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The UK is committed to generating **30 per cent of its electricity from renewable sources by 2020**. Wind, predominantly offshore, will provide most of this. However, **wind power comes at a cost** and it raises as many questions as it answers. How do you deal with the inherent unpredictability of wind? **How do you build and manage offshore turbines** that may be 200 miles from the nearest land? How do you bring new turbines on stream at a rate greater than one per day for the next ten years? And how do you integrate wind power to maintain a stable energy system?





Britain is committed to expanding its renewable **electricity generation** capacity, with particular focus on wind. But getting to scale means tackling significant challenges.

RELEASING THE POTENTIAL

Large-scale renewable energy production is already a reality in the UK – it currently stands at seven per cent¹ and the proportion is rising. Policies to promote industrial and domestic renewable generation – via the Green Deal, Feed in Tariffs, Renewable Obligation Certificates and forthcoming Energy Market Reform – and the government's decision to back the European Supergrid, are placing the political commitment to renewable energy firmly in the spotlight.

Onshore wind currently provides the bulk of the UK's renewable electricity and as of 2009, the UK offshore wind industry was already the largest in the world², thanks in part to active government support and the fact that it leverages the UK's long-standing expertise in manufacturing offshore infrastructure for the oil and gas industry.

In 2009, onshore wind farms generated the equivalent of two per cent of the UK's total electricity generation³. Offshore wind – described as "crucial" by the UK government – is catching up rapidly and will soon surpass onshore power in scale. The UK Renewable Energy Strategy anticipates onshore and offshore wind together providing more than two-thirds of the UK's renewable electricity mix by 2020, ie some 20 per cent or more of overall generation, representing more than a 2,000 per cent increase⁴.

2010 was a landmark year for wind power in the UK. An additional 1.1GW of capacity came on line, taking the number of operational turbines to more than 3,000 and on the evening of 6 September 2010 (albeit on an extraordinarily windy day) this provided 10 per cent of the UK's electricity demand.

As of June 2011, there are 300 operational projects with 3,184 turbines (onshore and offshore) and a combined capacity of 5,345MW.⁵ But there is still a long way to go to achieve the government's 30 per cent target, which will require in excess of 7,500 offshore turbines⁶ (there are less than 500 in operation today) and already there is turbulence. On two days during April

2011, wind turbines were generating more electricity in Scotland than could be absorbed by the grid and as a result six producers were paid approximately £890,000 in total not to produce⁷.

The circumstances which conspired to create this situation were complex – strong winds combined with high hydro output due to heavy rains – and will not occur every day. However, the very nature of wind, the subsidies for wind generation and the UK wholesale energy market mean that anomalies like this will become more and more frequent as the number of turbines increases.

Currently there is around 30GW of additional potential generating capacity in the pipeline with the Round 3 and Scottish sites. The government estimates the investment required to achieve this required increase in capacity by 2020 will be £100bn⁴. Unless there is a breakthrough change in turbine technology, an additional 7,000 offshore turbines will need to be installed at an average rate of about 15 per week, every week, for the next eight and a half years.

It is clear that there are significant investment, planning, and construction challenges ahead. Considerable technology innovation, production and deployment efficiencies and market scale will be needed to drive costs down to a level that can persist without subsidies. And it is clear that a sustainable energy system incorporating these target levels of wind-generated electricity will need a solution to the variability of wind production – both when it exceeds demand and when it does not.

WHY WIND?

The UK's 2008 Climate Change Act requires a 34 per cent cut in emissions by 2020. That same year, the energy supply sector produced 35 per cent of UK greenhouse gas emissions, with most coming from power stations – the biggest single contributor to the country's emissions total⁸. Carbon intensive energy supply will have to be replaced if the UK is going to stay on target



Renewables could also help to plug the looming energy gap. The UK could face blackouts as early as 2016⁹, as existing coal fired and nuclear power stations are phased out. Importing a high proportion of our energy is complicated, risky and, in any case, would require infrastructure and market changes that are only an option in the long term. Britain already imports over 30 per cent of its gas and that could reach 70 per cent by 2020. Imported power increases security risks and potential disruptions to supply, especially whilst the other markets to which the UK is connected continue to lack the same levels of transparency and open competition¹⁰. Denmark has already achieved more than 20 per cent of its generation from wind, a level to which the UK is heading. Inter-connectivity with neighbouring markets has caused severe financial issues in period of both extremely high and extremely low wind. Getting domestic replacement capacity on stream sooner rather than later is therefore critical.

Wind power will have a positive impact on energy security, but only if we can find a way to balance demand with supply in periods of high intermittency (such as when the wind does not blow, or when it blows and we do not have sufficient demand). This means demand response management in the form of smart grids, better storage solutions and dynamic shifting of consumption to those times of plenty. In all likelihood, it also means continued reliance on some level and some form of conventional back-up generation, the issues being: how to prevent this back-up driving up the net cost of generation; how to contain the emissions arising from the back-up; and how to prevent the economics of the back-up distorting the wholesale markets?

Getting wind power right could also enhance Britain's wider economic competitiveness and create new jobs. In the US, for example, the wind industry now employs more people than coal mining¹¹. The Danish wind industry is at the heart of its clean-tech exports which are the worlds highest at 3.4 per cent of GDP (compared to China in second place at 1.4 per cent)¹². Vestas alone has secured 12 per cent of the world market for turbines. Meeting the global demand for products and know-how presents significant opportunities for UK plc.

According to the government's Department of Energy and Climate Change (DECC), meeting renewable energy targets could generate £100bn of investment opportunities and up to half a million jobs in the renewable energy sector by 2020⁴.

Grid parity is going to be paramount. For the UK economy to be competitive with other countries, and so that we can phase out the high subsidies which currently make offshore wind three times as expensive as gas power, wind power needs to achieve grid parity, the point at which it is at least as cheap as grid energy from other, typically conventional, sources. Achieving this means driving renewables to scale and doing so in an integrated and efficient fashion, relying on the market innovation to change the cost equation rather than subsidies to alter the answer.

As with any substantially new enterprise, it's a chicken and egg challenge: you need demand to trigger innovation and scale economies, but you need capacity – and a market – to drive it in the first place. How do you light that fire?

Being smarter about wind farms

Sizewell nuclear power station B in Suffolk generates more than 1,100MW – about three per cent of UK energy needs. It covers an area of less than 50 hectares, and it has a dedicated rail link, good road connections and access to a skilled local workforce.

Many proposed offshore wind farms will rival and surpass the output of Sizewell B. But projects of this sort present logistical as well as technical challenges: wind farms are already planned 20 miles offshore and the Round 3 zones could see turbines nearly 200 miles from land, with sites that will cover tens and perhaps hundreds of square kilometres. Tomorrow's far-flung turbines will be a day's boat journey across the North Sea, with huge implications for installation and maintenance operations.

The sites will not only be large and hard to reach; to generate the same amount of energy as a nuclear plant, a wind farm may need 200-500 turbines. Each one requires monitoring, management and maintenance throughout its life. Standing between 60-200 meters high over the waves, the physical dimensions of individual turbines means deployment, operations and maintenance will be complicated and hazardous.

Necessarily, these distant and large-scale wind farms will need remote on-shore operations control centres, with sophisticated sensors providing the data to analyse and optimise operation and performance. Operational information and control instructions can be transmitted digitally and wirelessly but this, unfortunately, is not so for the generated power. In order to cope with the large distances, high-voltage direct current (HVDC) connections to the grid will be required, adding to the cost and complication of construction, maintenance and operation.

The wind farms of tomorrow must be designed and built in a smarter way today, with smart operation at their heart. They must then be operated in a smarter way in order to remain effective and viable long-term options.

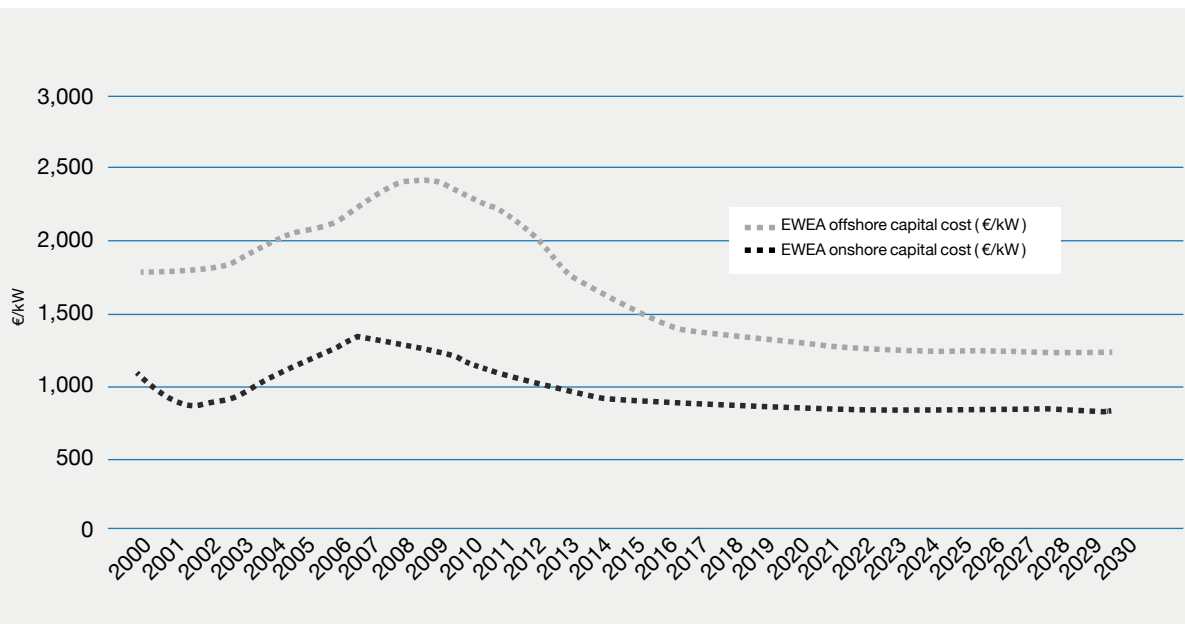


Cost of wind generation

Forecasting the future costs of energy presents challenges. The capital cost of developing generating capacity is subject to variations in the cost of raw materials and the demand within the supply chain. The cost of producing electricity is also influenced by the cost of fuel (oil, gas, coal or uranium), although for wind there is greater certainty, where wind is freely available.

Figure 1 shows how the cost of wind power development has varied over the last 10 years, with a steep increase in cost reflecting the limited number of manufacturers and an absence of economies of scale. Moving forward, the cost of production is set to fall, in line with a rapidly growing market and greater economies of scale, where for offshore wind the capital cost of developing a wind farm in 2030 will be almost half of that of 2008.

Figure 1: Cost of onshore and offshore wind (€/kW)¹³
European Commission / EWEA assumptions

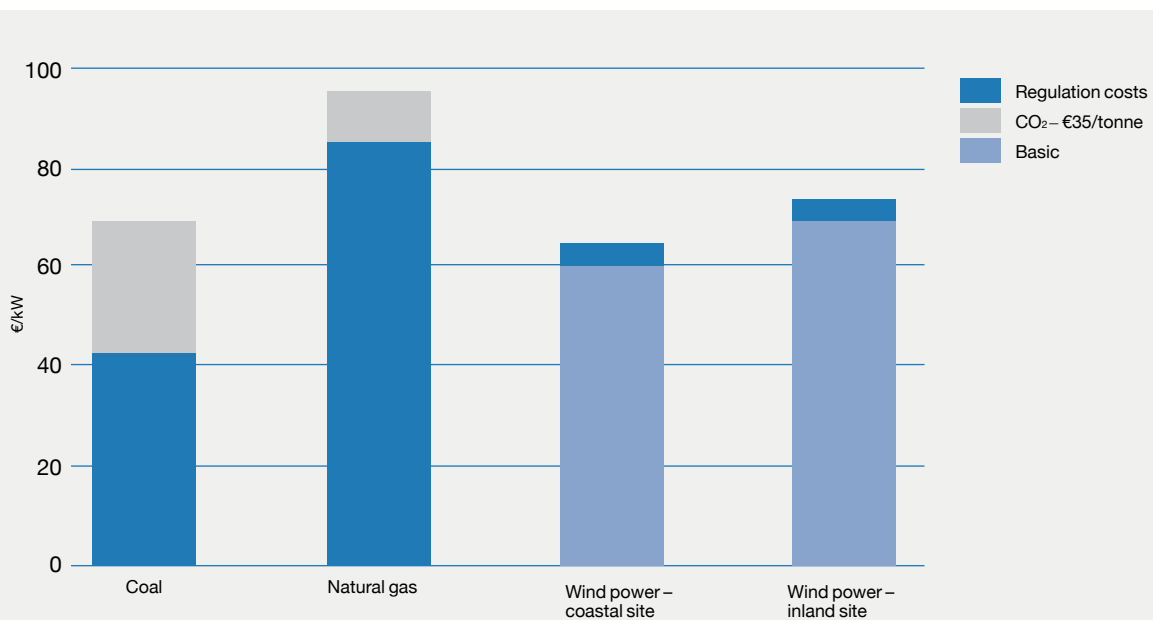


Source: EWEA, 2007



The cost of operating wind farms will vary between countries, depending on how the markets incentivise renewable technologies. Figure 2 shows how the typical cost of electricity production in Europe varies between technologies, based on the cost of planning, constructing and operating the facilities. The figures reflect oil at \$118 per barrel and carbon at €35 per tonne, which although above current prices (oil at \$102 per barrel and carbon at €16 per tonne), reflects the direction in which the market is moving. Under this scenario, both onshore and offshore wind power compare favourably with coal and gas.

Figure 2: Sensitivity analysis of costs of generated power comparing conventional plants with wind power, assuming increasing fossil fuel and CO₂ prices, year 2010 (constant €)¹³



Source: Risø DTU



Market interaction will determine economic viability. Wind farm operators, just as those of any other power plant, will be dependent upon efficient market trading to maximise returns, whether that is from selling produced power or trading the right to suspend production. The traders will need the right tools and information and the economy will need a market that doesn't result in perverse outcomes as a result of rational trading behaviour.

Wind power is variable and intermittent, with outputs varying from one hour to another, which makes this more difficult than for other types of generation whose output is both predictable and more controllable. If wind farm operators are to realise the financial benefits of efficient energy trading, they will need intelligent solutions for managing the risks inherent to wind and, in all likelihood, to balance a portfolio of wind and other forms of generation. Those with more accurate, granular and advanced prediction of their wind generation will be better able to make rapid trading decisions and to trade ahead of the physical market to secure better terms or avoid poor selling prices.

Weather forecasting already plays a role in the trading of, for example, heating oil where it affects demand. It is likely to be even more important for

traders concerned with variability of supply. Some reform to the UK wholesale market will be needed to both support back-up capacity and to prevent wind generators from "gaming the system" as appeared to happen in the April 2011 example mentioned earlier, in which shut-down rates of up to £800 per MWh were paid to wind farm generators compared to a bid of £28 from a coal fired plant.

2,000%
increase in offshore
wind capacity
required by 2020

Major investment is needed in the right equipment and capabilities. Mass production of wind turbines will require access to finance, raw materials and skills on an unprecedented scale. Massive schemes will need intelligent planning to prevent a scramble for scarce resources as well as vast and complex construction logistics, such as the development of new, specialist port facilities and shipping fleets. Commercial and operational as well as technical innovation will be critical.

Intermittent and less predictable generation will become the norm.

The variability of wind power has to be managed – if there's no wind, no electricity is generated and demand must be satisfied from elsewhere unless it can be curtailed. On the other hand, what do you do with surplus renewable energy? How and where will it be stored and by whom? Can it be used productively? Can it be exported – is it either technically feasible or economically viable? Do the interconnectors with sufficient capacity exist? At what price can we import and export power, if those we are trading with have the same surplus and shortfalls because they too are dealing with the same wind issues?

Intermittent output also means there will be a need for generation from other – typically non-renewable – technologies, such as gas generation. This in turn raises questions about capital spending, managing waste and dealing with the CO₂ emissions.

The grid needs to be upgraded. Connecting large numbers of offshore wind sites poses a significant issue. The so called "hedgehog model" where each site has its own dedicated connection, is impractical both from a cost point of view and, perhaps more pertinently, from the difficulty of getting planning permission for the multitude of overland transmission lines required from the coastal connection points. On the other hand the technology and standards for high voltage underwater "supergrid" requires considerable development.

Major changes to the management of our energy system are needed. Distributed and sometimes intermittent renewable generation has profound implications for the way in which the overall energy system is managed and supply and demand brought into balance. These include

Trading wind energy by predicting when and where the wind will blow

IBM ILOG is being used alongside IBM's Deep Thunder weather forecasting solution to provide wind farm operators with better forecast energy outputs allowing more effective and profitable market trading. Here, the ability of Deep Thunder to forecast localised wind conditions combined with ILOG's advanced decision making capabilities has the potential to enable wind farm operators to manage their wind farms with greater confidence and profitability. Deep Thunder was developed in the same IBM labs that developed Deep Blue which beat Gary Kasparov, then the world chess champion, and more recently Watson which won the Jeopardy! challenge, beating a number of human ex-champions.



When cars help make windmills work

IBM is a partner within Denmark's "Electric Vehicles in a Distributed and Integrated Market using Sustainable Energy and Open Networks" (EDISON) consortium. The purpose of the project is to use electric vehicles to supply electrical power during periods when wind farms are producing less energy and to absorb electrical power when the wind farms are producing more than the grid requires. To make this work, a new breed of metering, analysing, and controlling infrastructure is being developed so that electric cars can communicate intelligently with the grid to dynamically determine the time intervals when charging or discharging can take place.

IBM's role in the EDISON project involves, among other contributions, developing technologies that synchronize the charging (and, potentially, the re-discharging onto the grid) of the electric vehicles with the availability of wind in the grid. The same software solves another problem: the impact on the network of a large number of vehicles charging simultaneously. It is relatively early days in the EDISON, but progress is promising. This will have big implications for the UK where electric vehicles are predicted to number some eight million by 2050. IBM has been working with partners in the Energy Technologies Institute in the UK to assess the impact of these vehicles on the UK grid and their potential as "vehicle-to-grid" storage devices, and to design the necessary UK infrastructure that will help both electric vehicles and wind power integrate into the UK energy system.

significant changes to both the transmission and distribution (T&D) networks. For example, distributed renewable generation feeds into the grid at different points than the grid was designed for, often at lower voltage points rather than the high voltage hubs. This will require new technologies and approaches for managing and balancing the grid at a local level. Distributed storage technologies (electric vehicles, batteries and flywheels, compressed air and domestic heat are all mooted as possibilities) and demand management (whether effected by price incentive or appliance control) will both require smart grid technologies across the end-end system.

The challenge of integrating different types of renewable inputs – and, potentially, electricity storage – cannot be underestimated because, unlike conventional power stations, renewable inputs have very different generation characteristics, with output that may vary considerably from hour to hour.

Maintenance will be the key to operational profitability. Wind farms need to be maintained in dangerous working environments. The largest planned offshore wind farms will feature many hundreds of turbines. Maintaining the turbines over their life will require crews working full-time in some of Britain's harshest marine environments. The scale of maintenance operations is likely to involve full time crews and ships working in what could become the marine equivalent of painting the Forth Bridge – no sooner is one machine repaired than another requires attention. How can we minimise the exposure of workers to these risks whilst securing efficient maintenance of the assets?

The answer must lie more in reliability and fault resistance and in predictive operation and maintenance than in the efficiency of fixing things once they have broken down. Design will be crucial – both to create super-high levels of reliability and to build in smart operations. Reliability of new turbines is relatively high, but industry insiders expect this to change as they age – especially in areas such as gear boxes whose expected lifetime is perhaps only between a third and half of the turbine as a whole.

Environmental concerns will remain centre stage for wind power. The richest sources of renewable energy – where the wind blows hardest – include some of Britain's harshest marine and upland environments as well as some of our most beautiful natural scenery.

Such places are often remote from the populations and industries that could benefit from the energy they produce and crucially away from the current grid infrastructure. That isolation raises significant challenges, not least of which is the need for rows of new pylons across our precious landscapes.

Offshore wind avoids some of the environmental and social issues surrounding onshore wind, whether in the Home Counties or Scottish mountains, but is not without its challenges. Marine environments are every bit as fragile and valuable as highland moors and, onshore or off, connection to the grid means more physical infrastructure the likes of which is being protested against in rural communities across the land.

These challenges must be addressed quickly and the industry needs to set the pace if wind power is to become a successful part of the UK energy mix.

£100bn

investment in offshore
wind over the next
eight and a half
years



Wind power requires an entirely new approach to energy management. Smart solutions – instrumented, interconnected and intelligent – will be the key to harnessing its potential and **should shape every stage of renewable development, starting with solutions to determine the viability of schemes long before they reach the drawing board and reaching through to operational systems to maximise output and availability.**

WIND POWER: SMART SOLUTIONS

By Smart, we mean solutions – business processes and information systems – that create better outcomes by applying data-driven insight to orchestrate the implementation and operation of interconnected component parts. Smart solutions can help integrate wind into the UK energy mix at multiple levels, allowing businesses, designers and policy-makers to plan and build the right sort of generating capacity, at the right price, in the right places, to meet market needs:

- at the energy system level with the management of intermittent electrical generation and using pricing signals to balance supply and demand;
- at the wind farm level, using advanced modelling and analytics to design the installation; and
- at the turbine operation level through predictive maintenance and optimised operation using instrumented data from sensors on the machines.

For the most part, tomorrow's wind-based energy infrastructure will be characterised by its remoteness and relative inaccessibility. The relatively immature offshore wind industry must learn from the North Sea oil operators. The pace of development and the economics of the industry mean that it cannot afford to learn by its own mistakes as, it could be argued, the oil companies have done. Techniques such as remotely managing equipment's condition, utilising lifecycle asset management and operating wind farms from integrated control centres will all play a critical role and all require smart solutions. IBM is working with leading players in the wind industry in each of these areas to lever our knowledge of the oil, gas and utility industries.

Smart renewables will need a smart grid: There is not the opportunity with this paper to explore all aspects of the smart grid that the UK will need in the near future and indeed this is the subject of a separate IBM white paper. However, large scale wind generation will demand smart solutions to the operation of the grid and the orchestration of the end-to-end energy system.

Solutions cannot come quickly enough as circumstances will only push demand higher. The UK's appetite for electricity is prodigious, currently around

400 terawatt-hours (TWh) per year. That's a 25 per cent increase since 1990 and double the figure for 1965.

Warmer winters and a prolonged economic downturn will reduce demand, whereas a resurgent economy, colder winters and hotter summers (with increased uptake of air conditioning) will all increase peak demand significantly. Unfortunately for our planners, we need to design an energy system that can cope with all of these.

Peak demand will become even more difficult to manage. In the UK, peak periods already vary considerably in length, from the demand spike generated by a major sporting event, which might last minutes or hours, through to a prolonged cold spell which could drive up demand for weeks. Our challenge is to improve

Vestas high performance computing

Given the intermittency of wind power, wind farm owners are increasing pressure on manufacturers to guarantee wind outputs from their turbines before they commit to purchases. Each percentage point improvement in wind capacity can generate additional revenues of tens of millions of pounds, and the power generated from different locations and different configurations of machines can vary considerably.

Getting it right from the start is therefore critical. IBM is currently working with Vestas to deliver the biggest High Performance Computer (HPC) in Denmark. The HPC will analyse historic weather data to calculate the power that would be generated in a potential wind farm, running millions of scenarios to optimise design and layout and improve confidence levels in predicted generation.



our ability to anticipate and moderate peak demand in light of the new energy mix that includes intermittent, unpredictable renewable sources such as wind power.

Analytics will design better wind farms. Smarter life cycle planning begins with detailed modelling and evaluation to select the most suitable wind farm locations and the optimal layout of the turbines. And optimal does not necessarily mean maximum power – power needs to be balanced against minimising wear and tear from regular exposure to very strong winds. Modelling can also be applied to better design of the wind turbines, so that they are capable of producing more power, whilst at the same time minimising the wear caused by the varying wind speeds across the blades, which are brought about by their size.

We then need to model the operations, maintenance profiles and supply chains to address life cycle costs and returns, where small percentage point increases in wind farm outputs can yield significant returns.

Remote Condition Monitoring (RCM) provides a complete picture of each asset. Today we can measure a huge range of parameters automatically, remotely and in real time. This data can be communicated securely and instantly using a variety of communications techniques. The streams of data can be screened and analysed in real-time, before they are even stored in a database. The instrumented data can be combined with historic readings and with all forms of business information, where advanced and self-learning algorithms can detect patterns and predict outcomes.

RCM brings together sensor technologies – up to 400 individual sensed data points on each turbine – with advanced communications software and sophisticated back-office systems to interpret and derive value from raw data from the distant turbines. Video and even coastal radar can be incorporated to offer enhanced site-wide security.

At the day-to-day operational level, RCM automatically generates predictions and prioritised alarms, pinpointing turbines where there are problems and highlighting issues before failures occur. The ability to do this will become increasingly important as the size and heterogeneity of turbine arrays grows and, importantly, as they age well beyond their warranty period.

RCM will drive safe, efficient and cost-effective maintenance of remote infrastructure – essential to make the best use of a skilled workforce in hostile and remote offshore environments. RCM data will be used to support rational predictive regimes that reduce the maintenance burden. Scheduling maintenance during down time will be at the heart of the process.

Critically, advanced RCM solutions are not just about monitoring. They provide tools to actively manage remote assets, for example, by automatically deactivating equipment when – or even before – that equipment enters a failure mode. And with large generation single turbines on the horizon, proactive asset management is going to become essential: as turbine outputs increase, so does the revenue loss from a single turbine failure or even planned outage.

Smart RCM is also about learning, with archived historical performance data for each turbine, which allows real-time performance comparisons to be made.

Historic data can be fed back into the design process to yield long-term improvements in turbine and generator design. Learning from past performance patterns can be fed into the real-time screening of data streams at the heart of RCM.

Life Cycle Asset Management (LCAM) solutions will maximise availability. LCAM plays a critical part in scheduling equipment downtime – ensuring planned shut-downs take place when there's less wind, when the ships, parts and engineers are available and when suspension would have the least economic impact on lost production. That means having the ability to integrate everything from market dynamics to weather forecasting, spares and inventory management – and knowing the precise status of the rest of the generation fleet.

This involves reducing the reliance on wasteful fixed-interval inspections and placing a greater emphasis on condition-based maintenance, made possible because RCM provides the bulk of asset status data remotely. A better understanding of true asset condition also allows operators to choose to delay maintenance until it's most cost effective to carry out. Each percentage point improvement in wind turbine availability can yield over £4 million per year (based on IBM estimates for a 1 GW wind farm), so effective asset management will be critical to the economic viability of wind power.

Delivering asset management solutions to the wind industry

Operating and maintaining wind turbines that are sometimes hundreds of miles from land presents significant challenges. If the wind farms are to be viable, the availability and outputs from the turbines must be optimised – for a 1GW wind farm, each percentage point loss of performance can equate to over £4 million in lost revenue, not to mention the costs of maintenance.

IBM is leveraging its experience from the nuclear, oil and gas industries to deliver solutions for improving the efficiency of wind farms. Working with a major energy company in the US, IBM has implemented the IBM Wind Solution (based on IBM Tivoli MAXIMO – the leading maintenance solution used in asset-intensive industries), to co-ordinate the maintenance of thousands of wind turbines. The performance of the wind turbines is closely monitored and linked to hundreds of parts suppliers to optimise the maintenance schedule and procurement of parts, leading to significant improvements to asset availability and increased revenues.



Optimising the generation portfolio for Red Eléctrica de España

One of the biggest challenges facing energy operators is to optimise the utilisation of power sources across multiple sites and to maximise associated revenues. Red Eléctrica de España, the company in charge of managing the Spanish national power grid, uses IBM ILOG optimisation technology to regulate its power supply. One of the biggest challenges facing the utility is to dispatch available power sources at the lowest possible cost, whilst dispatching all the available wind energy. IBM ILOG has enabled this whilst realising savings of between €50,000 and €100,000 per day.

The ability to integrate asset management and RCM technologies yields a number of benefits, making it possible to organise supply chain and maintenance activities so everything runs smoothly. That means efficient deployment of staff, where exposure to hazards is minimised, and the ability to make the best use of costly resources, such as transport. This is critical when assets take 12 hours to reach at sea. And at the sharp end, rugged handheld solutions will allow maintenance staff to easily identify assets and individual components – and the precise maintenance actions required – all at the touch of a button.

LCAM / RCM will also assist operators in deciding when to carry out maintenance. This could include taking into account the availability of ocean going vessels, for which demand will be high, along with predications about weather and sea conditions that could hinder operations. This is important because it can cost upwards of €100,000 per day to lease a specialised ship.

Efficient life cycle management is not limited to operations and maintenance. Significant new physical infrastructure is required in the UK, in order for new plants to come on stream. Here, IBM's PlantLIF can be applied during the planning and construction phases to bridge the gaps between the design, build, commission, handover and operations.

By looking at the full lifecycle of a project, expensive resources can be better utilised – for example, the hiring of ships and cranes can be better scheduled with works to construct wind turbines and offshore platforms and install electrical systems and cabling. The complex supply chain can be engaged more efficiently to ensure that work time is maximised and the risks of failure at any of the critical paths delaying the project are minimised. Meanwhile an optimised delivery schedule will ensure that the costly storage and transportation of heavy and bulky turbine equipment is kept to a minimum.

Smart storage will make wind power smart. The variability in output and the relative inability to control supply in line with demand means that cost-efficient storage is key to getting the most out of our wind capacity – in both power and financial terms. More than this, it is key to integrating this capacity into the energy system whilst keeping electricity costs as low as possible, because of the back-up cost / shutdown payments issues. But the economics and technologies involved in storing this energy remain difficult issues.

Storage is required at scale and it would ideally be able to store energy before it entered the grid, isolating the existing grid from intermittency. However, large scale storage near offshore generation doesn't seem practical and there is limited realistic and viable potential for pumped-hydro storage, which remains the only commercially deployed large scale storage technology. So, we need a smart solution to storage, one which achieves scale and flexibility through cumulative technologies, with are more feasible and economically viable at smaller scale. The scale of this storage suggests it is best placed close to the eventual user (most likely a household or small device) so we need to be able to link this distributed storage with the renewable generation without adverse effects on the grid.

IBM is leading the way by researching ways to reduce the burden on large-scale or grid storage by distributing energy in a more efficient and reliable manner and flattening peak demand periods that contribute to increased carbon emissions, higher electricity costs and potential power outages.

Integrated Control Centres manage a portfolio of generation assets as a whole. Operators of complex assets know that there is benefit from combining the operations of multiple assets. Apart from shared technology and scale economies, there is learning to be gained across assets, efficiency from integrated control and synergies from combining decision making across the whole portfolio. This is especially true of generating assets where the underlying SCADA data can vary significantly between vendors and operators. Working with a large European energy operator, IBM found that closed SCADA systems were shielding valuable base data from the operator, so it was necessary to access sensor data directly.

IBM has worked with one of the largest global energy utilities to create Integrated Control Centres to monitor, control and balance outputs from a range of different generation technologies – from wind turbines at sea to gas fired power stations on land – to optimise the generation mix. The ability to centralise control and to visualise operations allows energy businesses to pool expertise and make the most of scarce skills. By bringing experts in fields such as electricity production, maintenance and logistics under one roof, silos are eliminated. And by bringing together both business and engineering data – with analysis in real time – it's possible to uncover hidden patterns and build improved systems.

It's a model that is already successfully used by the oil industry where IBM has helped leading global producers create "Advanced Collaborative Environments" at the heart of their on and offshore production. Remote condition monitoring and asset management technologies are two of the essential building blocks, providing an integrated control platform for every aspect of day-to-day operations.



It is clear is that significant renewable energy generation is already a reality. To date, the emphasis has been on getting physical infrastructure on the ground. **What's needed now is the digital infrastructure to make sense** of it all, getting the most from each wind farm and significantly reducing the costs of wind operations.

Issues IBM has found in wind farm operations

IBM provides specialist asset management solutions to the wind industry, drawing on extensive experience in asset-intensive industries such as oil and gas. Through our work with wind farm operators, we have helped address the challenges of efficiency, effectively integrating different sources of energy generation across an array of systems.

It is clear is that some operators are already losing revenue by failing to fully understand their assets. Critically, operators lack the systems to access and interpret wind turbine data. Faults are not identified early enough, leading to excessive downtimes and costly, ad hoc maintenance. The ability of these operators to trade on the wholesale market is also constrained by this lack of data compounded by poor forecasting techniques.

Those operators able to combine aggressive growth with the adoption of robust yet flexible data integration technologies will be the winners. Leaders are learning from their experience in the oil and gas markets and are combining RCM and LCAM technologies to organise and interpret their data more efficiently.

Of course, efficient management of wind farms does not just apply to the operational aspects of energy production. IBM has been working with Ecotricity, one of the UK's leading renewable energy companies, to re-engineer business processes. A new customer billing system was implemented, increasing the volume of customers billed on time to 95 per cent while reducing the number of inaccurate bills by 70 per cent. This led to significant cashflow improvements.

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