New Renewable Energy Technologies: Status and Prospects - Part 1 - Introduction

Bryan Leyland | May 02, 2014

The enthusiasm for new renewable energy technologies started off with the oil scare of the 1980s and restarted with the advent of the belief that man-made carbon dioxide was causing dangerous global warming. Worldwide hundreds of billions of dollars are now being spent on subsidizing wind and solar power and promoting marine power technologies based on waves, tidal currents and tidal barrages.

This series of articles reviews what has been achieved and speculates on the future prospects.

In the 1980s, the objective was reducing consumption of fossil fuels. The objective now is to reduce emissions of carbon dioxide from burning fossil fuels. This review of renewable energy technologies also examines alternative methods of reducing carbon dioxide emissions and also considers the proposition that man-made carbon dioxide has little effect on the climate.

None of these new renewable energy technologies [1] can guarantee to provide a substantial amount of electricity during peak demand periods. They are at the mercy of the wind, sun, tides or waves. In addition, the capacity factor - the ratio of the average output to the maximum output - varies between 10% and seldom exceeds 40%. So, for instance, a 1000 MW nuclear power station generates the same amount of energy as several thousand MW of renewable energy.

All over the world, renewable energy is subsidized by the taxpayer and consumer. "Feed in Tariffs", Production Tax Credits", "Renewable Portfolio Standards" and "Renewables Obligation Certificates" are all forms of subsidy. The developer benefits from these subsidies and tax breaks and in many cases he gets his money back in 3 to 5 years. The cost of the subsidies is added to the cost of electricity paid by all consumers or imposed on taxpayers. It is these subsidies, not economic merit, that has produced the recent explosion in renewable energy. Without the subsidies, no one would be building wind and solar farms for connection to the grid.

Consumers and taxpayers subsidize those rich enough to afford to "invest" in wind and solar power so the poor finish up subsidizing the rich.

There are also hidden subsidies in the form of free transmission, free backup and free system services such as frequency management and voltage support. The cost of these is passed on to all consumers. The consumer also pays for the construction and operation of open cycle gas turbines needed to support a power system with a high portion of renewables and also the extra fuel costs resulting from of the need to operate base load power stations on fluctuating loads to compensate for the rapidly fluctuating output of wind and solar farms.

Marine power technologies also receive large grants to develop various devices that, it is hoped, will be able to operate reliably and economically in a hostile environment. This is now been going on for 30 years and little progress seems to have been made. You as a way to get

Biofuels are also described as a "new" energy technology even though they have been around for hundreds of years. They were rapidly superseded by cheaper fossil fuels and hydropower. They are now heavily subsidized even though there is quite strong evidence that many biofuel technologies actually increase carbon dioxide emissions. As a result American corn has been used for ethanol manufacture rather than providing feed and the price of food grain has risen dramatically all over the world. One has to be impressed with the lobbying power of those who receive subsidies and benefit from regulations that require a percentage of ethanol in petrol.

REF:
[1] For convenience these are henceforth referred to simply as "renewable energy"

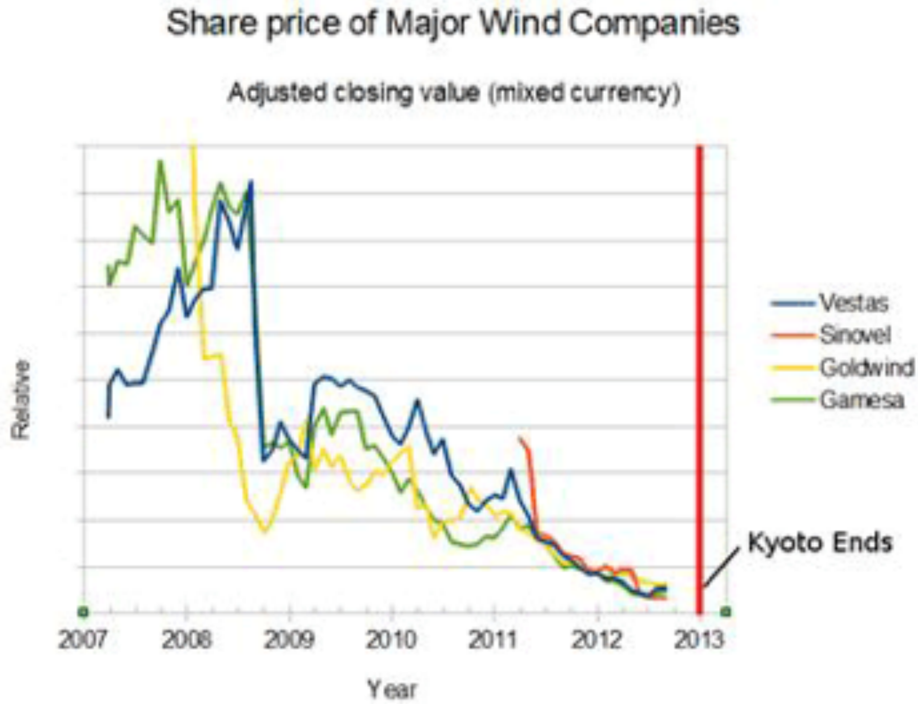
New Renewable Energy Technologies: Status and Prospects - Part 2 - Wind Power

Bryan Leyland | May 09, 2014

Wind power has been around for thousands of years. More than 300 years ago large areas of Holland and the Fens in the UK were drained using wind driven pumps. Because they were expensive to build and operate and the wind often did not blow when it was needed, they were replaced by low pressure steam driven pumping engines that, by today's standards, were inefficient and extremely expensive. The drive for efficiency and low cost led to them being replaced with higher pressure steam engines, diesel engines and finally electric pumps. Modern wind farms still suffer from high cost and intermittent operation.

Wind power has expanded very rapidly and worldwide there is now 300,000 MW of wind power. This expansion has been driven entirely by subsidies.

Modern wind turbines are a well established technology whose costs appear to be declining only slowly. As the chart shows, the share prices of most manufacturers of wind turbines have declined rapidly over the last few years so one can only conclude that manufacturing costs are still high and the current price decline is driven more by the need to get new orders than anything else.



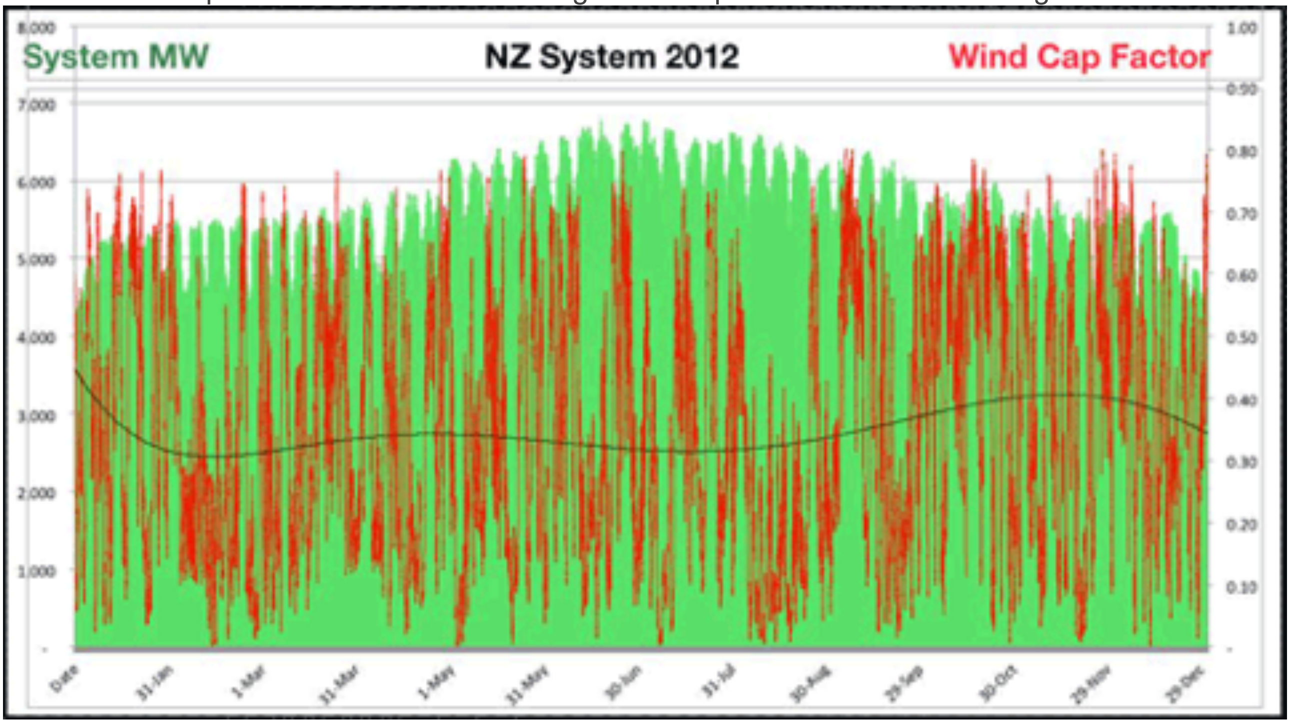
According to a study carried out by the International Renewable Energy Agency in 2012, (www.irena.org/publications) the cost of wind turbines is now about the same as it was in 2006. The completed cost of wind farms in United States in 2009 and 2010 averaged USD2100/kW. In 2006, the cost was about USD1600/kW. Operation and maintenance costs were about 1 cent/kWh and appear to increase as time goes on.

The IRENA study also calculates the long-term cost of power from a wind farm based on a 10% discount rate and 20 year life. For a capital cost of $2150/kW the cost is 9 cents/kWh at a 40% capacity factor and 13 cents at a more typical 25% capacity factor. These costs are above the current cost of fossil fuel generation in most countries.

A report by the American Tradition Institute entitled "The Hidden Costs of Wind Electricity"[2] shows a different picture because it ignores subsidies and factors in the costs of reserve plant, the fuel it will burn and transmission costs. As a result the US Energy Information Administration price of 8.2 cents for the bare cost of wind becomes 15.1 cents when subsidies are removed and the cost that wind imposes on the system is included. My own calculations on the cost of wind power in New Zealand came to a similar conclusion.

The output of wind farms fluctuates rapidly and unpredictably. Data from wind generation in New Zealand during 2012 shows that:

- - the maximum output from 622 MW of installed capacity is 500 MW - 80% of the installed capacity;
- - the maximum rate of increase and decrease in the output over a 30 minute period is 150 MW (60% of effective capacity per hour). For - - one hour the maximum rate of increase is 220 MW and for two hours, 300 MW;
- - for 10% of the time the output is effectively zero;
- - the output is above 50% for only 30% of the time;
- - from the 10th June to the 12th of July when the system demand was at its highest, the output was below 50% for about 60% of the time and was below 10% for some of the time;
- - the output was highest during October and November when it was raining and the snow was melting and the prices were below average;
- - the output was low from June to August when prices were above average.



The chart shows how much and how rapidly the wind farm output changes.
One conclusion from this is that the annual income for New Zealand wind farms is below the average spot price of electricity.

These conclusions would apply in many other countries.

All wind farms require backup when the wind is not blowing. This backup is usually provided by coal and gas-fired power stations that need to operate at outputs below the best efficiency point and change outputs rapidly. This leads to additional carbon dioxide emissions. Many power systems have been forced to build expensive new hydro pumped storage schemes or open cycle gas turbines to maintain system frequency when the wind drops suddenly. Open cycle gas turbines are expensive to install and less efficient than a modern combined cycle station so the system costs increase and the carbon dioxide saving is much less than estimated by the promoters of wind farms. Various calculations have indicated that the actual saving in carbon dioxide is 60% or, in some cases, much less, than the calculated savings.[3] The wind farm owners do not pay for the extra costs that they impose on the system.

The development of wind power often requires that new transmission lines are built. This is provided free of cost to the developers. Conventional power stations also get free transmission but they generate 2 to 3 times as much electricity per megawatt of installed capacity. Therefore the transmission cost burden created by the wind farms is much higher than it is for other technologies.

Future developments in wind power

Given that the technology is mature, there is little prospect of a major advance that will lead to higher outputs and lower costs. Some people argue that a switch from the three bladed to 2 bladed turbines will improve efficiency by up to 10%. But in industry that is scratching to survive and mass production is the norm, it is unlikely that any major manufacturer would be brave enough to risk challenging the consensus that three blades are the right solution. Even if they were, the chances are that the bankers would be reluctant to lend on them.

REF:

[2] http://www.atinstitute.org/wp-content/uploads/2012/12/Hidden-Cost.pdf

[3] In New Zealand, it is often claimed that our hydro stations can provide this backup. This is generally true in years with ample rainfall but, when the chips are down in a dry year, the hydro stations do not have sufficient water to back up for days or weeks of relative calm.

New Renewable Energy Technologies: Status and Prospects - Part 3 - Solar Power

Bryan Leyland | May 16, 2014

The current worldwide installed solar capacity is about 40,000 MW of photovoltaic power[4] and about 1,170 MW of concentrated solar power.[5]

Solar power in the form of photo voltaic cells has been around for many years. Over the last few years, the cost of the cells themselves has dropped rapidly until it is now around $1000/kW. At this price, many manufacturers of solar cells have gone bankrupt. Solyndra defaulted on $500 million loan from US taxpayers. The Chinese company Suntech, the largest manufacturer in the world, went bankrupt with debts of $1.6 billion.

One disincentive to solar power is the large land area required. A 1000 MW Concentrated Solar Power facility requires 6000 acres of land, enough for about ten coal-fired plants with the same rated output. Producing 1000 MW from photovoltaics requires over 12,000 acres of land.[6]

Since the costs are significantly higher than from conventional sources the development of solar power is driven entirely by subsidies. For residential installations the subsidies are often provided by "net metering" that offers the same price for imported and exported electricity. If the import and export are equal over a year, the consumer pays nothing. Yet the consumer exports electricity to the grid when it has little value - such as summer afternoons. In return, the consumer takes expensive electricity from the grid every night and, in particular on cold, cloudy winter days and nights. The consumer makes no contribution to the cost of the transmission and distribution system and the cost of the generation and fuel to provide his electricity when the sun is not shining.

Net metering finishes up being a subsidy from poor consumers who cannot afford solar panels to rich consumers who can. If everybody had solar panels and net metering the power industry would go broke, the power system would collapse and anarchy would prevail.

As a result of the subsidies, solar power is being developed in northern latitudes where there is less sunshine and where the skies are often cloudy. Typical capacity factors in desert areas are about 21% but in high latitudes they can be 10% or less. This leads to the absurd situation where Germany is the world's leading market for photovoltaic systems, with a total installed capacity of 17GW and a capacity factor of 10% in 2010. The German government is now reducing the very generous feed-in tariffs to slow the boom in the industry and reduce the €13bn paid out annually in incentives.[7]

A major disadvantage of solar power in high latitudes is that system peak demands nearly always occur in winter evenings. This is when solar power output is very low or, more often, zero. As a result, solar power generates most energy when it is not needed and virtually none when it is needed. The only way of mitigating this problem would be to come up with a technology that can provide low-cost, efficient long-term storage for electricity. No such technology exists and none is on the horizon.

In Germany during 2010 the total amount of power generated by photovoltaics was just 12TWh, or 2% of the total output of 603TWh.[8] If we assume an average PV system capacity of 13GW over the whole year, the theoretical output would have been 114TWh, giving a capacity factor of just 10.5%. A less efficient use of money would be hard to find.

In the UK, the government introduced the following feed-in tariffs in April 2010:[9]

- - Less than 4kW - 43.3p/kWh in first year, declining to 18.8p over 10 years
- - 4-10kW - 37.8p/kWh, reducing to 16.4p
- - 10-50kW - 32.9p/kWh, reducing to 14.3p
- - 50-100kW - 32.9p/kWh, reducing to 8.5p
- - Greater than 100kW - 30.7p/kWh, reducing to 8.5p (but with different rates of decline depending on size and when installed)

Many householders are putting their money into such schemes, which offer payback periods of less than ten years and a considerably higher rate of return than offered by bank savings accounts.

In the UK, the capacity factor would not be above 9%,[10] and could be significantly less. A 1000 MW nuclear station with a capacity factor of 90% would generate the same amount of energy as 10,000 MW of solar power.[11] Based on these figures, the equivalent installation cost of a 1000 MW solar farm PV is about $20,000/kW. This is more than three times the cost of nuclear power- and even more when an allowance is made for backup generation! In reality the price is even higher then calculated above: home installers typically offer to install a 2.5 kW unit for £12,500.[12] This works out at $8000/kW of nominal capacity. The equivalent price to nuclear is then more than $50,000/kW.

Solar power suffers from all the problems of wind because it generates no power at all in the night-time and a cloud going over the sun can drop the output by 60% in a very short period. So it too needs backup, system support and even more transmission capacity per unit of energy generated than wind power.

Future Developments in Solar Power

It is difficult to see how there can be any major improvements in the overall economics of solar power. It costs more than 3 times the cost of alternative methods of generation and even if the solar cells cost nothing, the cost of mounting, installation, cabling, inverters, transformers, grid connection and system support would still make the power too expensive to contemplate. However, as with wind, there is a niche market in isolated areas where the only power comes from small diesel generators.

REF:
[4] http://en.wikipedia.org/wiki/Photovoltaics
[5] http://en.wikipedia.org/wiki/Concentrated_solar_power
[6] http://en.wikipedia.org/wiki/Solar_power#Concentrating_solar_power
[7] http://www.reuters.com/article/2011/02/24/germany-solar-idUSLDE71N2KG20110224
[8] New Record for German Renewable Energy in 2010
[9] http://www.ofgem.gov.uk/Sustainability/Environment/fits/Documents1/Feed-in%20Tariff%20Table%201%20August%202011.pdf
[10] According to http://re.jrc.ec.europa.eu/pvgis/download/download.htm the capacity factor of UK solar cells at an optimum angle is 9.5%. Cells in Cyprus would have a capacity factor of 16.3%
[11] But even then, it is not equivalent because the solar units generate no power at night and during winter evenings when the system load is highest. At the very least, 1000 MW of backup generation is needed. This will be inefficient open cycle gas turbines as they are the only ones that are able to react sufficiently rapidly.
[12] http://www.solarcentury.co.uk/homes/how-to-buy/buy-outright

New Renewable Energy Technologies: Status and Prospects - Part 4 - Wave Power

Bryan Leyland | May 23, 2014

start image end image
The potential energy in waves is enormous, so it is not surprising that there have been many attempts to use them to generate electricity. But while the potential is there, harnessing it is neither easy nor cheap. It is extremely difficult to design something that will survive a storm and, at the same time, generate electricity efficiently and economically during average wave conditions.

Wave power became the focus of research in the 1980s during the oil price spike caused by OPEC. During this period devices like "Salter's Duck" and the "Oscillating Water Column" (OWC) were examples of the many devices that were developed and tested. For more information, see an article in The Engineer (Stephen Salter: pioneer of wave power[13]).

The Oscillating Water Column is essentially a closed upright tube, fixed to the seabed, with an opening near the base to admit waves. The water level in the tube rises, compressing air trapped at the top and driving a turbine generating electricity. An OWC that was carefully tuned for resonance was constructed on the coast near Bergen in Norway in 1985. This generated electricity reasonably successfully, but a storm broke off the upper part of the column, so that experiment was abandoned. Developments since then do not seem to have progressed the technology to any great extent.

Recently, many of the devices originally developed in the 1980s have been revived and a large amount of money has been put into them. One example is "Pelamis" which was originally developed by Prof Norman Bellamy at Coventry University. Although he abandoned it, it was revived a few years ago and three prototypes were moored off the coast of Portugal for a few months.[14] The picture on the right shows a prototype unit in action.[15] Maintenance turned out to be a problem and, in the end, it was abandoned due to "economic and technical problems".

Many other wave power devices have been designed and some prototypes have been built. A useful summary of many of the wave power devices being developed is given in Wikipedia.[16] No one appears to be near to building a commercial production version of any wave power device.

In mid 2011 Professor Bellamy patented a new concept for wave power. it consists of a tube floating on the surface of the ocean with an internal diaphragm that flips from one side of the tube to the other. Wave action causes the diaphragm to pump air along the tube. The discharged air drives an air turbine generating 1 MW or more. If the remaining technological challenges can be overcome, it may make all the other wave power devices obsolete.

Unless someone comes up with a brilliant new idea (and Prof Bellamy's latest proposal may prove to be one), it is difficult to be optimistic about wave power as a large scale alternative to conventional power stations. Although more consistent than wind and solar power, it is still is an unreliable and intermittent source of electricity.

Tidal Power

Another apparently attractive source of power is tides. Vast quantities of water are moved in a regular and predictable way, and particular geographies can concentrate the tidal flows into regions of high potential.

Tidal barrages

Barrage type schemes were first developed more than 1000 years ago. In Roman times there was a tidal mill in London and about 800 years ago there were 76 of them in London including two on London Bridge. These mills were superseded by the advent of steam engines.

In the 1960s, Electricité de France EDF) developed the 240 MW La Rance scheme in Brittany. No costings were made available so it was assumed that the cost was embarrassingly high. Nevertheless, it has been technically quite successful and, because the costs have now been fully depreciated, it generates electricity at a cost of about 1.8 c/kWh. No other tidal power schemes have been developed by EDF. There is also a small tidal power scheme in Russia and another in the Bay of Fundy in Canada.


Bird's eye view of Sihwa tidal plant, South Korea. Photo courtesy of Daewoo

The other current example of such a project is the 250 MW Sihwa scheme in Korea. The scheme is based on an existing barrage which was built to form a freshwater lake. When the lake became polluted the barrage was breached to flush the lake with seawater. It was then decided to build a tidal power scheme. Because it did not carry the cost of the barrage and other works, its cost of

$300 million ($1,200/kW) appears to be reasonable. With a capacity factor of about 25%, it is equivalent to a nuclear power station operating at 90% capacity factor and costing $4,300/kW. Given that a backup plant is also needed, there is no way that the scheme would have been economic if it had also needed to finance the barrage.

Over the last 70 years, an enormous amount of effort has been put into the Severn barrage in the UK. Unfortunately, the cost appears to be high - much higher than nuclear power. By October 2010, when Energy Secretary Chris Huhne announced that the government no longer saw a strategic case for the barrage, its estimated cost had risen to £30bn. The scheme adds little firm capacity to the system and would require a large amount of expensive backup generation.

Barrage type schemes suffer from the high cost of low head generating plant, high civil costs for the barrage, the powerhouse and the various control gates combined with a fluctuating power output. It is not easy to see how these problems can be overcome to the extent that tidal power generation could ever compete with conventional generation.

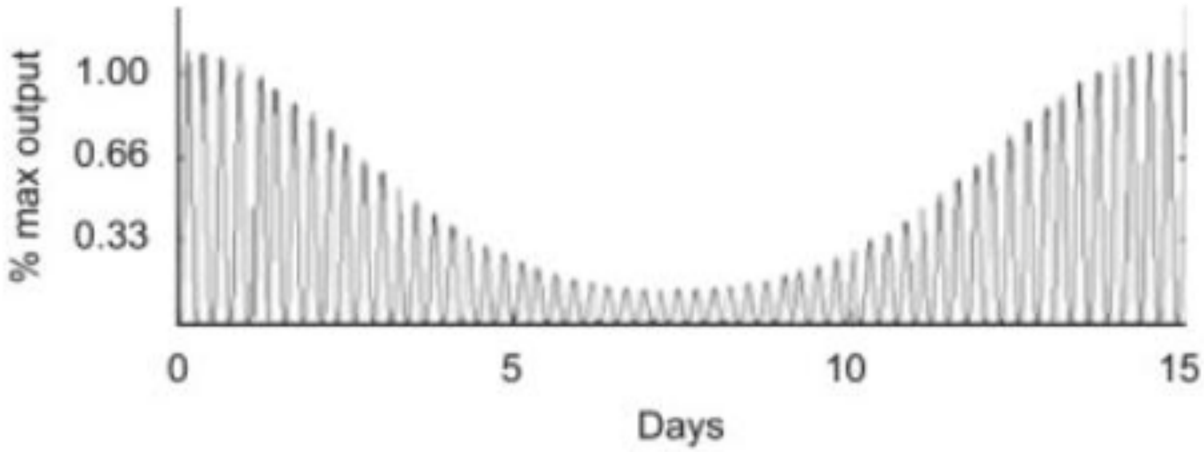


Fig. 3. The power output from a tidal device over a 15 day

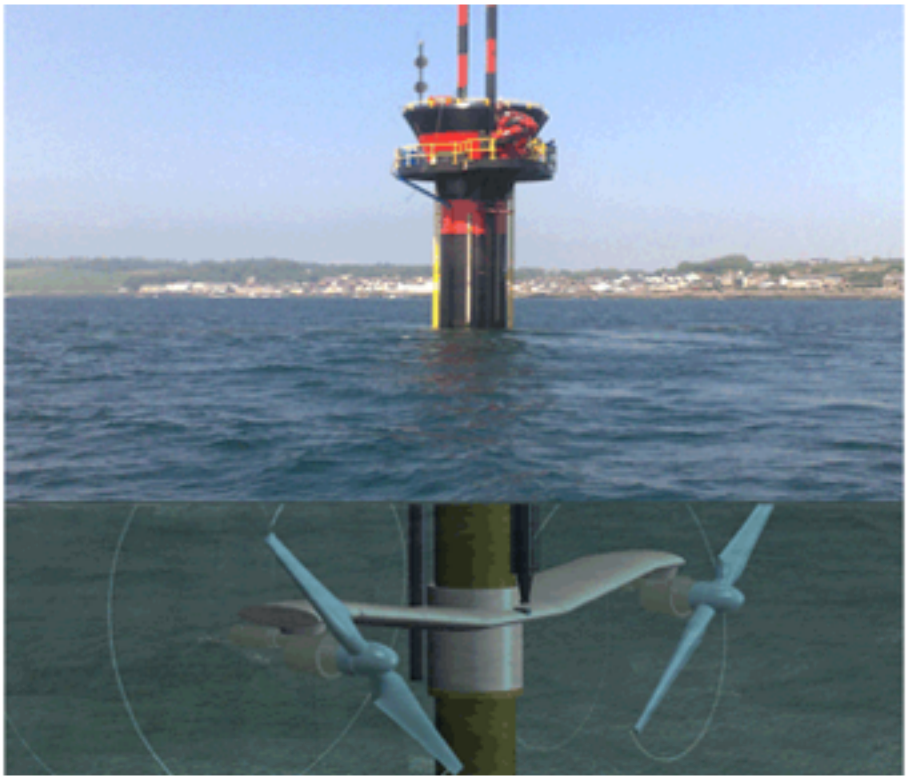
Tidal Stream Generation

Tidal stream generation uses tidal currents to generate electricity in the same way as a wind turbine does. Because water is more dense, the turbines do not need to be as big as wind turbines to deliver the same power. But against that, they generate power intermittently and they must survive in an aggressive environment with strong currents in two directions. As a result, they tend to be quite heavy and this means that they are inherently expensive.

The availability of subsidies and grants has spawned many interesting concepts for tidal stream generation. Most of them use propellers but one turbine has an outer casing with a hole in the middle surrounded by blades with the generator and magnetic bearings around the periphery. Other tidal current devices use flapping wing type arrangements that would appear to have major mechanical challenges.

Some prototypes have been tested and have a capacity factor of around 25%. As with conventional tidal power, they generate for a few hours a day and, as shown in the chart, generate much less during neap tides because the turbine power follows a cube law.

The most advanced development is that of SeaGen at Strangford Lough in Ireland, shown on the right. It feeds about 6,000MWh per annum into the grid.



It is probable that all tidal stream turbines will suffer from marine fouling. The best marine antifouling treatment lasts about 5 years, so they will have to be removed from the water, thoroughly cleaned and repainted at intervals of less than 5 years. The intervals may be much less because even a small number of barnacles can have a large effect on the efficiency of a propeller.

Tidal current turbines are a developing technology with many potential problems and, because they have to be very heavy, they will have problems competing with conventional generation. They also suffer from the problems of intermittency.

REF:
[13] Stephen Salter: pioneer of wave power
[14] http://www.pelamiswave.com/our-technology/development-history#Agucadoura
[15] Credit: Pelamis Wave Power
[16] http://en.wikipedia.org/wiki/Wave_power

New Renewable Energy Technologies: Status and Prospects - Part 5 - The Achilles Heel: Long Term Storage

Bryan Leyland | May 30, 2014

start image end image
The technologies described in this series generate electricity when their resource is available not when it is needed. In any power system, the generation must match the demand on a second by second basis. So, to go large-scale, renewable energy needs to find a technology that will store energy efficiently and at a low cost.

For periods of a few hours the most effective form of energy storage is hydro pumped storage. It stores energy by pumping water into an upper basin when the power price is low and generates when the price is high or there is a need to manage frequency.

Is also claimed that batteries - even the batteries of electric cars - can be used to support intermittent energy technologies. But they can only do so for a few hours and the cost is high because a single charge/discharge cycle on an electric car battery could easily cost more than 50 cents/kWh.[17]

All the technologies now being promoted provide backup for a few hours and at a very high price. But renewable energy generation is often seasonal and, even if it is not, calm or cloudy periods can last for many days. So the need is for a storage technology that can store electricity economically and efficiently for days, weeks, and maybe, months. No such technology is available and none is on the horizon. Until this problem is solved - and some doubt that it ever will be - new energy technologies can play no more than a bit part in the electricity generation scene.

Alternative technologies

If the objective is to reduce emissions of carbon dioxide, and if (against all the evidence) it is decided that massive subsidies are an effective way of doing it, then all the subsidies should be the same. If we lived in a rational world they would be the same for any technology that will reduce carbon dioxide. Obvious options are improving the efficiency of coal-fired power generation, converting from coal to gas and nuclear power.

All these technologies provide substantial reductions in carbon dioxide emissions and cost much less than renewables. At the moment, nuclear energy is quite expensive in most countries but, to a large extent, this is due to the fact that no modern nuclear power station has reached the stage of serial production. When this happens, substantial reductions in cost and construction time can be expected. Because it is widely - and wrongly - believed that nuclear power is dangerous, the very strict rules on safety and radiation also increase the cost.[18] Radiation limits are based on an arbitrary rule that predicts a linear death rate from radiation exposure as radiation increases. Research into actual mortalities has demonstrated that this is far from the truth and that radiation levels more than 200 times the level allowed for nuclear power stations are quite harmless.[19]

Is it an Exercise in Futility?

If the objective is to reduce emissions of carbon dioxide because they are believed to cause dangerous global warming it follows that if man-made global warming is not happening then there is no point in reducing carbon dioxide emissions.

We now know that the world has not warmed for the last 15 to 17 years and, according to the British Met office, it will not warm this side of 2018. This demonstrates that the climate models - that are the basis of the belief in dangerous global warming - are worthless. There is a vast amount of evidence based on sunspots, past climate cycles and the like that demonstrate that the current situation is simply natural climate change. This evidence is strongly opposed by those make money from renewable energy, carbon trading and research into various aspects of man-made global warming. It is also resisted by those who are committed to the concept for one reason or other and cannot afford to admit that they were wrong.

It can also be argued that renewable energy should be pursued because the world is running out of energy resources. The problem is that this is simply not true. For nuclear power, uranium reserves will last much more than 100 years - and much longer if breeder type reactors are used. Thorium can also be used as nuclear fuel and there is sufficient to supply all the energy the world needs for hundreds of years.

For fossil fuels, recent technological advances mean that enormous amounts of gas and oil that was previously locked up in shale deposits is now accessible. As a result, the fossil fuel energy resource can last for more than 100 years. But the largest fossil fuel resource is in clathrates - methane ice that has accumulated in deep water off many coastlines. The quantity available is mind-boggling.[20] The Americans and the Japanese have run successful pilot plants that can recover this resource.

Conclusions

1. New renewable energy technologies provide electricity that is expensive and intermittent and imposes many additional costs on the power system. Because they are intermittent, they can never play more than a bit part in electricity generation.

2. Nuclear power and fossil fuels can provide a reliable and economic supply of all the electricity we need for the foreseeable future

3. There is increasing evidence that man-made carbon dioxide does not cause dangerous global warming. This being the case, there is no need to promote expensive renewable energy to reduce emissions of a harmless gas that promotes the growth of plants.

REF:
[17] If the battery costs $20,000 and lasts for 2,000 cycles, the cost is $10 per 10 kWh cycle.
[18] In fact, it is, by a long chalk, the safest of all major forms of power generation. For instance, Chernobyl (a reactor that could not have been built in the Western world) killed less than 100 people. A single dam failure in China killed more than 25,000 people.
[19] This has now been confirmed by the United Nations Scientific Committee on the Effects of Atomic Radiation www.unscear.org
[20] http://www.scribd.com/doc/54116697/An-Assessment-of-World-Hydrocarbon-Resources-Rogner

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