Power Generation in the Future – New Challenges for Non-Destructive Testing and Technical Diagnostics

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Abstract. Around the world significant questions are being asked about the future of power generation. These questions arise because of concerns about global warming and climate change due to emissions from use of fossil fuels, concerns about the balance between the availability of energy resources and rapidly growing demand for energy (particularly in the developing economies) for power, heat and transport, and concerns about the rising price of fuels, particularly oil and gas.

This paper will describe the technologies which are emerging as a result of these trends and highlight the opportunities and challenges which will arise for Non-Destructive Testing and Diagnostic Technologies.

1. Growth of Energy Demand

The rapidly growing demand for energy is shown in Figure 1, from the IEA World Energy Outlook. Use of fossil fuels (coal, oil and gas) is forecast to almost double by 2030 with most of the growth coming from developing countries. Nuclear power, hydro and other renewables will also grow. In 2004 the WEO forecast predicted the split of new power plants over the different fuels as shown in Figure 2.

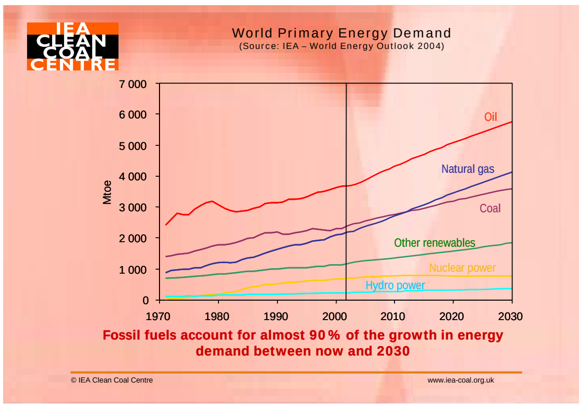

Figure 1 : World Primary Energy Demand

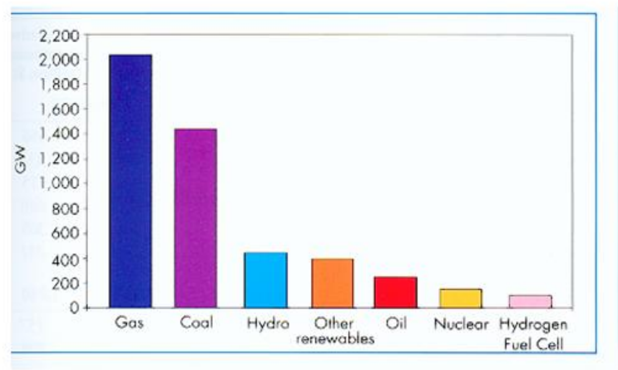

Figure 2 : Forecast Power Plant

2. Climate change and the need to reduce CO_2 emissions

As a result of the growth of fossil fuel use, Carbon dioxide emissions are predicted to grow from 20 to 40 Gt per year, just at the time when climate change scientists are calling for a 60% reduction compared to 1990 by 2050 in order to stabilise carbon dioxide levels at a level which will still cause an average 2°C global warming. Figure 3 shows IEA and European Commission predictions and indicates that around ½ of the CO_2 is from power generation, ¼ from transport and ¼ domestic and industrial.

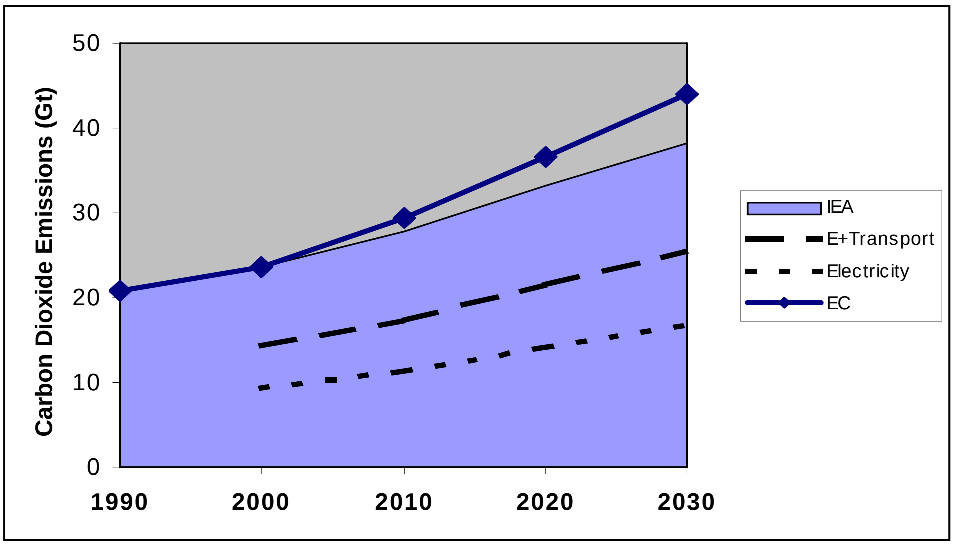

Figure 3 : IEA WEO estimates of world CO_2 emissions

3. Responses to energy challenges

The responses to these concerns have varied from country to country, with some countries (e.g. EU, Australia, Canada) more concerned about climate change and some (e.g. USA, China) more concerned about security of supplies. Climate Change was a priority topic at the G8 Summit in the UK in July 2005 and Energy a priority topic in Russia in July 2006. The countries which signed up to the Kyoto Protocol agreed to cut Greenhouse Gas Emissions (including CO_2) by 12.5% below 1990 levels by 2012. In Europe, the Kyoto Protocol has been implemented by a burden-sharing agreement and CO_2 allowances are being traded through the Emissions Trading System. A number of common threads emerge:

i) Increased use of gas as a cleaner source of energy and power in the short term.
ii) Rapid development of renewable energy sources.
iii) Renewed interest in nuclear power due to the long-term resource availability and the CO_2-free nature of power generation.
iv) Increased investment in the development of clean coal technologies designed to use the huge global resources of coal more cleanly.

All of these trends bring opportunities and challenges for NDT and Technical Diagnostics.

4. Increased use of gas for power generation

More pipelines are needed, many through hostile terrain and some through territory where terrorism is common. In normal circumstances, safety of pipelines must be ensured by careful inspection during installation (radiography or automated ultrasonic) and in-service (on-line inspection) to detect corrosion, fatigue cracking or gross damage. Due to the environmental consequences of methane leakage, increased attention must be given to leak detection (primarily at seals, compressors, bolted joints).

There is a huge growth in the transport of LNG (liquefied natural gas) by ship. This requires LNG terminals and large fleets of LNG ships. Both use nickel alloys and stainless steels and require careful NDT and leak detection.

5. Rapid development of renewable energy sources

In addition to hydroelectric projects (the largest by far being the 18 GW Three Gorges Dam project in China), there is rapid development of Wind Turbines generation capacity, mostly for onshore sites. In Europe, wind power has developed most rapidly in Denmark, Germany and Spain. Wind turbines have grown in size – now up to 5 MW^e – and in northern Europe there are now projects to instal wind turbines offshore in the shallow waters of the North Sea. The challenges for wind generation are the intermittency of the resource, the cost per unit of electricity and the achievement of satisfactory availability.

NDT challenges are testing methods for turbine blades, turbine towers and condition monitoring of gearboxes, rotor hubs and electrical equipment.

Wave and tidal power are at an earlier stage of development. Achievement of satisfactory availability will undoubtedly be a major challenge since repairs in the hostile marine environment will be exceptionally difficult.

Onshore Wind Turbine

Tidal Power Unit
Ocean Power Delivery "Pelamis"

Photovoltaics have a huge potential to generate power in hotter countries. NDT on PV materials is carried out on a micro-scale.

6. Renewed interest in Nuclear power generation

There is renewed interest in many countries due to the long-term availability of the resource, the CO_2-free nature of the power generation and the relatively low cost of power from this source. In China, thirty additional reactors are to be built by 2020. In the USA, a licencing process is underway for a new generation of reactors (APWR, ABWR, etc.) and in Finland the first EPWR – a new design based on French and German experience – is being built. The challenges to nuclear are public concerns over storage of nuclear waste, the protection of plant against terrorism and the operational safety.

NDT plays an important role in ensuring the safety of nuclear power plant, both through inspection during construction and in-service. It is essential that the lessons learned over about thirty years in inspection of the existing nuclear plant are transferred to the new. These include:

i) importance of design for inspectability;

ii) importance of inspection qualification (performance demonstration).

Generation IV reactors now being developed include new sodium-cooled fast reactor designs. This type of reactor which is already being built in India (500 MW^e) poses many challenges for NDT and condition monitoring including under-sodium viewing, ISI of austenitic and transition welds and tubing inspection.

7. Clean coal technology

There is increased investment in development and building of new coal-fired power plants, designed to use the huge global resources of coal more cleanly. There are two key steps towards cleaner coal:

i) Increased efficiency gives more electricity (MWh) and less CO_2 per tonne of coal burned. Figure 4 shows the evolution of coal-fired power plant efficiency. The “Best Available Technology” advanced supercritical power plant in 2006 – being built in Europe – is 46/47% efficient and emits about one-third less CO_2 than old inefficient plants. CO_2 emissions are reduced from >1000 g/kWh to 700 g/kWh.

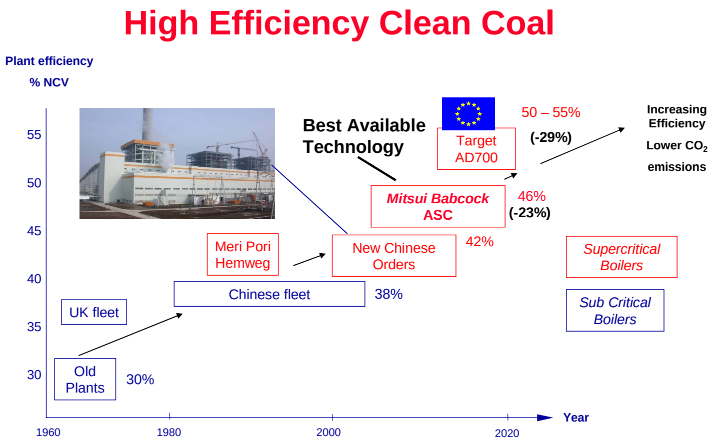

Figure 4 : Progressive improvement in efficiency and reduction of CO_2 emissions for coal-fired power plant

The target in Europe and the USA is plant with efficiency in the range 50-55%. The technology is being developed in Europe through a collaborative project known as AD-700. The steam pressure (350 bar) and temperature (700°C) of such a plant necessitate a step-change in materials from the ferritic, martensitic and austenitic steels used in BAT plants to nickel alloys (including In617 and Alloy 263).

Many of these materials are now being tested in a live-steam test loop at the E.ON Scholven Power Plant in Germany.

The 700°C plants will require careful inspection of these new materials during manufacture and monitoring in-service to determine how well the basic materials, weldments (including dissimilar metal welds) perform in service. Life assessment techniques will need to be developed.

ii) Carbon dioxide capture and storage (CCS).

To meet global CO_2 reduction targets the technology of CCS is essential. Carbon dioxide must be captured from the flue gas (separated from nitrogen), cooled and compressed and piped away for injection under the ground into storage reservoirs which may be oil-fields, depleted gas-fields or saline acquifers, see Figure 5.

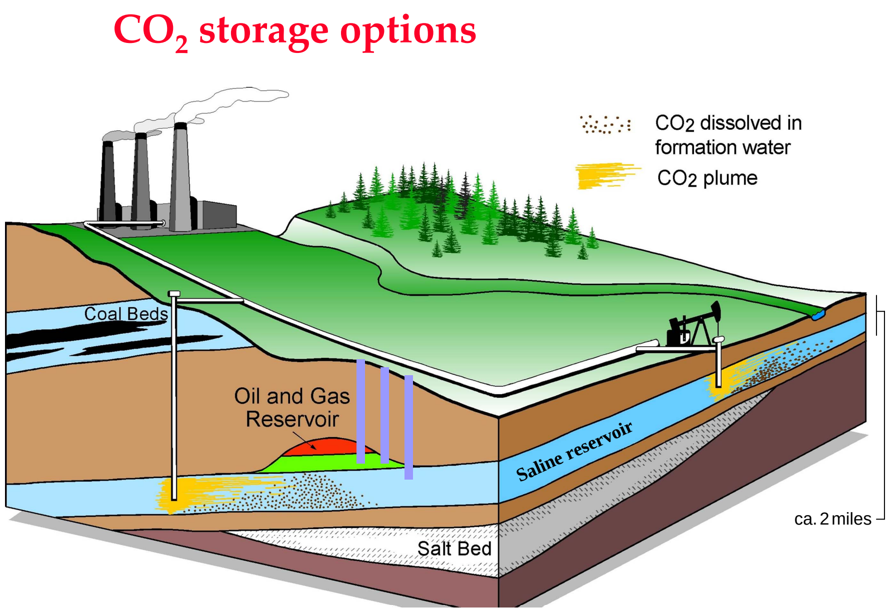

Figure 5 : Options for Carbon Dioxide

There are three technologies for carbon dioxide capture. These are post-combustion capture by scrubbing (probably with an amine), oxyfuel firing (where the combustion air is separated into nitrogen and oxygen) and pre-combustion capture (where the coal is first gasified, the syn-gas produced is converted to CO_2 and hydrogen and the hydrogen is separated and burned in a special gas turbine).

Each of these technologies will bring their own challenges for NDT. Storage also brings interesting challenges for NDT, including integrity of pipelines which carry CO_2 and the sealing of injection wells in CO_2 reservoirs.

8. Conclusions

- The changing Power Generation field will continue to stimulate new and important research, development and applications in NDT and Technical Dignostics;
- Global co-operation (scientific, technical and business) is essential to meet the Energy Supply, Safety, Environmental and Anti-Terrorist challenges of the 21st Century.