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Proceedings of the Coal-Fired Power Systems 94 -- Advances in IGCC and PFBC Review Meeting
Volume I

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Sponsored by
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Foreword

The Coal-Fired Power Systems 94 -- Advances in IGCC and PFBC Review Meeting was held June 21-23, 1994, at the Morgantown Energy Center (METC) in Morgantown, West Virginia. This Meeting was sponsored and hosted by METC, the Office of Fossil Energy, and the U.S. Department of Energy (DOE).

METC annually sponsors this conference for energy executives, engineers, scientists, and other interested parties to review the results of research and development projects; to discuss the status of advanced coal-fired power systems and future plans with the industrial contractors; and to discuss cooperative industrial-government research opportunities with METC's in-house engineers and scientists. Presentations included industrial contractor and METC in-house technology developments related to the production of power via coal-fired Integrated Gasification Combined Cycle (IGCC) and Pressurized Fluidized Bed Combustion (PFBC) systems, the summary status of clean coal technologies, and developments and advancements in advanced technology subsystems, such as hot gas cleanup. A keynote speaker and other representatives from the electric power industry also gave their assessment of advanced power systems.

This meeting contained 11 formal sessions and one poster session, and included 52 presentations and 24 poster presentations. The papers printed in this document have been produced from camera-ready manuscripts provided by the authors. They have been neither refereed nor extensively edited.

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A note of thanks is extended to the session chairpersons: Harvey M. Ness, Rita A. Bajura, Justin L. Beeson, Dale K. Schmidt, Donald L. Bonk, Randall J. Dellefield, Richard A. Dennis, Ronald K. Staubly, Darren J. Mollot, Theodore J. McMahon, Peter E. Botros, Lee D. Gasper-Galvin, and Susan K. Joines. Special recognition is given to J. Wayne Leonard, Vice-President and Chief Financial Officer of PSI Energy, for an interesting keynote speech on "Evolving Utility Business Structure and Impact on New Technology Application" and to Thomas F. Bechtel, Director of the Morgantown Energy Technology Center, for an informative speech on "The Role of Advanced Technology in the Future of the Power Generation Industry." We also thank Ron Wolk from the Energy Power Research Institute, Dale Simbeck from SFA Pacific, the presenters from the various offices of DOE, and the research contractors for their presentations.

Special thanks are extended to the Conference Services staff, the Graphics staff, and the Technical Writing staff of EG&G, Technical Services of West Virginia. These individuals are gratefully acknowledged for providing excellent coordination of and support services at the meeting.

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Session 1

Opening Commentaries

1.1 The Role of Advanced Technology in the Future of the Power Generation Industry

Thomas F. Bechtel
Morgantown Energy Technology Center

My talk today will attempt to portray a vision for the future of the electric power generation industry that has advanced technology as a key element. Given today's highly competitive markets, the demands on capital to meet environmental regulation on existing plants, and the technology risk adversity of the industry, you might be inclined to treat this vision as a fantasy conjured up by a gypsy fortune teller with a faulty crystal ball. However, if you grant me 30 minutes or so to look at how the industry's history has defined its culture, how today's economic and regulatory climate has constrained its strategy, and how certain technology options might give some of the players an unfair advantage, you might give the vision some credibility.

As William Faulkner so aptly put it; "The past is never past; it is always with us." With that in mind, I'd like to take you on a short "Back to the Future" look at the power generation industry. The electric power generation industry in the United States, as we know it today, can trace its roots to September, 1882, and Thomas Edison's Pearl Street Generating Station, which lighted a square mile of New York City with direct current produced by six 100-KW steam engine-driven dynamos. Edison's partner in that enterprise was Samuel Insull, his private secretary. They would eventually dominate the industry, Edison on the equipment side - Insull on the operating side. The steam engine/dynamo combination offered few economies of scale and many initial customers preferred self-generation, an approach that Edison feared would never provide the cost edge he wanted over the "hated gas industry". A letter written by Insull to friends in England just before Pearl Street opened, while he was still Edison's secretary is most illuminating. Let me read you an excerpt:

> "You ask me about electric light. Well, I have seen 700 lights burning, the current generated from the same dynamo-electric machine for the whole lot, all of them getting their current from the same main (i.e., street cables) of no less than eight miles in length. Edison gets eight lights or thereabouts of 16 candles each per indicated horsepower, which allows of his competing with gas. Into the details of the cost I cannot go, as it is not told to anybody.[1] Suffice to say that here in New York he can produce light and get a handsome profit on it at a charge to the consumer which would ruin the gas companies. There is not, however, that vast difference between the cost of the two lights which will allow him to be utterly oblivious of his friends, the gas producers; but his estimates show that he can compete with them and do it at a handsome profit. Besides he can furnish power by means of electric motors, which will give him an enormous pull over the gas companies as he will not have the greater part of his plant lying idle during 365 working days of the year, as the gas companies with but very slight exception must, as the business is at night; but he can sell electricity for power purposes by day, which means that his plant is never

idle, his capital is never running to waste, but is always earning money by night and by day alike. Edison will work just as the gas companies do. He will have central stations where the current will be generated (probably one station of about 15,000 lights to each square mile). This current will be conveyed along the streets underground by means of copper wire embedded in two-inch iron pipes insulated with a special form of insulation of his own invention. Branch pipes will be led into each house, and the electricity, whether for light or power (to us it is all the same), will be sold by means of a registration on an electric meter, which is the most ingenious and yet the simplest thing imaginable.[2] The district which he will light up first in New York has about 15,650 lights in the various buildings in the district and a great deal of power in varying amounts. He is getting contracts just as fast as his canvassers apply for them, and we have large gangs of men wiring the houses in anticipation of the time when we can lay our mains, erect our dynamo machinery and light up. I suppose this district will be all lighted up in from three to four months, and then you will see what you will see. - - -

"Menlo Park is practically abandoned. All experiments are finished[3]; all speculation on the probable results are dismissed; and Edison thinks, and so does everyone else who has looked into the matter, that success is assured. Of course, time alone can prove this. As for myself, I am not competent to judge but I can use my eyes, can see the success with which the houses, the fields, roads and depot have been illuminated here, and I can see nothing to disprove the assertations. His lamps last about 400 hours; at all events that is the estimate by a time test, i.e., by running them at about four times their ordinary candle power until the carbons break; but this estimate is every day falsified, and experience points to the conclusion that the life of his lamps will be much longer than the estimate. As for rivals, Edison has but little to fear, in fact, none, from them. - - -

"To carry out the gigantic undertaking of fighting the gas companies we have much to do. A great difficulty is to get our machinery manufactured. This Mr. Edison will attend to himself. He personally has taken a very large works for this purpose, where he will probably within the next six months have 1500 men at work. The various parts of the machines will be contracted out, one firm making one part in large quantities, another firm another part, and so on. At Mr. Edison's works ("Edison Machine Works"), all these parts will be assembled and put together. Then there is the lamp factory, in which Mr. Edison owns almost all the interest, for manufacturing lamps and which is now turning out one thousand lamps a day, the Electric Tube Company (of which I am secretary and Mr. E. President) for manufacturing our street mains. So you can imagine what Mr. Edison has to do, as he is the mainspring and ruling spirit of everything. And you can imagine also what I have to do as his private secretary. - -"

In 1883, Edison sent Insull out to promote central power stations to mid-sized town with few large building, customers that fit Edison's vision and equipment. However, the emergence of the electric streetcar and the superiority of Westinghouse's alternating current technology for that application did more than Edison's vision to make the central station a winner. The market boomed and Edison sent Insull to create his Schenectady Works. In 1892, J. P. Morgan created GE by merging Edison's assets with many others and focused it on manufacturing everything electrical. Insull left for Chicago to create the predecessor of the Commonwealth Edison Company and by 1930 controlled one-eighth of the nation's generation capacity, had personal assets exceeding $3 billion, and served as chairman or member of more than 100 corporate boards. His power evaporated in the 1930's, when his Ponzi scheme of overvalued assets, underrecognized costs, and "pegged stock prices" crumbled. He was tried for embezzlement, larceny, securities fraud, and Bankruptcy Act violations. Although he was found "not guilty" by the jury in each case, his notoriety resulted in the Public Utility Holding Company Act, which was just repealed by the Energy Policy Act of 1992, and the creation of a large public power system with TVA as the model.

In spite of the legal tainting, Insull is widely credited with the creation of the electric utility industry that is just now changing its basic structure. His Fisk Street Station, which came on line in October, 1903, with its 5-MW steam turbine-generators, completed the picture started when he broke with his mentor's technical practices, introduced DC-AC conversion, adopted Westinghouse's AC transmission technology, and the Wright peak demand kilowatt-hour meter in the 1890's. Prices dropped from 20 cents/kilowatt-hour in the 1890's to 8 cents/kilowatt-hour in 1910, fulfilling Edison's vision that "they would make electric power so cheap, that only the rich could afford to burn candles".

His focus on building volume and using technology to cut cost made him an industry advocate for "cost-shifting" as a way to make electric living available to the general public. Thus he contributed to the massive growth of the electrical appliance industry and broad public support for the electric utilities. He also promoted the idea of state regulation, an umbrella for his monopolies to operate under. That structural and technical foundation drove the industry to great growth and, with evolutionary development, sustained it on a declining cost curve until the 1950's; it "ran out of steam" (Figure 1) when the supercritical units turned out not to be cost effective. Nuclear power promised to change the paradigm; the boiler was dead and efficiency was not critical to the nuclear system's financial success. Variable cost would be so low that metering would be unnecessary; only a capacity charge for capital recovery would be needed. Thus ended a 70-year period in which equipment-supplier investments in technology reduced cost, grew volume, and fostered new product applications for an industry that was permitted to absorb new technology at a high rate because of its monopoly umbrella.

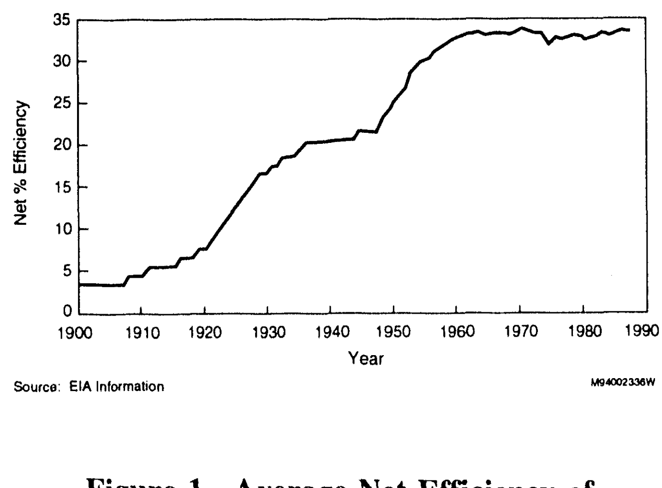

Figure 1. Average Net Efficiency of Coal-Fired Power Plants

Every decade from the 1950's to the 1990's has seen defining events that have irreversibly changed this industry. The 1950's saw the massive supplier price-fixing scandals that coupled with technology glitches to convince many customers and regulators that dependence on highly profitable vendors to deliver the industry's technology diet in response to competitive pressure was bad policy. The industry reacted by aggressively prosecuting these anti-trust violations, opening up the market to off-shore vendors, and creating the Electric Research Council to fund and manage a user-industry driven research and development program. These actions reduced supplier profits and put the funding burden for technology development and the control of research priorities on the equipment users, the electrical utilities.[4]

The 1960's also saw the emergence of commercial nuclear power and major blackouts, which put the integrity of the whole supply system in doubt. The peaking gas turbine solution to providing reliability through increased reserve margins looked good, but became a nuisance in the 1970's as gas turbines proved to be less reliable than desired in this cyclic load environment. When costs are declining and the supply is reliable, the customer tolerates minor transgressions; not so when the reverse is true. One broad-based industry action to counter customer reaction was the formation of the North American Electric Reliability Council to promote enhancements to generation and transmission reliability.

The shortage mentality and increased fuel costs, aided and abetted by the Arab oil boycott, the cost of compliance with the Clean Air Act (CAA), and the onerous interest rates in the 1970's sealed the coffin on the era of declining costs. These increased costs combined with the rate-basing of unneeded capacity in a period of slow economic growth, affectionately called "stagflation", led to unparalleled consumer "rate-shock". It also brought us the Public Utility Regulatory Policies Act (PURPA) and over-building by those with cheap money and limited operating competence, the Rural Electricification Administration (REA). But its defining moment was Three Mile Island, the beginning of the end (or hiatus depending upon your viewpoint) for nuclear power and its backlash of unrecoverable capital for the industry. Monday morning "prudency reviews" struck fear in the hearts of most utility CEO's, while operating cost "pass-throughs", justified by the Arab oil boycott, eliminated much of the incentive for efficient operations.

The 1980's saw Independent Power Producers (IPP), bidding, PURPA saturation, anxiety over new CAA revisions, very limited construction of new plants as the industry tried to work off excess capacity, and pressures for utilities to invest in demand-side management to reduce market growth[5].

The 1990's have already brought CAA revisions to capture the grandfathered capacity already in place when the 1977 act passed, climate change and electromagnetic fields (EMF) fear-mongering, pressure for open access to transmission capacity ("retail wheeling" to the in-crowd), an increasing involvement of the unregulated arms of the traditional electric utilities in the IPP market, and an emergence of the natural gas-fired gas turbine combined cycle as the technology of choice for new generation capacity.

What is the point of all this discussion of the past? We could cite the trite; i.e. "The past is prologue!" or "Those who ignore the lessons of history are doomed to repeat them." Moreover, it is with a sense of déjà vu that we point out that more than 100 years after Edison and Insull created this "bullet-proof" structure to nurture an infant industry, it is the "hated gas industry" working with and as independent power producers that has broken this "natural monopoly" and created a challenging new environment for those of us who see ourselves as "partners" with that industry.

One doesn't have to be much of a visionary to see a first decade of the next century where inter-utility price competition for baseload customers between the generating arms of newly unbundled (or as I prefer, "dis-integrated") electric utilities leads to further cost pressures on the small consumer and the associated backlash from this public on the regulatory structure. The analogy to the telephone system history is clear, although I'm not sure you'll get to choose who supplies electric power to your individual hotel room. As you know, the deregulation process is already underway in California, targeted to hit industrial users by 1996 and homeowners by 2002. Its particularly threatening to the California utilities, who charge electrical rates 50 percent higher than the national average. Experiments may come slower in the Northeast, where New England's utilities have a 20 percent variable production cost disadvantage, compared to mid-Atlantic competitors, and a 50 percent retail cost disadvantage; an untenable competitive environment for residential customers in New England if the capital cost recovery is on their backs instead of being written off as excess, with stockholders bearing the burden.

The traditional part of the electric power industry as it exists today has some classical textbook attributes:

- Low growth.
- Many, many, many competitors.
- Many low-margin vendors.
- Little, if any, product differentiation.
- Great difficulty in finding sites for new manufacturing capacity, even if needed.
- Severe price competition becoming even more so with open access.
- A distribution system that is difficult to expand.
- An aging manufacturing plant.
- High capacity utilization levels, approaching 85 percent at peak.

Put simply, we're dealing with a "mature" industry which is dependent on "mature" technology provided by "mature" suppliers for its bread and butter. It has all the characteristics classically attributed to "maturity" and as such is not inclined to invest in technology for future capacity growth. Instead, the emphasis is on getting the most from existing business assets, working on the marginal cost of existing operations and eliminating base cost, all with minimal investment (Figure 2). That translates into a focus on product cost reduction, improved reliability to enhance capacity utilization, excellent customer service, and shortening cycle time for responding to customer needs. That usually drives organizations to spend their limited research and development (R&D) funds working at the end of the product life cycle curve, where the emphasis is on risk reduction; one can't take much product development or application risk with small profit margins. A business in that situation literally "bets the business" in attempting rejuvenation through R&D on "paradigm shifting" products. Since dis-integration, read that divestiture, emphasizes owning only those assets that contribute directly to short-term profit, there is almost no attention to major system improvements. What power generation investor in that situation will take a potential bottom-line hit to bring new capacity on line, knowing that the incremental capacity cost will necessarily be borne by the captive customers, if there is such a thing? The lure of increasing capacity factors on existing assets by price-cutting to win base load customers from competitors will be irresistible. The transition will be difficult and the short-term profitability impact will be substantial and, in fact, unacceptable to

Management Activity or Function	Embryonic Industry	Growth Industry	Mature Industry	Aging Industry
Managerial role	Entrepreneur	Sophisticated market manager	Critical administrator	"Opportunistic Milker"
Managerial compensation	High variable/low fixed, fluctuating with performance	Balanced variable and fixed, individual and group rewards	Low variable - high fixed group rewards	Fixed only
Organization structure	Free-form or task force	Semi-permanent task force, product or market division	Business division plus task force for renewal	Pared-down division
Planning time frame	Long enough to draw Tentative Life Cycle	Long-range investment payout	Intermediate	Short-range
Planning content	By product/customer	By product and program	By product/market/function	By plant
Content of reporting system	Qualitative marketing unwritten	Qualitative and quantitative, early warning system, all functions	Quantitative, written production oriented	Numerical, oriented, to written balance sheet
Corporate departmental emphasis	Market research: New product development	Operations research: Organization development	Value analysis data processing taxes and insurance	Purchasing

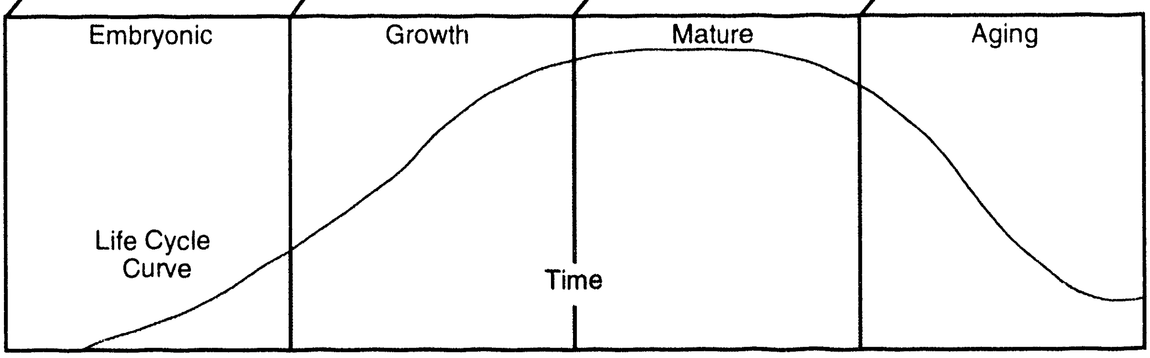

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Figure 2. Product Life Cycle

many utilities captive to this industry's traditional high equity capital structure as a consequence of their regulatory situation.

We're faced with the basic question: What does technology have to offer this deregulated, dis-integrated industry with extremely tight constraints on siting, discharges, and product distribution?

In our minds, the most important asset in this future is existing permitted sites, both the aged plants of the utilities and the industrial sites of their customers, both relatively free of Nimbyism. We see the traditional utilities fighting IPP's to invest to build capacity on the potential customer's site. If the customer company is young and healthy and looking to vertically integrate production, it may build its own capacity and in effect compete with the utility. If, on the other hand, the customer is in a mature industry situation, it may welcome the opportunity to divest a steam supply facility and let the utility play out its "customer-retention" strategy in competition with other potential suppliers.

METC's program is committed to helping the industry exploit this asset to the fullest; we're convinced that repowering is the most attractive technology-driven answer to the industry's current dilemma. Repowering offers a way to upgrade existing assets, coincidently grow capacity, and reduce the cost of electricity relative to other alternatives. For the neophyte, repowering is usually most cost-effective when it uses the steam turbine-generator, condenser, coal storage and handling facilities, and waste handling facilities at the existing location. Although specific requirements are sometimes less severe, one generally needs to meet the steam turbine's design point steam conditions, require no more coal, generate no more waste, and require no additional electrical transmission right-of-way. The opportunity is great. While only 18 GW of new coal capacity is projected by 2010, more than 60 GW of existing capacity will be more than 50 years old by that time, with more than 30 GW in the 65 to 250-MW range of interest for repowering. All of these plants are eligible for the CAA's 4-year compliance bonus if repowered with Clean Coal Technology.

The technologies in the METC portfolio that fit the bill in the repowering game are integrated gasification combined cycle (IGCC), pressurized fluidized bed (PFB), externally fired combined cycle (EFCC), and the advanced gas turbine system (ATS). Each option offers enhanced efficiency that promises increased dispatch hours, helping to write-off the capital investment while displacing an older, less environmentally attractive generation. A few examples of how the various options could work help to make the point.

The IGCC, which in its most cost-effective configuration increases plant output by 150 to 200 percent over its original steam turbine rating, can be a bad match in fuel, waste and transmission capacity unless we're talking about a multiple steam turbine plant. For example, if we start with two 100-MW steam turbines operating at 30 percent efficiency and convert one of them into an IGCC and retire the other, we end up with a 250 to 300-MW combined cycle at 50+ percent efficiency. That translates into a 25 to 50 percent increase in output and a 25 to 10 percent decrease in fuel use. The waste reduction could be even higher, depending on the pollution control option that would have been required for retrofit technology-based CAA compliance.

The PFB approach results in an output increase in the 35 to 50 percent range, resulting in an excellent repowering option. If we repower an existing 200-MW plant with first generation PFB, we end up with 250 to 300-MW plant operating at 40 percent efficiency; a 25 to 50 percent increase in output and a -6 percent/+12.6 percent change in fuel use. The big advantage vis-á-vis IGCC is in cost; we use the entire steam turbine capacity and add a gas turbine that is one-third to one-half the size of that employed on the IGCC. A second-generation PFB plant could do even better in the two turbine situation. If one turbine is converted and the other retained, the output increases by 70 to 100 MW at a system efficiency of 40 to 41 percent. A 35 to 50 percent increase in output while the fuel use change is in the +1/+10 percent range. Both steam turbines are used, and the gas turbine is only half that used in the IGCC case. Both PFB approaches are environmentally attractive because of excellent in-bed sulfur capture and excellent NO_x performance.

The EFCC is most attractive in smaller industrial applications, where it can be used with an atmospheric fludized bed (AFB) primary combustor and a coal fines-fueled topping combustor to meet a broad range of process steam needs without significant loose in cycle efficiency. Although the system tends to cost-optimize at the 70 to 100 percent power increase level, it also provides extreme fuel flexibility, which heavily impacts the definition of optimum.

Using the advanced gas turbine to do natural gas repowering can be extremely attractive, particularly if we employ staged construction to preserve the IGCC option and employ a gasifier that is not a net user or producer of steam. However, it suffers from the same deficiency as IGCC in producing a 150 to 200 percent increase in output relative to the existing steam demand.

We know that the global power generation market will be focused on new generation. We know that these same technologies will dominate these global new-plant markets, but that the relative competitive situation between technologies will change. However, we cannot ignore the role that low-cost electrical power plays in keeping the United States economy globally competitive. Repowering is the key to meeting this objective as the power generation industry transitions toward open markets. Recent Electric Power Research Institute (EPRI) and Gas Research Institute (GRI) studies reach the same conclusion; however, in keeping with Edison's original theme, they disagree on fuel choice. Natural gas retains its capital cost edge in repowering, so the fuel cost differential debate is critical for decision makers. By focusing our R&D effort at METC on gas turbine-based systems, we are striving to keep the fuel option open.

The policy question on DOE's table is clear: Once we've helped the electric power industry through the minefield of clean air and water regulation, natural gas deregulation, and electric power deregulation, all of which government created as beneficial public policy, is our involvement in funding R&D to meet the technology needs of a mature industry warranted in a free-market economy? Liquid fuel security, maybe; but is cheap electric power in the same league, even if we can tie it to global competitiveness and jobs? I don't know the answer, but with EPRI and GRI already in distress as a result of role-definition conflicts in a world where their supporting members are competitors, and DOE's role in question, our industry needs to find sound answers that are salable in today's tight budget climate.

Some of my associates in government are inclined to "hand wring" with you and focus their attention on the "mature end" (Figure 2) of the product life-cycle curve. However, we believe you can do that without us. You know your operations best and know where to best leverage investments to improve them. The university community will do its usual good job in understanding "what is", i.e. the "art-into-science" area, and training students to do what you already do even better. You may even become comfortable working cooperatively with your new competitors to understand new generic issues such as EMF and air-toxic health effects. We believe that government must be in league with the "paradigm shifters" that can remake your industry and offer attractive investment opportunities. We must focus on forging the future, not preserving the past.

If you look closely at our past and current performance, you won't find METC working on better pulverized coal boilers, better steam turbines, or better scrubbers; you'll find us working on the AFB which gets rid of two out of three of those components. You'll find us working to make gas turbines reliable base load generators that break the 40 percent efficiency barrier in a cost effective way with fuel flexibility that even gas turbine devotees wouldn't promise. You'll find us working on fuel cells, the ultraclean, ultraefficient, quiet, direct conversion machine that eliminates the concept of working fluid. To sum it up, when we find a pile of horse manure, we look for the pony and plan to raise race horses; others choose to get in the fertilizer business. We need your leadership in making sure the product focus is correct, the development cycle time is appropriate, and that the job we do is complete enough that your application risks are acceptable. The "new DOE" is more than open to your feedback; it will assertively seek it and will commit to reflect it in our actions. Unless our customers succeed, we have no reason for being. Thanks for your attention and hopefully your comments and questions.

REFERENCES

DRI/McGraw-Hill; "Repowering Potential in the Electric Utility Sector"; GRI-93/0169.

EPRI Journal; January/February, 1993.

General Electric Company; "Electric Utility Systems and Practices"; GEZ-2587A; 1969.

Gorowitz, B.; "A Century of Progress"; November, 1981.

Heppenheimer, T.A.; "American Prometheus"; AUDACITY Magazine; Summer, 1994.

Hewson, T.: "Potential Role of Fluid Bed Combustion Technologies for Utility Repowering"; Energy Ventures Analysis, Inc.; EPRI Fluid Bed Combustion for Power Generation Conference: Atlanta, Georgia; May 17, 1994.

Lubove, S.; "Another Monopoly Bites the Dust"; FORBES Magazine; May 23, 1994.

Newton, T.U. and J.D. Burkett; "PFBC Repowering - A Clean Air Act Driven Choice; EPRI Fluid Bed Combustion for Power Generation Conference: Atlanta, Georgia; May, 17, 1994.

THE ECONOMIST; "California Unplugged"; May 21, 1994.

The KIPLINGER WASHINGTON LETTER; April 29, 1994.

ENDNOTES

1. An astute observer would note that GE hasn't changed a bit in those hundred plus years.

2. When Edison and friends wanted to insult someone, they noted that "He lies like a gas meter.."

3. That man understood commercialization; no research for the fun of it.

4. This effort culminated in the early 1970's in the creation of an industry-controlled R&D coordinator-manager, the Electric Power Research Institute. The Congressional response to the "blackouts", with threats of forming a Federal agency to manage the industry's technology future, added impetus for the industry to act. Some pundits have noted that subsequent events have demonstrated that the concern that led them to act was well placed.

5. Insull probably spun in his grave on that last one.

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1.2 Evolving Utility Business Structure and Impact on New Technology Application

J. Wayne Leonard
PSI Energy, Inc.

I was asked to speak on the topic of the evolving business structure in the electric power industry and the effect on technology development. What is interesting about that premise is that for years many have believed and, in fact argued, just the opposite. That is, it is technology development that determines (or should determine) the business structure. And, the simple fact was that technology largely dictated that the electric power industry was a natural monopoly. That is, production conditions lead to a lower unit cost with ever increasing levels of output, resulting in a condition where costs are subadditive, so that a single firm can supply the entire market at a lower cost than can two or more firms. Thus competition can only increase costs and thus is not desirable. And, thus see vertically integrated electric utilities with partial or complete territorial integrity of exclusive franchise rights in return for accepting the obligation to serve all within that franchise territory at prescribed regulated prices.

And today, some are still locked into that debate, but right or wrong the idea of the electric power industry, as a natural monopoly and immune from competition, is not likely to survive to see the turn of the century. I will spend some time this morning explaining the views of economists, customers, and the financial markets on this subject, and why I think public policy and technology development is best served by this approach. And right up front, I should say mine is a minority opinion in the industry, particularly because I do not believe any of us are really prepared for the challenges we face.

From an economist viewpoint, it is important to keep mind that there are various services we receive in today's society which qualify for public utility status, but have never been regulated as such, or have been deregulated over the years. They provide essential services, exhibit scale or scope economies, are capital intensive, and have costs that vary by time of use (examples could be transportation sector or electric equipment companies). But to economists, what must justify public utility regulation is the necessity for the regulation, not the necessity of the services. Even with scale economies, a market with free entry need not have regulation to attain competitive pricing. The mere threat of rapid and substantial entry by potential competitors may do the job quite nicely.

Regulation is almost universally regarded as a questionable substitute for competition under conditions of a natural monopoly and is a poor substitute indeed when an industry is naturally competitive. Regulation carries with it the potential for anti-competitive effects even when there is a true natural monopoly. Many economists share this view, well stated by Clair Wilcox, who in 1966 wrote, "Regulation, at best, is a pallid substitute for competition. It cannot prescribe quality, force efficiency, or require innovation, because such action would invade the sphere of management. Competition does so, and the high-cost company is compelled to discover means whereby its costs can be reduced. Regulation fails to encourage performance in the public interest by offering rewards and penalties. Competition offers both."

What economists prefer and what generally promotes public policy interests is the replacement of effective regulation with effective competition. Effective competition puts strong pressures on firms to perform well by minimizing costs, holding prices to marginal costs, and by innovating rapidly in order to survive. But as technological conditions change to permit deregulation and the condition of effective competition, there are always public policy concerns that it may never actually take place if deregulation is allowed to occur. Even though the technology exists for effective competition, without proper controls, former monopoly firms may now be free to perpetuate their dominance without any constraint at all. As someone once said, regulation is like growing old, we would rather not do it, but consider the alternative.

With that in mind, do not expect totally unfettered competition in this country. In order to alleviate the possibility of neither effective regulation nor effective competition, you may well expect to see an ultimate industry structure whereby the electric grid is separated, heavily regulated, treated as a natural monopoly, and paid a largely fixed lease fee with incentives for good performance. A second natural monopoly would continue to exist as separate regional central dispatch, pooling, and economy trading processes. The pool company would, in effect, be an agent for the system users and decide how best to raise the required money to pay the grid co. They would do that through energy traders using basic market concepts to minimize the cost of meeting dispersed demand with dispersed production and determining when and how to expand the grid.

You then have generation companies and retail companies competing for the customers business. All with equal access to required natural monopoly services who would not have any vested or conflicting interests that come from having a private property interest in the outcome.

While there is considerable debate over whether all or any of this is needed from an economic efficiency standpoint, a new argument as to the benefits of retaining franchise utilities is now emerging and that is that the regulatory assurance of cost recovery affords utilities greater freedom to adopt new technologies, to innovate, and to lead in the implementation of other worthwhile endeavors like energy efficiency or global warming initiatives.

When this assertion is made by those outside the industry (and it has been), it creates a thoughtful discussion of the trade-offs and alternatives. When it is repeated by those in the industry, it sounds more like the child who kills his parents and then begs for mercy because he is an orphan. This is not an industry that voluntarily embraced either one of these initiatives or many others for that matter until long after the handwriting was on the wall.

You have to remember, this is an industry that argued wholesale wheeling could not/should not be done. And now says it is a matter of price, the higher of embedded or replacement. And has a large contingent promoting loop flow compensation at embedded cost, ignoring the fact that (1) your path was not chosen because your embedded price was higher than your neighbors, and (2) loop flows generally occur because your facilities are less utilized than your neighbors and to most people, underutilized capacity means you discount not raise your price. And, in any event, loop flow compensation at these prices will likely end many of the perfectly economic transactions we see today.

How credible will we be if we are seen promoting this as the outcome? Do we reasonably expect that we can use transmission pricing to thwart the purpose of the Energy Policy Act? And doesn't this type of debate and logic just help assure that we will ultimately be required to spin-off the grid co. and the dispatch and pooling process as separate companies.

This is industry that said SO_2 legislation was not needed and would raise rates 15 to 25 percent. After the bill was passed, very few utilities did not half their cost estimate and some (who previously said no harm to the environment) actually reversed their position and said they would not purchase allowances because they wanted to personally reduce SO_2 to protect the environment. Instead, they built rate base in the form of scrubbers.

It is an industry that says all the right things about global warming, signs up for the President's voluntary reduction program and in stark contrast to the priorities of foreign utilities, just weeks later a survey of the CEO's indicates an overwhelming majority ranked global warming near the bottom of their priorities, indicating it was not in the public interest. How does the industry argue before the U.S. Senate that competition is BAD because it will thwart our voluntary efforts to comply with global warming initiatives when the majority openly admits they do not even think global warming initiatives make sense, and it is not one of our priorities anyway.

It is an industry that took the position in the early 1980's that it would not build capacity anymore because the returns were too low and, when Independent Power Producers (IPPs) said they would and Congress moved to allow that to happen, the industry fought to maintain its monopoly position in the market, and keep others from accepting a role we appeared to not want just a few years earlier.

This is an industry that is currently arguing that retail wheeling is bad, but just the threat has prompted hundreds of millions of dollars of cost cuts. How do you convince a customer that that would have happened anyway or that there is not more to come as pressure is increased? If competition is not needed, why is it after years of arguing for 20 to 25 percent reserves, many are now announcing numbers as low as 6 percent. How is it that experiments with retail wheeling in other countries have not turned up the massive problems envisioned here?

It is an industry that argues to its customers "I had a deal" with regard to my past investment. I believed that you would be here, and it is unfair for you to leave and burden others with the stranded costs. But has little sympathy when the customer counters that "unfairness" to him is when his competitor just down the road is charged prices less than half what he pays—that he never signed up for that deal.

One utility is trying to charge a 165-MW customer an exit fee of $235 million for stranded investment (costs presumably left behind if the customer leaves). Doesn't the size of that number alone make it obvious why the customer wants to leave? How long will regulators listen to stranded investment arguments if that is the size of numbers we are going to put on the table? Is it credible to argue that you reasonably believed that customer would remain regardless of price? In the June 1 issue of Public Utility Fortnightly, 11 of 17 CEO's surveyed said the determining factor on who should pay for stranded investment is the "regulatory compact." In other words—it is the customer—plain and simple. "I have a deal" with regulators.

It is an industry that says all the right things about customer satisfaction and shows incredible numbers in this area, but understands very little about customer loyalty. And routinely finds itself in the fourth and last phase of the account death cycle, that is, lawsuits or litigation with its own customers. When a retail wheeling bill was recently proposed in Ohio, one utility immediately announced it was just another attempt of the large industrial user to take advantage of the poor residential consumer. Does this attitude create customer loyalty?

Why is it that when power outages occurred in the PJM pool in January, the industry was so surprised when a myriad of investigations were launched to determine what happened? Was it price or capability or what? When we routinely deliver the highest reliability levels in the world, why is it no one seems to trust us? And why was it that in the crisis, we discovered the transfer capability of one line in particular, was almost three times what we had previously said was possible?

For all the talk of wanting to be more competitive to cut costs, why do the majority of the CEO's still indicate in surveys that mergers are BAD—not in the public interest—when there is strong evidence as to benefits to customers and shareholders? How open minded do we appear to the outside world when it really comes down to it?

At the same time, there is little question that the industry has legitimate arguments on many issues related to past promises or a less-than-level playing field. There is no question utilities have been used as everything from a revenue collector for state Government to a vehicle to levy social costs on customers to facilitate public policy objectives. For example, you have seven states who assign externality values to resource choices.

More broadly, we are expected to invest hundreds of millions of dollars in demand side management equipment to be put in customer homes or businesses without any security they will even be our customer in the years ahead. The playing field is not level, and there are legitimate positions regarding the fairness of allowing third parties (who do not bear these types of costs) to cherrypick the system or allowing large industrials (for example) to escape with lower costs after the utility built facilities, legitimately and reasonably, expecting the customer to be there, leaving potentially billions of dollars in stranded investment to be borne by shareholders or other less elastic customers. The question is, given positions the industry has taken in the past on issues, the hard-line positions they are likely to take on these issues in the future, and the relationship we have established with customers and regulators, will anybody listen to any legitimate argument? Have we earned a seat at the bargaining table?

Meanwhile on Wall Street, in the last 6 months, we have seen stories by all the major business magazines signalling the dangers to the industry from competition. Typical of this was a story that appeared in Business Week on January 10 that quoted Vice President of Airco Gas & Gear plant in Joliet, Illinois, who pays twice as much per kilowatt-hour in Illinois as in Indiana, as wanting to import cheap Indiana power to Joliet. "Competition works in every other industry," he says "Why not electricity?"

At the same time, there seems to have been some sudden concern in the industry over what all this talk means and a sudden recognition that these changes are occurring not because rating agencies, Wall Street analysts, or even because renegade CEO's like PSI's Jim Rogers are predicting them, but because we are part of a global economy, and we have a regulatory system in this country that has produced industrial rates that vary from 3.0 to over 10¢ per kWh across the country, with self generation now below 4¢. Customers want choices and they want low cost. And they believe that a system that relies on market forces and competition (the same thing that has made them more efficient) will produce better results in the electric sector. As the Albuquerque city counselor said, "No other business in the world mismanages itself and then forces its customers to buy their product at exorbitant prices."

Every week, some business magazine is warning investors that the party is over for utility stocks. While the industry has outperformed the S&P 500 over the last 5 years, the fundamentals paint a very different picture. Book value has increased less than 1 percent per year. Earnings growth was negative from 1988 through 1992, up 11 percent in 93 due primarily to refinancing and extreme weather. Authorized ROE's by regulators have declined 9 of the last 10 years. Credit quality has continued its 20-year decline.

And dividend payout ratios are setting new records. And many would say poor fundamentals are the least of our problems. In the last 8 months or so, we have seen major announcements or papers written by all the rating agencies (in particular S&P) outlining the increased risks of competition and what that will mean to credit ratings. S&P now has over half the industry on negative outlook.

At the industries financial conference last November, the focus was on the changing business structure and competition, leaving Doug Preiser of Kidder Peabody to question whether the industry was prepared strategically and financially to deal with the changes that are likely to occur since many continued to deny the problems existed, and no one seemed to have a clear vision of what the new industry would look like.

At the financial conference, the speakers reminded you a great deal of Woody Allen's "speech to the graduates" when he said, "more than any other time in history, mankind faces a crossroads. One path leads to despair and utter hopelessness. The other, to total extinction. Let us pray we have the wisdom to choose correctly." He goes on to say that with regard to the predicament of modern man that "it can be stated one of two ways, though certain linguistic philosophers prefer to reduce it to a mathematical equation where it can be easily solved and even carried around in a wallet."

The point of this is that just as Woody Allen factiously wrote about modern man, there is a growing perception on Wall Street that our predicament in the electric utility is to choose between paths of hopelessness or extinction. And a growing concern that we believe the uncertainties and risks facing the industry can be reduced to a mathematical equation and then easily solved. And those that have seen competition develop in other regulated industries clearly realize it is not that simple. There is no black and white. There are no absolute answers. And those that seek such clarity before making decisions are doomed to spend eternity buried at the starting gate.

Most of the sell-side analysts are developing models to separate the winners from losers in a more competitive environment. Barry Abramson of Prudential recently concluded in his research report that there are no winners and losers from increased competition, only big losers and small losers, leading others to question why those in the industry who are promoting competition would engage in a kind of fratricide/suicide game.

The fact is competition is inevitable. The fact also is that two-thirds of the CEO's in the industry believe not just competition is inevitable, but retail wheeling is inevitable. As a result, in the words of Sandy Cohen's at Morgan Stanley, "the future is going to require a unique blend of communication, political, cost management, and operation skills combined with a clear, consistent focused strategy and an attitude of not only acceptance, but encouragement of change."

Leading me to the premise that the greatest risk we may well be facing is neither poor fundamentals nor increased competition, but whether or not we have the management skills, capabilities, and attitudes to not just manage the change, but change ourselves. It is our belief that without making commitment to shape the outcome and making the necessary compromises to be a part of the solution, we will end up with a porous monopoly franchise without any lessening of the obligation to serve and pricing at the lower of cost or market. That is what investors should see as the worst of all worlds— regulated competition. That may not be the path to extinction, but in our mind, it is damn close to utter despair. Asked to play the same game with two different sets of rules, increased competition and increased regulation.

We all need to understand that even with all the competitive pressures, (the injection of market forces) regulation is not fading, it is evolving. Regulators are no longer just in the business of trying to keep rates just and reasonable. They are playing a legitimate role of using their powers to prompt specific changes in utility behavior to facilitate broader public policy objectives. The regulator is still the 800-pound gorilla. And if you choose to wrestle the gorilla, you need to remember the old adage that the game is over when the gorilla gets tired, not when you do.

While it may be easier to appreciate why customers would not mind seeing a little cutthroat competition and short-term prices that could, as some have hypothesized, drop to 2 to 3¢ per kWh, or why intellectual economists who have never worked a day in the real-world of business would push to test their "theories" on how monopolies destroy consumer surplus through a real-world laboratory experiment in the mother of all monopolies, why should policymakers be so quick to want to fix what is not broken, particularly, at the potential risk to the financial health of the industry or to programs like energy efficiency and global warming initiatives?

For policymakers, there is a continual search for how to create a competitive advantage for your nation and your nation's people so that they prosper and continue to enjoy a rising standard of living. While there are not too many issues economists can not debate either side of, virtually all agree that society's wealth is determined by its supply of physical resources. That means that life is a zero sum game, one person's gain is another's loss. Over the centuries, this view has been responsible for numerous wars, revolutions, and Government policies.

As evidence of this, let us recall the enormously influential 1972 study, The Limits to Growth. This was a study performed by the Club of Rome—a collection of distinguished scientists, economists, and sociologists from 25 countries. Using the most sophisticated computer modeling available, the experts predicted that with the world's population growing at about 2 percent per year, the world's physical resource would be exhausted in the next few decades, with humanity wiped out by 2100. The study was widely accepted almost without question and, in fact, events of the next few years--soaring energy prices, shortages of energy, brownouts, and long lines at gasoline pumps--seemed to reinforce the premise.

But as we sit here today, the world did not come to an end. In fact, our effective supply of resources is greater today than it was then and is increasing. We have probably twice the oil resources that were estimated in 1973, three times the natural gas reserves, and prices reflect that abundance. In fact, the U.S. Office of Technology Assessment concluded that America's future has probably never been less constrained by the cost of natural resources.

All of this is true today because of technology. While society's wealth is still a function of our physical resources, we now recognize that technology controls the definition and the supply of those resources. Technology determines our supply of physical resources by fixing the efficiency with which we use those resources and our ability to find, obtain, distribute, and store them.

What makes resources valuable are their usefulness. And again technology gains that enhance either supply (like improved drilling or mining techniques) or demand (like fuel injection carburetors or high efficiency furnaces) increase the effective supply and the usefulness of our world's resources.

Peter Drucker once called John Maynard Keynes the legitimate heir and the liquidator of Adam Smith, but what we have learned over the years is that contrary to Keynes' predictions that increasing affluence stifles demand, in fact, we now know that people's needs are not absolute, but defined by technology. What people want is a function of what is available.

We increasingly have an economy made better off by demand-driven innovations. That is, imagine a need beyond the physiological limits and rely upon technology to satisfy it. Often used examples of this include President Roosevelt's ordering of a nuclear device that many experts doubted would ever be feasible, or President Kennedy's commitment to put man on the moon by the end of the 1960's, or to a lesser extent President Carter's declaration of the energy crisis during the 1970's as the moral equivalent of war.

The point is, we now accept the general premise that anything is possible and that technology is the great lever that can, in fact, move the world. Technology has given firms and nations the power to circumvent scarce factors via new products and new processes. It has nullified the importance of certain perceived constraints that once loomed large, such as those identified in The Limits to Growth study that predicted the end to mankind, and at the same time it has produced great wealth and power for its creators. And it has changed the standard of living forever for much of the world.

Relatedly, it is widely accepted that trade among nations is based, in part, on differing labor productivity in producing particular goods due again, in part, to technology differences. The technology gap theory says nations will export in industries in which firms lead in technology and then exports inevitably fall as the gap closes over time.

But even if we can all agree that technology development is the key to a nation's wealth and its competitive advantage, these theories still leave unanswered the questions as to why a productivity gap or technology difference emerges in the first place. Michael Porter in his work, *The Competitive Advantage of Nations*, seeks to answer this question--why some nations succeed and others fail in international competition. It is one of the most frequently asked economic questions of our time and is one of the central preoccupations of Government and industry in every nation.

No nation's pool of resources is unlimited, and the ideal is that they be deployed in the most productive uses possible. What Mr. Porter explores is the way a firm's proximate environment shapes its competitive success over time or why some organizations prosper and others fail. This is not the superficial bathroom reading material that popular business authors often turn out. This is based upon exhaustive scientific research which makes it more complex and technical than most people have the time or inclination to get through. To some, it's conclusions are controversial. To others, it stands alone as the most robust holistic theory explaining the creation of competitive advantage.

Porter's research clearly shows that companies with the same national home base appear to thrive, prosper, and dominate specific industry competition internationally. They do this in a way that is not explained by comparative factors of production—like rich endowments of natural resources, for example. In fact, many resource poor nations have been among the most successful trading nations.

And wage rates do not explain these differences either. Why is Germany, for example, home base for so many of the world leaders in making printing presses, luxury cars, or chemicals? Why does Sweden lead in heavy trucks and mining equipment? Why do the Japanese dominate consumers electronics or robotics?

The globalization of industries and the internationalization of companies would tempt one to conclude that this is a thing of the past, that the nation has lost its role in the international success of its firms, that companies have transcended countries. But in fact, Mr. Porter's work concludes that the role of the home nation seems to be as strong as or stronger than ever before.

The home base is where the essential competitive advantages are created. It is where the firms' strategy is set and the core process technologies are maintained. It will be the location of many of the most productive jobs and most advanced skills.

A key determinant of success in any industry was found to be strong competition on the domestic level, i.e., large numbers of strong domestic competitors. For example, the Japanese have 112 domestic rivals in machine tools and 34 in semi-conductors.

Another key determinant was found to be the existence of sophisticated, demanding domestic buyers. Buyers that constantly pressure suppliers to innovate and again, while the global theory of competition is intuitively appealing and certainly has some truth, the study reveals that physical and cultural proximity to these sophisticated buyers helps anticipate and satisfy their needs and creates an international competitive advantage.

In addition, early large home demand leads to scale economics in production and in learning. It leads to similar competitive advantages in related industries and it creates localized spin-offs and start-ups by former employees who create technological breakthroughs on their own. The silicon valleys, for example.

Toughened by domestic rivalry, firms are better able to compete abroad. Porter found that it is rare that companies succeed internationally in an industry without strong domestic competition. Domestic rivalry forces a nation's firms to seek higher order and ultimately more sustainable sources of competitive advantage. Domestic rivalry keeps each other honest in seeking Government support or Government protection which tends to slow the rate of change or product innovation.

Direct cooperation among competitors, an approach sometimes advocated as a means of avoiding duplication or achieving economics of scale, undermines competitive advantage by sapping incentives and eliminating diversity. Dr. Porter's theory emphasizes that market pressure and competition create innovation and technological advantages that can overcome inherent factor cost advantages.

Mr. Porter's work takes a very dim view of short-term investor's pressures to cut costs in lieu of making technological investments or upgrades, of financial stewards harvesting cash from entities for unrelated diversification efforts, of public policies or business structures that reduce the cost of failing to innovate or financially discourages technological advances because it makes obsolete the current fixed investment, and of horizontal mergers that reduce domestic rivalry. He views loss of domestic rivalry as a dry rot that slows the pace of innovation.

It is survival of the fittest, evolutionary biology, and what economist Joseph Sumpter called the constant creative destruction of capital, that is, the positive displacement of older obsolete capital equipment.

As to Government's role in all this, Mr. Porter believes Government should focus on education, setting high standards and assuring teaching is a prestigious and valued profession, and set policies that encourage research, including Government laboratories that focus on innovation and not just science and technology, with substantial dollar commitments to research universities.

The Government should stimulate commercial innovation by public policies directed toward domestic competition with strong antitrust regulation. The "national champion theory" fails the test of logic and history. Competition is neither wasteful nor excessive, but the essence of national competitive advantage.

Government as a buyer, should set stringent product specifications (particularly in anticipating standards that will spread internationally) and create an early demand for advanced products.

Suffice it to say deregulation of monopoly services or privatization of Government services are seen by Mr. Porter as obvious areas for immediate spurs to national advantage.

The electric utility industry fairs very badly under Michael Porter's theory. We have sophisticated technologies and suppliers that can not get to market. We have demanding, sophisticated customers who compete in world markets, but we have a system that basically ignores their needs. We had a case last week where service to a group of industrial customers of another utility was being interrupted under their tariff. They called PSI directly to buy power. We agreed to sell it to them for a price they accepted. The host utility, when contacted by the customer, refused to buy from us as opposed to interrupting the customer because under the tariff they had the right to curtail service. We actually did make an off-system sale last week to another out-of-state utility because customers who had been interrupted called us on their own to find power that was available.

Electricity is a service related to almost any product or service we hope to sell in world markets, but we have a system that has provided almost no rewards to encourage the utilities to be aggressive, to innovate or take risks, or if this example is any indication of how we routinely do business, penalties for failing to do so.

In the June 1 issue of Public Utility Fortnightly, Dr. Charles Studness, a respected researcher on electric utilities, wrote in response to consumer concerns that competition in the industry will thwart energy efficiency gains, "the progress of energy efficiency under the command-and-control process of regulation has been dismal. The heat rate of the electric utility industry is virtually the same now as it was during the energy crisis 20 years ago. Meanwhile, energy efficiency in the economy has risen 37 percent. Replacement of current generating facilities with new plant could reduce the energy used in electric generation by over 25 percent and the nation's overall energy consumption by 11 percent. However, these potential gains will not be realized unless there is strong incentive to replace obsolete plant. That incentive can be expected to develop under competition, but is unlikely to emerge under regulation. After all, regulation has done little to promote utility heat efficiency in the past, and is now leading utilities in the opposite direction."

As we speak, Norway, Chile, Argentina, and the United Kingdom have all moved to more rational regulatory schemes for electric service. Schemes that more closely resemble Michael Porter's prescription for achieving competitive advantage. Schemes that will likely mean greater rewards for innovation, greater imperative for technological change, greater pressures to improve—to be better, faster, or cheaper. Systems that will force electric utilities to be more demanding customers to <u>their</u> suppliers and more attentive suppliers to <u>their</u> customers. And as the rest of the world innovates, not only will the electric utility industry in this country lose competitive advantage, but (if you believe Michael Porter's theory on <u>home</u> base advantage) so will U.S. domestic <u>suppliers</u> to the industry and so will our <u>customers</u>.

Economists speak of the technology gap, the difference between the best production practice possible with current knowledge and the practice in actual use. How well a society does at closing that gap goes a long way to explain its national competitive advantages. But what is just as critical is the multiplier effect of technology. As all of you know, every new technological breakthrough or successful application is a link in a continuing chain of innovation. They are building blocks for tomorrow's successes.

Technology determines the value of our physical resources whether we are imagining superconductivity, super efficient batteries, cold fusion, or even the clean coal technology that DESTEC and the DOE are bringing to the Wabash River Station at PSI. The new world order is knowledge and technology based. A nation's wealth, its standard of living, the value of its physical resources are determined by its <u>technological</u> progress, its ability and willingness to invest in new technologies, to replace obsolete ways of doing business, and to constantly innovate.

The regulatory and business structure in this country for the electric utility industry, creates by nature, <u>stewards</u> of the existing assets. The desire to preserve and protect entrenched positions, to live off existing value and wealth instead of making new contributions. And, as I previously indicated, it has resulted in dismal financial fundaments for the industry—no earnings growth in 5 years and 80 percent of earnings.

But maybe more importantly, large industrial customers do not like the deal they have gotten, they do not like how they are treated, and regulators are under pressure to address these concerns. The industry has no choice but to change for its own self-preservation (if nothing else). But sometimes we are our own worst enemy.

We need to begin to back up the talk about wanting to be more competitive with more actions. We need to get the base case that we compare alternative scenarios to right, and for most, it is not full recovery of everything I have invested on the sole basis "I have a deal."

We need to start thinking about sunk costs and market forces, and we need to start thinking longer-term than today. And, quit declaring war on our own customers. It is a war you can not possibly win.

Peter Drucker says one of the five deadly sins is slaughtering tomorrow's opportunity on the altar of yesterday. Or as a more popular philosopher 40-year-old rock and roller, Meat Loaf, sings as he reflects on a simpler period of his youth that "Objects in the rear view mirror may appear closer than they are." And that regulatory compact train, that we missed during the last building cycle, and that some are still looking to ride on again, left the station a long time ago and it is not coming back.

And as someone once observed, an indication of insanity is doing the same thing over and over again, but expecting different results.

Our fear is that this is an industry headed down a path of tragic proportions. It is tragic because few industries in the nation have the competitive advantage the electric industry does over the rest of the world. We have as fine an infrastructure as exists in the entire world and we enjoy a substantial positive technology gap created by the fact that we have sophisticated suppliers and customers right at our door step.

And somewhere in the debate we have forgotten that and gotten lost in the forest. At times, seems as much a part of the problem as we are the solution. And, we have far more to offer.

What policymakers are looking for is not intellectually appealing philosophies that sound like they could have been conceived by old world philosophers, Hegal or Kant—pompous and pedantic, and with every statement qualified. They want industry that sounds more like American William James who made philosophy relevant by abandoning the search for the absolute in favor of a "Will it cut down trees?" approach to ideas, the belief that truth is tantamount to effectiveness and that philosophy should stick to answering questions that have "cash value," i.e., will make a significant difference in people's lives.

As electricity is an essential service—if your philosophy does not make people's lives better (and there are clearly trade-offs and conflicts), you are destined to be on the losing end (or at least left out of) the debate. And, technical reasons why something can not or should not be done just does not ring true from an industry that has proven time and time again when push comes to shove, we can always come up with a way to get it done.

This is an industry that needs to get on with life—to plan for the future instead of reminiscing about the past. We need to get past the feeling that suggesting change is tantamount to disloyalty. We need to deal with endings, with the potential mortality of the industry, and move on to create a compelling vision for the industry consistent with the new realities.

While Martin Luther King rallied people with "I have a dream," we have offered very little beyond the rhetoric of the constant "I have a deal." William James once observed that as human beings, we typically lead lives inferior to ourselves. That we are capable of so much more. Maybe no industry is more guilty of that than ours.

In his movie *Love & Death*, Woody Allen says about life that "The important thing is not to be bitter. You know if it turns out there is a God, I do not think He is evil. I think the worst that you can say about him is that, basically, he is an underachiever." And at the end of the day, I hope that is the worst you can say the regulatory system and business structure we have built over the last 75 years. It is not inherently evil, but it does produce, basically, underachievers.

In the end, the real reward for all of us comes from doing the right thing. being a business with a conscience, and finding a balance that satisfies the ambitions of the powerful (like our large institutional shareholders or our large industrial customers) without sacrificing the dreams of others and the rights of future generations to inherit a planet still capable of supporting life as we know it without the limits to growth some once predicted.

The industry is truly facing some potentially difficult times and difficult problems. As an industry, we need to get off this endless search for the absolute truth, whether it is global warming, transmission loop flows or retail wheeling, and develop a vision consistent with public policy issues and become a part of the solution.

As a last thought, you should consider that this is an industry increasingly populated by those coming from competitive environments. Like many of you out there today, they are risk takers. While they do not always understand the risks they may be taking, when you walk in a regulated world with multiple competing public policy interests, nonetheless they play not "to survive" but "to win."

They are analogous to professional card players, and I once heard a professional card player brag he could clean out any local game without ever looking at his cards. All he needed to do was observe how the "amateurs" played their hands. Because competition is externally focused, it is game theory. It is about knowing the difference between bluffing and believing. And most people are not very good or experienced at that.

You should all recall the scene in the movie where Butch Cassidy and the Sundance Kid are trapped on side of a mountain, 100 feet above a raging river on the one side, and a posse of sharp shooters on the other. In seconds, Sundance, the best fighter who ever held a gun, made the decision to jump into the river. Butch who could not swim, (and later admitted he had never actually shot anybody) at first chose to fight it out alone while clinging to the side of the mountain, but eventually chose to jump also.

That is what will happen in our industry. Surrounded by competitive pressures on the one side and the potential world of regulated competition or lower of cost or market prices on the other, the experienced fighters will instantly choose to seize control of their destiny, to voluntarily jump into the competitive world—recognizing they may be killed by the fall or drown in the river. But, preferring that to a certain future of a long, slow death clinging to the side of the mountain until you run out of bullets and food while the vultures circle overhead.

For those that do not believe policymakers have the votes to create full-scale competition, the question is how long anybody will be able to remain on the side of that mountain once others voluntarily start down the path of retail competition.

And I firmly believe while there may be some lean times for the industry in the near term and some unpleasant trade-offs in our future, that change is in our long-term best economic interest. The future is one of investment and technological innovation. Long-term competitive advantage emerges from pressure, challenge and adversity, rarely from the easy life.

And I would even go as far to say we have an almost moral obligation to future generations to change how we do business today. For throughout history, there may not be two more underestimated forces than the power of competition and the ability of technological change to exceed our expectations and even our imaginations. The challenge is there. We have only to accept it.

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Session 2

Changes in the Market and Technology Drivers

2.1 Overview of Global Utility Market for Advanced Coal Fired Systems

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__Abstract__

Coal reserves represent the major fossil energy storehouse of the earth. The most important current use for coal in the economically developed nations (OECD) is for electricity production. Increased production of electricity throughout the world is anticipated as the standard of living of developing nations approaches that of OECD nations. Coal is most likely to be the fuel for this additional production since it is widely distributed and will remain lower in cost than competitive fuels.

There are many technologies which can be used for the conversion of coal to electricity. Almost all current coal fueled electricity production is based on conventional combustion to produce high temperature, high pressure steam which is passed through expansion turbines which drive generators. Newer technologies based on atmospheric (AFBC) and pressurized fluidized bed combustion (PFBC) and gasification (IGCC) are beginning to penetrate the power generation market. The incentives for these technologies are the ability to use low quality fuel (AFBC), to achieve higher efficiencies (PFBC, IGCC) and to minimize all types of effluents and waste products (IGCC). Demonstrations of improved variations of these technologies are planned under the Department of Energy's (DOE) Clean Coal Technology program and by other organizations around the world.

This paper will discuss some of the criteria that must be considered by those responsible for selecting a coal fueled generating technology for a new power plant. These includes technology cost, maturity, environmentally detrimental emissions, waste products, supplier guarantees and subsidization. While the market for new coal fired power plants is likely to be very large during the next twenty to thirty years, it is impossible at this time to identify a clearly dominant technology parameter for selection. Both existing and advanced technology will share the market. Successful demonstrations, significant cost reductions, and new business approaches are required for advanced technology to capture a significant share of this market.

INTRODUCTION

Over the past 25 years the share of primary energy provided by electricity has steadily increased in the OECD countries even as the energy usage per unit of Gross National Product (GNP) has declined. This can be attributed to the increased use of more efficient industrial processes, automobiles, and power generation technology. There is also a strong positive correlation of electrical usage per capita with the GNP per capita. As the developing nations of the World seek to expand their economies, increased and efficient use of electric power is the key to achievement of this goal.

The fears of imminent exhaustion of fossil energy resources that were widely held 20 years ago now appear, at least for the moment, to be of little concern. Oil and gas continue to experience a reasonably constant ratio of annual production to reserves. Coal continues its long-held position as the world's most widely available fossil energy source with reserves available for several hundred years' consumption.

Although a significant expansion of natural gas use for electricity production is forecast for most OECD countries, regional imbalances between supply and demand are increasing and the need to transport gas over ever longer distances will raise costs. Despite the recent loss of some markets to gas, coal is expected to maintain its basic position as the mainstay of OECD power generation.

However, the main growth of electricity demand will be in the emerging economies. It is expected that about two thirds of the additional power generation capacity will be in those nations, most of it concentrated in China, India and the Pacific Rim. Projections by EIA are that coal usage in these regions will probably double in the next 30 years. In order to minimize the environmental impact, the adoption of the newer "clean coal technologies" assumes greater importance. In the near term time frame and in the emerging economies capital will be scarce and the tendency will be to adopt the lowest initial capital cost technology available. Technology transfer to these countries is probably best focused on the current state-of-the-art direct coal fired plant emissions control technology and the establishment of an infrastructure in these countries to supply equipment components, parts and services. As the new clean coal technology projects, based on Integrated Coal Gasification Combined Cycle (IGCC) Pressurized Fluidized Combustion (PFBC), complete their demonstration periods at commercial size over the next few years, wider deployment of advanced coal technology will begin. The most likely market segments for each technology are summarized in Table 1

Fuel Supplies

Coal constitutes the world's largest available supply of fossil energy. Reserves total about 300,000 Q (quadrillion BTU's of energy; 1500 billion tons) compared with 6000 Q (1000 billion barrels) of oil and 4000 Q (4000 trillion cubic feet) of natural gas. These reserve estimates represent an averaged view of the estimates of information that is available in the literature. The definition of reserves is also not precise but is usually accepted as the amount that can be extracted from the earth under present and expected local economic conditions with existing available technology. In 1990, the world consumed 136 Q of oil, 74 Q of natural gas and 93 Q of coal along with 21 Q of hydroelectric power and 20 Q of nuclear power.

These reserve and consumption figures indicate that the supply of fossil fuel in total could supply the needs of today's world population for hundreds of years. However the world's population continues to increase. The world's highly industrialized countries use far more energy per capita than the less developed countries. For example, in 1989 the United States used about 312, West Germany about 172, Japan about 130 and China about 23 million Btu per capita. The Energy Intensity of industrialized societies, which annually represents the ratio of the amount of energy consumed to the value of the goods produced, has historically risen during the early stages of their industrialization and then fallen. Most industrialized societies utilize an Energy Intensity of 0.3 - 0.4 metric tons of petroleum per $1000 of Gross Domestic Product. Improvements in efficiency of both the energy production and consumption processes drive these changes. As societies begin to industrialize they first use scarce capital resources to maximize the yield of products rather than to maximize fuel efficiency. As the level of technical sophistication increases, mechanical power is replaced by electricity which leads to more efficient means of production. The ratio of electrical energy to total energy consumed is an excellent measure of technical sophistication of a society. In the U.S. for example, this ratio has been increasing as the total energy required per unit of GNP has decreased. As a result of these offsetting trends - more efficient industrialized societies reducing their Energy Intensity and developing countries increasing theirs -- it is difficult to calculate the energy needs of the world's future population. It is clear though that for the near term, fossil fuel consumption will increase as the world's population and its standard of living increase simultaneously.

While at least for the near-term, the world supply of fossil fuels is adequate, the distribution of these fuels is very uneven. In 1990 the United States, China, and the USSR produced and consumed almost 50% of the world's energy.

In 1990 the United States consumed about 17.0 million barrels/day (MB/day) of petroleum or about 26% of the world's consumption, but produced only 9.0 MB/day (including 1.6 MB/day of natural gas liquids). The U.S. accounted for 12% of the world's production of petroleum in 1989 from only 3% of the world's reserves,. More than 80% of the world's oil reserves are contained in only eight countries, Saudi Arabia, Iraq, United Arab Emirates, Kuwait, Iran, Venezuela, USSR and Mexico. About 65% of the total is found in the Middle East.

Natural gas reserves are also narrowly distributed among the world's nations. About 37% is in the former USSR and 32% in the Middle East. Algeria, Venezuela, Canada, Indonesia, and Norway account for about 15%. The U.S. holds only about 4% of the world's reserves. The balance of the reserves are distributed throughout the world. Coal reserves, which by far represent most of the world's fossil fuel reserves, are concentrated in the U.S., the former USSR, and China with other significant reserves in Australia Germany, South Africa, India, Poland, Hungary and Columbia.

Technology Status - Current State Of The Art For Direct Coal Firing And Flue Gas Desulfurization (FGD)

The main competition for advanced clean coal technology particularly in Europe and Japan, are the direct pulverized coal supercritical units with FGD fueled with readily available, low sulfur, high ash fusion coals from Australia, Colombia, South Africa etc. and which incorporate low cost once through ocean cooling. These coals and cooling methods are particularly advantageous for technologies based on the Rankine steam cycle and are of lesser benefit to Brayton (i.e. gas turbine) cycles. Papers by ELSAMPROJEKT describe such plants in Denmark with efficiencies of 45-47% Lower Heating Value (LHV) basis. Conversion to U.S. conditions of 2.5 inches Hg condenser back pressure lowers the range to 42-4% LHV in line with the latest EPRI estimates.

Several technologies are available for reducing emissions of sulfur and nitrogen oxides and particulate matter from direct coal-fired power plants that are generally classified as:

- <u>Pre Combustion</u>— where sulfur and other impurities are removed from the fuel before it is burned.
- <u>Combustion</u> - where techniques to prevent pollutant emissions are applied at the boiler.
- <u>Post Combustion</u>—where the boiler flue gas is treated to reduce pollutants.

Current information for SO_X and NO_X control technologies are summarized in Tables 2 and 3. The mature status of these technologies make them formidable competitors with emerging IGCC and PFBC technologies.

Advanced Clean Coal Technologies

Currently about 56% of U.S. power is generated from coal, but increasingly stringent emission regulations are being enacted for coal-based power stations. The U.S. Department of Energy's (DOE) Clean Coal Technology (CCT) program of demonstration projects is being conducted in response to this urgent need for the commercial development of technologies which can provide confidence for the continued use of coal for power generation and to maintain the use of valuable existing generating sites and equipment. The demonstration projects noted in this paper cover both Integrated Gasification Combines Cycle (IGCC) and Pressurized Fluidized Bed Combustion (PFBC) technology. If operated successfully, these plants (and those in Europe, and Japan) should provide the basis for deployment of commercial plants about the year 2000.

However, the current coal technology of direct firing with flue gas desulfurization has also continued to improve and for low sulfur coals and at sites with sea water cooling its established history and low capital costs are at this point still quite competitive. Nevertheless, gasification, gas clean-up, PFBC, gas turbines and fuel cells are all technologies which have significant improvement and growth potential. In addition gas turbines can be designed to handle both natural gas and coal derived syngas. Gasification, if developed as planned, can provide the technology to ensure the continued operation of the considerable investment in gas turbine combined cycles in the event that natural gas is no longer economically available and thereby provide a smooth transition to coal use. This "Phased Construction" approach can also be applied to the "Repowering" of valuable existing sites and equipment.

Obtaining operating permits for new sites is an increasingly lengthy and problematic procedure in many OECD countries. Therefore perhaps the most valuable existing resources of power generating companies are the ownership of, use permits for, and the precedent of operation at existing sites. If space is available the addition of new generation at existing sites is often easier and the "Repowering" or reuse of some of the existing site equipment and infrastructure can represent significant cost savings.

IGCC

The next most important event in the schedule for IGCC commercialization is the recently initiated operation of the highly integrated SEP 253 MW GCC plant in the Netherlands using the Shell Coal Gasification Technology and a Siemens-KWU V94.2 1100°C gas turbine. This has a design efficiency of about 43% (LHV basis) and is designed to meet stringent emission standards. Single train IGCC plants using 1260°C firing temperature gas turbines are being designed and constructed for demonstration in 1995-2000 both in the U.S. under the DOE CCT program and in Europe.

The results from these demonstration plants will provide the basis for commercial IGCC plants anticipated to be deployed in the 2000+ time frame. The IGCC technology will also benefit greatly from advances made in gas turbine technology from both the DOE ATS program and other manufacturers' improvements which are expected to lead 1370-1425°C gas turbines being available in this same time frame. It is anticipated that increases in output and efficiency with such turbines will provide substantial capital and operating cost reductions for IGCC.

Six U.S. IGCC projects have been selected under DOE's CCT program. Three of these projects are proceeding PSI/Destec, Tampa Electric (TECO), and Sierra Pacific. The other three (ABB, TAMCO and Duke) are currently seeking to secure power purchase agreements and new sites. Information about the major ongoing IGCC projects is summarized in Tables 4a and 4b.

Pressurized Fluid Bed Combustion (PFBC)

Recent EPRI engineering studies of PFBC systems have projected that the capital costs of 320 MW PFBC units using modern supercritical steam cycles will be lower than IGCC in many applications and at similar efficiencies of 40-43%. PFBC technology is particularly suitable for moderate- to low-sulfur coals where the additional costs of handling the limestone required for SO_2 control and its associated solid waste products are sufficiently low to not offset the capital cost advantage. The smaller physical size of PFBC units is expected to provide an advantage over direct PC fired boilers, particularly in certain repowering applications at space constrained existing sites. Also, the added increment of power in repowering applications is 25% - 30% for PFBC compared to 200% for gasification which may make PFBC repowering more suitable for sites constrained by transmission capacity or not needed large incremental power additions.

Five 80 MW first-generation PFBC bubbling bed units using ABB Carbon technology are operating today in Sweden (2 units), Spain (1 unit), the United States (1 unit) and Japan (1 unit). The next major step for commercialization of bubbling PFBC is to scale the technology to 340 MW. Several bubbling PFBC projects at the 80 MW scale and one at the 340 MW scale are planned in Japan. Two additional 80 MW scale projects are being developed in Europe.

Circulating PFBC technology, which promises lower capital and operating costs, better operating characteristics and further emissions improvements, is in the pilot scale of development. A 150 MW demonstration which utilizes Ahlstrom/Pyropower technology, is planned by Midwest Power in 1997. The two developers of circulating PFBC, Ahlstrom/Pyropower and Deutsche Babcock/LLB, use ceramic hot gas filtration in their systems which requires considerable development before it is able to achieve utility-required reliability levels.

Both bubbling and circulating PFBC should be commercially available from three to five manufacturers at the 300-400 MW scale by 2000.

Advanced PFBC

The integration of gasification with Pressurized Fluidized Bed Combustion (IGPFBC) has the potential to achieve high efficiency and a reduction in capital costs over IGCC albeit at some sacrifice in environmental performance with regard to solid waste. Partial gasification of the coal yields a char which is fed to the PFBC unit. Supercritical steam cycles can be used with PFBC to give substantial efficiency gain to the steam cycle and the combined effect of integrating this with the coal gas fired Brayton Cycle (i.e., gas turbine) results in high efficiency. As with PFBC this technology will find its preferred application using low to moderate sulfur coals.

In Europe Ahlstrom and Deutsche-Babcock have pilot plants exploring this configuration. British Coal's Topping Cycle is similar but plans to use an Atmospheric FBC rather than PFBC on the char from a spouted fluid bed partial gasifier.

In the U.S. Foster Wheeler has been testing this IGPFBC concept at their 2.5 MWTh pilot plant in Livingston, NJ. Under DOE, Southern Company Services and EPRI sponsorship, scale-up to a 15 MWTh pilot plant is planned for the Power Systems Development Facility (PSDF) to be located at Wilsonville, Alabama. A 90 MWe project based on this technology, proposed by Air Products for a Kentucky location was recently selected by DOE under the CCT program. It plans to start-up in 1998.

Integration Of Gasification With Other Advanced Cycles (IGAC)

Power plants based on the integration of gasification with advanced gas turbine cycles such as the Humid Air Turbine (IGHAT) offer the potential of significant cost savings over IGCC while maintaining the low emission and high efficiency characteristics. In IGCC plants expensive syngas coolers are used at the gasifier outlet to raise steam. However with humid air cycles, a lower cost quench gasification system can be used with the quench providing hot water for use in air humidification. IGHAT will also have better part load efficiency that IGCC.

The Integration of Gasification with Compressed Air Storage combined with Humidification (IGCASH) can provide a very competitive intermediate load plant with low emissions and flexible operating characteristics. The lower cost quench gasification systems can also advantageously be used in this application. The gasification system and gas turbine operate continuously 24 hours/day typically delivering power to the grid about 16 hours/day and using the power about 8 hours/day (during the night) to compress air into a storage cavern. During the day air is withdrawn from the cavern to supply the combustion air to the gas turbine. The addition of natural gas fired turbo-expanders to operate off the same compressed air storage cavern as the IGCASH, can also provide additional low cost peaking capability (the CASHING concept).

It is anticipated that major components of currently available gas turbines and other equipment can be combined to produce these advance cycles. EPRI is continuing to study these concepts but no actual demonstration projects have yet been put together.

Integration Of Gasification With Fuel Cells (IGFC)

Studies conducted by DOE, EPRI and others in Europe show that the integration of gasification with molten carbonate or solid oxide Fuel Cells (IGFC) offers the potential of power plants with the lowest emissions and highest efficiency (> 54% LHV basis) of any coal based technology yet defined. However, at the current state of development and under the current standard economic least cost of electricity criteria the capital cost is still estimated to be too high, and the current R&D effort is therefore primarily aimed at obtaining crucial exposure experience of fuel cells to coal derived gas and at IGFC cost reduction. Early in 1994, EPRI completed a test of a 30 kW Molten Carbonate Fuel Cell on a slipstream of the syngas at the Destec 160 MW GCC plant in Plaquemine, LA.

The major fuel cell project currently underway is the 2 MW natural gas fired Molten Carbonate Fuel Cell (MCFC) demonstration plant due to begin operation in Santa Clara, CA in early 1995. Additional important projects are aimed at reducing the cost for fuel cell module assembly, gas manifolding and Balance of Plant (BOP) for multiple stack arrangements.

The demonstration of the IGFC concept at the ~ 10 MW scale, operating on a slip stream of a larger IGCC plant will probably occur in the late 90's to be followed by demonstration of a stand alone IGFC plant in the first decade of the 21st century with subsequent commercialization beyond that time frame. In the longer term the integration of biomass gasification with fuel cells could be a very effective way of efficiently using the dispersed biomass resource.

Market Penetration of New Technology

Outside the United States the market for new coal fired power plants will be very large over the next several decades. It will be primarily driven by the rate of economic growth of the developing nations. Rough estimates of the size of the market are in the range of 20,000 to 40,000 MW per year through 2020. This is based on 1992 World Energy Council projections, which are summarized in Table 5, of increases in worldwide electricity production in that time period from 11,500 TWh in 1990 to 22,700 TWh in 2020 which can be converted into a total capacity increase of about 100,000 MW/year and an assumption that 20-40% would be coal fueled. The percentage growth in each of the markets in presented in Table 6. These estimates can be cross-checked against coal production estimates. EIA projected coal production increasing from 5100 to 6400 million short tons per year from 1991 to 2010. This would support an annual increase of about 25,000 MW of coal fired generation. EIA data on world wide coal consumption is summarized in Table 7.

Obviously these are only projections. They were developed from historical trend lines which involve population growth, Energy Intensity, GNP increase and a likely host of other factors. The key question is how will the responsible parties in each national(or local) situation decide on what their next power plant will be and what will it be fueled with?

The China Market

China is the key example that is focused on here to illustrate some of the challenges of bringing new technology to new markets. The market for new coal fired power plants in China will probably continue to be the largest in the world during the next two or three decades. China is the world's largest producer of coal. In 1990 production was 1.08 billion tons which equaled about 25% of world production. About 29% of this was used for power production which resulted in 75.6% of total generation. Generating capacity at end of 1992 totaled 166 GW. Current plans are to increase capacity at a 9% annual rate with the objectives of reaching production levels of 980 TWh in 1995 and 1500 TWh in 2000 with installed capacities of 200 and 300 GW respectively.

The principles for development of power production in China have been stated as follows-" develop thermal power vigorously, exploit hydropower energetically and develop nuclear power appropriately". The implications are that the current high percentage of coal fueled thermal power will likely increase. The great distances between coal mines and markets for coal and power result in 40% of all rail traffic committed to the movement of coal.

As a result, there is a desire to develop large mine mouth power plants to free up the rail system .

As shown in Table 8, a large number of relationships with international organizations have been developed to facilitate technology transfer into this huge market. It is apparent that these relationships will facilitate the introduction of new technologies from companies and countries that have taken the initiative. Because foreign exchange resources have been limited in the past, there has also been a major effort to develop the capability to manufacture much of the required equipment domestically.

Recently completed thermal power projects and those planned for the next eight years are listed in Table 9. It is most likely that those planned for the beginning of that period will be conventional stations. However, toward the end of that time it is anticipated that advanced technologies will be considered. Texaco Development Corporation recently reported that it had entered into its tenth license for gasification technology in China. These are all syngas plants but the experience being gained now will support IGCC technology in the future.

Decision Factors

There are a large number of factors involved in choosing the technology for a new power plant. Some of these can be approached analytically but others will be approached on a qualitative basis. The major factors are:

<u>Analytically based</u>
Projected heat rate
Emissions
Capital costs
Fuel costs
Labor costs and staffing requirements
Other operating costs
Degree of subsidization offered

<u>Qualitatively based</u>

Maturity of Technology(i.e., number of commercial installations, success of existing units, status of demonstration programs,)
Quality of vendor team
Quality of vendor commitment and guarantees
Complexity(perceived ability of local people to successfully operate the plant)
Country of origin of the technology and vendors
State-of-the-art versus outdated technology

As in all other aspects of life, it is always easier to deal with analytical assessments. It is fairly simple to put together a proposal which describes a coal fired plant in detail. Cost, performance, and reliability projections which have been developed can be defended on the basis of background data, calculations and assumptions However, the relative probability of success of a specific customer making a technical decision on strictly analytical grounds is unknown and will vary with the situation. Therefore dependence on analytical work to sell technology to a new customer is usually inadequate. Marketing advanced coal technology will be a daunting task.

The key unresolved issue with these new technologies is that their immaturity as measured by few current commercial installations is real. Costs have not yet been substantially reduced through elimination of redundancy based on successful commercial operation. Few vendors are willing to take on the risk of delivering a fixed price power plant project. New approaches to competing in this market should be developed.

New Project Approaches

The traditional categories used in calculating the cost of electricity for a planned project are the capital investment, fuel, fixed and variable operating expenses, and byproduct revenue and disposal costs In order to meet competitive market requirements, it is suggested that a new approach be used in which projects are developed from the top down rather than the bottom up. What this means is setting targets for each of the cost categories so that the total cost meets the market need. The typical vendor or A/E in the power plant supply business historically develops a design to meet the clients capacity requirement , then calculates the total investment required in a business as usual fashion. If the COE computation doesn't meet the market requirement, the first response is to see how one of the other participants in the project can cut their costs. In discussions with individual vendors, it is usual to hear statements about how they have cut their costs to the bone but are sure that the other participants have a lot of fat in their estimates.

The traditional practice of treating each project as a one-of-a-kind design which is developed sequentially is very expensive and perhaps outdated. Is it possible to think more in terms of a product development rather than a project development approach? In that way concurrent efforts by the process design, mechanical design, procurement, construction planning and operating teams could be integrated from the beginning of the project to minimize ultimate costs. This approach requires bringing together a team of selected vendors who will coordinate their efforts to put together a market priced offering. Whether the costs of such a product can meet market needs is open to question. If it does not, the parties involved can come to a decision on whether to offer the product or not. Since many of the costs involved would not have to be repeated for subsequent projects, the subsequent projects could be profitable enough to offset the potential losses resulting from subsidization of the initial project.

Repowering

Existing power plants sites are very valuable assets to power companies. All permits required for operation of the existing equipment are in hand. Tie-ins with the transmission system to move power from the site exist. However, many of the sites are equipped with inefficient generation equipment that results in a very low utilization factor. This situation represents a financial opportunity for those utilities that would like to add power capacity to meet load growth. Depending on the site, the incremental investment cost may be low enough to allow the utility to develop a project that is competitive with its other alternatives. In this way coal fueled projects may be able to compete with green-field natural gas combined cycle projects. A very careful analysis is required to determine if the potential savings from utilization of old equipment with a finite remaining life is attractive. However, as was stated previously, the most valuable attribute of an existing coal fired power generation site is its acceptance by the surrounding community.

Minimizing the Risk

Perhaps the single greatest concern facing the potential buyer of an new coal technology plant is how to minimize his risk. The key issues are whether the plant will meet its performance, reliability, availability and maintenance goals so that the project investment criteria can be met. This of course assumes that the fuel and electricity prices meet their market projections.

Most of the components in fluidized bed combustion and in gasification plants are in conventional use in other industries and their performance and reliability can be predicted with a fair degree of uncertainty. This information should be used in rigorous reliability analyses in the same way that process engineers can carefully calculate plant heat rate to four significant figures. The reliability should be designed into the plants, with weak components eliminated and redundancy used only where it is cost effective.

Personnel training should be very formal and long term utilizing tours of duty at existing IGCC and PFBC demonstration plants as well as simulators which have been validated to the extent possible in existing plants, and video archives which have captured the experience of previous plant operations.

If all of the elements above can be accomplished properly then the probability of a minimum period startup and smooth transition into commercial operation can be enhanced. It is vital that the efforts of all teams that get involved are integrated from the beginning. If they are not, the risk of an unsuccessful project is greatly increased.

There is a cliché often used when discussing a new technology project with utility personnel (or indeed with others in any industrial organization), that pioneers usually get shot in the back. In addition the rewards to the early adopters of new technology often disappear in the fog of startup problems, poorer than design performance, and higher than predicted O&M expenses. It is far safer to be the owner of the second or third plant rather than the first.

The question is how to increase the comfort factor so that the project owner is more willing to take on the risk. There is a clear market reward for plants with an 8 — 10 point higher fuel efficiency if base load coal plants are the least cost option. Risk acceptance and minimization requires that the major components in the plant have been demonstrated elsewhere at a scale that is close to the new plant. Even more important is a successful demonstration of the integrated operation of those components. One of the key benefits of the DOE Clean Coal Technology program is that it provides an opportunity for these demonstrations. Most buyers have a rational "show me" attitude where a visit to a successfully operating demonstration plant is worth many visionary presentations.

New financial approaches are also likely to have an important market impact. For example the concept of Build—Own—Operate—Transfer may be appealing to utilities in developing countries and their bankers since the risk of performance and project cost is transferred to the project developers rather than the ultimate owners. It should also be presumed that in return for acceptance of the risks that many of the rewards would also flow to the developers. Perhaps a more equitable arrangement of risk and rewards between the initial developers and ultimate owners would encourage new coal technology projects to be formulated and consummated.

Conclusions

Although there may be a few near term opportunities for some of the new clean coal technologies in Eastern Europe and other regions of the world, in this time frame technology transfer to these countries is probably best focused on the current state of the art direct coal fired plant with emissions control technology and the establishment of an infrastructure in these countries to supply equipment, components, parts and services. As the new clean technology projects complete their demonstration periods in OECD nations over the next few years, there will then be an infrastructure in place to support the wider deployment of advanced coal technology.

More efficient and cleaner power plants are being offered commercially for both natural gas and coal. Higher firing temperature and innovative gas turbine systems continued to evolve and are entering the market place. Coal fueled systems which utilize total gasification or pressured fluidized bed combustion both promise to provide efficiencies of about 45% when combined with those gas turbines with firing temperatures of 2300 to 2500°F which will be available prior to the year 2000. Major demonstration projects are underway in the United States of America and Europe at the 250-310 MW scale which will qualify these technologies for acceptance in the utility market.

Significant improvements are also underway with high temperature aeroderivative gas turbines and fuel cells. While the early market for each of these appears to be natural gas fired power plants, they can be utilized with clean coal gas when the economics are appropriate. Sophisticated gas turbine based cycles and simpler fuel cycles can generate electricity at over 60% efficiency on natural gas and over 50% on coal.

Marketing new coal fired technology to developing nations will require that vendors from the OECD countries develop business strategies that reduce the cost of the delivered power plant to the buyer, perhaps by subsidization, and more importantly reduce the risks involved. A few of the ways to reduce risk are to successfully complete current and planned demonstration project, design reliability into the project at the beginning since retrofits will be difficult and expensive, establish relationships with people and institutions in developing countries that can facilitate communication with the objective of avoiding misunderstanding, and carefully train, at existing plants, those people who will be involved in new technology projects.

Table 1. Markets—PC+FGD, PFBC & IGCC

	PC+FGD	PFBC	IGCC
Low S coal	√	√	—
Medium S coal	√	√	√
High S coal		—	√
Environmental Site constraints			√
Size < 200 MW		√	?
200-350 MW	√	√	√
500 MW	√		√
Repowering Need significant new power	N/A		√
Modest increment only required		√	
Site T&D constraint		√	
Stringent site environmental constraints			
—Air			√
—Solid waste			√

Table 2. Direct Coal Fired Plants

SO2 Control Options

Option	% S Removal	Capital Costs $/kW
Physical Coal Cleaning	30-50 (Pyritic S only)	Australia
Furnace Sorbent Injection + Economizer & Duct Injection	20-40 (Limestone) 40-60 (Lime) Up to 70	50-100
Wet Limestone FGD + Additives	90-95 Up to 98	200 (1-3 times more for Retrofit)
Regenerable FGD		> Limestone FGD
Spray FGD		< Limestone FGD

Table 3. Direct Coal Fired Plants

NOx Control Options

		Costs	
Option	% NOx Removal	Capital Costs $/kW	Operating Mills/kWh
Low NOx Burner + Reburn	40-60	5-25	
SCR + Low NOx Burner	80 90	60-90	4-6
SNCR	30-55	5-15	0.5-2.0

Table 4a. DOE CCT GCC Projects in Progress

Project	Technology	Efficiency % LHV	MWe	Application	Start-up
PSI/Destec -Wabash River	Destec 2 stage Entrained O_2 Blown Cold Gas GE 7 FA	40	265	Repowering	Mid 1995
Tampa Electric Polk County	Texaco Entrained O_2 Blown Hot & Cold Gas Clean up GE 7 FA	42	260	Greenfield	Mid 1996
Sierra Pacific -Pinon Pine	KRW Fluid Bed Air Blown Hot Gas Clean up GE 6 FA	42	95	Existing Site	Late1996

Table 4b. European GCC Projects In Progress

Project	Technology	Efficiency % LHV	MWe	Applications	Start-up
SEP —Buggenum, Netherlands	Shell Entrained O2 Blown Cold Gas Clean up V.94.2	43	284 (Gross) 253 (Net)	Green Field	Early 1994
ELCOGAS —Puertollano, Spain	PRENFLO Entrained O2 Blown Cold Gas Clean up V.94.3	45	335 (Gross) 300 (Net)	Green Field	Mid 1996
RWE —KOBRA Hurth, Germany	HT Winkler Fluid Bed Air Blown Cold Gas Clean up V.94.3	45	357 (Gross) 312 (Net) (+27 from Residues in FBC)	Green Field	Post 2000

Table 5. Total Electricity Generation, TWh (Not as Primary Energy)

TWh	1960	1970	1980	1990	2020*
North America	958.0	1844.4	2731.4	3534.7	4700
Latin America	72.0	160.5	385.0	624.6	2500
Western Europe	611.7	1238.6	1892.1	2427.3	3850
Central Eastern Europe	74.5	184.1	336.0	372.8	600
Newly Independent States of Former USSR	292.1	735.6	1274.9	1722.1	2400
Middle East & N. Africa	10.2	36.6	117.2	273.4	1150
Sub Saharan Africa	30.2	74.2	148.2	220.5	700
Pacific (inc. Central Planned	230.0	615.1	1196.9	1997.7	5500
Asia)	(70.3)	(140.4)	(354.6)	(680.9)	(2650)
South Asia	22.8	71.2	139.9	318.6	1250
World	2301.5	4960.3	8221.6	11490.9	22700

Table 6. Growth Rates in Electricity Generation, %p.a.

	1960-1970	1970-1980	1980-1990	1990-2020	(1960-1990)
North America	6.8	4.0	2.6	1.0	4.4
Latin America	8.3	9.1	5.0	4.7	7.6
Western Europe	7.3	4.3	2.5	1.5	4.6
Central Eastern Europe	9.5	6.2	1.0	1.7	5.4
Newly Independent States of Former USSR	9.7	5.7	3.1	1.1	5.9
Middle East & N. Africa	13.6	12.3	8.8	5.0	11.9
Sub Saharan Africa	9.4	7.2	4.1	3.8	6.9
Pacific (inc. Central Planned	10.3	6.9	5.3	3.4	7.4
Asia)	(7.2)	(9.7)	(6.7)	(4.6)	(7.8)
South Asia	12.1	7.0	8.6	4.7	9.3
World	8.0	5.2	3.4	2.3	5.4

* Projection by WEC
Sources: UN Energy Statistics Yearbook, WEC

Table 7. World Coal Comsumption
(Million Short Tons)

			U.S. EIA Base Projections		
Market Economies		1991	1995	2000	2010
OECD		(2015)	(2094)	(2150)	(2285)
	U.S.	888	947	987	1135
	Canada	56	68	83	90
	Japan	127	134	134	136
	Europe	832	825	821	795
	Other	112	120	124	128
OPEC		11	13	14	18
Other Developing Countries		575	585	646	744
Total Market Economies		(2601)	(2692)	(2810)	(3047)
Centrally Planned Economies		(2501)	(2746)	(2988)	(3432)
	China	1192	1441	1685	2113
	Former Soviet Union	725	720	723	741
	Other	585	586	580	578
World Total		5102	5439	5798	6479

Table 8. Cooperative Agreements/Memoranda of Understanding Signed with Foreign Partners

Chinese Partnership	Foreign Partnership	Country
DIC, MEP	TEPCO	Japan
DIC, MEP	EDF	France
DIC, MEP	ENEL	Italy
DIC, MEP	DPIE	Australia
Northeast China Power Group Corp.	Hokuriku Electric Power Company	Japan
Northeast China Power Group Corp.	SECV	Australia
Jilin Electric Power	Hokuriku Electric Power Company	Japan
Heilongjiang Electric Power Company	Tohoku Electric Power Company	Japan
East China Power Group Corp.	KEPCO	Japan
Central China Power Group Corp.	Chuba Electric Power Company	Japan
Northwest China Power Group Corp.	Shikoku Electric Power Company	Japan
Zhejiang Electric Power Co.	EDF	France
Shandong Electric Power Co.	Pacific Power Company	Australia
Shandong Electric Pcwer Co.	CESP	Brazil
Shandong Electric Power Co.	Kyushu Electric Power Company	Japan
EPPEI	EDF	France
EPIRI	JEPIC	Japan

DIC: Dept. of Int'l Cooperation
MEP: Ministry of Electric Power
DPIE: Dept. of Primary Industries & Energy
TEPCO: Tokyo Electric Power Company

EDF: Electricité de France
KEPCO: Kansai Electric Power Company
CESP: Companhia Energetica de Sao Paulo
SECV: State Electricity Commission of Victoria

Table 9. The Sino-Foreign Joint Venture Thermal Power Projects Completed and Planned (1986-2002) (BOT, BOO)

Completed Projects

No	Projects	Installed Capacity (Nox x MW)	Schedule	Estimated Loan U.S. ($M)	Source of Loan	Location (Province, Municipality,Region)
1.	Beilungang	2 x 600	1986-1993	390.00	World Bank	Zhejiang
2.	Ligang	2 x 350	1988-1992	245.00	Spain & Italy	Jiangsu
3.	Wujing	2 x 300	1988-1992	190.00	World Bank	Shanghai
4.	Shidongkou	2 x 600	1988-1992	413.06	EDC, USA	Shanghai

Planned Projects

	Projects	Installed Capacity (Nos x MW)	Location (Province, Municipality, Region)
1.	Waigaoquiao (phase 2)	2 x 800 or 2 x 1000	Shanghai
2.	Jiaxing (phase 2)	4 x 600	Zhejiang
3.	Ligang (phase 2)	2 x 350	Jiangsu
4.	Ligang (phase 3)	2 x 600	Jiangsu
5.	Shidongkou (phase 2)	2 x 600	Shanghai
6.	Yangcheng	4 x 600	Shanxi
7.	Tuoketuo No. 2	4 x 600	Inner Mongolia
8.	Daihai	4 x 600	Inner Mongolia
9.	Datong No. 2	2 x 600	Shanxi
10.	Shalingzi (phase 2)	2 x 600	Hebei
11.	Shuangyashan	2 x 600	Heilongjiang
12.	Zhuhai	2 x 600	Guangdong
13.	Beihai	2 x 350	Guangzi
14.	Xidu	2 x 660	Jiangsu
15.	Rizhao	2 x 350	Shandong
16.	Shjiliquan	2 x 300	Shandong
17.	Laicheng	2 x 600	Shandong
18.	Shiheng (phase 2)	2 x 300	Shandong
19.	Heze (phase 2)	2 x 300	Shandong
20.	Meizhouwan	2 x 350	Fujian
21.	Songyu	2 x 350	Fujian
22.	Hanchuan (phase 2)	2 x 300	Hubei
23.	Pingu	2 x 600	Beijing
24.	Expansion of Liaoning	2 x 300	Liaoning
25.	Shenmu	2 x 350	Shaanxi
26.	Dalian (phase 2)	2 x 350	Commissioned in the early "Ninth Five-year Plan" period
27.	Dandong	2 x 350	Commissioned in the early "Ninth Five-year Plan" period
28.	Nantong (phase 2)	2 x 350	Commissioned in the early "Ninth Five-year Plan" period
29.	Fuzhou (phase 2)	4 x 660	Commissioned in the early & middle "Ninth Five-year Plan" period
30.	Yueyang (phase 2)	2 x 350	Commissioned in the middle "Ninth Five-year Plan" period
31.	Shidongkou No. 2 (phase 2)	2 x 600	Commissioned in the middle & latter "Ninth Five-year Plan" period
32.	Luohuang (phase 2)	2 x 350	Commissioned in the middle & latter "Ninth Five-year Plan" period
33.	Shantou (phase 2)	2 x 350	Commissioned in the middle & latter "Ninth Five-year Plan" period
34.	Yingkou (phase 2)	2 x 600	Commissioned in the middle & latter "Ninth Five-year Plan" period

BOT: Build-Own (Operate) - Transfer BOO: Build-Own-Operate

2.2

Overview of the Independent Power Producer (IPP) Market for Advanced Coal-Fired Systems

by

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INTRODUCTION

U.S. electric utilities traditionally are granted exclusive franchises to sell retail electricity in given geographical service areas. In return, the utilities agree to be regulated by public utility commissions (PUCs) that determine electricity prices for different classes of customers based on the utility's "cost of service," which includes a return on the utility's undepreciated capital investment (the "rate base"). With most large utilities being integrated, the regulatory structure covers electricity generation, transmission, and distribution through retail sales.

Regulation initially helped to stabilize the electric utility business, but ultimately inhibited it from reacting to the competitive changes now occurring worldwide for nearly all businesses. This fact and the subsequent deregulation of the electric power industry now are driving the growth of independent power producers (IPPs) and dramatically impacting the technology mix of new power generation capacity.

THE EVOLUTION OF THE U.S. ELECTRIC POWER INDUSTRY [1]

The rapid growth of the nascent U.S. electric power business during the late 19th and early 20th centuries soon attracted government regulation. Thus insulated from "ruinous competition," the industry quickly became concentrated. Stronger utilities absorbed their weaker neighbors and investor-owned utilities consolidated into even fewer holding companies. By 1932, three such holding companies controlled over 44% of U.S. electricity production. Holding company abuses led to the Public Utility Holding Company Act (PUHCA) of 1935, causing many holding companies to break up and extending control over the interstate transmission and sale of electricity to what is now the Federal Energy Regulatory Commission (FERC).

U.S. utilities thrived following World War II, as new technologies -- such as large, high-efficiency pulverized coal (PC) plants and high voltage transmission -- drove down power costs. Between 1945 and 1965, the average electricity price fell by nearly 50% in real terms to about 1.5¢/kWh. Demand grew by 7% a year, and regulatory reviews usually were short proceedings to reduce rates as costs declined.

However, in the late 1960s and early 1970s, events reversed the decline in power costs and irreversibly altered the electric utility industry's future course. These events included:

- increased environmental regulations
- increased fuel costs
- unexpected expenses with nuclear technology
- declining load growth
- changes in regulatory practice

Many utilities had looked to nuclear power to solve their environmental problems and alleviate their dependence on fossil fuels. However, nuclear plants' economies of scale dictated large units having long construction lead times and lacking operating flexibility. These characteristics clashed with uncertain load growth and with future load-following and cycling capacity needs. Three Mile Island effectively eliminated nuclear as a generation option in the United States, stalling construction of many nuclear plants and exacerbating the financial repercussions for utilities.

Low ($\approx$ 2%) annual load growth and eventual completion of many nuclear plants subsequently created widespread excess capacity. Inclusion of high-capital-cost nuclear plants in the rate base also threatened to significantly increase power costs. To minimize such "rate shock," PUCs disallowed or deferred recovery of nuclear plant investments, imposing severe financial strain on utilities.

THE EMERGENCE OF DEREGULATION AND COMPETITION [1]

In 1978, the Public Utility Regulatory Policies Act (PURPA) was passed, requiring utilities to buy power from Qualifying Facilities (QFs) -- unregulated cogeneration units and small power producers using waste or renewable fuels. Cogeneration QFs had to meet specific operating, efficiency, and ownership standards. Small power producers had to meet size, fuel use, and ownership standards. PURPA regulations were to be established by FERC and administered by state PUCs.

Local utilities were compelled to buy power from QFs at "avoided costs," as determined by PUCs, that ranged from marginal operating costs for utilities having excess capacity to cases that included the full capital and fuel charges for a new generation unit. California's Standard Offer No. 4, since discontinued, based avoided costs on $38/barrel oil and years of built-in escalation. After gas prices fell, such contracts became "gold mines" for organizations operating gas-fired QFs. Some utilities have since bought back these contracts, finding this option cheaper than buying the expensive power.

In 1978, concerns over oil and natural gas shortages precipitated the Fuel Use Act. This law prohibited utilities from building oil- or gas-fired capacity if planned operation exceeded 1,000 hours annually, thereby confining new oil and gas use to peaking units. Consequently, only high capital cost alternatives -- coal or nuclear -- remained available to utilities for baseload power capacity. QFs, however, were not similarly restricted and, when gas prices began falling in the early 1980s, were able to sell power at avoided costs based on the utility's "next new coal plant."

To correct this imbalance, the Fuel Use Act was amended in 1987 to allow utilities to build gas- or oil-fired generation capacity if it included provision for future conversion to coal. Successful demonstration of coal gasification, led by the Electric Power Research Institute (EPRI), in the mid-1980s made coal conversion a credible option for gas-fired combustion turbines and combined cycles.

PUCs, following guidelines proposed by FERC, subsequently took regulatory actions that were key to the emergence of competition in the electric power industry. These actions included the following key elements:

- Limiting avoided costs to the utility's least expensive alternative

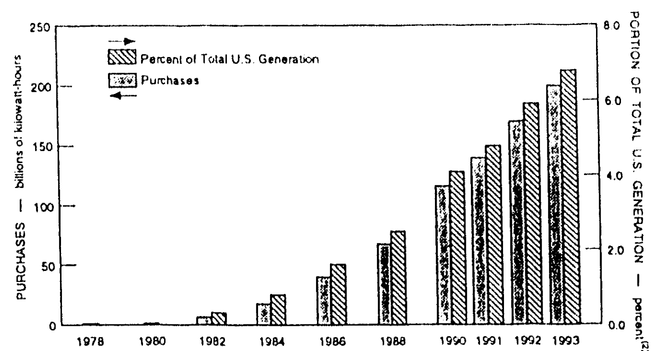
- Allowing competitive bidding to establish avoided costs (-- a practice currently endorsed by most PUCs)

- Creating IPPs, a class of non-utility power producers that are not QFs but can sell unregulated power to electric utilities.

IPPs had a strong interest in building power plants but were severely constrained by two limitations -- PUHCA requirements and transmission access

PUHCA was the biggest legal obstacle to IPPs. To avoid regulation as a utility under PUHCA, IPPs either had to be a QF under PURPA or have a complicated ownership structure limiting a non-utility partner to a maximum of 10% ownership. Without guaranteed transmission access, IPPs also could be stranded with no place to sell power if the local utility refused to take it. Since utilities had to accept power from QFs, non-utility generators (NUGs) developed cogeneration projects -- so-called "PURPA machines" -- having only token thermal loads -- e.g., heating a greenhouse -- in order to obtain QF status.

As Figure 1 indicates, NUGs built an increasing amount of new generating capacity throughout the 1980s. In 1989, the capacity added by NUGs -- 7,000 MW -- equaled that added by regulated utilities. Figure 2 shows that, over the same period, the overall constant dollar retail price of electricity sold by U.S. electric utilities declined significantly.



(1)Total non-utility power producer generation is approximately 50% larger than these figures. (2)SFA Pacific, Inc. estimate

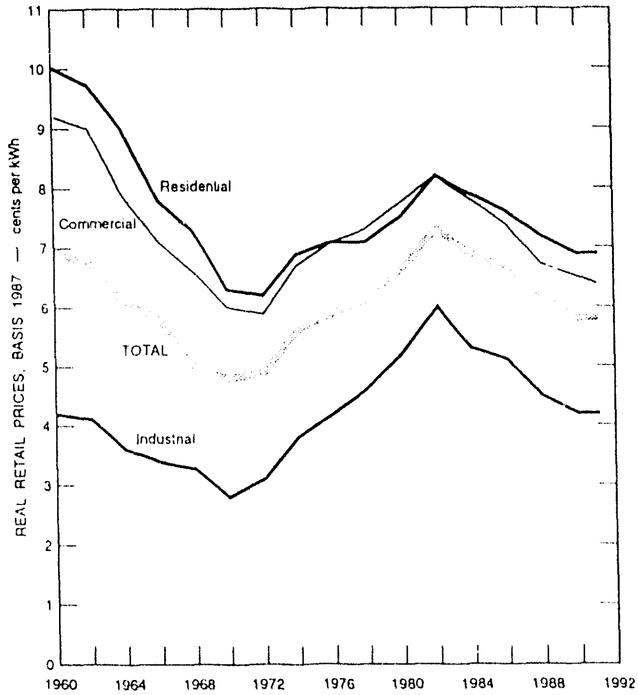
Source: DOE and SFA Pacific, Inc.

Figure 1. Electricity Purchased From Non-Utility Power Producers by Electric Utilities in the U.S.(1) [Billion (10^6) Kilowatt-Hours]

The Energy Policy Act of 1992 facilitated NUG projects and reduced the associated regulatory burden and business risks by:

• creating a new class of unregulated power producers -- Exempt Wholesale Generators (EWGs)

• directing FERC to allow transmission access by EWGs to sell wholesale electricity in interstate markets



Source: DOE/Energy Information Administration

Figure 2. Real Retail Prices of Electricity Sold By Electric Utilities in the U.S., 1960-1991

• allowing companies generating and selling both wholesale and retail power in foreign markets exemption from PUHCA regulations

• eliminating PURPA's restriction of 50% utility ownership of a NUG facility

The Energy Policy Act portends an increasingly competitive wholesale power market that can be supplied by EWGs selling power without price regulation. Utilities that purchase the power for retail sales remain regulated, and PUCs may play a role in approving wholesale power sales agreements. To date, most power sales prices are being determined by bidding systems whereby utilities request proposals and select winners based on cost and other factors such as dispatchability. NUGs have responded to such solicitations in large numbers, with offers to supply power often exceeding the requested amount by a factor of ten.

LOOKING AHEAD: THE 'NEW ORDER' OF ELECTRIC POWER GENERATION [1]

Experience has shown that many unregulated power producers are:

• aggressive in developing projects
• undeterred by environmental regulations
• willing to adopt new technology
• not biased against gas, as many utilities are or have been

Deregulation of electric power generation will continue, with EWGs and cogenerators supplying most new baseload capacity. Clean-burning natural gas will be the fuel of choice because it eases facility siting and lowers capital costs. Gas also will be preferred for new peaking capacity, even if its price rises significantly, because utilities want to minimize their capital investment in equipment having a low capacity factor. Peaking capacity most likely will be built by utilities, although unregulated companies have bid to supply peaking units.

NERC forecasts that the net growth of new generation capacity will average only 1.2%

Table 1
Current Status of U.S. Electric Power Generation
(Nameplate Capacity)

	Capacity, MW January 1992	Capacity, MW January 1993	Increase, % 1992-1993
Type of Facility			
Electric Utility	740,000	742,300	0.3
Non-Utility			
Cogenerators	37,100	40,700	9.7
Small Power Producers	10,000	10,200	2.0
Other (EWGs)	2,900	4,300	48.3
Total Non-Utility	50,000	55,200	10.4
Total U.S. Capacity	**790,000**	**797,500**	**0.9**
Type of Fuel--Non-Utility			
Coal	7,600	8,600	2.6
Oil	1,400	1,500	7.1
Natural Gas	21,800	24,900	14.2
Biomass (Wood)	9,300	9,600	3.2
Waste Fuels	3,600	3,800	5.5
Hydro, Wind, Solar, Other	6,300	6,800	7.9
Total	**50,000**	**55,200**	**10.4**

Source: Edison Electric Institute (EEI) and SFA Pacific, Inc.

over the next decade. Although a somewhat higher growth rate -- 1.7% -- is anticipated for peak demand, the higher rate can be absorbed by the current excess capacity.

As Table 1 shows, the total net (nameplate) generation capacity added by U.S. electric utilities grew by only 2,300 MW, or 0.3%, in 1992. However, new capacity added by NUGs increased by 5,200 MW, or 10.4%. Over half the new NUG capacity uses natural gas.

NUG power has grown so much in some parts of the United States that utilities cannot always absorb the power produced. Most new power contracts with larger NUG facilities therefore allow the utility to reduce power purchases when demand is low. At such times, the NUG typically receives a payment to cover fixed costs. According to EEI, of the 55,000 MW of NUG capacity, 12% is fully dispatchable, 22% is partly dispatchable.

The other major area addressed by the Energy Policy Act, transmission access, will be more difficult to implement. Key issues are the price to be charged for wheeling power and the management of electricity load flows.

Although the Energy Policy Act prohibits interstate sales by NUGs to retail customers, some PUCs want to allow retail wheeling within their state. If successful on an intrastate basis, interstate retail wheeling undoubtedly will be implemented.

New technology has facilitated unregulated power generation. The emergence of highly efficient and reliable combustion turbines and combined cycles with low environmental emissions has allowed the siting of power generation and cogeneration facilities at numerous industrial sites. While electric utilities have been reluctant to install combustion turbines because of bad experiences with early models in the late 1960s and early 1970s, combustion turbines are the technology of choice for NUGs.

NUGs also have embraced new technologies promising lower cost operation -- and greater profits. For example, NUGs essentially commercialized atmospheric pressure circulating fluidized bed combustion (CFBC) in the 1980s. NUGs also have been receptive to new emission control technology, such as selective catalytic reduction, to avoid regulatory siting delays and bring facilities on line faster. Utilities, however, sell power on a cost-of-service basis and reap no reward for taking technical risks. They therefore tend to be extremely risk averse, avoiding new technologies.

A CASE FOR ADVANCED COAL-BASED POWER [2-5]

In most locales, making an economic case for coal-based power of any kind currently is difficult due to low prices and ample supplies of natural gas. Moreover, near-term capacity requirements in the United States and Europe are largely for cycling and peaking service, for which coal is not competitive with combustion turbine systems having far lower capital costs.

However, as erosion of the supply/demand balance drives natural gas prices up and new baseload capacity needs emerge, coal-based power will again become economic. Based on recent technical and commercial successes and on current commercial demonstration programs, coal gasification will dramatically challenge direct-coal-fired power for this market. Coal gasification has fundamental advantages over direct coal-firing in environmental performance, efficiency, and flexibility.

Coal gasification has demonstrated superior environmental performance with respect to air, water, and solid waste. A coal gasification combined cycle (CGCC) power plant can match the emissions levels of a natural gas combined cycle plant. A CGCC's aqueous effluents are significantly less than for direct coal-fired steam cycles because a CGCC's steam cycle produces less than 40% of the system's overall power generation. Most coal gasification processes produce a granular non-leachable slag having little or no fly ash. This is the only solid waste, since sulfur is recovered and sold in purified elemental form. Direct combustion systems produce 2-3 times the amount of solid waste.

With CGCC, 65-80% of overall power output is generated from the high temperature combustion turbine-based topping cycle. This provides high overall efficiencies and much higher power-to-cogenerated heat ratios, compared to steam cycles. Several coal gasification developer/vendors (e.g., Texaco, Destec, Shell) now offer CGCC designs, based on commercially proven technology, having electric power efficiencies greater than 40% (HHV) for standalone power plants. This equates to a heat rate of 8,500 Btu/kWh. If cogeneration is considered, the electric power and overall efficiencies can exceed 50% and 80%, respectively.

Flexibility to meet the market requirements of competitive power production will be essential for individual generators. Self-generation and cogeneration, both already widely practiced, will expand greatly in response to the economics of deregulated generation. Combustion turbine-based technology has clear flexibility advantages for both. Combustion-turbine based systems using natural or coal-derived gas are more flexible in terms of size and configuration than direct coal-fired systems. For example, aeroderivative combustion turbines can be built in various smaller sizes and produce the highest electric power-to-cogenerated heat ratio. Fuel gas also can be transported to numerous small combustion turbines located at a distance from one large coal gasification plant.

Since the majority of new generation capacity now being installed is natural gas combined cycle, coal-derived fuel gas replacement, another aspect of CGCC flexibility, could be important in the future. Medium-BTU coal gas produced in oxygen-blown coal gasification processes is easily fired in combustion turbines originally designed to fire natural gas. For maximum benefit, future conversion to CGCC should be planned in advance. SFA Pacific's evaluations indicate that coal-based power generation again becomes economical when natural gas prices reach the range of $5-6 per million BTU.

In view of U.S. environmental mandates, repowering of old coal-fired power plants with coal-derived gas may be an attractive option, especially in high-sulfur-coal regions. The use of coal gasification/combustion turbine-based repowering to achieve environmental compliance currently is being commercially demonstrated as part of DOE's Clean Coal Technology program.

Synthesis gas coproduction is another potentially attractive option for improving CGCC's flexibility and economics, especially for new power plants that could be required to operate in cycling service in the future.

Pressurized fluidized bed combustion (PFBC) currently is being demonstrated, even as promoters are transforming PFBC designs to improve efficiency. The "advanced" PFBC designs essentially are highly integrated, air-blown CGCC designs with hot gas cleanup aimed at increasing PFBC's low gas turboexpander-to-steam turbine power ratio, thereby improving efficiency. However, PFBC, advanced PFBC and advanced CGCC systems all face major technical and economic challenges in achieving their potential advantages relative to well-designed conventional PC or CGCC plants. The key issues are environmental performance (NO_x, HAPs, solid waste), turboexpander operation with dirty high-temperature gas, and the impact of deregulation on competitive power generation options, especially cogeneration. The lack of short-term markets for advanced coal technologies makes continued government support critical if these challenges are to be resolved.

INTERNATIONAL POWER GENERATION [5]

NUGs in the United States have built new power plants on time and on budget. This success has been carefully observed by the international community, and independent power production has recently spread to many areas of the world. Unlike regulated utilities, NUGs receive no allowances for funds used during construction, thus having a strong incentive to build and commission plants quickly. They also have strong incentives to keep them running, since they receive no revenue if no power is sold (-- unlike regulated utilities, which can earn a return on a rate-based plant even if it is idle). This efficiency of plant construction and operation convinced the World Bank to require any country requesting a loan for power generation facilities to offer the option of private ownership and operation.

Over 125 IPPs now are active in about 50 countries. Table 2 shows the leading IPPs. Exxon Energy, with nearly 6,000 MW, leads the list because of its large holdings in China Light & Power in Hong Kong. However, Mission Energy, an affiliate of Southern California Edison, has the greatest diversity of projects. Five of the top ten IPPs are from Europe and Asia.

Table 2
Top Independent Power Firms by Net Project Ownership

Net Ownership, MW	Company
>5,000	Exxon Energy
2,000-3,000	Mission Energy National Power Int'l. Enron Power
1,000-2,000	PowerGen Sithe Energies AES Hopewell Holdings Destec Energy British Gas CMS Generation U.S. Generating Cogen Technologies
500-1,000	Cogentrix Dominion Energy Southern Electric Int'l. Wheelabrator Intercontinental J. Makowski Texaco Tractebel Trans Alta Energy

Source: Independent Power Report (McGraw-Hill) and SFA Pacific,Inc.

IPPs are closely watching the countries having the greatest need for new power generation capacity. Private power needs outside the United States and Canada reportedly grew by 64% in 1993 to 487,000 MW. China's booming economy and increased interest in private sector participation have, over the last year, doubled some estimates of that country's potential private power needs, although such estimates may be inflated by many projects that will never be built.

The enormous overall growth in coal-fired utility power plants in China -- perhaps by as much as 17-20 GW per year between 1995 and 2000, 70-80% of it coal-based -- provides the current market for vendors of large coal-fired power plant technology. The corresponding market in developed nations is bleak due to excess capacity and the proliferation of NUG capacity using primarily natural gas.

The growth in coal-fired generation in China also is well timed for IPPs. According to various reports, over 60 GW of electric power generation capacity in China now is being solicited for IPP ownership of build-own-operate-transfer (BOOT). The IPPs' capital and construction and operating expertise will be invaluable to China. The IPPs' biggest challenge will be financing and payment terms.

China currently is building "world class" 300-600 MW PC power plants. These plants include low-NO_x burners and electrostatic precipitators, but usually are without SO_2 controls due to the low sulfur content of Chinese coals.

In the future, the Chinese electric utility industry will want coal-fired plants based on advanced technologies such as CFBC, pressurized fluidized bed combustion (PFBC), and CGCC. All three technologies offer higher efficiency and lower emissions than current Chinese coal-fired power plants. Fluidized bed systems are advantageous for use in China due to the high ash content and variability of its coals. Also, the low sulfur content of most Chinese coals greatly reduces solid waste disposal problems. However, all three advanced coal technologies also require technology transfer, additional imported components, higher capital cost, and the highest quality construction, operation, and maintenance. The success of these advanced coal-fired power plant technologies in China will be greatly enhanced by the presence of IPPs and BOOT.

Though generally of less interest to the international coal technology community, industrial sector coal use in China is perhaps more important than utility sector use, for the following reasons:

• the annual tonnage increase in industrial coal use, currently about 550 million tons per year and over half of total coal use, will equal the growth in utility consumption

• industrial coal use is China's largest source of air pollution

• industrial cogeneration -- using either simple domestic or advanced coal technology -- potentially can far exceed the efficiencies of the most advanced standalone power plants

• many parts of China's industrial sector are experienced in international trade and technology licensing

• "hard currency" is available to the industrial sector, making IPP and BOOT financing and payment terms much easier than those for utility projects.

CFBC is clearly favored for new industrial boilers in China due to fines content, coal variability, low sulfur content -- and the highly successful CFBC boiler experience in the United States. SFA Pacific's FBC database shows 19 licensed CFBC units -- based on Ahlstrom/Pyropower and Riley/Deutsche Babcock technology -- at 10 locations in China with a total steam generation capacity of 2,700 tons/hour. Longer-term, coal gasification will be even better for industrial cogeneration in China. Texaco already has several coal gasification projects in China's industrial sector in conjunction with combustion turbine-based cogeneration, industrial fuel gas, and synthesis gas chemicals. The industrial use of coal gasification will greatly expand as China converts from an oil exporter to an oil importer. [6]

The U.S. government's current efforts to assist development of clean coal technology projects in China constitute a win-win" situation. They help China improve its environment while furthering commercialization of the most promising U.S. clean coal technologies.

OUTLOOK

The deregulation of electric power generation will continue to expand worldwide. Problems relating to transmission access in the United States will be resolved, once pricing mechanisms are worked out. Retail wheeling likely will be allowed in several states and could result in a nationwide power brokering system with the transmission lines serving as common carriers. Electric utilities still interested in operating generation facilities will set them up as EWGs to maximize profitability.

Combustion turbine-based technology increasingly will dominate fossil generation in the developed nations. Coal gasification combined cycle is the only coal technology that is synergistic with natural gas-fired combustion turbine systems and will therefore find markets when coal-based power generation again becomes economic after the year 2000.

Markets for IPP power generation are expanding worldwide, particularly among the developing nations. China provides the current market for vendors of large coal-fired power plant technology, currently in the form of "world class" PC plants. In the future, China will seek advanced coal-based power generation options. The U.S. government's assistance to advanced coal technologies assures that the U.S. will continue to be the world leader in both independent power production and clean coal technology.

REFERENCES

1. S. Vejtasa, "The 'New Order' of Electric Power Generation," *The SFA Quarterly Report*, a private multisponsored report, SFA Pacific, Inc. April, 1994.

2. R.L. Dickenson and D.R. Simbeck (SFA Pacific, Inc.), "Coal Gasification-Based Electric Power -- The Present and Future," technical keynote presentation at the JSME-ASME International Conference on Power Engineering - 93 (ICOPE - 93), Tokyo, September 12-16, 1993.

3. *Combustion Turbine Power Systems: Analysis of Technology, Fuels, and Economics*, SFA Pacific, Inc., a private multisponsored analysis, August 1993.

4. A.D. Karp and D.R. Simbeck (SFA Pacific, Inc.), "The Future of Combustion Turbine Technology for Industrial and Utility Power Generation," presented at the 16th National Industrial Technology Conference, Houston, April 13-14, 1994.

5. D.R. Simbeck et al, *Coal Gasification Guidebook: Status, Applications, and Technology*, EPRI Report TR-102034, December, 1993.

6. D.R. Simbeck and R.L. Dickenson (SFA Pacific, Inc.) and L.D. Carter (U.S. Department of Energy), "Coal Utilization in China: Technology Options by Sector," presented at the IEA Second International Conference on the Clean and Efficient Use of Coal and Lignite: Its Role in Energy, Environment, and Life," Hong Kong, November 30 - December 3, 1993.

2.3 The Search for Innovative Technology

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Office of Clean Coal Technology

ABSTRACT

The Clean Coal Technology Demonstration Program is but one phase of a research and development effort embarked on a continuous search for innovative technologies that over the years have been needed to overcome the barriers that have threatened the continued use of coal as an energy source. The significance of past technology development in coal utilization is perhaps best evident in the historic trends in thermal efficiency and output capacity of coal-fired plants. The thermal efficiency of these facilities has increased from 5 percent in the late 1800s to nearly 45 percent by the early 1990s. This increase has resulted in an 86 percent reduction in fuel consumption per kilowatt hour of power produced. During this same period, boiler size has increased from 50 kilowatts to 1,200 megawatts, causing the cost of new generating capacity to drop by over 60 percent.

While these significant achievements were being made in thermal efficiency and cost of generation, however, new societal and institutional demands have been evolving. The fundamental changes in the technology of coal utilization are now being driven by another significant factor--environmental control requirements. As a result, environmental performance criteria have been raised over the past decade to a level equivalent with the classical criteria of cost and reliability. It is now necessary to consider each of these criteria also in the search for new innovative concepts. In spite of these new requirements, continued progress in the development of coal utilization technology is not only expected, but is in progress. Such concepts as Integrated Gasification Combined Cycle, Pressurized Fluidized-Bed Combustors, fuel cells, magnetohydrodynamics, etc., hold the promise of being able to connect thermal energy into electrical energy at efficiencies of 55 to 60 percent. At the same time, these systems in themselves and as part of advanced cycles will reduce any associated environmental impact.

It is possible through the continued development, demonstration, and commercialization of clean coal technology to establish coal in the 21st century as a fuel that can be stored and transported in an environmentally clean and aesthetically acceptable manner, that supplies reliable competitively priced power, that can be a source of industrial steam and power, and that serves as a feedstock for value-added refined fuels and products that can be used cleanly and efficiently.

Continued development of innovative advances in coal utilization will reverse the inaccurate, negative image of coal, replacing it with an updated public view of coal as an economic, stable, efficient, and environmentally responsive fuel of choice.