Is gas really cheapest?

What is the true cost of generating a kWh of electricity? Adjusting for risk overturns the conventional wisdom.

Shimon Awerbuch, *SPRU-Tyndall Centre for Climate Change Research, University of Sussex, UK*

How does the current favourite option – gas-fired generation – compare with wind, solar and other renewables? How reliable are the numbers produced by energy planners and other experts? It is widely believed that gas combined cycle (gas-CC) is the "least-cost" alternative – with a kWh cost in the region of 3 US ¢/kWh, give or take. This figure is often compared with renewables such as wind at roughly 4 US ¢/kWh. Photovoltaics (PV) and other solar alternatives are generally not even "in the ballpark," with estimated costs in the range 15-25 US ¢/kWh depending on location. Do these figures reflect economic reality? Is gas really the cheapest alternative?

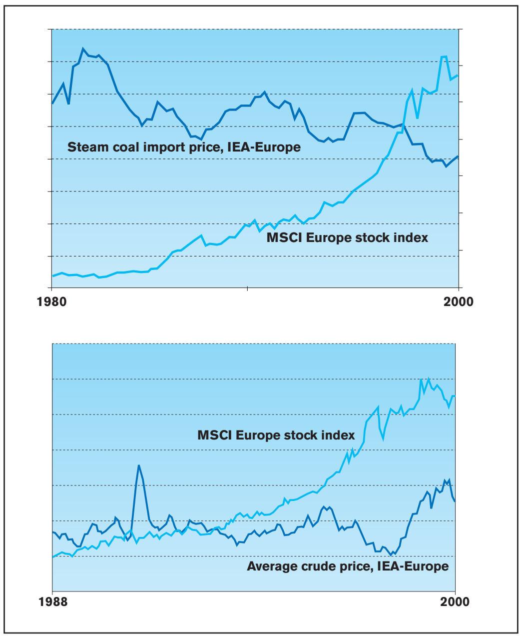
Developing reasonably reliable cost estimates for fossil-based generation – estimates that serve as effective benchmarks against which to evaluate renewables – is not a simple matter. Yet analysts routinely treat it as such, discounting projected fuel and operating costs to the present using arbitrarily chosen discount rates, including the firm's weighted average cost of capital, which is irrelevant to this computation. Such procedures yield meaningless kWh cost estimates and tell us little about the relative cost of fossil-fired generation vis-à-vis wind and other capital intensive, fixed-cost renewables. It astonishes me that cost figures so devoid of economic meaning form the basis for important EU policy and corporate energy investments.

Why are traditional levelised cost-of-electricity (COE) estimates so wildly unreliable? The short answer is: they ignore market risk – as well as its absence. The market risk idea has been around since Nobel Laureate William Sharpe and John Lintner developed the capital asset pricing model (CAPM) 40 years ago. As any finance student knows, figuring out the present value of a stream of annual costs involves an assessment of its risk. Unless risk is factored in, present values are not comparable.

The present value concept allows analysts to compare cost streams with different time-shapes. For example, the economic cost of a wind turbine with large up-front capital costs and small yearly maintenance outlays can be compared to a gas-fired project with small up-front outlays and higher annual fuel and maintenance costs. The discount rate converts future outlays to their present values; higher rates yield lower present values. The computation is simple, but applying it properly requires a degree of sophistication and knowledge about capital market theory and risk.

Most Fortune 500 firms incorporate basic risk ideas in their capital budgeting procedures. These concepts are surprisingly straightforward: cash flow streams with higher systematic risk – a component of total risk – must be discounted at higher rates. Applying these ideas, even roughly, produces much better levelised generating cost estimates than using a single rate for all cost streams. For example, fixed O&M, property taxes, contractual obligations and a variety of other outlays are legally binding or otherwise unavoidable as long as the firm or project generates sufficient income to cover them. Such fixed or mandatory costs are called "debt-equivalents." They are correctly discounted at the project's post-tax cost of debt. Fossil fuel costs, on the other hand, are relatively risky. They seem to vary negatively with economic activity, rising during bad economic times, just when people can least afford them.

The correct rate for discounting such outlays is very low (around 0 to 2 per cent). Lower discount rates produce larger present values. Discounting a future stream of fossil fuel outlays at 2 per cent, as compared to the traditional 5 per cent, 7 per cent or even 10 per cent, raises its present value cost substantially. Given the empirical evidence, traditional cost-of-electricity analyses clearly discount gas and other fossil outlays much too heavily. This significantly understates the true cost of these fuels.



European fossil prices tend to move inversely with economic activity (MSCI = Morgan Stanley Capital International)

Risk, price volatility and economic activity

A basic finance theory idea is that risk directly affects the present value of a cost or benefit stream. Risk affects estimated electricity generating costs: a €100 yearly outlay for fossil fuel does not have the same present value cost as a €100 yearly outlay for fixed maintenance or interest payments. The present value cost of the fuel outlay is greater. Capital markets reveal the cost of risk. This cost is relevant for investors as well as electricity consumers who are not investors.

Utility and government electricity analysts are rarely trained in finance and hence do not integrate these fundamentals. They do what is familiar: they arbitrarily "select" a single discount rate for all generating project costs. Leading agencies, including the European Commission (EC) and the International Energy Agency (IEA), continue to produce COE estimates using the traditional arbitrary approaches. The authors of the widely cited *Cost of generating electricity* (IEA/NEA/OECD, 1998) for example, justify their arbitrary use of 5 per cent and 10 per cent discounts with the astonishing assertion that there exists "no consensus view" on how to properly adjust generating costs for risk (p 27). Finance theoreticians would vehemently disagree. They would argue that there indeed does exist a well-developed consensus, which can be found in any undergraduate finance textbook. Traditional COE approaches such as the ones used by the IEA and the EC, always bias in favour of low-cost/high-risk fossil alternatives over costlier, lower-risk renewables such as wind and solar. If financial investors used such approximations they would choose only risky, high-flying stocks and junk bonds to the exclusion of government bonds and other low risk securities.

Price volatility contributes only partly to fossil price risk. What really drives fossil risk in a finance sense is the systematic correlation between its price movements and the returns to other assets. As a growing body of evidence indicates, fossil price volatility depresses macroeconomic activity as measured by GDP growth. (Raphael Sauter and I review this evidence in a recent IEA Research Paper, *Oil price volatility and economic activity: a survey and literature review*, September 2002). These ideas seem widely acknowledged although their full implications for COE estimation are not understood. *Business Week*, for example, recently reported that high oil prices could dampen quarterly US economic activity to the tune of $50 billion. This is the un-diversifiable societal risk of fossil-price volatility. Its steep costs easily swamp the total estimated public sector investments required to accelerate renewable energy in IEA countries. Individual fossil project risk is simply the microeconomic consequence of this relationship. A generator's fossil fuel costs rise during bad economic times – just when returns

Author's email address: s.awerbuch@sussex.ac.uk
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to other assets are down. Market power seems to enable gas-based generators to shift these costs and risks to electricity consumers, but this does not make the risk disappear. The negative relationship between fossil prices and economic activity also has significant implications for energy security as Martin Berger and I discuss in a February 2003 IEA research paper (http://www.iea.org/techno/renew/port.pdf).

European policy makers have not effectively integrated these ideas into their energy security and diversity decisions.

COE estimates for gas generation

Traditional approaches for estimating levelised generating costs often discount projected fuel prices at arbitrary rates of 5 per cent or 7 per cent or even 10 per cent. Given a 7 per cent discount, a typical energy conversion efficiency of 55 per cent along with 85 per cent capacity factors, energy planners will generally estimate a levelised fuel cost for gas-CC around 2 US ¢/kWh. When fixed and variable maintenance costs are added, the total generating cost is usually about 3 US ¢/kWh (Column I of table).

Finance theory produces a considerably different picture, with estimates ranging from 5 ¢/kWh to over 7 ¢/kWh. The lower range is based on the assumption that forecast fuel prices represent the 30-year fixed-contract price at which generators can obtain fuel (Column II of table). This assumption removes considerable risk from the future fuel outlays, which in turn produces a more favourable generating cost estimate. A 30-year contractual fuel purchase obligation is easy to value, as previously discussed: as long as the firm generates sufficient income, it will be legally bound to honour its contractual obligation, which makes the risk of this outlay stream very similar to the risk of a corporate bond. This means that projected contractual fuel outlays must be discounted at an average post-tax cost of debt – currently around 4 per cent, which in turn produces a tax-inclusive levelised fuel cost of 3.8 ¢/kWh – nearly twice the traditional estimate. When present value O&M costs are added, the total COE turns out to be about 5 US ¢/kWh, as compared with the traditional 3 cent estimate. This illustration makes an important point: the theoretically defensible estimate for gas-fired generation with virtually all fossil risk removed is about 60 per cent higher than widely believed.

A second point is that despite measurement problems and recent controversy, the capital asset pricing model (CAPM) can be applied in a straightforward, non-controversial manner to produce COE estimates that have clear economic interpretation and are significantly more meaningful than traditional estimates. Empirical CAPM problems do not significantly impact levelised generating cost estimation.

Column III shows a second, less optimistic set of estimates, based on the idea that historic fossil price risk is the best guide to the future. This approach incorporates empirically derived historic fossil price movements relative to the returns to a broadly diversified portfolio as might be represented by the MSCI Europe Index. The resulting levelised fuel costs are about 6.0 ¢/kWh, with a total COE of 7.3 ¢/kWh.

These finance-based COE estimates have a clear economic interpretation: they represent the estimated value of a 30-year firm contract for the delivery of gas-CC generated electricity if perfect markets for such contracts existed. The range of the tax-inclusive cost estimates lies between 5 and 7.3 US ¢/kWh. Where the true answer lies depends a great deal on whether fuel price volatility over the last five years is a good indicator of fuel price volatility for the next 30 years. If it is, then the best estimate lies near the upper range of 7.3 cents. Where the proper answer lies is further affected by whether fossil prices will continue to move inversely with economic activity or whether, as some predict, they will decouple and behave more like other commodities. Either way, the important idea remains unshakable: even with nearly all fossil price risk removed, the economically interpretable levelised generating cost estimate for gas is a minimum of 5.0 US ¢/kWh – two-thirds higher than traditional models indicate.

Some analysts and policy makers will find it difficult to accept these results. They confuse levelised costs with actual observed costs. Levelised costs are not real. They are imaginary, time-weighted averages that have no physical interpretation. Like any averaging procedure, they can be very misleading. For example, by using projected annual gas-CC generating costs and their certainty-equivalents (the certainty-equivalent of a risky cash flow is the riskless cash flow with the same present value) it is possible to construct an expected set of prices for PV electricity that lies much closer to the cost of gas-CC prices – within 15 per cent towards the end of the planning horizon – than widely cited levelised costs would indicate. When technological options are sufficiently disparate, levelised costs can severely distort important inter-temporal cost information for generating alternatives. Levelised costs are a shortcut. They have allowed analysts to present complex inter-temporal cost information using a single number. This may have been OK when generating options consisted of technologically and financially homogeneous fossil alternatives. Given the technological array available today, levelised costs may no longer give policy makers all the decision information they need.

kWh cost estimates for gas combined cycle generation (US cents/kWh)

	(I) Traditional estimate	Finance-orientated estimates (II) Lower range estimate (debt-equivalent fuel outlays)	(III) Upper range estimate (empirically derived historic fuel-price risk)
Fuel discount	7%	3.9%	1.3%
Levelised fuel cost	2.0 cents	3.8 cents	6.0 cents
Fixed O&M discount	7%	3.9%	3.9%
Variable O&M discount	7%	4.6%	4.6%
Levelised O&M costs	0.3 cents	0.5 cents	0.5 cents
Levelised capital costs	0.5 cents	0.7 cents	0.7 cents
Total generating cost	2.9 cents	5.0 cents	7.3 cents

Time for a rethink?

Levelised kWh cost estimates are intricately tied to the way cost is modelled or conceptualised. Moreover, as is the case for any long-lived asset, figuring out what it has actually cost to operate the asset during a particular year – the quintessential accounting challenge – is highly dependent on a number of assumptions, including the conceptual manner in which capital is recovered.

Generating technologies do not come with an attached cost meter so that true operating costs in any given period can theoretically not be known until the end of the asset's life. Anything else is an educated guess. This means that we need to treat all estimates with some scepticism. This applies to ex ante levelised estimates as well as ex post accounting results.

Standard finance-oriented models produce gas-fired kWh cost estimates considerably higher than traditional estimates. Properly evaluated, using risk-based procedures, the costs for wind and a number of other renewables are well below the 5 cent lower bound CAPM estimate of gas-fired electricity. The challenge is to learn how to fully exploit the special attributes of these technologies in a network setting. This will likely involve changing the manner in which electricity networks are operated and regulated.

Distributed renewables provide the first opportunity to fully re-engineer the century-old electricity production and delivery process. Things change and the old network needs to learn new tricks. It needs to become "informated" in order to fulfill its new role of facilitating the electricity marketplace. These ideas are discussed in *Unlocking the benefits of restructuring: a blueprint for transmission* (S Awerbuch, L Hyman, and A Vesey, PUR, 1999).

Innovative regulatory mechanisms for exploiting so-called intermittence and other special attributes of the more passive renewable alternatives will help reduce overall cost and create efficient generating portfolios that effectively implement EU energy security and diversity objectives. Indeed, it is time to replace the naïve practice of comparing generating alternatives, with techniques that compare alternative generating portfolios and strategies. Martin Berger and I develop such portfolio approaches in our February 2003 IEA research paper.

Cost estimation is always risky, but we have choices and some control. We can choose theoretically defensible cost models that are at least approximately correct, or, we can continue to use outmoded procedures that will be correct only by accident. Given current fuel price forecasts, the economic evidence clearly supports the conclusion that the expected 30-year cost of firm gas-fired electricity is at least 5 ¢/ kWh. Despite this overwhelming evidence, the traditional 3 cent COE estimate is still widely used for investment and policy making, which should at the very least prompt widespread debate.

European policy makers can ill afford to base crucial energy decisions on the output of outdated cost models developed around the time of the Model T Ford and since widely abandoned in other industries. It is time to bring the best contemporary tools available to our energy policy decisions. These show that the risk-adjusted cost of gas-fired generation over the next three decades is in the range 5 - 7 ¢/kWh.