The Energy Storage Business Proposition

Anthony Price (Swanbarton Limited, United Kingdom) price @ swanbarton.com;
Dr Graeme Bathurst (TNEI Services Ltd.)

1. Introduction

The delivery of a successful energy storage project combines factors such as technology, project economics, and the commercial and regulatory frameworks. The hoped-for implementation of energy storage projects, which we envisaged at the first EESAT meeting in 1998, has not happened and yet the drivers for implementation are as strong as ever. Although there is now a strong technical framework that can support distributed and renewable generation, this has not passed through to promoters of energy storage on a significant scale. We have seen several viable technologies proposed for projects, but the adoption rate for electrical energy storage projects remains slow. Both cost and industry's reactions are drivers in assessing take up of new technologies. [i] It will be a sign of a mature market, when projects become too numerous to list individually.

This paper discusses the business issues that concern the development of electrical energy storage projects and impact of the project host, and the project size on the successful implementation.

2. Electrical Energy Storage Applications

The purpose of storage is to absorb energy and release it at a future point in time, for a technical or commercial reason. In an ideal world, the application gives both benefits. The sustainability argument can often be used as a benefit both for and against storage. The perceived need for renewable or sustainable power generation is now so strong that some developers will refuse to acknowledge that electrical energy storage can play a part in the operation of a power system. But this analysis should be based on total system costs. In some instances developers do not wish to mention the role of storage so as to avoid the need to increase costs of the project. Yet the European Wind Energy Association acknowledges that the system impact of renewables could be significant when penetration of renewables exceeds 20%.[ii] However, except in a few special cases, this ratio has not been reached. Despite optimism, large numbers of large storage devices have not been deployed, instead strong arguments against the need for storage have been made, often hinging on the inherent losses of the storage medium and power conversion systems.

But the issue is not financial, it must encompass the entire system operation. All power systems must operate such that supply must equal the demand plus the losses in the system. If new forms of generation, (solar, wind etc) are not dispatchable, then there is a requirement for more modulation (on a just-in-time basis) of either other forms of generation or the demand.

The purpose of including electrical energy storage on a power network is to store energy and recover it because it would be lower cost (financial, environmental or societal) than it would be to generate the energy from a primary source at a later time. So for example, at the domestic level, a householder with a domestic scale wind turbine or solar panel could store energy rather than buying it later in the day from the utility. The purchasing decision may be simply economic, or more likely to have other attributes, such as sustainability or social standing attached to it. The larger the project, the more likely that it must be economically efficient. Economics usually outweigh other considerations as the capital commitment rises. Commercial rates of return are expected and it is unlikely that energy storage projects would receive a derogation in this respect.

Energy storage is often just one possible technology that can be considered for a particular application. An electrical storage technology therefore has to compete commercially with competitors such as new distribution or transmission lines, new baseload or peaking plant, thermal storage, demand side management and responsive load solutions as well as the test of doing nothing.

A simple classification of scale and storage opportunities is shown in table 1.

Sector	Scale	Application	Comments
Domestic	0.5 kW - 10 kW	Optimisation of self generation, avoiding low net metering tariffs, providing off grid capability	Little impact on network[iii]. Installation to comply with domestic wiring regulations. Low level of planning and consenting requirements. Low level of capital expense. Potentially high $ / kW
Small industrial and commercial	5 - 500 kW	Integration of self generation, avoidance of peak demand charges, possible simple energy trading	Planning and consenting issues may be significant, depending on requirement for new build. Little impact on network. Capital expense. Regulatory issues with the Distribution Network Operator (DNO)
Industrial and Commercial	500 kW - 5 MW	Tariff management, UPS, site co-generation or self generation	Planning and consenting certain to be required. Formal application to DNO needed for connection. Regulatory considerations (generation / distribution / supply licence?)
Utility	500 kW - 5 MW	Distribution deferral	Planning and consenting under utility legislation. Significant capital cost.
Large scale	5 MW - 50 MW +	Energy trading, ancillary services trading	Planning and consenting have significant issues (including time) Significant capital cost, low specific cost High cost of electrical connection. Connection usually to DNO, exceptionally to TSO. High Project engineering cost

Table 1 Scale and application of electrical energy storage opportunities

3. Connection costs

Connecting an electrical energy storage device to the network can comprise several alternatives of varying complexity and cost. Small, single phase storage projects may almost be "plug and play" while MW size projects will require switchgear and transformers and high voltage connections in accordance with codes and regulations.[iv].

Some projects, for example, connecting a battery to a wind farm to smooth the output, would be location specific. Others, such as providing system reserves can be located almost anywhere on a network.

The costs of an electrical connection at higher power ratings involves considerably more complexity and more cost. Typically as the power rating rises, the connection voltage needs to be higher. The Network Company will also be required to consider the impact of the storage device on other users on the network. So for example while a 1 - 10 MW project could be connected at voltages up to say 11 kV, a 5- 20 MW project should be connected at 33 kV, and projects at the higher power range would need connections at 132 kV.[v]

An energy storage project shares several characteristics to a distributed generation project. The network connection will need suitable switchgear and protection, Most storage projects will need a power conversion system which can be useful when considering the real and reactive output of the device and also the fault current limits that are set by the network operator.

As an illustration, we have estimated the connection costs for storage devices of different power ratings, and then calculated the specific cost of the connection (£ / kW). (See table 2) The connection costs have been drawn from published costs of connection provided by Distribution Network Operators in the UK, moderated by experience. At the higher voltage levels, the costs assume that a new substation is required. We can see that this analysis produces a stepped specific cost curve.

The connection costs are lowest at the 11 kV level, assuming that there is spare capacity at the substation. As the voltage level of the connection increases, it is likely that a new substation would be required to accommodate the power level of the storage device, resulting in a substantial increase of costs, which is reflected in the specific cost level.

Connection voltage	Power rating	Cost of connection, (including transformer if needed and circuit breakers etc)	Specific cost £ / kW
240 V	1 kW	£5	£5 / kW
415 V	500 kW	£3,000	£6 /kW
3,300 V	1 MW	£20,000	£20 / kW
11 kV	10 MW	£120,000	£12/ kW
33 kV	25 MW	£1 500 000	£60 / kW
132 kV	100 MW	£7,000,000	£70 / kW
220 kV	200 MW	£16,000,000	£80 / kW
400 kV	1000 MW	£100,000,000	£100 / kW

Table 2 Connection voltage, power ratings and costs

4. The energy industry value chain

The power industry sits within the overall energy chain. Electricity is just one energy vector, perhaps most convenient, but sharing space next to other vectors such as coal, oil and gas. In the future, vectors such as hydrogen or compressed air may re-emerge[vi] to be commercially significant.

A simplified value chain for the power industry is shown in figure 1.

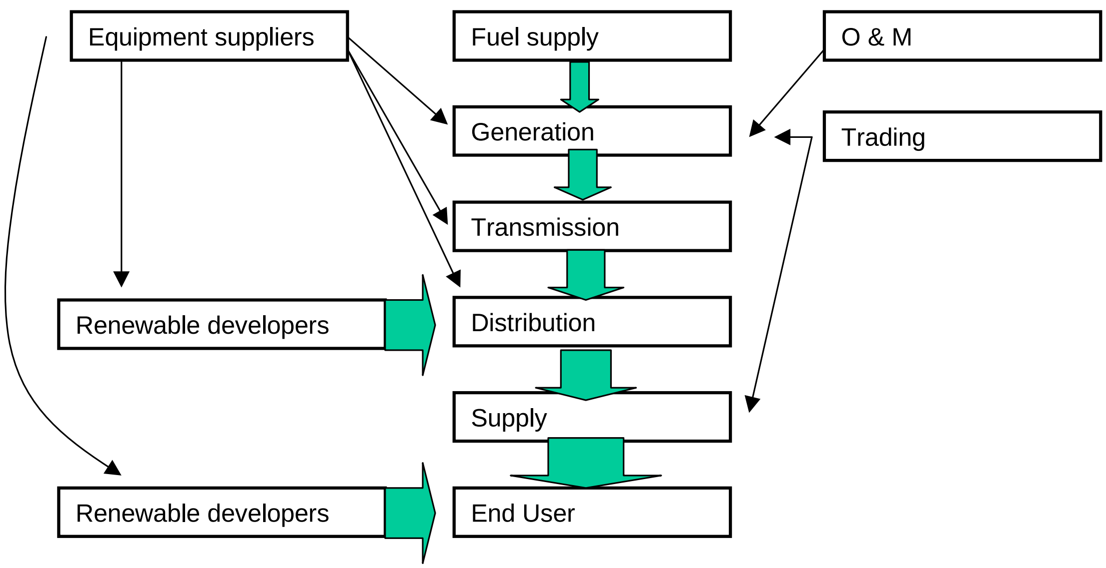

Figure 1. A simplified value chain for the power industry

In the deregulated / re-regulated power industry, artificial boundaries exist between the various components of the value chain. Generally the owner of the asset controls its value. So the generation owner gains value from the difference of the power sold against the fuel and operating cost inputs. The transmission / distribution owner gains value from the service payments made by the users for carrying the power. The value of the electricity increases as it flows through the chain.

But regulatory pressure to split generation and supply from the wires or network businesses means that it is unlikely that one incumbent can gain all the benefit from a storage device. Revenue streams must be shared, if full value is to be extracted. The energy storage vision proposed in the EU Smartgrids proposal and also by similar groups, assumes widespread deployment of devices, yet gives no clarity as to the recovery of costs or the generation of profit. It assumes that storage can work for the common good, but gives no grounds for creation of a common income to repay the owners and operators of the plant. For the storage device to earn income, it must take this from the profit between buying and selling. But if the storage is used to smooth the output of generators with demand, intra-day price spikes are suppressed reducing the chance for income recovery.

A further consideration is that as storage is added to a system, it depresses the earning opportunity for subsequent plants. This makes it more unlikely that standalone storage operators will invest in a second plant on the system, or in other words, the prize goes to the first incumbent.

A supply company owning storage can use it to balance purchases and sales of a time based power, thereby controlling the value of the store. In contrast, an end user owning storage has an advantage over the supply company and the upstream enterprises of distribution, transmission and distribution by, for example, adjusting tariffs, reducing demand charges, or avoiding or reducing time of day pricing. However the test of the business proposition rests on how the value is obtained for the owner of the storage unit, If the benefits are enjoyed in different parts of the value chain from where the costs are suffered and there isn't common ownership sub-optimal economic decisions are very hard to avoid.

5. Business costs

Installing small projects at the domestic scale (ratings of kW) can be very time consuming, either for the homeowner / installer or for the project manager /developer. However homeowners often do not cost their own time (although they find it valuable) and may be able to push costs onto other activities. (This may be why some of the most significant developments are made by entrepreneurs in their own back yard.) In any case, energy transaction costs are a necessary domestic expense. If energy were to be sold back to the supply company, through net metering or some other transaction, it would be expected to be a simple procedural transaction. The purchasing decision for the energy storage project is unlikely to be made on the basis of cost alone.

At higher power ratings, an industrial or commercial consumer with a half hourly reading meter and time of day pricing for power would be able to benefit from using storage through a reasonably simple alteration to the energy bill, which would reflect actual purchases and sales. Another easy route to capturing value is through the reduction in demand charges, where a customer may pay a demand charge based on the highest demand in a particular time period (month or year).

Such demand charge reduction is a commercially simple method of extracting value, and indeed calculating value for a potential user. Where demand charges are published as a tariff the customer can compare the tariff reduction for each kW saved against the running costs of the energy storage system.

A distribution utility, working in a separated utility environment, faces more business complications, at least in the UK and several other European Countries. Separation of business activities under the current regulatory regime means that distribution network operators (DNO) may not be involved in energy supplies. Accordingly a DNO, who might want to use a small storage plant to support a remote part of the network, receives the benefit of the storage plant against their asset cost, but suffers regulatory pressure against any trading income for energy actually used. This is at variance to the wish to see storage as an enabling technology for active network management.

A project developer, building a storage plant for speculative purposes, such as energy trading[vii] or sales of network ancillary services, can incur significant business costs. Risks increase with the length of the project and the uncertainty in forecasting future energy trends. Developers without a generation or demand portfolio will suffer the expense of establishing a full (24 hour / day & 7 day / week) trading desk. Even if trading is out-sourced, costs can be significant, especially for a solitary energy storage device of less than about 20 MW. Alternatives to electrical energy storage, such as thermal, ice or demand side load management can avoid these transaction costs. A convenient metric is to consider the daily energy throughput of the storage device, and to then calculate the value-added component. This value-added component will have to remunerate the capital costs of the project (both amortisation and financing). Unfortunately, increasing the power of the storage rating to capture the lower transaction costs, tends to increase the initial capital costs as shown in table 2.

A special case to be considered is the demand side response activities such as those proposed by Responsive Load[viii] and others. The concept is to introduce a load shedding device into domestic items such as refrigerators. These are programmed to respond to low or high frequency in the network and can provide response in support of the network. The storage component is provided by the thermal inertia of the refrigerator. The value proposition has yet to be evaluated. One suggestion is that all appliances sold will be mandated to have such a device added to them, perhaps at a cost of about $20. The consumer may be indifferent to the additional cost and pay anyway. When the device is used the network operator can capture the value at no additional capital cost, just the operational cost. This might well reduce the market for other storage developers (and generators) to offer frequency regulation and reserve services to the network. An alternative is that customers are re-imbursed the additional capital cost of the control device plus a bonus for accepting it, in return for the developing negotiating and contracting with the system operator for the provision of frequency and reserve services.

6. Impact on Planning for storage proposals

Domestic level storage installations might often be completed with the minimum of formality. Planning, consenting or permitting may not be required, as is becoming the case with micro generators such as small wind turbines or solar panels. Larger installations may require more complex review by local or national planning authorities. Large battery installations in the EU would require environmental impact assessments, triggered by the area of the project, not the power or energy storage capacity. Threshold limits for hazardous chemicals, typically used in electrochemical storage (such as batteries) may be reached even for quite low energy projects, again demanding additional time and expense in project development.

Discussions with several large power utilities suggest that small-scale projects incur unreasonably high overheads, making them unattractive commercially. Yet the same companies are reluctant to commit to large-scale projects because they would be relying on unproven technology or perceive other risks.

National and International Standards are complex and varied and are still evolving for many storage types. Different entities may be subject to different standards, for example a commercial industrial facility may be required to meet a standard such as the National Electric Code in the USA, whereas a utility installing storage is only required to comply with the National Electric Safety Code, which is less onerous.

6. Investment Planning

The United Kingdom Energy Research Centre published their report on "Investment in Electricity Generation[ix]" in May 2007. This report supports the anecdotal evidence existing in the storage industry on reasons for investment in new capacity. The UKERC reports on the role of government intervention in the power industry, from its beginnings to today. The power industry relies on consideration of long term projects, fifteen years is normal, and most large scale infrastructure is planned for a forty year life.

As well as considering the risks of capital investment, it becomes much more likely that investors will be wary of the risks in the potential income stream. In competitive markets, producers look to the product price for signals to invest. If electricity supply becomes tight relative to demand, reflecting a shortage of generation capacity, then prices should rise, incentivising investment in new generation capacity. But timing is not simple. There can be several years of low prices (close to short run marginal costs) which are too low to encourage new plant. Suddenly prices spike above the threshold for new entry. Investors race to bring on new plant, which is ideally low cost. A glut of new plant, and prices again fall. The impact on promoters of storage is considerable. Storage projects should be in favour as they are quick to construct, and have low running costs. Furthermore, storage projects are almost independent of fuel price uncertainty. Table 3[x] shows the risks assessed by a developer of generation.

The report goes on to characterise the investment decision, including assessment on the project rate of return and the investment profile for the investor. Investors have their own views as to the hurdle rates that an investment should achieve. This is related to the investor's weighted average cost of capital. A portfolio player (one that owns a wide range of assets, of different types, locations, and performance stands to gain most from developing storage.

	Price risks	Technical Risks	Financial Risks
Costs	Fuel price CO2 price	Capital Cost O&M cost Decommissioning and waste Regulation	Weighted cost of capital Credit Risk
Revenues	Electricity Price	Utilisation levels (and timing of utilisation which can be important for price) Build time	Contractual Risk

Table 3 Risks directly affecting a company's cash flow calculation

The opportunity for developing energy storage projects is more complex. The project developer not only has their own investment criteria to meet, but must also consider the risk profile of the project. At the present time, most storage equipment is sold by a manufacturer to a user or project developer. We might assume that the manufacturer sells at a price level to provide a satisfactory rate of return for his shareholders. The project developer needs to be equally satisfied. But the rates of return expected by participants in the value chain vary. Generating companies may look for high rates of return (in the 10 - 20 % range), whereas a network company, heavily regulated and very risk averse may be satisfied with a much lower rate (say 5 - 10%). If a developer can achieve a high rate of return by building a windfarm, is it rational to expect the same company to accept a lower rate of return to build a storage plant? Investment decisions should be based on calculations that only include risk once, that is a positive NPV is satisfactory if the risk has already been factored into the test discount rate. [Anthony, if you accept the PREF approach adopted by NP a developer should be happy with a positive NPV from any project (low or high risk) because the risk has been factored into the discount rate – unfortiunately, few investors are this rational]

Costs of ownership of an energy storage plant vary depending on the technology and its duty cycle, It will also be sensitive to the input fuel cost (which can reflect the cost of gas or coal). The US DOE estimate that total annual running costs of a 4 hr battery system vary between $670 and $900 / kW / year for a 4 hour battery at 5 c / kWh fuel price and $320 and $680 / kW / year for an 8 hour battery also at 5 c / kWh fuel price.[xi] Revenue estimates for energy storage applications range from $100 - 200 / kW / year for simple arbitrage to higher values for reserve power applications. (An availability payment of $10 / MW / hour would equate to $44/ kW / year for a plant scheduled for 50% of the time.)

7. Points for Discussion

It seems likely therefore that deployment of storage will be in one of three forms:

i) at small (domestic level) where rates of return are not crucial in the project decision,
ii) in MW size increments as part of a portfolio
iii) at large multi MW scale, where the high capital costs for balance of plant, connection and business activities can be recovered across a larger business enterprise.

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[i] Learning rates for energy technologies, Alan McDonald, Leo Schrattenholzer, Energy Policy 29 (2001) 255 - 261
[ii] Large scale integration of wind energy in the European power supply; analysis, issues and recommendations A Report by EWEA December 2005
[iii] Small scale generation is now considered in the "Micropower" category for which many license exemptions are made
[iv] The "Distribution Code" would apply to projects in England, Scotland and Wales.
[v] Western Power Distribution, Connection Considerations for Distributed Generation, April 2004
[vi] Town gas was a blend of hydrogen and carbon monoxide. Compressed air and hydraulic power were used Paris and London in the 19th and 20th centuries.
[vii] The Economies of Energy Storage, C Gatzen, IRES, 2006 gives some useful illustrations of project examples
[viii] www.rltec.com (accessed August 2007)
[ix] Investment in electricity generation - the role of costs, incentives and risks. UKERC, May 2007
[x] Ibid
[xi] Long vs Short-Term Energy Storage: Sensitivity Analysis, S Schoenung and W Hassenzahl. SAND2007-4253