Alternative Energy Technologies

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Scope

- Wave and tidal
- Wind
- Biomass
- Hydrogen
- Fuel Cells
- Solar (PV)

Wave and Tidal Energy

Capable of delivering significant amounts of power

Many variants under development

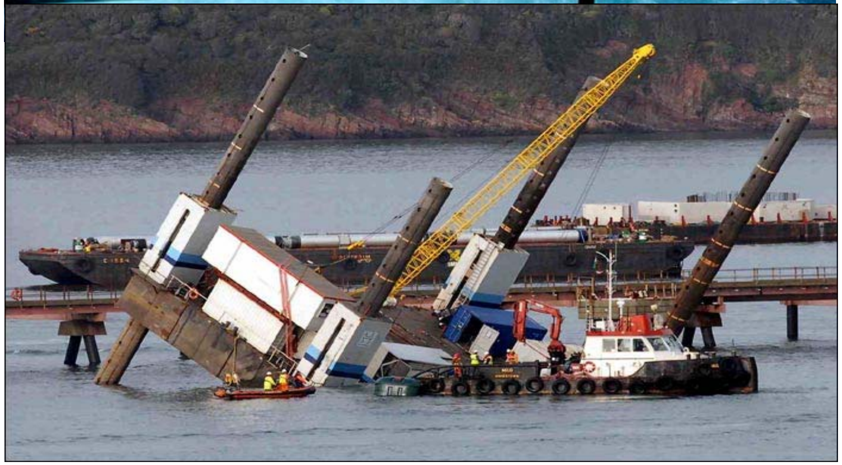
Devices in development or at sea:

- Nodding duck
- Pelamis – 750 kW
- Seaflow – 300 kW
- Seagen – 1500 kW
- Swan Turbines
- Limpet – 500 kW
- Sea Snail – 100 kW
- TidEl
- Archimedes Wave Swing
- Open Hydro – 250 kW

Energy Materials

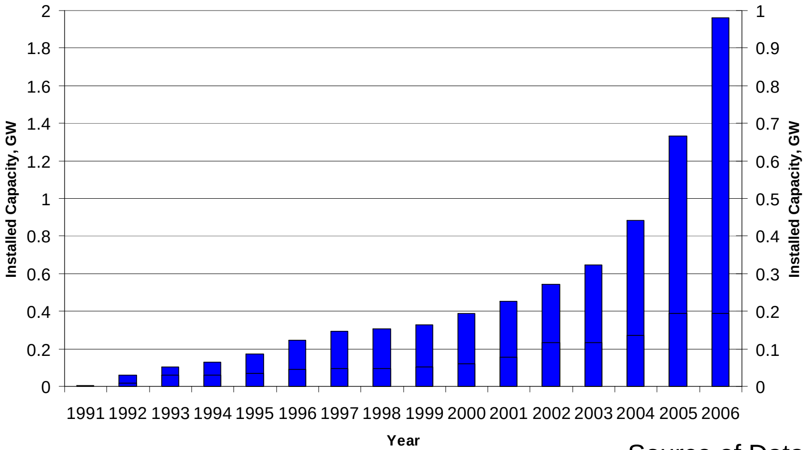
Wave and Tidal-Materials Challenges

- Coatings – abrasion resistance, anti-fouling, corrosion resistance
- Advanced magnetic materials (low wear)
- Lubricants
- Concrete structures
- Seals
- Materials selection criteria
- Composites and ceramics
- Reliability/risk analysis



Wind Turbines

- Average size of wind turbines increasing
- Turbine capacity to blade diameter ratio increasing
- Wider operating window – variable pitch/constant speed designs
- More advanced materials (wood – glass fibre reinforced plastic GRP – carbon fibres)
- Improved manufacturing and smarter use of materials
- Two piece blades



Source of Data: British Wind Energy

-Wind turbine capacity has increased seven-fold over last ten years.

-Wind as a percentage of total generating capacity: 0.42% 1997, 1.18% 2004

-Wind farms: (2007) 149 operational (2.1GW), 38 under construction (1.4GW),

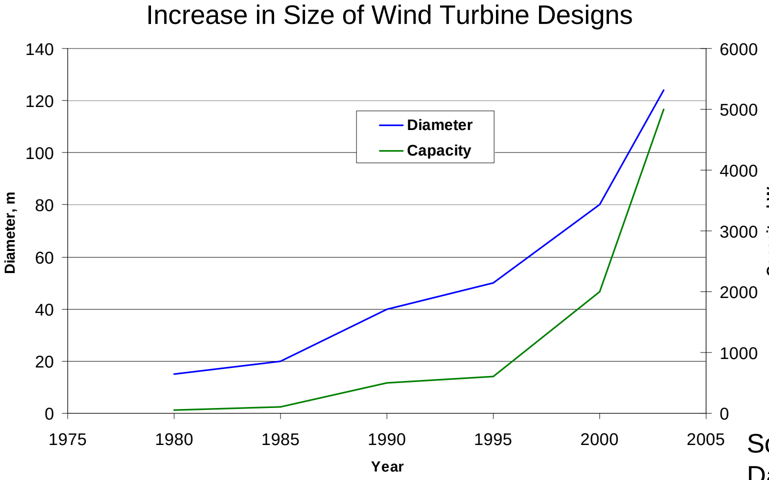
- 102 consented (3.8GW), 232 in planning (10.9GW), Total 18.2GW

Materials UK
Owned by the materials community

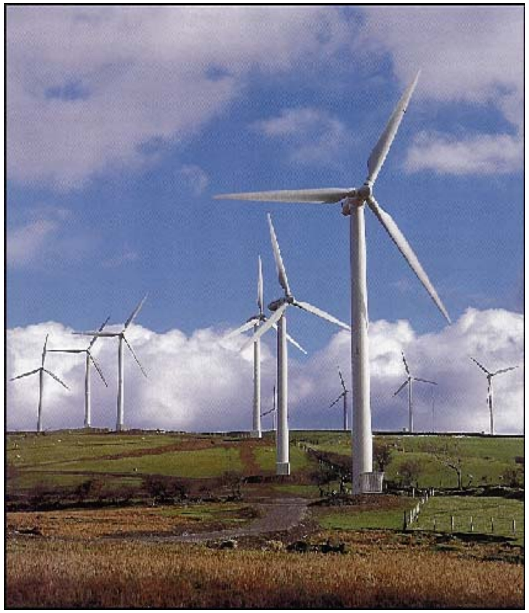
Energy Materials

Wind Turbines-Materials Challenges

- **Development of materials / designs / processing techniques e.g. sandwich constructions, joints, FRP pre-forming, etc.**
- **Development of test and modelling methods for materials characterisation for harsh environments**
- **Development and application of NDI techniques for accurate / rapid defect detection**
- **Development of standards and certification procedures**
- **Development of test and modelling methods for lifecycle analysis/fatigue performance of constituent materials, sub-components and major structures i.e. blades**
- **Structural health monitoring techniques**



Source of Data: European Wind Energy Association



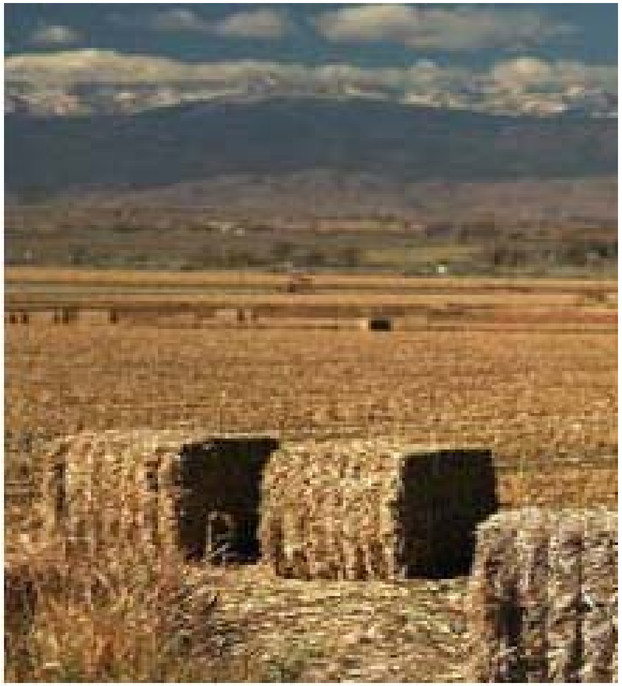
Biomass

Biomass is used

-in co-firing as a low-C substitute for fossil fuels, and

-in dedicated systems using waste biomass and energy crops

- Uses adapted 'conventional' heat and power technologies
- Significant quantities are available for small-to-medium plants from 'waste' sources
- Contains contaminants which can cause fouling and corrosion of system components
- Potential for significant growth



- Agricultural/domestic waste
  – wood chips, sawdust, bark, straw, rice husks, bagasse, coconut fibre, sewage sludge, etc.
- Energy crops
  – willow, miscanthus, eucalyptus, etc.

Biomass-Materials Challenges

- Improved alloys and coatings for heat exchange and gas turbine/gas engines
- Life prediction modelling for heat exchangers to optimise maintenance and repair
- Monitoring of corrosion and contaminants in order to provide early warning of problems
- Improved repair/refurbishment procedures

Fouling of a superheater in a biomass boiler

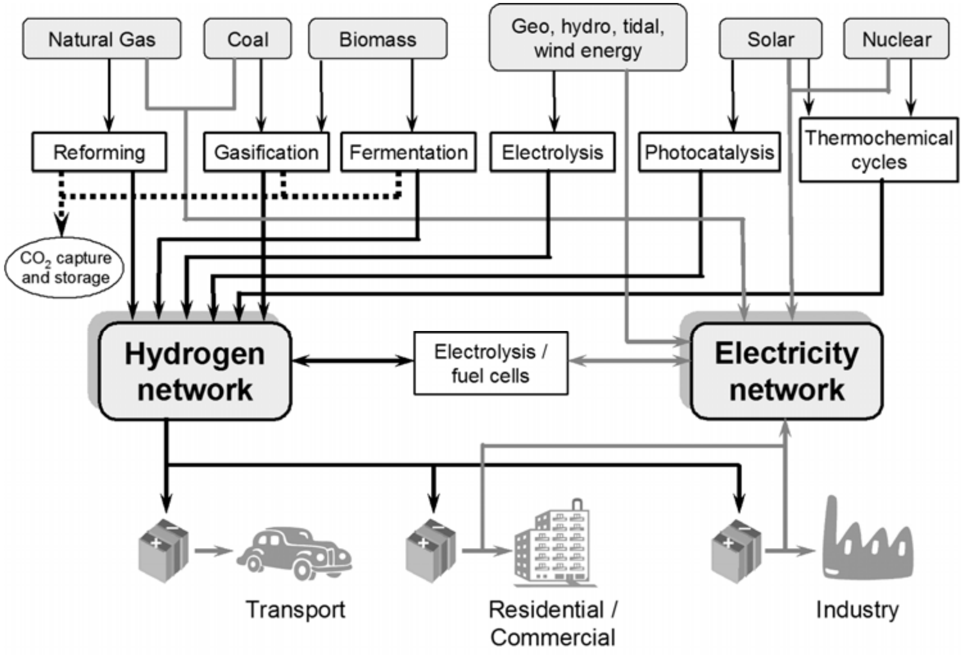
X20

T22

Corrosion of superheater materials in a Swedish biomass plant

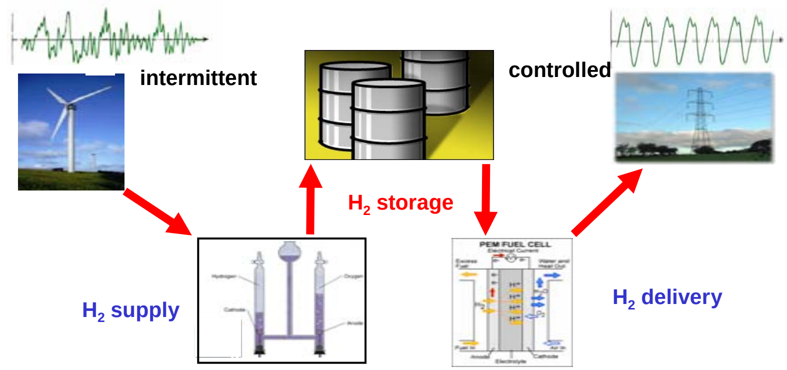
Hydrogen

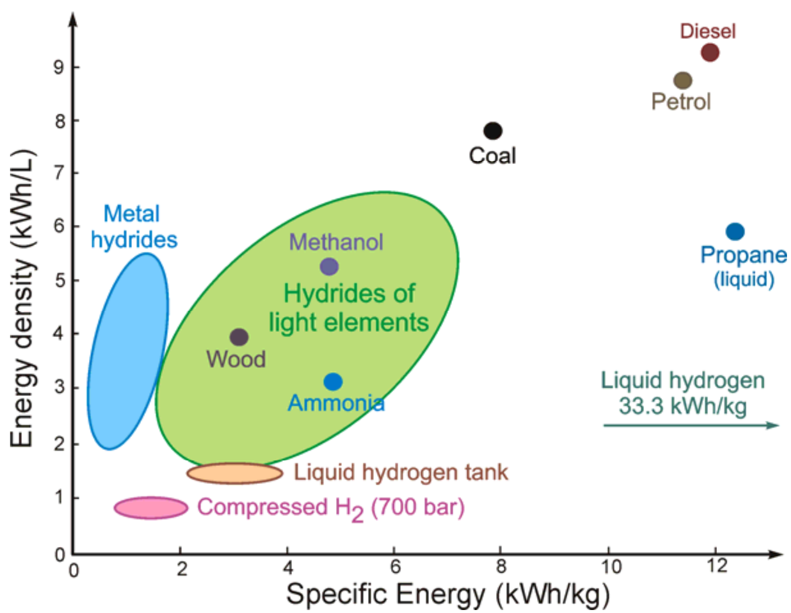
- An important, versatile energy carrier for the future for power and transport applications
- Can be derived from multiple sources
  - Fossil fuels
  - Nuclear
  - Renewables
- Safety in use and storage are key issues



Hydrogen-Materials Challenges

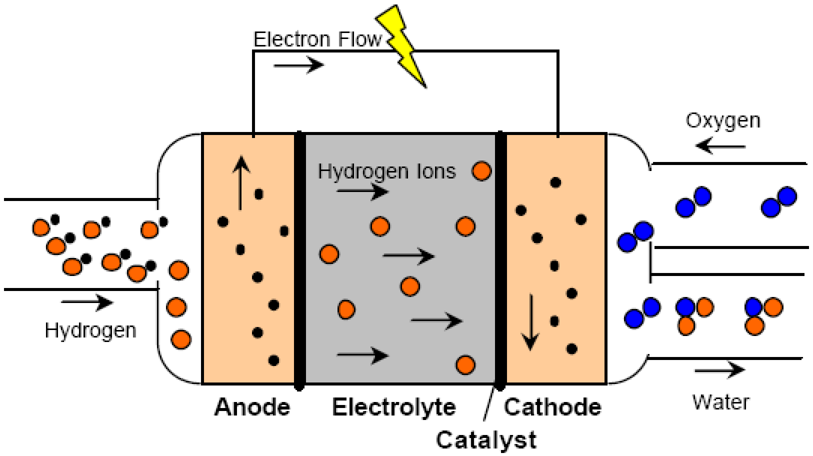
- New materials – particularly for H_2 storage and H_2 sensors
- Catalysts for reduced cost H_2 production
- Membranes and separation media to reduce the cost of meeting the hydrogen purity requirements of fuel cells, and other applications.
- Advanced Instrumentation and Characterisation Techniques.
- Modelling of the interaction of H_2 with materials, embrittlement, and electron transfer processes in solids to enhance photocatalysts and photoelectrochemical processes





Fuel Cells

- A key energy conversion technology which can operate with fossil fuels and H_2
- Being developed for energy and transport applications
- High efficiency
- Can be integrated into advanced cycles with gas turbines, etc.



PEM Fuel Cell powered bus

PEM Stack

Fuel Cells- Materials Challenges

- Scale-up - efficient processes providing low cost products
- Understanding of failure mechanisms and durability issues
- Fabrication techniques and manufacturing consistency
- Inspection techniques to ensure the supply of high quality components
- New and improved existing materials - increased conductivity for cell and stack components
- Environmentally stable materials

The six principal fuel cell types.

Fuel Cell Type	Operation Temp. (°C)	Features	Principal Application
Polymer Electrolyte Membrane (*PEMFC*)	60 - 80	High power density, Pt catalyst, must be kept wet, poisoned by CO	Mobile power
Alkaline (*AFC*)	50 - 200	High power density, cannot tolerate CO_2	Space flight
Phosphoric acid (*PAFC*)	~ 220	Medium power density, Pt catalyst sensitive to CO	Stationary power
Direct Methanol (*DMFC*)	60 – 120	Medium power density, , high Pt content	Electronics - Laptops mobile phones
Molten Carbonate (*MCFC*)	~ 650	Low power density, Ni Catalyst, needs CO_2 recycle	Stationary power
Solid Oxide (*SOFC*)	500 - 1000	Medium power density, accepts CO as a fuel	Stationary power

Energy Materials

Solar - Photovoltaic

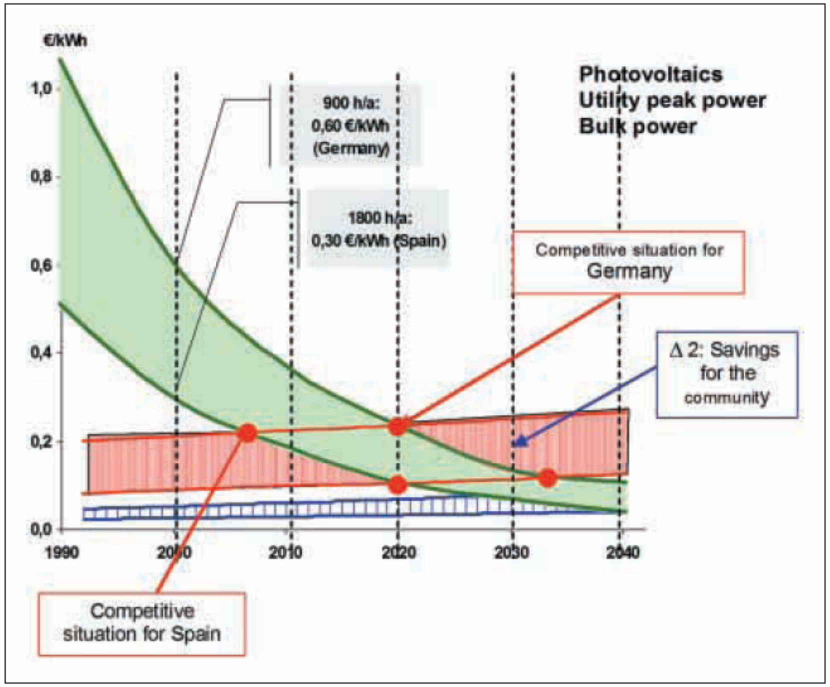
- Versatile energy technology, suitable for many built environment and other applications
- Costs are 'up-front', with low on-going operational and maintenance costs
- Suitable for mass production
- Critically dependent on materials technology
- Various technology options
  - crystalline silicon technology
  - types of thin-film technology including amorphous silicon, compound semiconductors (GaInP/GaAs) & polycrystalline compound semiconductor (CIGS, CdTe)
  - dye-sensitised (Gratzel) cells
  - nanocrystalline and polymer technologies

Eden Centre, Cornwall

Sharp module factory, Wrexham Manufacturing 220 MW per year for the European market.

Solar-Photovoltaic- Materials Challenges

- **Low cost materials**
  - quartz to Si and advanced crystal & Si ribbon growth
  - plastic optics for concentrators
  - thermal conductors
- **Improved design**
  - rear contact cells for mass production & high efficiency cell structures - crystalline Si
  - cell concepts for flexible substrates for thin film PV
  - improved concentrators for wide angles
- **Improved, sustainable materials**
  - module materials for crystalline Si (e.g. polymers) for improved stability and life
  - alternative transparent conducting oxides
  - improved deposition technologies - thin film PV
  - low band-gap semiconducting polymers & sensitiser dyes for excitonic PV
  - anti-reflective coatings for thermal
- **Durability and life modelling of materials**
- **Improved fabrication**
  - large area modules and high volumes
  - testing and QC procedures



Projected Reduction in PV Energy costs in Europe. Reproduced from the European Photovoltaic Industry Association (EPIA) Roadmap.

UK Skills and Capabilities

- Vary depending on the particular technology, e.g.
  - for fuel cells - UK has leading-edge manufacturers (e.g. Johnson Matthey Fuel Cells & Rolls-Royce Fuel Cells)
  - for wind energy - UK strength lies in the deployment of technologies from overseas, e.g. offshore wind farms
- The UK has well established capabilities in:
  - manufacturing
  - servicing
  - system integration
  - technical consultancy
- Also, UK strength lies in the strong links between universities, Research & Technology Organisations (RTOs) and industry

R & D Priorities

- **Structural Materials**
- **Functional Materials**
- **Materials processing, fabrication and integration**
- **Environmental Resistance and Protective Systems**
- **Life Cycle Modelling**

Generic Material Requirements

- Condition monitoring and ‘smart sensors’
- Development of ‘field deployable’ non-destructive evaluation (NDE) techniques
- Development of standards and certification procedures
- Testing and characterisation procedures
- Repair, rejuvenation and recycling of expensive materials
- Investigation into fundamental failure mechanisms in advanced materials

Conclusions

- Alternative energy technologies have a key role to play in overcoming climate change – and all have a role

- Materials technology in all its forms is critical if these technologies are to become commercially available at the time they are most needed

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