HARDMAN&CO.

Renewable Generation

Coming of Age

By Nigel Hawkins, Hardman & Co Analyst

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Executive summary

- This Investment **Research Paper** addresses the issue of renewable power generation in the UK and in mainland Europe, which – after the deep-seated financial crisis of 2008/09 and the ensuing recession – now has better prospects of achieving critical mass. It also considers investment perspectives.
- In recent years, there has been a major shift in favour of renewable generation. It has been led by wind generation, mainly on-shore but also increasingly off-shore. In the UK's case, there has been a sea-change in operating costs, illustrated by the successful bids by three leading energy companies – EdP, Orsted and Engie – to build and operate North Sea wind farms.
- Share prices of virtually all leading energy companies have slumped over the past decade, with EdF and the two German companies, E.On and RWE, being dire performers. The latter two companies have undertaken major restructuring in the light of the highly contentious decision by the German Government in 2011 to end nuclear power generation by 2022.
- Nevertheless, some energy companies have prospered of late. Denmark's long-established turbine manufacturer, Vestas, has seen a 20x rise in its share price since its nadir in November 2012. Also, in Denmark, the re-named Orsted, which focuses on renewable generation, has seen its shares rise by ca.25% since its IPO in late 2017.
- In the UK, smaller renewable power investment funds, such as Bluefield Solar, TRIG and Next Energy Solar, have met investor expectations and have delivered a steadily rising dividend stream.
- It is self-evident that ***wind-power generation*** is the key renewable source. Recent figures show EU wind capacity of 169 GW, a small percentage of which are off-shore wind plants.
- ***Solar power*** is beginning to make a real impact, certainly in terms of capacity. EU PV-generated solar capacity has now reached 107 GW.
- ***Marine-sourced generation*** projects struggle. The iconic Rance plant in Normandy – built in the 1960s – seems destined to stand alone, since no new large EU tidal schemes are close to fruition, while wave power technology is currently well short of achieving commercial viability.
- ***Biomass*** continues to face major challenges. Despite the very expensive – and nearly complete – Drax conversion programme, new biomass projects are few, although some are being delivered, notably in Finland and Germany.
- New ***hydro-power*** projects, too, are scarce, although a few, including SSE's troubled 100 MW scheme at Glendoe, have been delivered in recent years.
- Whilst ***geo-thermal energy*** thrives in Iceland, its impact elsewhere is very limited; it barely features in EU energy statistics. Similarly, generated power from ***fuel cells*** is also minimal.
- In Germany, the *Energiewende* is underway in the electricity sector, with nuclear power generation ending by 2022 – a policy that has seen shares in E.On and RWE plunge. Such a scenario can only boost the renewables sector there, despite the financial collapse of some wind and solar developers.

History and background

The windmills of antiquity

The generation of renewable power is hardly a recent innovation. Aside from some of the windmills of antiquity – a few of which are still standing – part of the Industrial Revolution was powered by renewable sources, most notably the textile industry in Yorkshire and Lancashire, which relied heavily on water power.

Overseas, the low-lying lands of Holland were dominated by windmills, many of which are still operational to this day.

King Coal and nuclear

However, throughout much of the 20th century, leading European nations relied initially on coal and subsequently on nuclear sources for their base-load requirements, although the use of gas, especially in the UK, became far more important in the last decade of the 20th century.

In recent years, climate change issues – such as carbon emissions – have come to the fore. This trend has been a key driver in developing renewable generation. Nonetheless, despite technology improvements, the need – in some cases – for large subsidies and the inability to operate as base-load plant remain.

While political support for renewable power generation is widespread, its adoption has been far more complex. However, following the Berlin Renewable Energy Conference in 2004, the EU was legally obliged to adopt a more pro-active stance to promote renewable generation investment.

Subsidy-driven

To enable the shift from fossil-fuel generation to a portfolio that is increasingly based on renewables output, a wide range of subsidies have been introduced, ranging from straightforward price per MWh premium payments to Contracts for Differences (CfDs). In Germany, the use of 'feed-in' tariffs has been pivotal in ensuring that renewable generation plant is called up for use when its output becomes available.

Renewable generation advances

Over the past decade, renewable generation has played a far more prominent role than previously. In 2017, renewables-generated output in the EU accounted for ca.18% of total output: most of this output was generated from either wind farms or solar plants.

In consequence, output from fossil-fuel plants, especially in Germany and the UK, has declined. In some countries, nuclear power output has also fallen, as old plants have been decommissioned and not replaced.

Challenges of the financial crisis

Nonetheless, the advent of the financial crisis of 2008/09 presented real problems for the renewable generation sector. In many countries, public debt levels have soared, with a serious impact on borrowing costs. Many EU governments sought aggressively to reduce public expenditure, with renewable subsidies being an obvious target for cost-cutting: Spain was particularly aggressive in adopting this stance.

The future's bright – the future's renewables

However, a decade on, the prospects for renewable power generation look infinitely brighter.

Current scenario

Orsted's optimism

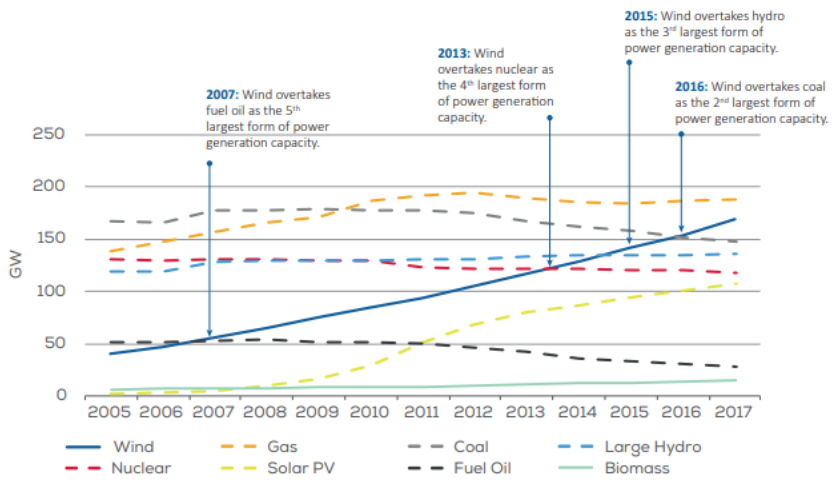
At present, renewable generation – after a testing time and considerable dependence on subsidies – is prospering. Undoubtedly, wind is to the fore, both on-shore and increasingly off-shore. Leading Danish renewable generation company, Orsted, currently has generation capacity of 11.9 GW (including projects that have received a final investment decision). By 2030, it expects that its capacity will reach 30 GW.

This more optimistic scenario is a far cry from the experiences of recent decades where gas-fired, coal-fired and nuclear generation – the latter pair were crucial elements from the early 1960s until the 1990s – have dominated electricity output. And it is only in recent years that on-shore wind output has made a meaningful contribution to overall output.

Sea-change in the generation mix

Consequently, following the wide-ranging economic turmoil of recent years, the EU's generation mix has become increasingly varied. The graph below shows how EU capacity developed between 2005 and 2017 and, more specifically, how wind-generated capacity has assumed much greater importance.

The development of wind-power in the EU



Source: WindEurope

More specifically, the table below traces the use of renewables generation – on a four-year sequential basis between 2004 and 2016 – across all current EU members.

Share of renewable energy in gross final energy consumption				
Country (%)	2004	2008	2012	2016
Austria	22.5	27.8	31.5	33.5
Belgium	1.9	3.6	7.2	8.7
Bulgaria	9.4	10.5	16.0	18.8
Croatia	23.5	22.0	26.8	28.3
Cyprus	3.1	5.1	6.8	9.3
Czech Rep.	6.8	8.6	12.8	14.9
Denmark	14.9	18.6	25.7	32.2
Estonia	18.4	18.9	25.8	28.8
Finland	29.2	31.3	34.4	38.7
France	9.5	11.3	13.4	16.0
Germany	5.8	8.6	12.1	14.8
Greece	6.9	8.0	13.5	15.2
Hungary	4.4	8.6	15.5	14.2
Ireland	2.4	4.1	7.1	9.5
Italy	6.3	11.5	15.4	17.4
Latvia	32.8	29.8	35.7	37.2
Lithuania	17.2	17.8	21.4	25.6
Luxemburg	0.9	2.8	3.1	5.4
Malta	0.1	0.2	2.8	6.0
Netherlands	2.0	3.6	4.7	6.0
Poland	6.9	7.7	10.9	11.3
Portugal	19.2	23.0	24.6	28.5
Romania	16.3	20.5	22.8	25.0
Slovakia	6.4	7.7	10.4	12.0
Slovenia	16.1	15.0	20.8	21.3
Spain	8.4	10.8	14.3	17.3
Sweden	38.7	45.3	51.1	53.8
UK	1.1	2.7	4.6	9.3

Source: European Environment Agency (EEA)

Looking forward – and despite the recent benefits of cheap coal input prices – the coal generation component is expected to decline, especially if the carbon price increases markedly.

Nuclear generation to wind down

Given that Germany is abandoning nuclear power as from 2022 and that Italy, Spain and Sweden, *inter alia*, have no plans to build replacement nuclear plant, EU nuclear output seems certain to be dominated by France from the start of the 2020s. Further investment in renewable generation is anticipated, notably from those countries that have lagged in this respect.

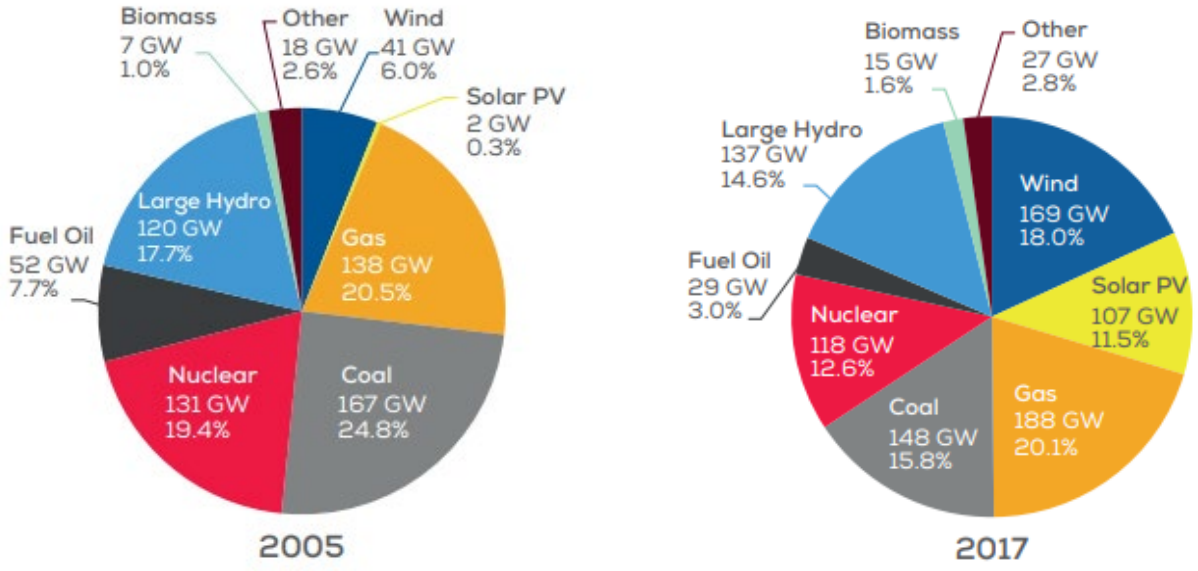
However, much of the new investment seems likely to be wind-related. In terms of regions, the south of Germany – especially Bavaria and Baden Württemberg – is widely expected to be the focus of much new energy investment, including heavy expenditure on grid connections.

Sharp change in investment profiles

Indeed, this scenario is underpinned by the generation investment profile of recent years. Coal generation investment has fallen markedly, while few new gas-fired plants have been built of late. And, as for nuclear power, France is – by some way – the largest investor in new nuclear-build; it also faces heavy expenditure to modernise its existing nuclear fleet.

The shift in EU generation sources between 2005 and 2017 is shown by the two pie charts below.

Share of installed capacity in 2005 and 2017



Source: WindEurope

Solar power surge

Apart from the marked increase in wind generation capacity, it is the emergence of solar power from just 2 GW in 2005 to over 100 GW just 12 years later that is most noteworthy: much of it has been built in Germany.

Major players

The power of monopolies

For many decades, EU energy provision was undertaken by integrated monopoly businesses, most of which were publicly owned. As privatisation developed from the 1980s onwards, this scenario changed, as some leading energy companies were sold to the private sector. In many cases – most obviously with ENEL in Italy – the monopoly aspects were retained.

There were two major exceptions to this structure.

The E.On/RWE duopoly

First, in Germany, there was a duopoly, instead of a monopoly. After consolidation, two leading players emerged, E.On and RWE: the former was more dependent upon nuclear output, while the latter was predominantly coal-based. For both companies, renewable generation was a low priority, despite Germany being at the centre of the political movement to promote 'green' power.

UK electricity supply privatisation

Second, in the UK, the electricity supply industry was split up, with virtually all the major businesses being privatised. Similarly, a duopoly was created, with PowerGen and National Power being dominant; both were eventually subsumed – into E.On and RWE, respectively.

In the intervening period, there have been many developments in terms of the core energy portfolios of the leading energy players. In particular, investment in new nuclear power has been minimal – France and, to a lesser extent, the UK and Finland being exceptions.

And, in recent years, these companies have begun investing in renewable power, although – in most cases – it remains a modest component of their plant portfolio.

For EdF, E.On and RWE, renewables investment was accorded a low priority – certainly compared with Iberdrola: their emphasis was on generation output from their nuclear and fossil-fuel plants, in both Germany and overseas.

Iberdrola was among the first of the EU's major players to focus on both wind generation and solar power; heavy investment followed. ENEL and SSE (with its many hydro plants) and the state-owned Vattenfall of Sweden have also been to the fore in prioritising renewable generation investment.

Nonetheless, the share price performances over the past decade of these energy companies have, with a few exceptions, generally been dire.

Electricity utilities are not recession-proof

The realisation that electricity utilities – especially those heavily involved in generation – were anything but recession-proof took time to become apparent. But the 2008/09 financial crisis and the ensuing recession soon demonstrated how exposed they were – and far more so than those utilities that were dependent upon price-regulated network businesses.

Subsequently, with the switch away from fossil fuels and the environmental priority accorded to renewable generation, along with tighter regulation and ongoing political concerns, it is not surprising that their share price ratings remain depressed.

Germany's 2011 nuclear stunner

Indeed, the most egregious case of political intervention was the German Government's sudden decision in 2011 to abandon nuclear power generation by 2022 – a policy that did immense damage to the projected cashflows of both E.On and RWE.

Dire share price performers

The table below shows the share prices of the worst-performing five major energy players since their peak – the date of the latter is highlighted. In some cases, especially for E.On and RWE, adjustments have been necessary to take account of their changed corporate status.

Share price performances of leading energy companies

Company	Price peak	Date	Current price	Decline (%)
EdF	€85.5	11/07	€14.1	84
E.On	€49.3	1/08	€9.5	81
RWE	€97.7	1/08	€21.4	78
Engie	€43.0	6/08	€13.9	68
Centrica	402p	9/13	135p	66

Source: Bloomberg

Nuclear – a common factor in share price plunges

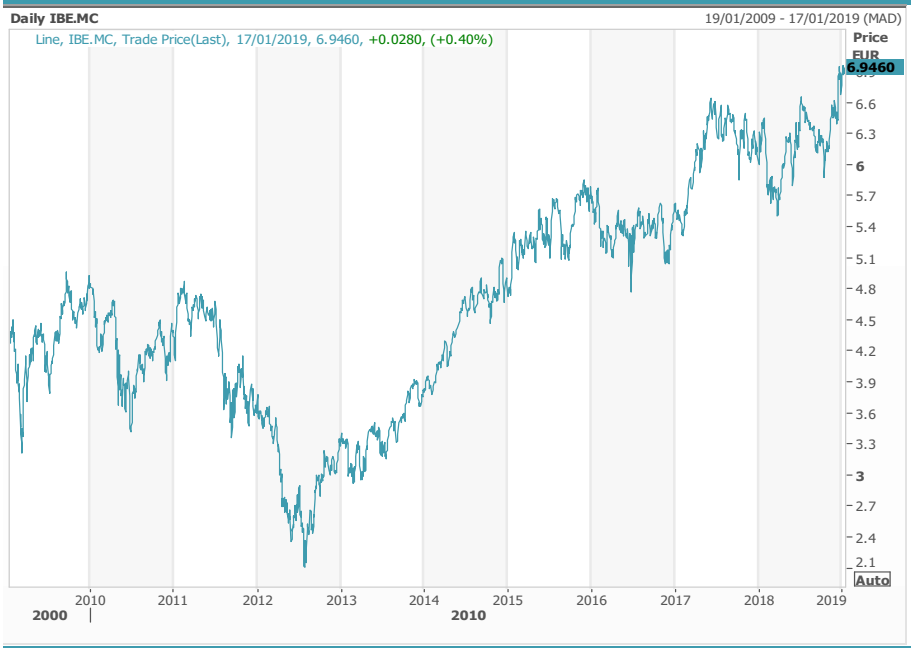
The plunging share price ratings of industry leviathans such as the nuclear-dominated – and effectively state-owned – EdF and both E.On and RWE really are dreadful. Undoubtedly, the nuclear factor has been pivotal in this respect.

But Iberdrola outperforms

Less obviously, it is notable how Iberdrola, which embraced renewable generation with gusto far earlier than others, has been a resilient performer. Almost a generation ago, it reaffirmed its determination to invest heavily in wind-power, as well as confirming that solar power development was a long-term priority. Both polices have been firmly vindicated.

The graph below shows how Iberdrola has outperformed other major EU energy companies over the past decade, even though its core market, Spain, suffered particularly badly from the post 2008/09 recession (and we note that youth unemployment remains extremely high there to this day).

Iberdrola 10-year share price chart



Source: Eikon Thomson Reuters

Other players

While Iberdrola's emphasis on renewable generation has enabled it to prosper – at least in relative terms to other major EU energy players – there have been other companies that have also delivered enhanced shareholder value from renewable generation in recent years.

Renewable generation IPOs have stumbled

Indeed, in riding this trend, some undertook IPOs, with the specific intention of enhancing their overall rating through a separate stock market quotation. In some cases, this worked for a short period but, except for Portugal's EDP Renovaveis' IPO, all have been reversed. In any event, the latter, whose parent company EdP owns an 82.6% stake, might end up as part of China Three Gorges (CTG), which has launched a contested offer for EdP itself.

Of the other IPOs, Iberdrola's Renovables and EdF's Energies Nouvelles were both reversed in 2011. ENEL's Green Power spin-off was bought back more recently.

The ill-fated SSE/Innogy tie-up

Furthermore, as part of the major restructuring of RWE, its Innogy business, which encompasses renewable power, as well as grid, infrastructure assets and electricity supply, was spun out of the parent; the latter still owns 76.8% of the company. There are plans for E.On to acquire Innogy, although the collapse of the proposed SSE/Innogy energy supply deal has cast some doubt on whether this transaction will proceed. In any event, its renewable element currently accounts for ca.15% of Innogy's total EBITDA.

Nonetheless, other quoted stocks have become more prominent in the renewable energy space. Aside from the 'Big Six', Renewable Investment Funds have become more significant.

The Greencoat wind model

In the UK, Greencoat UK, currently capitalised at £1.5bn, is a typical example. Its focus is UK wind generation. There are more than 30 plants within its portfolio, of which 93% are on-shore. Its shareholdings, with a few exceptions, vary between 51% and full ownership. Total net capacity is 785 MW.

Greencoat plans to become more involved in off-shore wind development. Currently, it holds a 25% stake in the 90 MW Rhyl Flats wind farm, which is located off the North Wales coast.

The Renewable Investment Group (TRIG), with its current capitalisation of £1.1bn, is primarily an investor in renewable generation. Currently, it is invested in 61 separate projects, of which 32 are wind-generation and 28 are solar-power; one is focused on battery storage.

NextEnergy Solar prospers

NextEnergy Solar, which focuses exclusively on the solar space, has thrived in recent years, as it has steadily built up its 569 MW portfolio, which is largely based in the south of England, where average irradiation levels are comparatively higher than further northwards.

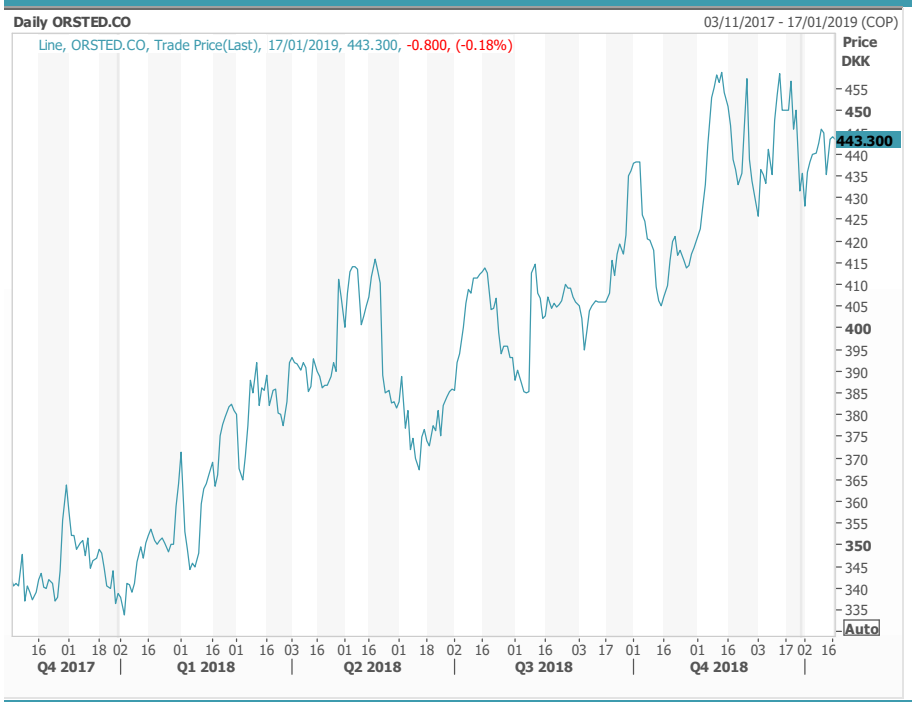
Overseas, the re-named Orsted, emerging from Denmark's Dong Energy, has prospered. Dong was formed in 2006 as the Danish energy sector was consolidated. Orsted's generation portfolio is heavily biased towards renewable generation; it has ambitions to operate ca.30 GW of renewable generation plant by 2030.

Denmark's Orsted thrives

Since its successful IPO in November 2017, Orsted has seen its share price rise by around a quarter, as investors increasingly accord a higher rating to renewable generation, especially as costs fall and subsidies become far less prevalent.

Orsted's share price graph is reproduced below – its current market capitalisation is ca.£22bn.

Orsted share price chart from 3 November 2017



Source: Eikon Thomson Reuters

Turbine manufacturers

In assessing renewable energy – and its prospects – it is important not to overlook the wind-turbine manufacturers, who play a key role. Some of the very large off-shore turbines, notably the Siemens SG 8.0-167 DD (depicted below), which has a rotor diameter of 167 metres, are extremely costly to build and to deploy. Clearly, these costs are integral, along with the net selling price, in determining a project's financial viability.

Siemens SG 8.0-167 DD

Source: Siemens Gamesa

In recent years, the market shares of leading turbine manufacturers have changed quite markedly, with the 2017 merger between Siemens' wind-turbine division and Spain's Gamesa being key. Along with Denmark's Vestas, this joint venture controls a third of the wind-turbine market.

Siemens Gamesa now in pole position

The table below, which was compiled by Statista data from 2017, shows how the major turbine manufacturers dominate the turbine market – the off-shore element is becoming especially important. The latest figures suggest that Siemens Gamesa is now the largest supplier.

Wind-turbine market shares

Company	Country	Market share (%)
Vestas	Denmark	16.7
Siemens Gamesa	Germany/Spain	16.6
Goldwind	China	10.5
General Electric Wind	US	7.6
Enercon	Germany	6.6

Source: Statista

While Vestas looks recently to have lost its pole position to the Siemens Gamesa joint venture, its recovery has been quite remarkable.

As recently as November 2012, its shares had plummeted to just 25.3DK; subsequently, they have increased by ca.20x, following some major restructuring and a widening recognition that the off-shore wind sector, especially in the windy Baltic Sea, offered major opportunities. This deeply impressive transformation – in

Vestas at rock bottom in 2012, but now prospering

noted contrast to the fortunes of many larger EU energy players – is illustrated by the 10-year graph below.

Vestas 10-year share price chart

Source: Eikon Thomson Reuters

The General Electric plunge

By contrast, General Electric – for so long the bellwether of industrial America – has seen its shares plunge by almost 90% – as at December 2018 – off their autumn 2000 peak. Given the fundamental restructuring under way in several of its key divisions, it is self-evident that some of its wind-related assets might be put up for sale.

Subsidies/regulation

Kick-starting renewables

In order to kick-start the renewable generation sector, the payments of very substantial subsidies have been undertaken. The subsidy regimes vary from country to country, as do the amounts received. Indeed, some EU countries still use a 'feed-in' tariff mechanism.

RO closed to new entrants in 2017

As the cost of renewable generation falls, subsidies are being pared back. Many governments are under considerable pressure to cut back on their expenditure – or at least to curtail its growth. Importantly, there have been a few attempts to impose retrospective cuts in subsidies. And, in 2017, the UK's Renewables Obligation (RO) was closed to new renewables generation capacity.

Off-shore wind cost targets comfortably breached

Also, in the UK, there was an ambitious target to cut off-shore wind operating costs to £100 per MW – the target date was 2018. In the event, during the preceding year, there were winning bids to develop two North Sea wind-sites at £57.50 per MWh (2012 prices) – a stunning result. Against this background, using an auction system has become increasingly common, especially since it delivers pricing tension – as the above examples demonstrate.

Consequently, much of the price regulation imposed on many on-shore electricity activities has been replaced by the bidding mechanism. However, for one-off projects, such as the controversial – and, for the moment at least, discarded Swansea Bay Tidal Lagoon Scheme – the Treasury still makes the final judgment in terms of the available subsidy.

Seven renewable technologies

It is generally recognised that there are seven leading sources of renewable generation, each of which is discussed briefly below.

Some of these sources, such as wind-power, are widely used throughout Europe: Denmark has pioneered this trend. Despite the financial crisis, there has been heavy investment in wind-power generation over the past decade; lucrative public subsidies have undoubtedly played a key role in this development.

In 2017, EU wind-generation capacity amounted to ca.169 GW, compared with a paltry 3 GW in 2000.

Germany leads EU solar power capacity

The solar sector, too, has expanded substantially in recent years, due to increased use of photo-voltaics (PV), which operate through the conversion of light into electricity. At December 2016, Germany's solar capacity exceeded 41 GW, while the figure for Italy was almost 20 GW. Generous subsidies, particularly via 'feed-in' tariffs, have been pivotal in building up EU solar power capacity.

The five other renewable generation sources are far less advanced, with developments on the marine front – both tidal power and wave power – taking an immeasurably long time to progress.

Similar viewpoints are applicable to other potential renewable sources, including biomass projects that have experienced real difficulties in surmounting many risks – financial, technical and raw material provision, among others. Nonetheless, many biomass plants do exist, especially in Finland and Germany.

Iceland stands virtually alone on geo-thermal generation

In terms of geo-thermal plant, Iceland is the most dependent on such sources for its power, although Italy does operate a substantial number of small geo-thermal plants, notably in Tuscany. Elsewhere in the EU, its use is limited.

Widespread use of fuel cells for power generation is still looking very long-term, despite their successful deployment on Apollo 11, which famously landed the first men on the moon in July 1969.

The nuclear paradox

There is some debate, too, as to whether nuclear should be categorised as a renewable power source, due mainly to the mining and industrial processes needed to produce nuclear fuel rods. Furthermore, given various nuclear disasters, including Chernobyl and Fukushima, nuclear generation cannot be fairly described as totally environmentally friendly. However, a section on the key nuclear issues has been included near the end of this Paper.

Wind

On-shore

In the UK – if embedded hydro-power plants are disregarded – on-shore wind generation has provided most of the renewable power over the past two decades. At privatisation in the early 1990s, there were several wind turbines in operation, but it was some years before on-shore wind capacity began to produce power in meaningful quantities.

Many developers have faced major delays in securing the necessary planning approvals. Furthermore, the various financial regimes underpinning renewables investment have been complex and, in several cases, have lacked the necessary long-term assurances.

Consistent wind is ideal

Ideally, a wind farm should attract consistent levels of wind throughout the year, and especially during winter peak-demand periods. In England, utilisation levels have often fallen below 30%, thereby making the financial case for new investment more challenging. In Scotland, however, the wind blows more regularly – a factor that ensures that utilisation levels often exceed 30%.

Against this background, it is hardly surprising that Scotland's two integrated energy companies, the Iberdrola-owned ScottishPower and SSE, have been at the forefront of UK wind-power investment.

The UK's largest on-shore wind farm is the 539 MW plant at Whitelee, near Glasgow, owned by ScottishPower; there are 215 turbines in operation there.

The Baltic will be key for off-shore wind investment

In mainland Europe, wind-power has developed from the pioneering turbines in Denmark, built mainly by the locally based Vestas. In fact, two countries – Germany and Spain – now dominate the mainland European wind-power landscape, as the table below clearly illustrates. The overwhelming majority of the capacity is on-shore wind, although German investment in the Baltic Sea is being racked up.

Mainland Europe wind capacity at December 2017

Country	Capacity (GW)
Germany	56.1
Spain	23.2
France	13.8
Italy	9.5
Sweden	6.7
Poland	5.9
Denmark	5.5
Portugal	5.3
Netherlands	4.3
Ireland	3.1
Romania	3.0
Belgium	2.8
Austria	2.8
Greece	2.7
Finland	2.1

Source: Wind in Power 2017

Nuclear's close-down in Germany will drive renewable investment there

In Germany's case, its leading capacity position seems set to grow further as more wind plants are built, especially in the prime area of northern Germany, near either the Baltic Sea or the North Sea. The discontinuation of nuclear-power generation there by 2022 seems certain to boost demand for new wind-power plants.

Spain's position is rather different. Having provided lavish incentives to develop wind-power, the financial crisis of recent years has caused subsidies to be cut. Consequently, wind-power investment levels have fallen, especially since 2011.

In recent years, both Italy and France have expanded their wind-power capacity. In the case of Italy, it has built on-shore wind turbines not only on the mainland – especially in the south of the country – but also on the islands of Sardinia and Sicily. Somewhat belatedly – and despite its low level of carbon emissions – France has also begun to invest in on-shore wind-power.

Denmark is a key wind generation player

With Vestas' pronounced recovery, Denmark continues to be a key wind-power market, although the best sites in the Jutland region have already been developed.

Further north, the Swedish coast continues to attract wind-power investors, although its leading energy company, Vattenfall, has been more prominent with its various off-shore wind initiatives.

Poland's north coast, which borders the Baltic Sea and is notable for consistent wind speeds, has also attracted investment as developers benefit from the various incentives on offer. In seeking to cut its high level of carbon emissions, Poland plans to lower its near total dependence on coal-fired plant for its electricity production.

Fantanele/Cosealac in Romania is vast – a harbinger for the future?

The Romanian coast, on the west of the Black Sea, also offers real attractions to wind-power developers as the colourful image of the massive Fantanele/Cosealac project demonstrates below. This 600 MW plant is the largest wind-power plant in mainland Europe: it is now owned by CEZ, the dominant Czech energy company.

CEZ wind farm, Romania

Source: CEZ

Off-shore

While its off-shore wind capacity cannot compete with China's mega on-shore Gansu project, the UK is Europe's largest off-shore wind generator with a total capacity of more than 7 GW – a figure that is set to rise sharply. This investment has been underpinned by the Government's firm commitment to develop off-shore wind resources.

The £57.50 per MWh game-changer

In 2017, the off-shore wind sector was surprised by the very low successful bids – of £57.50 (at 2012 prices) for 15-year CfDs – to develop Hornsea 2 and the Moray East sites. Orsted and Engie were the winning bidders for the former while the EdP-led consortium was successful with its bid for the latter.

By 2018, it had been hoped that off-shore wind-power generation would cost less than £100 per MWh, which would compare with the inflation-adjusted £92.50 per MWh Government guarantee for the nuclear output from Hinkley Point C.

In fact, various UK off-shore projects have materialised in recent years, although most of the developers have been overseas utilities, including Orsted and Vattenfall.

North Sea is prime site

The UK's off-shore wind plants are located predominantly on the east coast, stretching south of the Humber Estuary down to the east Kent coast. Until recently, the most notable project had been the 630 MW London Array scheme, for which 175 turbines were erected at a cost of £1.8bn. However, Phase 2 of the project, with a further 370 MW of planned capacity, has so far not proceeded.

On the UK's west coast, there are various off-shore wind turbines located in the Irish Sea, centred around the Isle of Man. Most notable is the 659 MW Walney Extension, which is now the UK's largest wind farm: Orsted is the leading shareholder.

The table below shows the leading EU off-shore wind developments. While the fact that the UK is surrounded by sea is, of course, a pivotal factor, the experience of operating oil and gas rigs way out into the North Sea has also proved very useful in a sector where the UK has declared aspirations to be a global leader.

EU/UK off-shore wind farms

Wind farm	Country	Capacity (MW)
Walney Extension	UK	659
London Array	UK	630
Gemini	Netherlands	600
Gode Wind (1 + 2)	Germany	582
Gwynt y Mor	UK	576
Race Bank	UK	573
Greater Gabbard	UK	504

Source: Nigel Hawkins Associates

Orsted and Vattenfall to the fore

As with on-shore wind development, Denmark has been to the fore in erecting wind turbines off-shore. Its most important investment is the 400 MW Anholt scheme, along with the Horns Rev project off Jutland. When Horns Rev 3 is built, the latter's capacity will exceed 400 MW, with 49 turbines being deployed. Vattenfall, too, has invested in off-shore wind-power plant not only in UK waters but also in the Baltic Sea.

Vattenfall off-shore wind farm in Scandinavia

Source: Vattenfall: photo ex Hans Blomberg

Germany, too, has been prioritising its off-shore wind investment in the Baltic Sea and off the west coast of Schleswig-Holstein. In particular, the 400 MW BARD scheme, off the island of Borkum, might well prove to be the first of many German off-shore wind farms: it was commissioned in 2013. After experiencing major financial difficulties, it is now for sale, with bids of over €1bn being anticipated.

Further large off-shore wind farms are planned, which – assuming the wind blows consistently – should help offset the major load losses from the discontinuation of German nuclear power generation in 2022.

Of course, for many land-locked European countries, off-shore wind generation is not feasible. Unit costs, too, are currently higher, especially since off-shore wind turbines are generally far larger than their on-shore counterparts. This trend has undoubtedly benefited Siemens Gamesa and Vestas, which have now assumed lead roles in building off-shore turbines.

Marine

a) Tidal

The predictability of tidal power

Given the strong tides surrounding the UK, there has long been interest in harnessing these resources to generate power. While the supply of tidal power is very predictable, the average utilisation factor is normally low – at most, a few hours either side of high tide. Furthermore, the capital expenditure costs are likely to be substantial, although the running costs should be very low given that the power source – tidal water – is effectively free.

Within the UK, there has been considerable – and long-lasting – debate about harnessing the power from the Severn Bore in the Bristol Channel. Various permutations of a Severn Barrage, which would be constructed across the Bristol Channel, have been carefully analysed.

The many Severn Barrage options

A barrage near the Channel's estuary would produce most power but it would also be the most expensive given its greater width. DECC's report on the proposed Severn Barrage, which was published in 2010, concluded that there were seven leading options, with a cost ranging between £10bn and £34bn; such a barrage could be expected to remain operational for 120 years.

However, even the most modest of these seven options raises a raft of issues, ranging from technical engineering specifications to hefty capital costs, along with various environmental concerns, including the impact on the high local bird population.

Swansea Bay project binned – for the moment

Extensive plans were drawn up for a proposed £1.3bn tidal lagoon project in Swansea Bay. However, not surprisingly, the Government has declined to provide the necessary subsidy: a strike price of just under £90 per MWh – with a much extended 90-year duration period – was reputedly submitted.

It seems unlikely either that the proposed Cardiff Bay project will materialise given the Swansea Bay precedent notwithstanding the extensive costs involved.

On a far more modest scale, the 1.2 MW Strangford Lough scheme in Northern Ireland has been in operation since 2008. However, the potentially much larger MeyGen tidal array project in the Pentland Firth in Scotland has suffered serious delays. While some foundations have been built, key engineering and financial decisions remain outstanding for the new owners, SIMEC Atlantis.

Rance stands alone

Elsewhere in Europe, France's iconic 240 MW Rance tidal project on the Normandy coast stands alone. This tidal plant was opened in 1966 and generates power on a consistent basis each day, subject to occasional outages. Even though its capacity has subsequently been exceeded by South Korea's Sihwa Lake project, no EU country has come close to replicating the size of the Rance tidal scheme, which is depicted below.

EdF's tidal plant at Rance

Source: EdF

b) Wave-power

Generating power from waves has been a challenge dating right back to classical times. In recent years, the UK Government has contributed financial backing based on developing a workable system.

Efforts to harness wave-power have been undertaken in Scotland, notably on the north west coast where currents are particularly strong. To date, though, the breakthrough has proved elusive, with scalability always likely to be a major challenge.

Similarly, both Orsted and Vattenfall have been involved in seeking to generate wave-power in Scandinavian waters. And in Portugal, the Agucadoura wave farm enjoyed a short-lived existence in 2008.

Painstakingly slow

So far, as in the UK, progress in developing wave-power in mainland Europe has been very slow. Scalability has been a recurring problem, along with the need to design equipment that can withstand the fiercest of winter storms.

Hydro

SSE leads the UK hydro sub-sector

For many decades, hydro-power has made a major contribution to UK electricity generation, especially in Scotland. Heavy investment took place in the early years of the 20th century.

As such, SSE now owns a formidable portfolio of hydro-power plants, which account for most hydro-power output in Scotland. However, virtually all the best UK sites have already been exploited so that recent hydro-generation investment, except for SSE's troubled 100 MW plant at Glendoe, has been modest.

Importantly, a 1.7 GW pumped storage plant was built at Dinorwig in Wales; it was fully commissioned back in 1984 and provides substantial power at very short notice – as little as 16 seconds. A smaller – but similar – 360 MW facility was built at Ffestiniog in 1963.

Elsewhere in Europe, hydro-power is an important component of generated output, especially in Scandinavia.

Norway's almost total hydro dependence

In Norway, where the state-owned Statkraft is the dominant utility, no less than 99% of all power production is water-generated. Vattenfall, too, relies heavily on its various hydro-power plants in Sweden. In both countries, the topography is ideal for using this valuable resource.

However, it is France that is the leading EU hydro-power generator. Mainly through its many plants alongside the River Rhone, EdF owns 20 GW of hydro-power in

France, which account for ca.10% of total French production. As part of this process, it operates some 436 hydro-power plants and installations as well as 622 dams.

Spain, too, uses the water flowing down from the mountains in the north of the country for power generation purposes. Iberdrola operates many hydro plants in Spain with a combined capacity of 10 GW. Historically, rainfall levels there have been unreliable so that fossil-fuel plants have often been used as back-up to supply power when lengthy periods of near drought occur.

In northern Portugal, Ibedrola is undertaking the challenging 1.2 GW Tamega scheme, with three dams; the first phase is due to be opened in 2021.

The innovative Walchensee/Kochelsee scheme

Germany has several hydro plants with a total capacity exceeding 100 MW, including those at Iffezheim, Ryburg-Schworstadt and Laufenberg. However, its most renowned – and innovative – hydro-power scheme is on the Walchensee in Bavaria: the nearest comparator in mainland Europe – albeit with a far smaller capacity – to the Dinorwig plant in Wales. The 124 MW Walchensee plant is currently owned by E.On and has operated since 1924.

The scheme itself (illustrated below) relies on water being transferred between the Walchensee and the Kochelsee, thereby enabling short-term peak demand to be met. The two neighbouring lakes are at very different levels so that water can be transferred back to the higher lake, Walchensee, during periods of low demand.

E.On hydro scheme at Walchensee-Kochelsee

Source: E.On

Most large hydro schemes are outside Europe

The largest hydro-power plant in Europe is at the Iron Gates, where the River Danube flows through a small gorge from Serbia to Romania: even with a capacity of more than 2.2 GW, it lies just outside the top 50-rated hydro plants worldwide. The second-largest European hydro plant is Cleuson-Dixence in Switzerland, with a capacity of just over 2 GW.

There are many hydro-power projects now under construction, most of which are small. There are real opportunities for such projects in parts of Eastern Europe, especially in the constituents of the old Yugoslavia, notably Croatia.

Beyond Europe, there are several mega hydro plants, generally built across great rivers. The highly controversial Three Gorges project in China is, by some way, the largest with a capacity of 22.5 GW. The legendary Hoover Dam in the US, various schemes in Brazil and the Aswan High Dam in Egypt, built over the Nile, are other world-renowned examples.

Biomass

Governments back biomass

Because of their ability both to generate power and to consume waste products, biomass plants have consistently enjoyed strong backing from central governments and especially from departments responsible for waste-related issues. Locally, however, there has often been opposition from nearby residents to a proposed biomass plant and major difficulties in securing the necessary planning approvals.

In the UK, the Arbre biomass project, located near the former Eggborough coal-fired station, initially offered high hopes. However, after just eight days of operation, notwithstanding ca.£30m of costs, operations at the Arbre project were unceremoniously closed.

Eye-watering subsidies

However, the somewhat larger 4.0 GW power station at Drax has been refining its biomass strategy for many years – and has been supported by eye-watering subsidies. Of its six 660 MW units, four have already been converted from coal to biomass while the remaining two are expected to become gas-fired. Samples of the wood-based pellets used are shown below.

Pellets used at Drax power station in Yorkshire

Source: Creative Commons

In recent years, many small UK biomass projects have been unable to secure funding, although some schemes have proceeded, including the long-standing 35 MW Slough Combined Heat and Power (CHP) wood/fibre plant – the UK's largest dedicated biomass facility – and two agriculturally based plants of a similar capacity at Thetford and Ely, fuelled by poultry litter and straw, respectively.

Some large coal-fired plants, whose closure is due in part to the implementation of the Large Combustion Plant Directive (LCPD), have also sought substantial subsidies to convert to biomass, mostly in vain. They include the now demolished Tilbury and Ironbridge plants.

In Europe, there are many biomass plants, with Finland being the dominant operator: pulp and paper residue is widely used there as fuel. The largest biomass co-generation plant in the world, the 265 MW Alholmens Kraft facility, is well-known for its forest residue fuelling; several others, with capacities of between 100 MW and 200 MW, use wood or paper.

Clearly, biomass in Finland enjoys considerable support, especially in terms of raising the finance to build such plants. The use of various fuel sources is also noteworthy.

In Germany, too, biomass is popular, albeit with a far larger number of smaller plants, many of which are aligned with industrial production processes. RWE has been at the forefront of such developments. A typical example is the 30 MW thermal CHP plant at Siegen Wittgenstein, which was commissioned in 2010; it is fuelled by wood and provides heat for a nearby pellet plant.

In Austria, biomass units are also very common. Most of Austria's domestically produced electricity is generated from either hydro-power or biomass sources; the latter includes the 16 MW facility at Simmering near Vienna, which lies close to the much larger fossil-fuel plant.

Geo-thermal

The UK is a virtual non-starter in geo-thermal

In most countries, geo-thermal power plays – at best – a minimal role. Despite some research, especially in Cornwall during the 1980s, the UK's geo-thermal resources needed to produce electricity commercially are barely existent. There are, though, plans to build a small geo-thermal unit as part of the high-profile Eden project in Cornwall.

Iceland's Hellisheioi

Overseas, a very different scenario applies. In Iceland, geo-thermal power contributes ca.25% of total generated output: virtually all the remainder is produced from hydro-power sources. In fact, Iceland operates five major geo-thermal plants of which the largest is the 303 MW Hellisheioi plant – the world's third-largest geo-thermal power station: an image of this plant is reproduced below.

Hellisheioi geo-thermal power station, Iceland

Source: Creative Commons

Elsewhere within mainland Europe, Italy is the most significant user of geo-thermal energy to meet its power requirements. ENEL operates a portfolio of 34 geo-thermal plants – mainly in Tuscany – and has a total geo-thermal capacity in Italy of

a formidable 876 MW; the portfolio includes the world's first geo-thermal plant at Lardarello, which was built in 1911.

Iceland aside, geo-thermal power remains a rarity in Europe – a real contrast with the 1.5 GW active installed capacity of the Geysers plant in the US as well as with the many geo-thermal sites in New Zealand.

Solar

Solar power – now on the rise

Following many years of development, solar power is now making a significant impact, especially in the warmer states of the US. In Europe, too, it has made real progress in recent years, despite the impact of the post 2008/09 recession.

There are two main types of solar power. By far the more prominent in terms of electricity generated is PV technology, which enables the conversion of light into electricity. As such, many PV sites have been developed primarily to contribute substantial amounts of electricity to the local grid.

NextEnergy Solar is a major UK player in this field. Aside from a few Italian plants, its portfolio is limited to the UK, where it operates 79 plants with an average capacity of 8.3 MW. Given the large number of standard plants, operational risks are spread, although any serious shortfall of irradiation would adversely affect overall returns.

The second form of solar power is Concentrated Solar Power (CSP), which uses mirrors and lenses to deflect onto a small area so that the light can create enough heat from which power can be generated; many houses now have solar panels installed.

Germany well ahead in the EU

Within mainland Europe, the use of solar power has varied considerably. Partly due to its very favourable 'feed-in' tariff mechanism, Germany's installed solar capacity, especially using PV technology, is well ahead of any other EU member, as shown in the table below. Italy, with above-average irradiation levels, has the EU's second-highest solar capacity.

Solar generation capacity at December 2016

Country	GW
Germany	41.3
Italy	19.3
UK	11.6
France	7.2
Spain	4.8
Belgium	3.4
Greece	2.6
Czech Republic	2.0
Netherlands	2.0

Source: Eurostat

In recent years, Germany has expanded its solar capacity markedly, with Freiburg in Baden-Württemberg being the most high-profile champion of solar-power technology.

With a favourable climate, Italy has been investing heavily in solar. Spain, too, has been prominent in awarding substantial subsidies to PV solar projects, although these generous financial benefits were controversially reduced – or, in some cases, eliminated – as the recession had its financial impact from 2009 onwards. Nonetheless, within Spain, there are several solar farms with capacities of between 100 MW and 150 MW. A typical solar plant in Spain, operated by Iberdrola, is shown below.

Iberdrola solar plant

Source: Iberdrola

US and China lead global growth in solar power

For the future, it seems apparent that – on a global basis – the US and China will be the key solar-based generators. In the US, there is abundant sunlight, especially south of the Mason-Dixon Line. In China's case, it has been aggressive in exporting solar chips at very low prices, thereby seriously under-cutting leading EU producers, some of whom have subsequently gone bankrupt.

Fuel cells

The eternal quest – still proving elusive

In the long term, fuel cells will assuredly have a key role to play in supplying energy, especially if they can offer durable storage potential and all the financial savings that would accrue – a quest that has so far proved elusive.

Within the UK, development work continues, led by the AIM-quoted Ceres Power, which – as a leader in low cost, next generation fuel cell technology – has made discernible progress of late. In common with others, it is still seeking to develop a product that is reliable, scalable and can be produced commercially; such a technological breakthrough is unlikely for some years.

In mainland Europe, similar efforts are being pursued through a series of research programmes, which extend well beyond electricity generation. Many such studies are focussing on fuel-cell technology with a slant towards hydrogen cells.

And, if a credible, and commercially viable, system of electricity storage could be developed – thereby eliminating the need to build expensive, peak-load, back-up plants – the benefits would be substantial.

Nuclear

Nuclear power since the 1950s

Nuclear power in the UK dates to the opening of the world's first-ever commercial nuclear reactor at Calder Hall in 1956. In subsequent years, the UK's nuclear power capacity expanded, both through the first-generation Magnox plants and the later Advanced Gas-Cooled Reactors (AGRs). Subsequently, the first – and only – Pressurised Water Reactor (PWR) was built in the UK; this 2 GW plant at Sizewell B was commissioned in 1995.

Following the 1986 Chernobyl disaster in modern-day Ukraine, the UK eschewed any new investment in nuclear plant; moreover, gas-fired plants were becoming increasingly efficient. In addition, the privatisation of the electricity supply industry in the early 1990s made major nuclear power investment unattractive and risk-laden because of the very long-term pay-back period.

Nonetheless, in recent years, the UK Government has provided substantial financial incentives to potential investors in new nuclear-build, which it welcomes both for its capacity to provide much-needed base-load generation but also because of its ability to lower overall carbon emissions.

The infamous £92.50 per MWh CfD for Hinkley Point C

Hence, the Government has awarded a very generous – and inflation-adjusted – £92.50 per MWh 35-year CfD to the effectively publicly owned EdF, which is building 3.2 GW of new nuclear capacity – costing an estimated £24.5bn (including interest) – at Hinkley Point C in Somerset.

The construction of Hinkley Point C is now underway. Assuming it is completed close to budget and within the expected time period – a highly unlikely scenario – it is anticipated that further new nuclear plants will be constructed.

However, the Moorside nuclear project in Cumbria is now close to collapse while its Welsh counterpart at Wylfa is also seriously struggling to remain a live project. There is, though, undoubted interest from Chinese nuclear power investors, particularly in the future of the Bradwell site in Essex and of the Sizewell C site in Suffolk.

Financing remains a key issue, with proposals that a Regulatory Asset Base (RAB) methodology should be adopted, which would enable potential nuclear developers to receive substantial revenues prior to the station's actual commissioning.

In mainland Europe, nuclear power has faced testing challenges, apart from in France where it dominates electricity generation – and, despite the current French Government's policy to promote wind-power generation, seems set to do so for the foreseeable future. EdF currently operates 58 nuclear plants in France with a name-plate capacity of more than 63 GW.

Chernobyl's repercussions on new nuclear build

Unquestionably, the Chernobyl disaster in 1986 had major repercussions, with most proposed European nuclear investment being deferred for more than a generation. Aside from ongoing nuclear investment in France, the Czech Republic did build the 2.1 GW Temelin nuclear plant (depicted below): the two units were commissioned in 2002 and 2003, respectively.

CEZ nuclear plant at Temelin

Source: CEZ

Olkiluoto way over budget – and very late

Of the third-generation nuclear plants, Finland led the way with its pioneering Olkiluoto nuclear project. However, for various reasons, its costs have soared and its projected completion date, originally 2010, is now given as late 2019 assuming its commissioning tests are successful – an astonishing saga of over-runs.

Flamanville – another tale of nuclear woe

EdF is building its first-of-a-kind (FOAK) third-generation nuclear plant at Flamanville in Normandy. As with Olkiluoto, the original costs and completion dates have proven to be far too optimistic, even after making allowance for many design changes after the Fukushima disaster in 2011. EdF's latest cost projection for its 1.6 GW Flamanville plant is ca.€10.9bn: the revised completion date is 2020 at the earliest.

Elsewhere in Europe, new nuclear-build is looking highly unlikely. None of Germany, Spain, Italy, Switzerland or Sweden is expected to undertake new nuclear build; in most cases, politics preclude this option. Several countries are expected to emulate Germany and let their existing plants run for a few years, having decided not to replace them with new nuclear power stations.

Conclusion

An inviting gap for renewables generation

Mainly for political reasons – and despite comparatively low oil and gas prices – renewable power generation will become increasingly important, even if its base-load contribution is modest. With fossil-fuel generation being heavily constrained by environmental issues and with coal and nuclear plant being effectively phased out in many – although not all – European countries, an inviting gap has opened for renewable generation.

Leading the way will be on-shore and off-shore wind farms; the former currently dominates EU renewable generation output along with embedded hydro-power. But off-shore wind offers very attractive prospects, especially following the sea-change in costs – as evidenced by recent bidding trends in the North Sea.

And solar-power is now beginning to make a real impact, especially in Germany and elsewhere in Southern Europe.

Delivering major biomass projects continues to be a challenge, except in Finland, while developing geo-thermal plants within Europe seems to be the prerogative of Iceland. Neither new marine schemes – wave or tidal – nor fuel cells are expected to play a major role for some years, certainly within Europe.

The sun is shining on renewables

However, having survived the tough years of recession following the 2008/09 financial crisis and the consequential cuts in subsidies, the renewable generation sector now seems to have a brighter future – if the numerous political, regulatory, technical and funding challenges can be overcome.

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