Keynote Address: EPRI's global coal initiative

by S. Dalton*

Synopsis

The use of coal for power generation is being questioned in many developed countries, as a result of ever-tightening environmental restrictions and concerns about the potential impact of CO_2 emissions on climate. Coal will continue to be the fuel of choice for new power plants for many developing countries with large percentages of the world's population, because of its relatively low cost and broad availability. Even in many of the developed countries that are under pressure, coal will continue to fuel large percentages of power due to the installed base. Using coal efficiently and in an environmentally responsible manner will be a challenge for technology and politics in this new century, with the politics played out on the world stage. Coal use will vary in the next few decades, including short-term changes such as the use of more diverse coals and the increased use of efficient ultra-supercritical boilers to longer term 'refining' of coal to produce a range of energy and chemical outputs. This paper outlines EPRI's Global Coal Initiative aimed at needed developments and demonstrations that support the long-term vision of environmentally sound and economical coal use for power generation, and discusses some of the forces that are driving this development effort.

Introduction

The inter-relationships between key drivers economic, policy and technology will define which coal technologies are utilized in this new century[1].

The Electricity Supply Roadmap—driving our strategy

EPRI has worked with approximately 150 companies to develop a long-term view of where the power industry must go to in the future. The process starts with a vision of the future and works back to chart out a path, rather than starting with the current portfolio of work. Clearly, additional generation will be required to meet the needs of an increasing world population. The Electricity Supply Roadmap, part of EPRI's Electricity Technology Roadmap, is guided by an ultimate goal for the power generation industry worldwide.

A robust portfolio of technologies that provide reliable, affordable electricity, with capacity and resource flexibility to meet global market needs—on a sustainable basis—with acceptable environmental impacts.

Implementation will vary, naturally, from developed to developing countries, and from region to region based on indigenous resources and on economic, environmental, and political factors. Hence the need for a portfolio of solutions. An 'options' approach to managing this portfolio will help manage the risks of uncertainty inherent with the economic, policy and technology drivers. Although not specifically addressed in this paper, developments in gas turbine, fuel cell and renewable energy technologies will impact the relative market position of coal technologies. In the short term, the competition for coal for new power generation in developed countries, including the U.S., is natural gas. Nuclear, renewables and hydroelectric power generation will all be needed in addition to coal to meet growing world demand for power.

With world population expected to double over the next 50 years, and with electrification clearly accepted as one of the key technologies required to provide even minimum acceptable standard of living (for light, clean water, pollution control), the needs for additional generation will grow. Even with expected efficiency improvements, analysts suggest that global electricity production will need to climb by more than a factor of four by 2050 from 13×10^{12} kWh today to about 60×10^{12} kWh. The implications for new generating capacity are staggering. About 10,000 GW will be needed, which represents the construction of a new 1000-MW unit on the average of every two days for 50 years.

---

* *Fossil Steam Plant Product Line EPRI Palo Alto, CA, USA.*

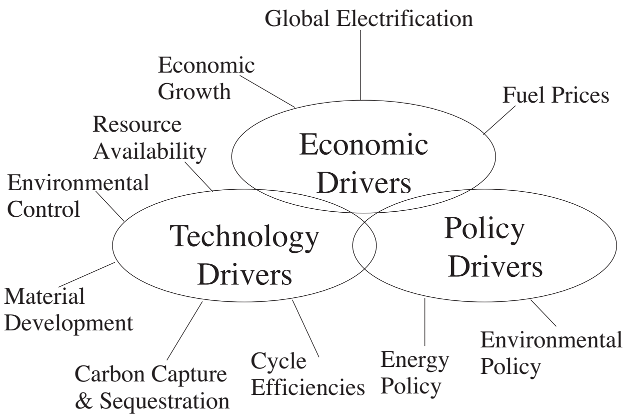


Figure 1—Key drivers for the use of coal in the new century

From a practical perspective, it will be very difficult to meet this demand for power. Doing so affordably and with minimal environmental impacts will require an unparalleled degree of success in a broad research and development programme. This success will depend on the cooperative effort of public and private sectors from around the world—hence the need for the Electricity Supply Roadmap.

The Electricity Supply Roadmap presents 'desired destinations' over three nominal timeframes:

50 years (2050), to encompass truly new and innovative technologies, not simply extrapolation of today's development efforts. Fifty years allows for capital stock turnover and widespread adoption of new technology, both traditionally long processes in the electric power industry. For coal, this allows for zero emission of CO_2 via capture and sequestration, and the establishment of a hydrogen and electricity-based energy system, as well as widespread 'refining' of coal.

20 years (2020), to assess both mid-term opportunities and the technical foundation we can expect to be available to draw on for continuing R&D to reach the destinations of 2050. In the mid-term we can envision advanced systems that are efficient and low CO_2 emitters, such as advanced Pressurized Fluidized Bed Combustion (PFBC), and gasification.

10 years (2010), to ensure achievement of important interim steps for coal and nuclear power technologies. These R&D destinations maintain the economic viability of installed plants and the infrastructure needed for near-term power system diversity and stability, as well as enable ready adoption of advanced coal designs. In the relativley short term we can see advances in conventional fluid bed and pulverized coal fired such as the ultra-supercritical plant.

The EPRI Roadmap effort has identified several critical knowledge gaps, which must be closed to achieve the desired technology destinations.

- Double the thermal and resource efficiency of coal-based generation to reduce emissions by half.
- High-temperature materials and designs for ultra-supercritical steam cycles.
- Hot gas cleanup for gasification and PFBC systems.
- Commercially viable advanced co-production systems (coal and biomass refineries).
- Higher efficiency and reduced emissions associated with coal processing through low-cost air separation and advanced catalysts, and coal and biomass process development.
- Carbon capture and sequestration technology with cost <$40/tonne of carbon.

EPRI's Roadmap effort is closely aligned with other long-range thinking in the industry, including DOE's Vision 21[2], which aims at development of an energy 'plex' producing not only power at very high efficiency, but multiple products, at near zero emissions. DOE's goals of 60% efficiency, emissions 1/10 of U.S. New Source Performance Standard, and capture and permanent sequestration at a cost of <$40/tonne of carbon are extremely aggressive goals. They aim at the same destinations as the EPRI goals above, if not the same values.

Other organizations such as the U.S. Coal Utilization Research Council have also put together aggressive goals for high efficiency, low emission energy production using coal. Outside the U.S., a number of power producers and coal interests have developed important regional or special coal strategies that fit with the overall need to keep the coal option viable. We have been working with firms in Europe, Africa and Australia to make sure the different needs in each region are factored into the Global Coal Initiative.

EPRI believes that a public/private partnership that brings together generation, supply and public interests in consortia to meet these challenges will be the best way to realize these visions.

Coal technologies-an overview

Coal-fired power plants currently supply over half of the electricity generated in the United States. Despite some switching of existing power plants to natural gas and the startup of new gas turbine/combined-cycle plants, the utilization of coal will provide the bulk of U.S. power in the near-term. Moreover, clean coal technologies can help to cap natural gas prices by providing an economically competitive and environmentally acceptable alternative. Repowering existing coal plant sites with new clean coal technologies such as ultra-supercritical pulverized-coal (USC-PC) boilers, integrated gasification combined cycle (ICGG), and pressurized fluidized-bed combustion (PFBC) is the least-cost means of introducing these technologies, since much of the existing support infrastructure can be reused. In some cases, repowering with natural gas or simply the addition of new gas turbine capacity at a coal site may provide the most economical 'transition' strategy to ultimate clean coal repowering. Outside the United States, China and India have large coal reserves, but only small reserves of natural gas and little gas delivery infrastructure. Their rapidly growing economies will continue to use domestic coal to supply the majority of their power supply needs.

Ultra-supercritical (USC) Pulverized-Coal (PC) plants

For the immediate future, conventional sub-critical pulverized-coal plants will be the major technology deployed in these growing markets in developing countries. Supercritical plants will gradually increase their market share as domestic manufacturing capability of key components is developed and limitations on the coal supply infrastructure drive a desire for higher efficiencies.

Several large PC plants with USC steam conditions in the size ranges of 400–1000 MW have entered commercial service in Japan and Europe over the past 5 years. The design heat rates for these plants are about 5% and 7% respectively lower than standard sub-critical plants. Initial reports about the performance of these plants are very encouraging. The longer-term reliability of these plants is of key importance to the future of this technology. At the current time the lead in the manufacture of the key materials for these plants clearly lies in Japan and Europe. Research, development and demonstration programmes are under way in these countries aimed at materials capable of withstanding steam conditions up to 650°C and perhaps to 700°C. If successful this would result in USC designs with heat rates 10–12% lower than the standard sub-critical designs[3].

Atmospheric Fluidized Bed Combustion (AFBC) plants

One of the proven advantages of AFBC is its ability, if correctly designed for, to handle a variety of low value, high ash coals and other waste materials. The value of such waste fuel sources can often be assumed to be zero or possibly even of negative value if the waste piles incur ongoing costs and environmental penalties. The use of AFBC can be economic in such circumstances particularly if some additional value can be assigned to the removal of these waste piles and the neutralization of the acid runoff from these piles with the lime containing solid waste from the AFBC.

Both India and China intend to use their indigenous coals for a majority of their future power needs. Most of the India coal is ~40% ash and the average coal burnt in Chinese power plants is ~25–30% ash. South Africa has accumulated large piles of coal preparation plant wastes. Low value low quality fuels are widely distributed around the world[4].

Larger CFBC units of 400–600 MW have been designed and studied by Foster Wheeler and EDF. These plants feature multiple furnace modules with a 'pant leg' type design. At these sizes supercritical steam turbines can be used to provide higher efficiencies and economies of scale so that they should be able to compete effectively in the larger PC market-place.

Integrated Gasification Ccombined Cycle (IGCC)

Coal power destinations can be achieved by combining state-of-the-art gas turbines with improved fuel processing technologies. Advanced Integrated Gasification-combined Cycle (IGCC) units, for example, promise excellent efficiency along with low emissions of air pollutants; inert, commercially usable solid by-products; options of co-production of clean fuels, hydrogen, and other chemicals; and CO_2 removal capability. Integrating such IGCC units with fuel cells offers the potential for 60% plant efficiency. Three coal-based IGCC plants with capacities of 250 MW are currently in operation. Other 250–500 MW IGCC plants fuelled with very low cost petroleum coke and heavy oil have recently started operation or are under construction in many parts of the world.

Key R&D challenges for improved gasification technologies that can reduce plant capital costs, include high-temperature ceramic membrane air separation units with markedly reduced power consumption, continuous dry coal feed and ash/slag removal systems, fluidized-bed gasifiers to accommodate low-grade feedstocks, lower-cost syngas coolers with improved materials for steam superheating, and high-temperature hydrogen separation membranes. Improved syngas cleanup systems are also needed, including the capability to remove alkaline and other particulate material at 1100–1450°F (590–790°C) and possibly also to remove sulphur species, nitrogen species, and trace elements defined as Hazardous Air Pollutants.

IGCC plants can meet extremely strict environmental and emission standards and may be applicable to particular locations that have such requirements. If emissions including CO_2 were subjected to externality charges or taxes this would make IGCC a more attractive technology. Several studies have shown that if CO_2 removal from fossil-based power plants is required for subsequent disposal, use or sequestration, it would be much less costly to remove the CO_2 from syngas under pressure prior to combustion rather than removal from the huge volume of stack gases after combustion at atmospheric pressure[5].

Pressurized Fluidized-bed Combustion (PFBC)

First generation PFBC plants are currently only available in the bubbling bed mode at the 80–100 MW module size. The future of bubbling bed PFBC technology depends on the successful scale-up to the 350 MW and 250 MW units in Japan. The current U.S. PFBC programme is mainly based on the Foster Wheeler circulating bed PFBC and the so-called 'second generation' technologies being tested at the Process Systems Development Facility (PSDF) 50 ton/day pilot plants in Wilsonville, Alabama. This technology is under consideration for being scaled up, in a phased programme, at a utility site (originally Lakeland, Florida). If this scale-up is successful a further scale-up will be necessary up to a size where it might compete in the new coal plant power market in maybe +2015.

The PSDF development of the Foster Wheeler and Kellogg gasifiers is also important for other reasons. The world needs fluid bed gasifiers to handle high ash coals (prevalent in India, South Africa and much of China) and the lower-rank lower-cost U.S. Western coals. The addition of fluid bed gasifers at existing coal sites with the unconverted char being sent to an existing boiler can be a low cost way of adding advanced coal technology at existing sites. However, a pathway to scale-up beyond the PSDF size needs to be established if this is to become an option[5].

Environmental policy and the impact on coal

The environmental policy decisions made in the next decade will have a major impact on which coal technologies are utilized and this may vary from country to country.

The electric power industry is already being called upon to make further reductions in emissions of SO_2 and NO_x, and even to reduce CO_2 emissions. In anticipation of these changes, various studies have addressed the potential ecinomic and market effects of environmental proposals, including carbon emission reductions called for under the Kyoto Protocol. EPRI earlier this year released its Energy-Environment Policy Integration and Coordination Study (e-EPIC), using National Energy Modeling System (NEMS) and other models.

The results indicate that proposed SO_2, NO_x and CO_2 restrictions referred to in this study as the 'Current Policy Direction' could have wide-ranging and significant effects on the U.S. energy system, effectively determining many aspects of national energy policy. The next one to two decades would see substantial shifts in the mix of fuels used to generate electricity and increases in electricity prices. Effects of inefficient technology deployments and fuel market changes could last even longer, over several decades. The results indicate that coordinating carbon reductions with technological advances is the key to making deep reductions in emissions while achieving a smooth transition to a sustainable, efficient U.S. energy system.

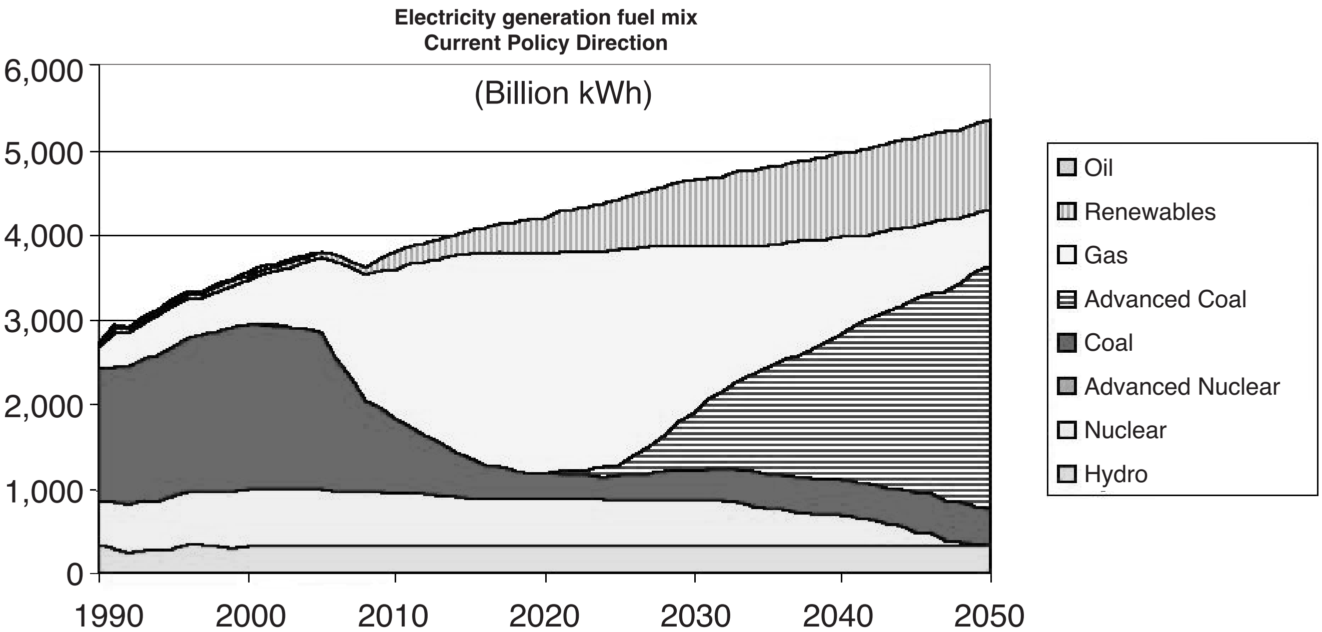
The Current Policy Direction would require large emission reductions before critical technological advances can be accomplished and deployed. NO_x and SO_2 emissions would first be reduced by retrofitting existing electric generating units (especially those using coal) with emission control equipment, combined with fuel switching and greater reliance on existing and new natural gas-fired power plants. However, subsequent CO_2 emission reduction requirements would lead to large shifts in fuel use, idling or retiring many coal-fired electric generating units. Although renewable energy technologies are projected to expand rapidly under the Current Policy Direction, the major gap in the energy supply for electric generation due to phasing out coal would have to be filled largely by increased use of natural gas. These shifts are shown in Figure 2.

Under the Current Policy Direction, the natural gas share of electricity generation would rise from about 15% today to 60% by 2020. Meanwhile, coal-fired generation's share would drop from over 55% to less than 10%, effectively abandoning most of the U.S. coal infrastructure and reducing the diversity of the fuels used in the overall U.S. energy system.

Looking out further in time, toward 2050, natural gas prices are projected to rise due to a sustained increase in demand and, eventually, a reduction in reserves. Beginning in about 2025, continuing technology advances (coupled with these rising gas prices) are projected to make electric generation using other fuels increasingly attractive to meet both environmental constraints and rising demand for electricity. The result is a projected fuel swing revitalizing the role of coal (shown as 'Advanced Coal' in Figure 2 to differentiate it from coal used with current technologies) and expanding renewable energy, thus reversing the previous rapid swing away from coal. This path, if it could be successfully followed, might ultimately restore the diversity and flexibility of the overall U.S. energy system, but it raises the question of whether there is a better way to reach a similar end point while avoiding or minimizing disruptive fuel swings and high costs and risks to the U.S. energy system and economy. Further, there are important questions about the feasibility of following this path[6].

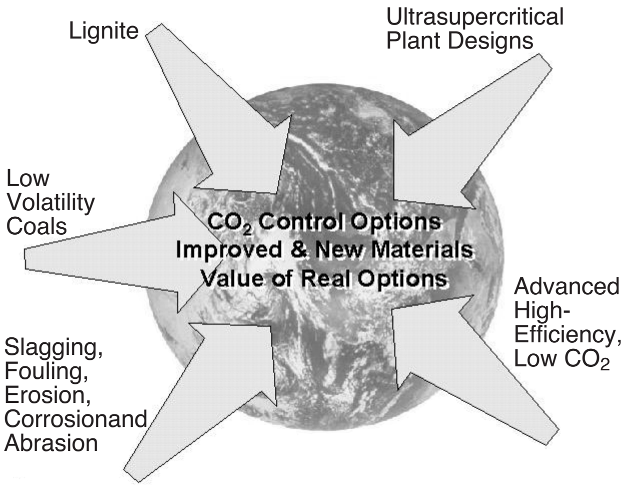
The EPRI Global Coal Initiative—maintaining the strategic value of coal

The primary objective of the EPRI Global Coal Initiative (GCI) is to help maintain the strategic value of using coal for worldwide power generation, both in existing plants and as a clean, efficient generation source in future fossil power plants. This Initiative is aimed at involving the world's major coal-using electricity generators, coal suppliers and public organizations in a collaborative R&D programme to meet this objective through successful completion of a portfolio of projects that are focused on both the short- and long-term needs of these companies. EPRI has developed several new projects specifically focused on meeting short-term operational needs—such as deposition and combustion



Source: E-EPIC analyses (EPRI, 2000)

Figure 2—Project fuel mix for U.S. electric generation under the current policy direction



performance with difficult coals and the need for more robust materials of construction—that are increasingly of concern to global power producers. These projects will help sustain current fuel diversity as a hedge against price fluctuations, enhance the value of existing coal plants, and provide options for using coal in new plants. At the same time, other projects are designed to meet the long-term objectives of resolving the carbon/energy conflict, contributing to a sustainable energy future, and helping coal compete at near-zero emissions by 2020. The Global Coal Initiative supports the goals identified in EPRI's Electricity Technology Roadmap.

EPRI's Global Coal Initiative currently includes nine programmes, to help address a wide variety of coal-related issues, selected to complement programmes by organizations around the world.

Core technologies

- *Value of real options*. Develop models to determine the value of coal to the nation (first case will cover the USA, then other countries), to assess specific R&D strategies for the development of new technology options, and determine the value to specific companies of an investment in coal technology R&D
- *Improved and new materials*. Reduce the cost and duration of developing and qualifying new materials that will have longer service lives and allow operation at more severe conditions. These would be via using sophisticated modelling techniques for materials development aimed at a number of advanced coal processing needs
- *CO_2 control options*. Evaluate technological approaches and costs, as well as regional, societal and legal issues for power plants that choose to—or could be required to—separate and sequester CO_2.

Near-term issues

- *Slagging, fouling, erosion, corrosion and abrasion*. Develop innovative solutions to operating problems with difficult ash coals, aimed primarily at specific coal
- *Low volatility coals*. Provide innovative methods for using these lower-cost coals while maintaining high efficiency and low NO_x emissions
- *Lignite high-moisture and slagging*. Develop solutions to slagging in power plants that burn high-moisture lignite.

Longer—term issues

- *Ultra-supercritical plant designs*. Evaluate and develop cost-effective, durable materials for advanced steam cycles in next generation plants with steam temperatures that exceed 760°C (1400°F)
- *Advanced high-efficiency, low CO_2*. Develop and evaluate advanced approaches to coal-fired generation that specifically address issues the climate change challenge. This includes gasification, coal 'refining' and advanced PFBC concepts for example
- *Life cycle costing*. Developing life cycle costing and impacts of coal by working with the Australian consortium on 'Coal in a Sustainable Society' to develop cases for a variety of coal technologies.

Current status of the Global Coal Initiative

The Global Coal Initiative is being developed through ongoing discussions with worldwide power producers and others with an interest in coal. These others include coal and rail companies, equipment vendors, banks, and various government agencies and foundations, all of which can participate in the initiative. EPRI will work with public and private interests to obtain maximum leverage for funding and ensure the greatest value for participants.

One of the industry efforts, on ultra-supercritical boiler design, builds off global development and EPRI's longer-range strategic science and technology effort that resulted in our March 2000 report[7] on this topic. Working with the Coal Utilization Research Council, the U.S. boiler manufacturers, the State of Ohio and DOE we have developed a programme of research that can be advanced jointly with public and private funding. DOE recently awarded an initial phase of work to EPRI and a team of manufacturers to define this major boiler materials programme. We expect this will be a $20M+ multi-year programme.

One other item that has already achieved critical mass for funding is our 'Real Options' study. The first deliverable of this project looks at the value of having the coal option on a national basis for the U.S. We have received funding from one major 'power producer' and are in the process of closing funding with others, as well as several coal companies. We have started work and expect deliverables by early 2001 to be used in the national debate over fuel options. We believe this will be attractive internationally as well since the real options methodology is widely respected and the analysis method could be used in a number of countries.

A third area where there is intense interest is our work with ESKOM and PowerGen to develop the Low-Volatile Coal project. This is aimed at some of the lower volatile or off-specification coals and how best to burn them in low-NO_x burners without combustion stability, NO_x or unburned carbon issues. This will include a number of combustion tests at appropriate international facilities, aimed at these coals. A number of our European members are working with this team to set up an international collaboration to resolve these issues.

An area that has received some attention in Australia is an effort spearheaded by the coal interests to develop life cycle costing for coal. This effort titled 'Coal in a Sustainable Society' should help understand the relative value of the coal generation. Based on a presentation made by that group earlier this year, we arranged to support this effort providing technical and support and providing input from our many Australian generator-members.

Other parts of the Global Coal Initiative are described in more detail on EPRI's web site, www.epri.com under the power generation heading or interested parties can contact us at EPRI (my e-mail is sdalton@epri.com).

Summary—an EPRI perspective

With 30% of world power generation from coal today, and the prospect of increasing coal use in many regions of the world, coal remains one of the backbones of power generation. Yet because of environmental pressures, particularly global CO_2 emissions, coal will need to improve its economic and environmental performance to continue as a major generation fuel. EPRI's Global Coal Initiative is aimed at helping to make coal more competitive as a current fuel and more acceptable in the long—term. We believe that power generation using coal can be both competitive and environmentally acceptable. We will need *all* the generation options, including coal generation, in a world of 9–10 billion people who expect improved standards of living.

References

1. COURTRIGHT, H. and DALTON, S. EPRI's view of Global Coal Technologies for the New Century. EPRI paper, September 11–14, 2000, *Pittsburgh Coal Conference*.
2. FEIBUS, H. Vision 21—A technical Strategy for Coal in the Next Century—DOE Clearwater Conference 1998.
3. Operating Experience and Risk Assessment of Clean Coal Technologies 1999, EPRI TR-114084.
4. Engineering Economic Evaluation of Clean-Coal Technologies 1999, EPRI TR-114080.
5. HOLT, N. Comments to National Research Council Committee on R&D Opportunities for Advanced Fossil Fueled Energy Complex, EPRI, June 1999.
6. HESTER, G. E-EPIC Executive Report, EPRI, December 1999.
7. Materials for Ultra Supercritical Fossil Plants, EPRI, 2000, Tr-114750. ◆

Sixth Annual Course on The Design of Slurry Pipeline Systems*

Paterson & Cooke Consulting Engineers will present the sixth annual course on the design of slurry pipeline systems in March 2001 at the Breakwater Lodge in Cape Town's Victoria & Alfred Waterfront.

The course was established to provide guidance for the design of slurry pipeline systems for the mining and processing industries. Slurry pipeline transportation is not adequately covered in most undergraduate engineering courses. Consequently, engineers are generally ill equipped when faced with the task of designing a slurry transportation system or establishing why a system does not perform its required duty. The course aims to address this problem by giving delegates a sound understanding of slurry flow mechanisms and an appreciation of the design requirements for a successful slurry pipeline transportation system.

To date over 170 delegates from the Netherlands, Canada, Brazil, Botswana, Namibia, Zimbabwe and South Africa have attended the course. It has proven to be an extremely popular course and is always fully booked. Over the years the course has changed to accomodate the needs of the delegates, and is now a blend of theoretical and practical instruction with slurry flow loop demonstrations during lectures.

The course covers the following:.

- flow behaviour and modelling of different types of slurries
- centrifugal and positive displacement pumps
- pump and pipeline wear
- instrumentation and laboratory techniques
- valves for slurry service
- hydraulic design and engineering considerations.

Where possible the course is tailored to suit the delegate's requirements. For example additional lectures on the design of backfill distribution systems and high concentration slurry flow may be presented depending on the delegate profile.

A fully instrumented slurry test loop is used during the lectures to show various aspects of slurry pipeline flow. Visual observations of the flow phenomena give delegates and insight into the physical slurry behaviour and clarifies theoretical aspects. The course concludes with design examples which give the delegates an opportunity to apply the principles and techniques presented during the lectures.

The course will be held from 14 to 16 March 2001 at the Graduate School of Business, University of Cape Town, Breakwater Lodge, Victoria & Alfred Waterfront, Cape Town. ◆

* *Contact: Ferial Perin, Tel: + 27 (021) 683 4734, Fax: + 27 (021) 683 4168, e-mail: ferial@pcce.co.za.*