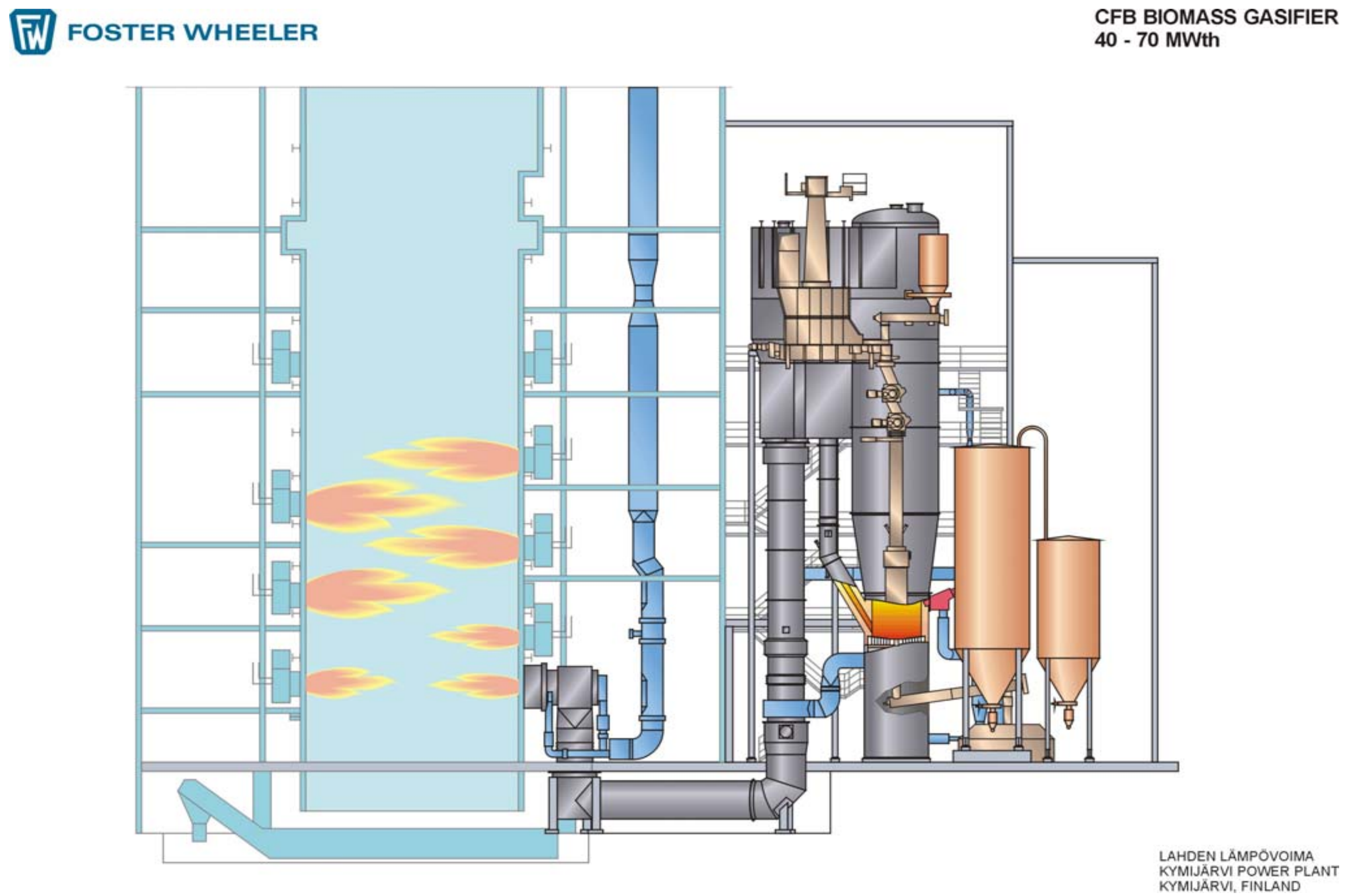


CP, TPS daughter since 2002
supplier of 3 installations in Sweden

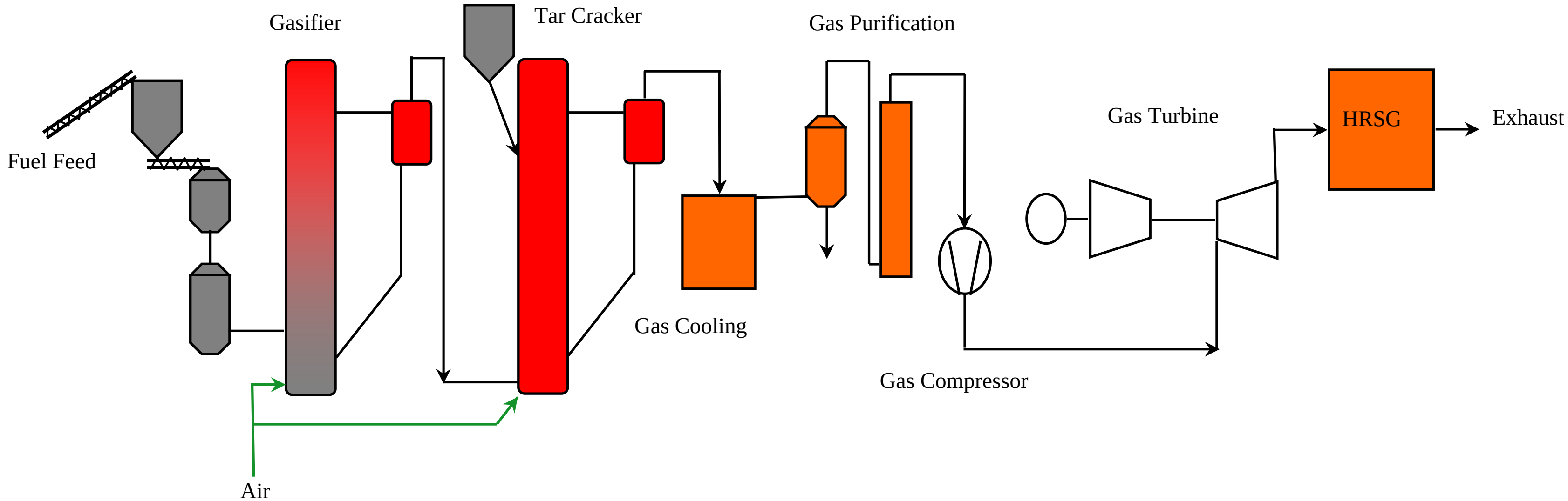
VTT PROCESSES

VTT

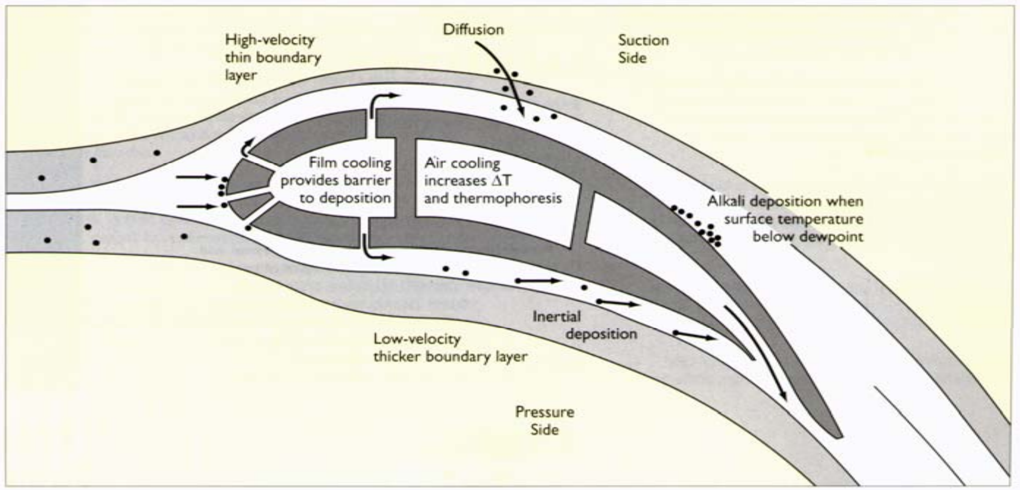
Foster Wheeler CFB Gasifier in Lahti, Finland



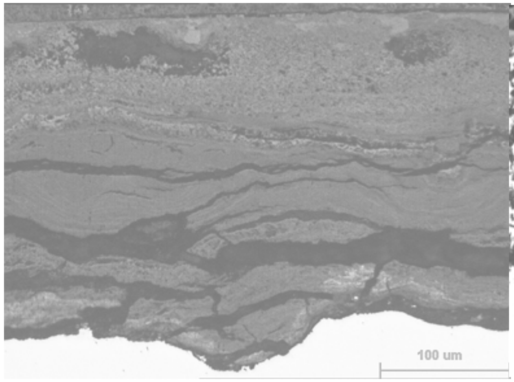
Biomass Gasification Combined Cycle



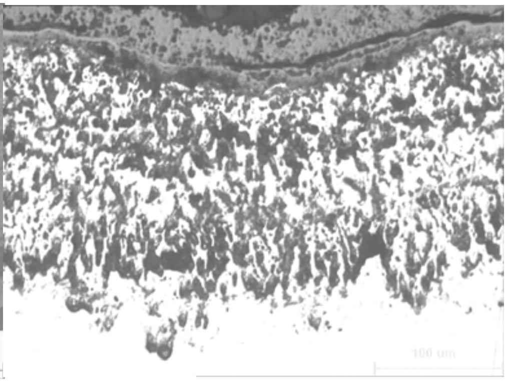
Biomass Gasification
Materials and Related Issues



CMSX-4 – 700ºC



CMSX-4 – 900ºC



- Fouling and corrosion of syngas cooler
- Fuel variability – CV, moisture, etc.
- Contaminants - S, Cl, trace metals, etc.
- Fuel feeding/blending
- Fuel handling
- Fuel gas cleaning – e.g. NH_3 reduction
- Combustion engine and gas turbine deposition and corrosion

Wind : Wave & Tidal : Solar : Hydrogen

Brian Cane
TWI Ltd
Co-Chair: Alternative Energy Task Group

Wind (onshore & offshore)

Wave & Tidal

Solar (thermal & photovoltaics (PV))

Hydrogen (production/delivery & storage)

Some of the drivers and life-cycle materials challenges ……….

Wind Energy Market

- Installed capacity exceeds 1 GW in July 2005
  - 446 MW was installed in 2005 (90 MW of which offshore)
- Current capacity 1.94 GW (1717 turbines, 135 projects)
- Target of 7.5 GW by 2010 (10% UK capacity)

Wind: main drivers – reduced capital, installation and O&M costs (offshore)

Design & manufacture/installation

- efficient fatigue design of composites (blades)
- greater use of composites (C-fibre) – lightweighting
- high productivity fabrication/installation of foundations
- improved reliability drive train
- anti-fouling & erosion protection coatings- nano structured
- smart structures

Life Management

- remote structural health monitoring & NDT
- risk-based maintenance planning
- damage tolerance and remaining life modelling

Re-cycling

- composites (C-fibre)

Wave & Tidal Energy Market

- 10 to 15 years behind wind
- Learning the lessons from Wind
- Accessible UK Wave resource estimated at 50 TWh/yr (DTI ETSU)
- UK Tidal resource of 42 potential sites contributing 36 TWh/y (DTI ETSU)
- Pilot demonstration projects on-going (e.g. MCT, OPD)

Wave & Tidal: main drivers – lower costs & greater performance

Courtesy Ocean Power Delivery

Courtesy Marine Current Turbines

Design & construction

- efficient fatigue design & fabrication
- use of composites – lightweighting/durability
- anti-fouling & erosion/corrosion protection coatings
- durable seals and bearings
- moorings & sea-bed foundations

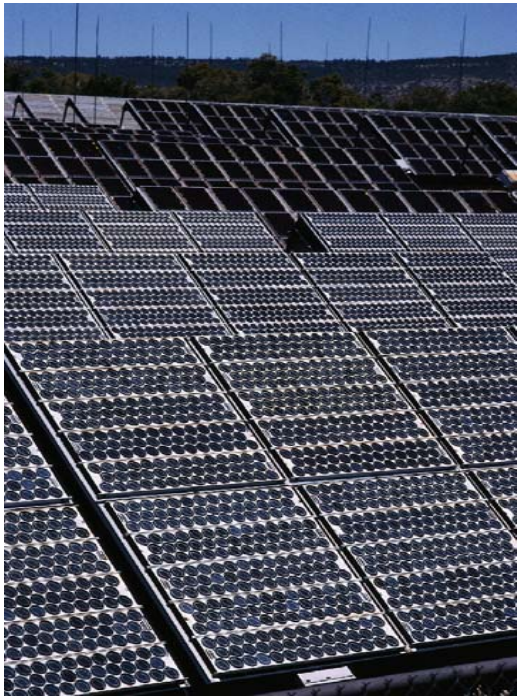
Life Management

- remote condition/corrosion monitoring & NDT
- risk-based inspection/maintenance planning
- damage tolerance and remaining life modelling

Re-cycling

- where composites are used

Solar: main drivers – lower costs, greater performance and durability



Design & manufacture (PV)

- lower cost Si PV processing
- process development for large area thin-film cell designs
- new PV cell types
- anti-reflective & anti-fouling coatings(solar-thermal & PV)

Life Management

- in-field performance & degradation modelling
- effects of meteorological conditions (eg: thermal cycling)

Re-cycling

- recovery of Si from spent PV cells

Hydrogen: main drivers – lower cost H2 production, delivery & storage

Design & Manufacture

- volume manufacture of distributed H2 production equipment
- lower cost materials/fabrication for electrolysers
- dissimilar material joining to integrate components/subsystems
- non-permeable coatings/HIC prevention - pipelines & bulk storage
- volume manufacturing of C-composite pressure storage systems
- performance of BOP materials in high pressure H2
- reduced cost/weight of solid state storage systems (hydrides)

Life Management

- rapid, non-invasive inspection of storage systems
- damage tolerance/fitness for service of storage vessels

Re-cycling

- C-fibre composites
- coatings on recyclable materials

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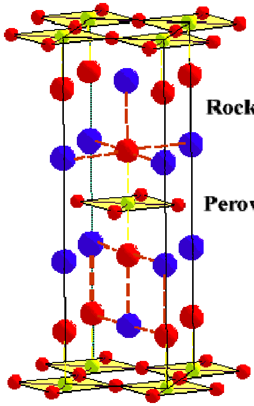
Fuel Cells and Related Devices
Materials Challenges



J. A. Kilner

Department of Materials, Imperial College, London
and
United Kingdom Energy Research Centre (UKERC)

Devices under development

Solid Oxide Fuel Cells

Proton Exchange Membrane Fuel Cells

Electrolysers

Syngas membranes

fuel cells UK

INDUSTRY ASSOCIATION

- Baxi
- BOC
- Calor Gas
- Ceramic Fuel Cells
- Ceres Power
- City University
- CMR Fuel Cells
- E.On
- Fuel Cell Application Facility
- Fuel Cell Control
- Intelligent Energy
- Johnson Matthey
- Philip Sharman
- Porvair
- Precision Micro
- Renew Tees Valley
- Rolls-Royce Fuel Cells Systems
- Rupert Gammon
- University of Birmingham
- Unitec Ceramics
- Voller Energy

Universities

Imperial College
Newcastle
St Andrews
Nottingham
Loughborough
Liverpool
Reading
Surrey
Cambridge
City University
Birmingham
Cranfield

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Energy Materials

SUPERGEN Fuel Cells

powering a greener future

The University of Nottingham

Imperial College London

CeresPower

Rolls Royce

dstl

JM

University of St Andrews

EaStCHEM

University of Newcastle upon Tyne

EPSRC
Engineering and Physical Sciences Research Council

Town Meeting – 24 November 2006

Main Industrial Organisations

Solid Oxide

Rolls Royce Fuel Cell Systems
Ceres Power

Fuel Cells Scotland Ltd

QinetiQ

St Andrews Fuel Cells Ltd

Alkaline

Alternative Fuel Systems Ltd.

Eneco ltd

PEM

CMR Fuel Cells Ltd

Dart Sensors Ltd.

Intelligent Energy

ITM Power PLC

JM Fuel Cells

QinetiQ

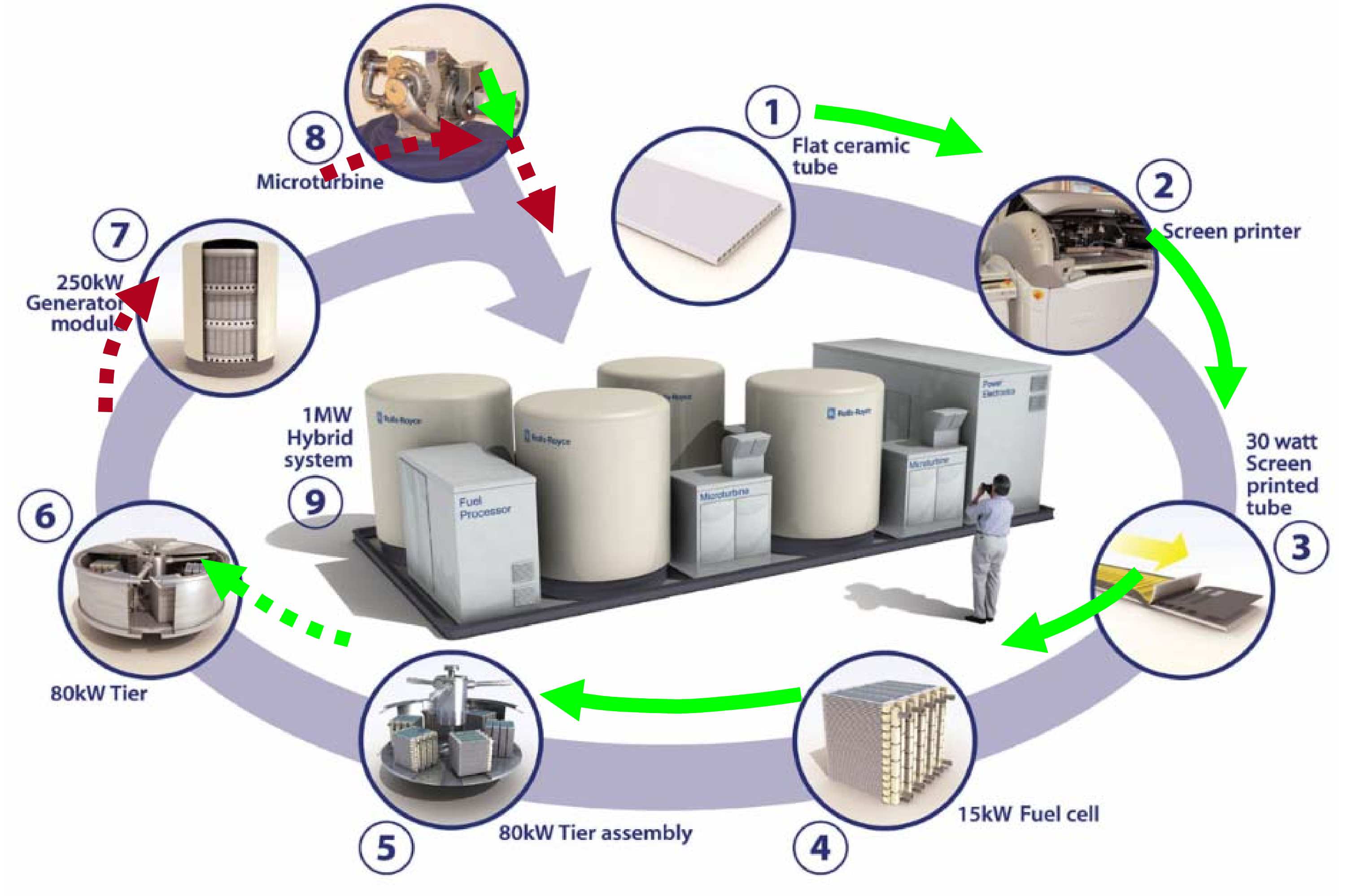
Voller Energy

Govt. Labs

Defence Science and technology Laboratory [DSTL]

National Physical Laboratory (NPL)

RRFCS Development Programme Objective – 1MW SOFC Unit



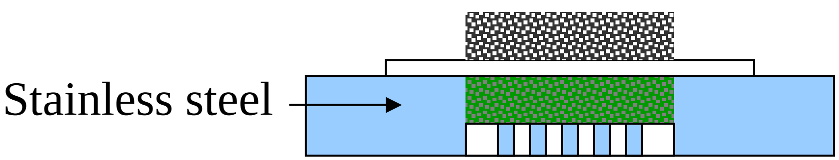
Ceres Power Metal-supported SOFC

$Ce_{0.9}Gd_{0.1}O_{2-x}$ electrolyte.

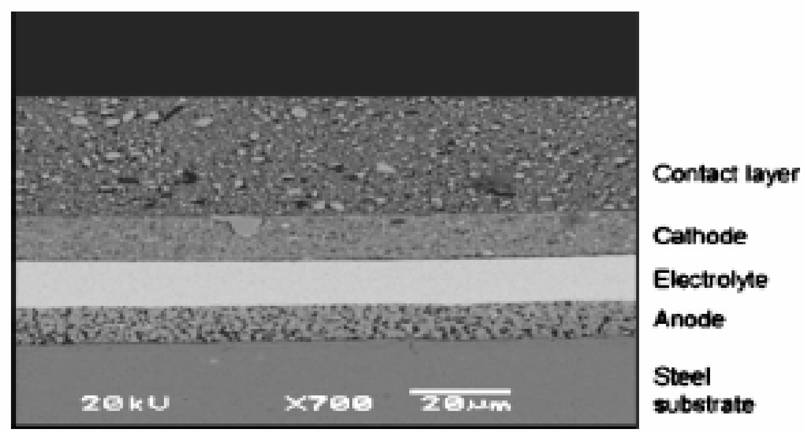
$La_{0.6}Sr_{0.4}Co_{0.2}Fe_{0.8}O_{3-\delta}$ + CGO cathode, 10-30 μm thick.

Cr ferritic stainless steel foil support, 100-300 μm thick.

Ni + CGO anode, 20-30 μm thick.

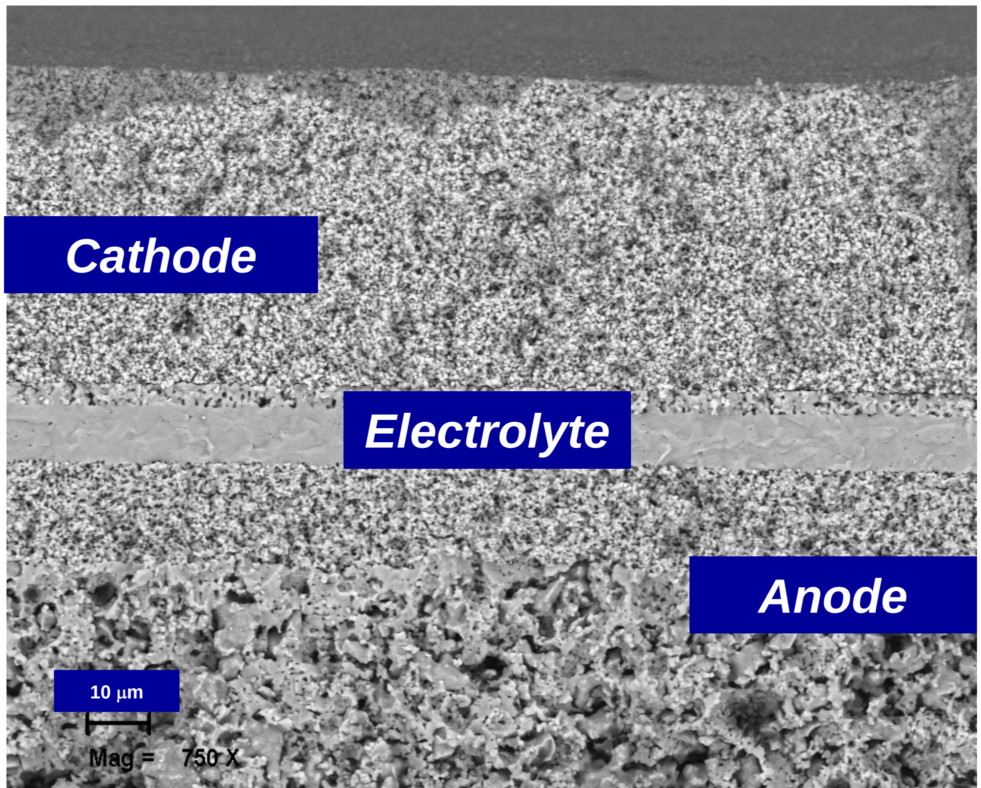


Stainless steel-supported



CeresPower limited

Typical Ceramic Structure



- *Anode* – nickel-zirconia cermet, ~ 1 mm thick
- *Electrolyte* – yttria-stabilized zirconia (YSZ), ~ 5 μm thick
- *Cathode* –lanthanum strontium manganese oxide, ~ 50 μm thick

Solid Oxide Fuel Cells

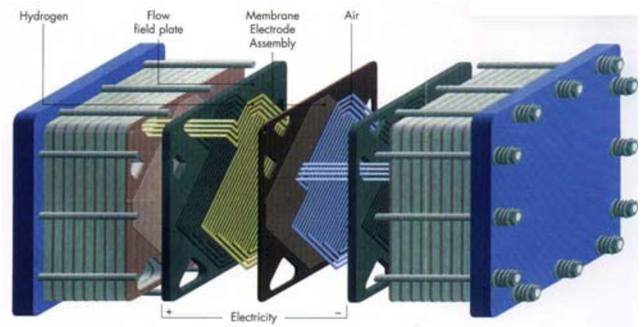
Issues:

- **Performance**
  - **Low temperature materials electrolytes and cathodes**
  - **Microstructural optimisation composite materials**

- **Cost**
  - **Ease of manufacture (sintering and co-sintering)**
  - **Less "exotic" materials**
- **Durability**
  - **Redox stable anodes**
  - **Stable BoP materials for high temperature environments (steam)**

PEMFC

Issues:



Ballard PEM Fuel Cell Stack

- Performance
  - Better catalysts (less pt loading)
  - High temperature membranes
  - Better electrodes structures
- Costs
  - Less Pt and cheaper membranes (nafion expensive)
  - Better cathodes
- Durability
  - Stability against peroxide

Thank You

Any Questions?