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Financial considerations of exploiting fuel cell technology

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1. Introduction

Fuel cells were invented around 1839. If a technology is promising, but not quite commercialised for 160 years, there is bound to be some scepticism from the rest of the world when it is announced, as it has been with increasing frequency in the 1990s, that fuel cells are on the verge of being commercial energy convertors. Observers have been told a similar story, though with less insistence, for many years. Nevertheless, it now appears to be true that fuel cells really are close to commercial status, and this means that practical questions about how they will enter the energy system start to become important. Among these practical questions, economic and financial issues are clearly central.

These economic and financial issues are now considered, not from a narrow perspective of financial analysis (though some technical issues of finance and economics are raised), but rather from an analysis of the wide range of factors that will impact on financial and economic outcomes. In this process, some explicit attention is given to the status of the technologies, established and novel, that fuel cells must compete against, because the success of the fuel cell is at least as importantly determined by changes in the status of competing technologies as changes in fuel cells themselves.

2. Scope of paper

It is impossible to cover the range of technical approaches to fuel cells and their many possible practical applications here. It has been decided to concentrate on PEM technology for two main reasons: (1) PEM technology promises to have significant applications in both major possible markets for fuel cell technology — automotive transport and power; [1]; and (2) because the scale of PEM units is small, and the markets are large, it offers the best hopes for major cost reductions as a result of volume effects in production.

The two markets (automobiles and power) are, however, very different, and commercialisation in each case depends on decisions that need to be made by very different actors — domestic consumers, energy intermediary companies and electric utilities on the one hand, and large automobile manufacturers on the other. These differences, both in the actors involved and the markets in which they exist, mean that the financial issues (e.g., perception and management of risk) appear in quite different guises. Attention is concentrated on power issues.

3. Economic and financial evaluation of fuel cells

It is increasingly common to find quantitative studies that show fuel cell technology to be economically or financially superior to its rivals. [2] Despite many promising developments, it remains true, however, that fuel cells are not yet being purchased in a routine way as a competitive technology. Why is there a gap between the apparently superior economics of fuel cells in a number of applications, and the fact that they remain largely pre-commercial in reality?

Part of the explanation for this apparent contradiction is that most of the analyses showing superior financial performance are conducted by those with intellectual or commercial vested interests. This is at least in part caused by ‘appraisal optimism’. [3] Proponents of any new technology systematically (but often unconsciously) employ assumptions that are favourable to their own technology, and unfavourable to its rivals. It is often presumed that there will be rapid technical advance in the favoured technology,

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[1] I rely for much factual material in this paper on the very good paper by Colella [1]. This is available from the Library, SPRU, University of Sussex, Mantell Building, Falmer, Brighton BN1 9RF (Tel.: +44-1273-686758).

[2] A relatively early example is by Ogden and Nitsch [7], Tables 29 and 30, pp. 999 and 1000, which show lower life cycle costs for fuel cell transportation than for gasoline-driven cars.

[3] A term originally proposed by the UK Treasury to reflect the fact that most public sector projects in the UK were coming in well over budget.

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but limited or even no advance in competitive technologies. A subtle form of optimism occurs when a development favourable to one's preferred technology is credited to evaluations of one's own technology, but not equally credited to rivals. An example is the use of the expectation that regulators may in various ways increasingly favour technologies with characteristics such as low emissions.

The classic historic case of appraisal optimism with serious economic consequences is that of nuclear power. Advocates and even apparently dispassionate observers persuaded utilities and Governments that nuclear would be the cheapest route to power, with results that are now all too clear [4] (no OECD country has ordered a new nuclear plant for some years; the USA has not done so for a quarter of a century). For fuel cells and all other promising new technologies, it is vital to be rigorous in ensuring that comparisons are done on a fair and duly sceptical basis.

The obvious framework for the financial evaluation of fuel cells is investment appraisal using conventional discounted cash flow (DCF) analysis, as advocated by financial analysts, economists and most businesses. Future cash flows, positive and negative, are set out for all future years of project lifetimes and these are brought to a present value by the use of a discount rate. Positive present value implies that the project should go ahead: negative, that it should be avoided.

While this kind of technique makes sense in a normal business context, there has been a growing tendency in recent years to argue that for many kinds of investment decision, DCF should be supplemented by other forms of analysis which talk the language of options and option values. [5] This revised approach takes account of the fact that certain kinds of investment decision — originally especially for R&D, but increasingly for a wider range of investment projects — create options that may be exploited in the future, and lead to further new benefits as a consequence. In the case of R&D, successful project completion will often open up a range of investment possibilities exploiting the new R&D-based discoveries. Where this seems to be likely, the project appraisal adds to the DCF calculation of the original project the 'call' (option) value of subsequent investments that the original investment makes possible.

In the case of fuel cells, early investment of a demonstration or pilot nature may lead to a wider range of commercial investment options in later years, and arguably, such prospects should be factored in to the original appraisal. However, the evaluation of these option prospects is subject to great uncertainty, and delay can bring costs as well as benefits (e.g., competing technologies may develop quickly). The space opened up for new forms of appraisal optimism in the use of option pricing techniques is considerable, and it is therefore not clear that traditional DCF methods should yet be supplanted.

4. Input assumptions

Once technique is established, attention turns to the assumptions that are to be made in the financial analysis. How much attention is needed for each type of input assumption depends on three kinds of consideration:

- whether the input assumption is unique to fuel cells or common to a number of technologies, including the main competitors;
- whether the input assumption is under the control of the technology or project developer, or determined by wider economic and social forces;
- whether variations in the input assumption have a large impact on the viability of fuel cell-based projects.

Where a project input is common to competing technologies and not within the control of the developer, it is reasonable to give it little attention. The classic case here is the price of natural gas (it is assumed here that natural gas will be the predominant source of hydrogen for power sector fuel cells). [6] Natural gas is also used by many competing technologies, for example, in gas engines, gas turbines and central heating boilers, and changes in its value will tend to affect both fuel cells and its rivals to roughly the same degree. For present purposes, it is a variable to be ignored.

Variables that do need to be considered in detail are those which are unique to the technology and in principle under the developer's control (such variables are critically the basis for potential competitive edge), and those which make a big difference to the financial outcome.

This suggests two principal focal points for financial analysis:

- *The construction and installation cost of fuel cells*. These meet all three criteria: unique, under developer's control, and critical to the financial outcome.
- *The discount rate used in the appraisal*. This variable is not entirely unique to the project and only partly under the control of the developer. However, the value of the discount rate is critical to the financial outcome. In addition, discount rates have been rising sharply in recent years, especially in the power industry, and this in turn makes the construction and installation cost even more vital as the cost of using capital rises.

These arguments suggest that the main focus for the remainder of the analysis should be the construction costs and the discount rate. However, before considering the specifics, it is first necessary to turn to the wider forces that affect their values.

[4] The history of nuclear cost under-estimation is well-documented. See for instance, Refs. [4,9] for analysis and data.

[5] A good common-sense exposition of this view is provided in Ref. [3].

[6] See Ref. [6] for a discussion of distributed generation and its fuel sources.

5. Wider forces affecting construction costs and discount rates

There are three main kinds of force that need to be analysed if a fair view of the prospects for fuel cells is to be gained. These are: the impact of Government and regulation; the pattern of technological change; and the changing business environment surrounding fuel cell development. Subsequently, the impact of these factors on construction costs and discount rates will be discussed.

5.1. The impact of Government

In the 1970s, developers of innovative energy technologies looked to Governments to subsidise their efforts. In the wake of the oil crises, these hopes were often fulfilled and large amounts of public money were paid for a wide range of energy technology development. Since the mid 1980s, such programmes have mostly been in retreat, and little new money is now available for straight subsidy of technology development.

A partial exception to this trend is that Governments have been willing to subsidise, usually on a modest scale, technologies which show particular promise in terms of their environmental performance. However, fuel cells, in their most likely commercial forms, do not offer greater advantage in efficiency or resource saving than a number of other technologies, so it would be unwise to expect differential help for fuel cells over alternatives from this source. These factors mean that the possible new emphasis on tradable permits or carbon taxes will also have at best a modest effect on fuel cells.

The one possible exception to this argument is that Governments placing emphasis on vehicles with low emissions at the point of use may give strong incentives to fuel cells as an automotive technology, but it would be unwise to rely on such Governmental intervention as a major driver.

However, Governments have also been active in quite new directions in recent years, especially in the power sector, where extensive liberalisation has been taking place in almost all the industrialised countries. Liberalisation has meant the introduction of at least some competition into the electricity generation business as well as into electricity retailing, activities which were previously almost entirely monopolistic.

This has had a number of repercussions. One is that the introduction of competition has increased the financial risk of generation investment: and as argued below, higher risk tends to increase discount rates and penalises capital-intensive investments. On the other hand, more competition implies a larger number of companies and a smaller scale of activity. This means that the previously monolithic electricity supply industry is becoming more diverse, and there is a new interest in smaller-scale technologies as well as new ways to supply retail customers. Energy retailers, unencumbered by transmission and distribution assets, may find decentralised, micro-level CHP schemes, which bypass bulk electricity transport, increasingly attractive. This will benefit fuel cells by helping to get them into the frame of realistic decision-making.

The new interest in distributed generation may also lead to favourable regulatory repercussions, such as recognition that local sources of power, by relieving large utilities of the need to make transport investments, should attract locational credits. Such possibilities are under active discussion in a number of countries. Again, while fuel cells will not be alone in deriving benefit, they may be in a good position to exploit such new developments.

5.2. Changes in technological trajectories

Up till a decade or so ago, the ‘iron rule’ of economies of scale seemed to operate in the power industry. This said that the only way to cheaper power per unit was to increase continuously the size of individual generating units (Strictly, these are economies of ‘dimension’ rather than ‘scale’.). As a consequence, the characteristic size of generating units increased from around 30 MW in 1945 to 1300 MW by the late 1970s. At this point, further economies started to become exhausted, and for a while, a relatively large range of unit sizes co-existed in the market — roughly 500 to 1300 MW, though even 500 MW is very large in relation to the scale of fuel cells.

Gradually, through the 1980s and into the 1990s, it became apparent that the scale argument was breaking down. First, advantage to scale had never been so universal as first claimed and was heavily influenced by three factors: the monopolistic character of the industry, the needs of rapid growth in the 1960s, and the apparent requirements of nuclear technology. Second, the rise of natural gas as fuel for the power sector illustrated the possibilities of smaller-scale generation without loss of efficiency or cheapness — the gas turbine and the new forms of industrial combined heat and power were the first signs of this. This was a part of an economy-wide change in trajectory towards technologies that could benefit from the precision and flexibility offered by information and communication technologies.

In this context, the scale of large power projects began to be seen as symptoms of inflexibility and slowness. These underlying changes in technology were accompanied and reinforced by institutional change, as described above, in which the scale of some of the enterprises involved often became smaller, and small-scale technologies began to enter their potential decision process.

In this changed situation, the advantages of smaller, diverse and dispersed technologies began to become evident. Large generating units had to be sited in locations distant from consumers and needed long-distance transport: smaller units avoided transport costs. Electricity systems began to grow more slowly and less predictably, so that small increments to capacity became more attractive, with reductions in risk, and much quicker returns to investment [8].

For these kinds of reasons, with technological change and liberalisation in some ways mutually reinforcing, small-scale technologies like fuel cells began to get serious consideration at the centre of the power industry, not just at its periphery. However, none of these changes guaranteed that fuel cells would do well. Once smaller-scale technologies became interesting to important parts of the industry, then a vast array of competing technologies also came into view, all the way from traditional and well-established technologies like diesel engines to high tech and much newer technologies like solar photovoltaics. The changes of the past decade have been arguably a necessary condition for the success of fuel cells: they could not possibly be a sufficient condition.

5.3. Changes in business strategies

A necessary condition for technologies to succeed is that the various established industrial interests in a market are, minimally, not threatened by the spread of the new technology and, preferably, advantaged by it. The fact that practical PEM devices will initially need fossil fuel as a feedstock has meant that the natural gas and coal industries have tended to regard the technology as an opportunity rather than a threat [5]. However, the utility sector was always more problematic.

For as long as electricity supply was dominated by large, monopolistic and usually integrated utilities, the prospects for small-scale generation options were very limited. Not only were they beneath the minimum scale of management interest, they were also a direct threat to important parts of existing businesses. If local sources of power meant that large transmission and distribution networks became less necessary, established utilities would be left with assets that would at least in part be ‘stranded’ and unprofitable. Liberalisation gave some new companies, unencumbered by existing assets and the need to protect them, a potential interest in small-scale, local options.

It has clearly been an important strategy in recent years for PEM fuel cell developers — predominantly quite small companies — to form alliances with larger firms both in the automobile sector, and — more important from the present perspective — the electricity industry. Over the last 3 years, several such alliances have been forming, with such companies as Alstom, EBARA and DTE Energy. These alliances can, in principle, increase cash flows into development work and, most important of all, help overcome the problem of low volume manufacture by offering the possibility of large orders with consequent reductions in unit cost.

As yet, there has not been widespread collaboration between utilities and fuel cell developers, but as the market liberalises the opportunities for utilities to exercise obstructive positions diminishes and new companies — especially retailers — may see fuel cells as a potential competitive weapon.

6. Construction costs

The discussion of Government, technology and industrial alliances has established that most of the main potential obstacles to fuel cell development at small scale have been largely removed at a structural level. This provides necessary, but far from sufficient conditions for fuel cells to compete successfully in power markets. It does mean, however, that technical efforts to reduce construction costs, by further innovation and by volume manufacturing efforts, now have a chance of leading to real success. As argued above, reductions in unit construction costs are the single most important variable in making fuel cells more competitive.

The volume manufacturing effect deserves further discussion. In the discussion of economies of scale in generating plant sizes, it was argued above that scale effects were now relatively unimportant, and that small-scale technologies could compete effectively with large units. These economies of ‘scale’ are essentially economies of dimension or unit size, and have been rendered less important by processes of technological change. The scale effects from volume manufacture are quite different in type: they are essentially economies of ‘number’ and they are of undiminished importance [9].

Indeed, their practical import may now be larger than when commercial unit sizes were larger. This is because there is potentially a need for many more units of small-scale technologies than is the case with larger units, and this gives the ‘scale’ effect more chance to work — the numbers of units produced will be in the thousands, rather than tens or at most a few hundreds. For this reason, apparently optimistic predictions of unit cost reductions for PEM fuel cells may actually be more firmly based than for other larger-scale technologies where production runs will inevitably be smaller.

It is very difficult to conduct a realistic quantitative discussion of fuel cell construction costs and their evolution. There are several reasons for this:

- There are relatively few sizeable, quasi-commercial projects yet in existence;
- In an increasingly competitive market, many estimates of construction costs are commercially confidential and unavailable;
- Where estimates are available, they will often suffer from conscious or unconscious variants of appraisal optimism; and
- There are severe difficulties in comparing like with like. In particular, the assumptions and boundary conditions may vary substantially between different studies and render comparisons difficult. Difficulties may arise over

such factors as whether or not transmission and distribution costs saved are counted in an analysis, whether heat supply costs avoided are factored in variable or total cost terms, or what value the discount rate takes. These may all cause arbitrary variation in results.

Equally, it is impossible to be categoric about what the target construction costs will need to be to make fuel cells competitive. Much will depend on the precise circumstances of projects (e.g., assumptions about grid operation, or about the ratio between heat and power loads, etc.) However, what is very clear is that the target values (construction costs per kilowatt) at which fuel cell systems need to aim are falling rapidly. In the early 1990s, it was possible to think of $1000/kWe as a realistic target, and fuel cell developers sometimes still quote ranges of $500 to $2000/kWe as targets for the products [1].

However, the advent of high efficiency–low cost combined cycle gas turbine systems (CCGTs) has led the way in reducing the construction costs of new power facilities. In most OECD markets, reliable, low-risk CCGT systems ~ 300 MWe can now be installed for less than $500/kWe and the trend is still downwards.

In this context, the capacity of fuel cell systems generally 200 kWe–10 MWe, to generate at much lower cost through volume production effects seems critical. Differences between current estimates of construction costs and projected mass manufacture levels can differ by over an order of magnitude ($1000/kWe against lows of $50/kWe). Even though these two figures are not on a like-for-like comparison, they indicate that there are substantial possibilities for PEM unit costs to fall at large enough production volumes.

7. Discount rates

The value of discount rates used in project appraisal cannot be determined by project developers, but they can be influenced by increasing prospective reliability and therefore lower financial risk. While liberalisation has brought some real advantages to developers of small-scale technology, it has also brought the major problem of higher discount rates. There are two reinforcing reasons for this large rise in rates:

- Utilities used to exist either in the public sector or in a very low risk and regulated private sector with substantial monopoly power. In either case, they had access to very cheap capital and could correspondingly appraise investments at low discount rates. Utilities are now more often privately owned and rarely have access to such cheap capital: they are increasingly incorporated into normal capital markets;
- As competition increases, so the risk of generating investments increases. Under most private sector approaches to estimating discount rates (e.g., the capital asset pricing model), the riskiness of individual projects is reflected in the value of the discount rate. As fuel cell projects will generally be perceived by markets as above average risk, this will tend further to increase discount rates.

As discount rates rise, they imply a higher cost of capital, and this has a twofold effect on appraisal results:

- Investment, in general, becomes harder to justify (all possible investments must pass a more stringent test);
- Within those projects that are approved, there is an increasing bias against capital-intensive investments (those with high capital spend per unit of output).

Examples of the strength of the discount rate effect can be seen in the case of nuclear power investment in the UK in the 1980s. The Sizewell B project appeared to be viable (positive net present value) at a 5% public sector discount rate and was approved on that basis in 1987. By 1989, the official rate had risen to 8% and the next project, Hinkley Point C, was at the margin of apparent viability (though with lower expected construction costs than Sizewell). By 1994, the nuclear utility Nuclear Electric was advised that the lowest possible discount rate for a nuclear project would be 11%, and at this rate, the proposed Sizewell C was a large loss-maker, though the construction costs were even lower than those expected at Hinkley Point C [2].

As fuel cell projects are capital-intensive and high discount rates are virtually certain, this provides a significant obstacle. While the value of the discount rate is largely market-driven, fuel cell developers can influence the rate downwards by demonstrating reducing risks. Partly, this will develop over time as experience with the technology matures, but, in addition, the alliances with larger companies will also reduce risks and therefore, the cost of investment.

8. Conclusions

While it is always possible to formulate the problem of slow fuel cell or other technology development in terms of financial analysis (in DCF terms, negative net present values), it is important to go beyond the numbers to the wider forces affecting the financial and economic analysis. Until quite recently, there were large public policy, technological and business barriers to fuel cell (and other small technology) development that were always going to make the narrow financial case problematic in the power sector.

Recent changes — especially liberalisation in the power industry, technological change favouring smaller unit sizes, and a set of emerging business alliances that should help fuel cells — collectively mean that these institutional barriers to fuel cell commercialisation have lost much of their force. This constitutes a necessary, but not sufficient condition for commercial implementation of fuel cells. The new problem is that a whole host of other small-scale technologies are now in the competitive frame as well as fuel cells. But the positive message is that the possibility for cost reduction from mass scale manufacture, as well as further technical change, is very substantial for PEM cells. Exploiting these opportunities will allow the necessary conditions now established for success to be turned into sufficient conditions.

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