Improved Economics in Power Generation: What Long-Term Role for Solid Fossil Fuels?

*By Thomas Trumpy**

This article is not about coal and lignite. It is about realistic *least cost planning* for the future power generation needs of Europe - Western, Central and Eastern - and elsewhere. Responsible planning to ensure competitive energy for an economy requires planning for the economic life and lifetime operating costs of a power plant, rather than seeking short-term financial savings on a long-term productive capital asset. This is obvious and generally accepted. Therefore, consider this article a reminder of economic realities, not as a new discovery.

New Power Plants - A Replacement-driven Market

A modern electric power plant has an expected useful life of over thirty years, including replacement of shorter life elements such as gas turbines.

Industry and communities develop around power plants to benefit from the jobs power plants create:

- Directly (e.g., power plant operation and sometimes coal or lignite mining) and
- Indirectly by access to cheap power and heat which create a favorable local economic environment (e.g., use of cogeneration, combined heat and power - CHP).

Power plant-suckled communities then wish their power plants to be invisible, silent and totally nonpolluting.

The community does not want the power plant to disappear - and fears that employment may disappear if the power plant closes. The community, however, strongly opposes expansion of the power plant!

This is the dilemma of the power plant industry, a dilemma which has lead to increasing difficulty of finding sites for new power plants to meet our need for power. This NIMBY factor (Not in my backyard!) has, in the last thirty years, made power plant sites increasingly *permanent*. Where a CHP plant serves a community the power plant will be maintained even in a politically hostile environment. A good example is the very expensive and environmentally scrubbed Tiefstack CHP plant in Hamburg harbor (coal-fired, fluidized bed with a gas-fired topping and auxiliary turbine).

Tiefstack was not a new plant, it was a replacement plant. Over 60 percent of the *new* power plants planned in both western and eastern Europe up to 2010 will be replacement plants, 320,000 megawatts of replacement plant out of a total of 525,000 megawatts. The European replacement market is half the world replacement market. Increasingly power generators will be forced to repower old power plants at existing sites, frequently sites which now house dependent communities.

Using more efficient, modern technology such as upgrading or repowering will frequently rebuild the power plant, discretely increasing its generating capacity. Modern technology for all fossil fuels permits doubling the generating capacity in the same plant area and with less pollution. The new plant will be nicely boxed in and may have neither a huge chimney nor a visible cooling tower to remind neighbors that there is a power plant in their backyard!

Urban sites are expensive, so new plants in old sites will use all possible means to improve their efficiency. Such means are better technology, combinations of fuel and of technologies better to follow demand curves, and sale of excess heat through CHP, which permits major gains in system efficiency. Such plants may burn high quality hard coal (e.g., in super-critical pulverized fuel plants), coal, lignite, bio-fuel or municipal waste (e.g., in fluidized bed plants) and will generally use gas and oil for topping (generally in simple or combined cycle gas turbines) to provide greater overall efficiency and to cover peak loads with more expensive fuels.

Now let us approach the utilities' *decision tree*. For the reasons stated above, many replacement power plants will be constrained to use existing sites and, despite the high cost of meeting stringent environmental rules, to use whatever fuel or fuels are most available and meet local criteria. In such cases, the power generator must perform a local *least cost plan* within the imposed limits and then agree how to plan tariffs, and who should pay for such higher cost power, which will frequently be gas-fired.

New Power Plants - A Demand Growth-driven Market

There is growing world demand for reliable, economic, clean power. In a paper presented in 1995 at the ASME Cogen Turbo Conference in Vienna, per capita power demand of the areas of the world was estimated.

- In 1992 the air-conditioned United States used 1.2 kW per capita, with no end to growth!
- Western Europe used just over half that, 0.63 kW per capita. The market is expected to reach saturation at 0.8 kW per capita by 2010, still a 27 percent growth per capita, which must then be adjusted for population growth.
- Eastern and Central Europe used 0.5 kW per capita in 1992, and we know much of that use was very inefficient. Use is expected to level off at 0.7 kW per capita by 2030, still an increase of 35 percent, then to be adjusted for population growth.

From 1992 to 2010 Europe is expected to build 205,000 mW of new power plants, plus 320,000 mW of replacement power plant, a total of 525,000 mW of power plant additions, of which 40 percent, 230,000 mW are expected to be gas-fired (see Table 1).

At a conservative average current cost of US$ 1.2 million per megawatt, that is $630 billion, $36 billion per year - and Europe is only 20 percent of world additions.

Assuming no new nuclear plants, and limited contribution from new hydro and renewables to 2010, and assuming that new plants have roughly 40 percent efficiency and 4500 hours annual use, the new 205,000 mW of power plants in Europe will use about 200 mtoe or 1.4 trillion barrels of oil *more* each year.

Meeting Growing Demand for Coal and Gas

We can also express this additional annual fuel need as 300 mtce (million tonnes coal equivalent), but following the ASME paper's assumption of a 40 percent role for gas we will need additional annual production of up to 180 mtce of coal and 130

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Sources and references are available from the author.

billion m^3 of gas for the power plants built before 2010.

As we are talking about planned power plants being commissioned in the next 15 years with a life expectancy until 2030 to 2050, we should be sure of availability of fuel supplies for the life of those plants – and for 3 million mW or more of new plants to be built in the world from 2010 to 2030 (See Table 1).

Table 1
Cumulative Power Generation Additions and Replacments Since 1992
The Specific Role of Industrial Gas Turbines[1]

1992 to 2000

Type	New			Replacement			Total		
	Total GW	GT GW	GT %	Total GW	GT GW	GT %	Total GW	GT GW	GT %
EUROPE									
West	85	45	53	100	50	50	185	95	52
East	0			30	15	50	30	15	50
Total	85	45	53	130	65	50	215	110	51
ASIA									
Japan	51	15	29	20	5	25	71	20	28
China	100	10	10	10	-	-	110	10	9
Total	295	65	22	30	5	17	325	70	22
AMERICAS									
USA	75	50	67	70	50	71	145	100	69
Total	105	58	55	80	55	69	185	113	61
WORLD	606	223	37	250	132	53	856	350	41

2000 to 2010

Type	New			Replacement			Total		
	Total GW	GT GW	GT %	Total GW	GT GW	GT %	Total GW	GT GW	GT %
EUROPE									
West	60	35	58	120	60	50	180	85	47
East	60	10	16	70	25	36	130	35	27
Total	140	35	25	190	85	45	310	120	39
ASIA									
Japan	51	25	49	60	25	42	111	50	45
China	200	20	10	40	5	13	240	25	10
Total	580	125	22	100	30	30	680	300	49
AMERICAS									
USA	125	80	64	180	100	56	305	180	59
Total	164	90	72	190	105	55	354	195	55
WORLD	1104	352	32	500	219	44	1604	576	36

[1] Gas turbines (GT) assumed in combined cycle.

Derived from *Power Engineering International*, March/April 1996, p.28, indicated source "The Future World Market for Industrial Gas Turbines", Presentation at ASME Cogen Turbo Conference, Vienna, August 1995.

If the world needs 200 mtce of additional annual coal and lignite production by 2010, I think I can find it at a price under US$ 50 per tce. Twist their arms and the world coal industry will sell all that coal for under US$ 10 per barrel of oil. Some lignite supplies, as at Krasnojarsk, are available at under US$ 10 per tce, US$ 1.50 per barrel. Do you want a firm price to 2010, why not? The reserves are known, and the other costs are labor, equipment and self-produced power. U.S. coal mines sell to power plants on long-term contracts with only cost escalation. Why not in Europe and other parts of the world?

I can find the coal for tomorrow! Who will give me the source and price for the 2020 gas? And 2030? And 2050?

The Cost of Electric Power – Fuel Cost

Why should we start discussing economics of power generation by discussing fuel cost? Because:

- Despite the acknowledged low price of natural gas now, fuel cost is over 60 percent of total cost of power from gas-fired power plants (coal costs between 20 percent and 35 percent of the total cost of coal-fired power plants.)
- The cost of gas per kWh is 150 percent to 300 percent of the cost of coal and lignite.

A recent U.S. Utility Data Institute study compared the cost of U.S. power plants on a 5-year average cost per net megawatt hour. In total costs, nineteen of the cheapest twenty plants were solid fossil fuel-fired. Cheapest was a Wyoming lignite-fired plant. Its cost was US$ .0095 per kWh. The cheapest nuclear plant in Virginia had a cost of US$ .013 per kWh.

The operating costs, excluding capital and fuel, of gas-fired plants were lowest. The cheapest coal-fired plant had nonfuel costs 12.5 percent higher than the cheapest gas-fired plant. Other studies confirm that the operating costs of a coal-fired plant (excluding capital and fuel) can be 30 to 50 percent above gas-fired plants.

However, nonfuel costs are only 25 percent of total costs (with a range of 15 to 30 percent for coal-fired plant). Such costs for gas-fired plants are only 12 to 25 percent lower than for modern coal fired plants with full environmental protection. Even if nonfuel costs of gas-fired plants are 40 percent lower than such costs for coal-fired plants, the *saving* would be under 10 percent of total costs.

At today's bargain prices for gas, gas costs double the cost of coal per kWh. A power plant cannot be economic over its 20+ year life while paying a premium of 100 percent on fuel to save under 10 percent elsewhere. The extra fuel cost already absorbs all the front end capital cost savings of gas-fired power.

Gas turbines are the power industry's Lada – cheap to buy, expensive to run!

When power plants are chosen on short-term advantage, such as 3 to 5 years payback used by third party financiers (Independent Power Producers, IPP) the importance of initial plant costs and speed of purchasing and commissioning are emphasized. This favors gas turbines which will cost the user far more over the plant life cycle. Many comparisons prepared to promote gas limit themselves to twenty or twenty-five year cost analyses so as to avoid showing the savings from coal-fired plant when it is fully amortized – but will run for another ten years at *zero* capital cost, while the gas turbine plant must be repowered.

Least Cost Planning

A *least cost planning* analysis must be based on life of investment for a forty year life of installation and twenty to fifty year estimated fuel costs, not based on spot fuel prices, nor costs of new plant, nor IPP ideas of short-term payback.

First, a power producer must prepare a global plan for the entire installed capacity of the system including present plant, planned plant and needed new or replacement plant through the end of the useful life of the planned plant. This global plan should consider past, present and future for a *minimum* of thirty years:

- Age of plant and life of plant (including retrofit and repowering),
- Efficiency, technologies and possible improvements,

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Fossil Fuel's Long-Term Role *(continued from page 13)*

- Logistic needs (fuel, ash and scrubber waste storage and disposal),
- Environmental limits (and remedies and costs),
- All costs for all levels of operation as mentioned above,
- All possible sources of revenue (sale of power, heat and waste; any premium for municipal waste burning or other disposal, and any possible subsidies),
- Expected demand curves, daily and seasonal, and possible strategies to modify them (Demand Side Management, DSM programs, interruptible contracts, programs of grid power purchase and exchanges).

The goals are economic power and heat for a healthy economy and lowest economic levels of pollution for a healthy citizenry. It is important to remember the primacy of the former goal, the economic goal, as in a market economy, money wasted through uneconomic baseload power production will constrain funds possibly available for environmental protection and for investment in *green* energies and DSM and energy savings.

Load Factor - Another Essential Guesstimate

The economic efficiency of a power production system, or of a single plant, is a function, therefore, principally of fuel cost, and of total costs.

However, the other major element in total costs per kWh produced, capital and fixed overheads, is largely a function of the *load*, the number of hours of use of the plant as base load or peak load supply.

For this reason the plan of the functioning of the entire installed capacity, season-by-season and year-by-year is needed to plan the power needs.

For a utility, production of power is its source of revenues; its rate of asset utilization is the means of covering fixed and overhead costs, so management generally will try to sell all the power every plant can produce.

Economically managed power systems have complicated processes to select which of the available capacity will be *dispatched* and in which order. The more hours per year for which a plant is used (dispatched) the more revenue it earns.

For this reason the developer of a power project attempts to obtain *take-or-pay* contracts with its power and heat buyers so that the producer, not the customer, decides when to operate the plant. Unless the price for such supply-push power is negotiated very strictly (i.e., capped), the public interest will suffer if such power costs more than other power available to the grid, and hence to the public. If price-capped IPPs are bankrupted, that is sad, but is it better than forcing the public to pay for uneconomic power?

There are many methods for dispatching power from one or another power plant, and thus allocating power production markets, and revenues, to plants:

- In the case of a monopoly public service as in France, the State decides.
- The United Kingdom chose a short term auction of power to the grid. This apparently equitable system is subject to manipulation by suppliers of rapid response power (gas turbine or hydro-top-spin) who can drive off the market suppliers of lower cost power with longer load-following cycles (particularly classic coal-fired plants). It is also subject to the deliberately obscure *contract for differences* which mitigates the *free market* effect.
- Little Belgium avoids the economic and regional problems of analyzing which plants might provide the least cost power. All fuels are given a theoretical equal cost by the Calorie Pool which assures distribution of work between the linguistic regions, profits for the utility and high prices for consumers!
- The United States has a complicated, legalistic reporting system. It seems to work there.

These are caricatures - but in analyzing the economics of future power production the expected use rate (annual hours amortization) of new plant is most important.

The use rate, baseload or peakload, is most important in comparing the expected production costs of capital intensive plants (nuclear, dammed hydro, coal and lignite) and capital intensive systems (mine-mouth lignite and coal plants).

Contractual commitments and public-private agreements or regulations are needed to define how power plants are managed and will be managed for forty years.

Assumptions must be agreed on expected growth of power use, and on possible load reduction through savings programs, DSM and more efficient use techniques.

General assumptions of use levels must be corrected for the need to cover peak loads, or to provide interruptible tariffs for users who forego peak periods.

Planning and agreeing expected total system load, and its daily and seasonal profile is an unrealistic ideal. It is also a practical necessity, as the choices of the appropriate power production needs are based precisely on the level of use of plant, and on the baseload use compared to peak load needs.

Planning, Guessing and Gambling

Least cost planning is dependent on accurate planning and forecasting of load profiles and of plant use. For example, appropriate choices may be summarized as:

- For over 6000 annual hours: nuclear, lignite, coal and dammed hydro. Plant siting will be determined by resource and water availability, generally as extracting power-only plant, with long-distance transmission of power produced.
- For over 4000 annual hours: flow-through hydro, fluidized bed coal, gas-fired combine cycle plants in co-generation mode.
- For over 2000 annual hours use: top-spin hydro, gas topping on all types of plants (including coal-fired and nuclear), gas turbine combined cycle, motors.
- Under 2000 annual hours use: top-spin hydro, gas turbines, motors, and maximum reliance on grid exchanges, particularly for shorter cycles of demand.

This *decision tree* can be derived for each case from a cost analysis:

Costs=	**Capital Costs +**	**Operating Costs +**	**Fuel Costs**
• type	• front end	• price indexed	• cost based (coal, nuclear) • or price indexed • or economic rent (oil, gas)
• base	• years service or annual hours use	• years service & operating periods	• operating hours +/- tariff fluctuation

- The capital costs are generally fairly well known in advance.
- The selling price of power can generally be indexed on a basis at least equal to the operating costs (for a normally expected annual level of operation.)
- The RISK, the *wild card* element is therefore FUEL COST, the LARGEST COST.

This risk is a purely optional risk, which appears to have no winning chance!

If a cost-based fuel is chosen (uranium, lignite or coal), costs of production and transport are normally all cost of living linked costs: equipment, labor, self-produced energy. Thus long term cost-plus, cost-indexed contracts, as in the United States, are suitable.

Large amounts of coal and lignite are available at a cost equivalent to under US$ 8 per barrel for oil. That is the *world market price* for energy.

Coal is a diversely owned, worldwide industry with present suppliers facing overcapacity for another thirty years at least.

An OPEC-like cartel is unimaginable, particularly for the huge OECD producers.

There is no serious possibility for the price of oil or gas to remain below *twice* the price of world traded coal in the period to about 2040 which we should consider for fuel prices in planning new power plants.

Least cost planning for power production offers three levels of choice of risk:

LOW Risk: cost-based fuel, stabilization of load and total demand.
MEDIUM Risk: some overcapacity, develop CHP, use gas turbines for peak load.
HIGH Risk: Pray for reliable nuclear, cheap renewables, plentiful gas/oil!

The Risk of Risk

How can the power industry achieve improved economics? In many ways, but one clear lesson in economics is that higher risk requires higher rewards.

Deliberate choice of high-cost, high-risk fuel for power generation cannot and will not be economic, except perhaps for topping and peak loads, always backed-up with a reserve of oil for high-priced security for gas-peak-load crises.

Unfortunately choice is needed. Gas turbines are cheaper than coal-fired plant but they cannot burn coal. Many coal-fired plants could burn oil or gas, but once the higher investment costs are sunk, the more economic fuel is used.

The ASME paper from which Table 1 is derived is right. The trend to reliance on gas turbines will peak before 2010 and then decline. The realistic choice is planning now for greater and more efficient use of coal in the next century.

Power producers which choose a high risk path, condemning themselves to produce only high-cost uneconomic power, will be sanctioned by financial markets. They will lose their greatest asset, their credit ratings. They will be required to pay more for capital as well as for fuel. Their plants will be dispatched less; they will sell less power. Despite lower initial investment, they will not cover costs and debt payments.

They will cry WHOOPS as they fall into insolvency, as imprudent IPPs have already done in the United States. Let them fail. Do not save industrial dinosaurs. Elimination of the power industries' *Ladas* will improve industry economics.

As indicated at the start, responsible planning to ensure competitive energy for an economy requires planning for the economic life and lifetime operating costs of a power plant, rather than seeking short-term financial savings on a long-term productive capital asset.

Crude Oil on an Upward Trend? *(continued from page 11)*

of Energy, Issue 19, No 2, February 1997, pp. 4-6.

[2] The Centre for Global Energy Studies (CGES), *OPEC Issues*, London, 1996, p. 59.

[3] A.W. Jessup, "Price Pressures: Revisited," p.5.

[4] CGES, *Oil Market Prospects*, Volume 2, Issue 2, March-April 1997, p.2, Also IEA, *World Energy Statistics*.

[5] Sheikh Ahmed Zaki Yamani, "Containment Is Too Risky," *Petroleum Review*, May 1997, p. 209.

[6] Data from OPEC *Statistical Bulletin, 1996*.

[7] Sheikh Ahmed Zaki Yamani, "Containment Is Too Risky," pp. 210-211.