Petroleum industry and renewables

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In this paper, we review activity by the large petroleum majors in the renewables sector. Oil companies have traditionally invested in other energy sectors (e.g., coal, nuclear) but in recent years the trend has been to concentrate on the petroleum sector. The low price of oil throughout the last decade of the 20th century limited the scope for speculative investments outside the core oil and gas business. Most majors sold off other ventures, although there were some notable long term investors in solar. As we enter the new century certain major oil and gas companies are once again investing in alternative energy to become broader 'energy' companies. This trend is the result of greater awareness of future energy demand, greater pressure and incentives to reduce emissions in their own operations, and the promotion of social responsibility and other general sustainability issues.

Increasing awareness in the petroleum industry of the sustainability agenda, and resulting reporting to the economic, environmental and social bottom lines – the 'Triple Bottom Line' (Jowitt et al, 2005) - is leading to company mission statements that reflect a broader energy business agenda. For example, Shell's criteria are to respect and safeguard people, to engage and work with stakeholders, maximize benefits to the community, minimize impact on the environment, use resources efficiently, maximize profitability. Total's criteria are to integrate operations into the local community, minimize the environmental impact, enhance the value of hydrocarbon resources, develop new energy sources, improve products and their use. From these aspirational statements, the drivers of efficiency and use of renewables can be increasingly justified to shareholders as emerging company activities.

Definition of renewable energy

The Royal Society of Edinburgh (2006), in the Inquiry into Energy Issues for Scotland, defined renewable energy as 'energy flows that occur naturally and continuously in the environment, such as energy from the wind, waves and tide. Such sources are essentially inexhaustible, unlike fossil fuels which are limited in supply'. Clearly solar fits within this definition. Hydroelectric and geothermal are potentially limited as both can be depleted but we consider these briefly in our review. Biofuels require planting, harvesting, and processing and thus could be considered to fall outwith of this definition, for the purpose of this review. Companies are involved in energy efficiencies and carbon capture and storage which also reduce carbon emissions, but these topics are not considered in this review.

Oil company activity

These days it is relatively easy to survey a company's activities by what is released through the Web. A survey conducted in each of the last three years reveals some interesting trends (Table 1) with respect to renewables in the petroleum industry.

Whilst this table is rather subjective as search engines tend to find a mix of internal/external documents, reports/comments, activities/observations, and even negative comments, we can use the table as a starting point. Perhaps the higher level of activity in European companies and the general increase in activity each year are significant trends. We considered ExxonMobil's 2004 comments to be rather negative towards more renewables as an investment (largely because of unsuccessful investments in earlier years that had been divested as ExxonMobil focused on its core oil and gas interests). However, more recently these comments have become more neutral, if not actually evidence of positive action. We will use the ranking in Table 1 to consider the sorts of activities major companies are actually getting involved in.

Shell

Shell Renewables (Shell, 2006) was established in 1997 (as one of the five core businesses of the Shell Group) and has a focus on alternative energy, claiming the broadest alternative energy portfolio of any major company, with activities in biofuels, hydrogen, solar, and wind. Shell claims to be one of the largest wind power developers (a partner in 750 MW

Company	2004	2005	2006
Shell	1150	1250	1182
BP	150	167	200
Total	105	148	153
ChevronTexaco	36	51	72
ExxonMobil	-40	10	30
ConocoPhillips	5	12	31

Table 1 *Survey of 'renewables' hits on major oil companies websites using their own search engines.*

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of capacity, 350 MW of which is Shell's share). The company believes that a large expansion in wind power will require moving offshore as the winds are stronger, larger turbines can be used, and the visual impact is lower. Shell WindEnergy has been involved in offshore wind farms in the UK (partner in the development off the coast of Blyth) and an onshore wind farm in Spain (La Muela), is involved in an offshore development in the Netherlands (Windpark Egmond-aan-Zee), onshore in a refinery in Germany (Harburg), has sites under development in the USA (Rock River, Wyoming; White Deer, and Brazos Texas; Cabazon and Whitewater California; Colorado Green, Colorado), and has further plans for the UK (the proposed 1000 MW London Array in the Thames Estuary), France (offshore Liberon in the Mediterranean), and China. Shell WindEnergy has a focus on utility-scale developments that add significant power to the grid in these areas. They do not manufacture turbines.

Shell Solar is a leading developer of next generation solar technology including Shell's Copper Indium Diselenide (CIS) thin-film technology. The commercial focus is to make solar cells faster to develop a competitive advantage over its competitors. CIS is a metal solution that is sprayed onto glass sheets in layers. Their smooth black appearance is well suited to urban areas. Further developments can be expected from a new partnership with a major glass producer. Shell has developed rural operations in Sri Lanka, India, Philippines, China, and Indonesia in areas where communities have no or limited access to grid power. Shell has divested its silicon activities in this field and might even be trying to leave solar by selling its CIS interests.

Additionally, in support of renewables development, Shell sponsors an annual competition for the development of low carbon technologies (Shell Springboard). Shell has also started to invest in renewable technologies in the offshore oil and gas sector in the North Sea (Fig. 1).

Figure 1 *A view of Shell's Cutter Platform in the Southern North Sea, installed in 2006. The wind and solar devices power the platform and are installed purely for commercial reasons (Sweeney, pers com). The installation itself was based on offshore wind farm technology.*

BP

BP's strategy in this sector is centred on BP Alternative Energy, launched in 2005, and is being well-advertised as addressing four priorities: solar, hydrogen, wind, and natural gas generation (Edwards, 2006). BP has expressed an ambition to be world leader in low-carbon power generation and intends to spending $8 billion over 10 years on alternatives. BP has stayed with solar for the last 30 years but only very recently has this business has become profitable. Interestingly BP entered the solar business by buying Lucas Energy Systems in 1980, with Amoco purchasing Solarex (established in 1973) and Exxon's Solar Power Corporation in 1984, these investments being the precursor to BP Solar's strong position in the sector today.

BP Solar (BP, 2006a) manufactures, designs, and installs photovoltaic solar electric products. There are installations in over 160 countries and production facilities in US, Spain, India and Australia with capacity projected to produce 200 MW in 2006. Recent projects profiled on its web page include Germany, India, Angola, Australia, Philippines, USA, and China. The Shenzen 1 MW Green Garden solar project is China's largest grid-connected solar electricity system in one of the world's fastest growing solar markets. BP is searching for new techniques to develop cheaper silicon technology (BP, 2006b).

BP's wind energy business has developed two wind power sites in the Netherlands to date. The first site, in Rotterdam, opened in 2002 with installed 22.5 MW at a refinery. The second site at an oil terminal in Amsterdam installed 9 MW. There is also a proposed site in the UK for seven turbines. BP intends to grow its business from 30 MW today to 450 MW in the next three years. Its aspiration is to become one of the world's leading wind developers by 2015. Its position is helped by being a significant landowner in the US where wind farms 10 times the size of those built to date are planned. BP's recent agreement with Clipper Windpower to supply a potential 2250 MW of additional turbines for its global wind portfolio (BP, 2006b) reinforces a commitment to this sector.

Total

Total report activity in Renewable Energy under its Corporate Social Responsibility (CSR) section of its web page (Total, 2006). Total has an activity in solar cells dating back to 1983 through Total Energie (now Tenesol). Total is taking part in two large-scale electrification projects, in South Africa and Morocco.

Total has a number of wind farm projects in northern France. The first, at the Mardyck refinery, near Dunkirk with installed capacity of 12 MW, supplies electricity for the refinery, to the grid, and allows different technologies to be tested for onshore and offshore developments. A planned development will be France's largest onshore wind farm (90 MW) in the Aveyron region. Its adverts carry the slogan 'our energy is your energy' and depict wind turbines under the strapline 'bringing new winds of change'.

More recently, Total has emerged as a significant investor in marine renewable energy. In 2006 it announced an investment in Scotrenewables Marine Power, an Orkney-based marine energy company, to develop tidal turbines. This followed an investment in a wave-energy plant in Spain in 2003 with technology from Ocean Power Technologies from the USA. Total has an agreement with its partners in the Spanish site, Iberdrola, to study potential marine sites along the French Coast (Total, 2005).

In hydro-power, Total has a stake in a hydro-electric plant in Argentina that generates 1400 MW, which is about 8% of Argentina's total consumption.

ChevronTexaco

ChevronTexaco is one of the few major US oil companies with a renewable energy group activity (ChevronTexaco, 2006). Renewable energy activity is spread across two groups – Emerging Energy and ChevronTexaco Energy Solutions. These groups focused and targeted investments to integrate renewables in an expanded energy strategy in addition to the use of renewables in its own operations. Since 1999, ChevronTexaco has spent $60 million in investments in renewables.

In wind energy, ChevronTexaco is exploring a project in the Gulf of Mexico to reuse offshore platforms to create a 25-50 MW project. This project would provide power for offshore oilfield operations with excess being sold to the grid. In Texas and Colorado there are also 50 MW projects to install wind power on old oil producing properties in support of operations. ChevronTexaco also owns 31% of the BP-operated Rotterdam wind plant (see BP above).

In 2003, ChevronTexaco installed solar facility in California to help power oilfield operations (500 kW). ChevronTexaco has invested in Konarka, a US company, to develop low-cost flexible solar power.

ChevronTexaco also has a significant activity in geothermal energy, through recent acquisition of Unocal, but this technology is currently outside the scope of this review.

ExxonMobil

ExxonMobil was an early investor in solar but felt the low returns in the industry didn't warrant further shareholder investment and its businesses were sold off (Exxon's solar business was sold to Amoco, see BP above). This is represented by the negative activity in renewables in 2004 (Table 1) as most of the comments emphasized the fact that ExxonMobil wasn't being distracted by investment in non-core renewable activities. Greenpeace has pointed out that ExxonMobil doesn't invest in renewables (ExxonMobil, 2006a), despite having invested $500 million prior to the 1990s. ExxonMobil contends that the ultimate contribution of biofuels, wind, and solar to global energy supplies in 2030 will be only 2% (ExxonMobil, 2006b). In contrast, ExxonMobil is very active in developing energy efficiency technology and also a significant investor in battery technology for hybrid cars. It is also a significant sponsor (with a commitment of up to $100 million over 10 years) of the Global Climate and Energy Project at Stanford University which includes research into the biological production of hydrogen, the development of nano-materials for fuel cells to new photovoltaic cells to lower the cost for solar power. ExxonMobil is a partner in the recent Cutter Platform in the North Sea (Fig. 1).

ConocoPhillips

ConocoPhilips has an emerging technology portfolio to enable investment in '..technical programs that are pioneering the future energy landscape, including renewable energy..' However, there are few details of specific projects (ConocoPhillips, 2006)

Other petroleum industry activity in the renewable sector.

Talisman is developing the North Sea's first offshore wind farm utilizing oil field infrastructure (Beatrice Wind Farm Demonstrator Project) with partners Scottish and Southern Energy. The Beatrice wind farm project has seen the installation of two turbines in the summer of 2006. Installations of this type and at this time are taking advantage of opportunities presented by the maturing of North Sea developments and infrastructure which can be reutilized as sites for alternative primary energy gathering.

Norsk Hydro's Technology Ventures Group is a shareholder in Pelamis (Norsk Hydro, 2006), the world's first commercial wave energy device, an $8 million project by Enersis, 5 km off the coast of Portugal. Norsk-Hydro is a large producer of hydro power with annual production of 9 TWh. To compliment this, Hydro increasingly also prioritizes other renewable energy. Expansion of the Tyin power plant in western Norway will provide 200 GWh and the Havøygavlen wind power park in northern Norway will produce 120 GWh. Hydro's Energy sector actively reviews additional wind power initiatives.

The *AAPG Bulletin* reported recently on the Natural Energy Engine introduced to run on a variety of renewable and alternative fuel sources (biomass, solar, and geothermal) to power 'nodding donkeys'. This is an interesting development to enable greater use of renewables in petroleum operations.

Renewables sector activity by the petroleum industry

Photovoltaics

The oil industry has a long history of involvement with photovoltaics (PV). In the mid-1980s, ARCO Solar (a subsidiary of ARCO in the USA) was the world's largest PV manufacturer. ARCO Solar was acquired by Siemens AG (Germany) in 1990, which in turn returned it to an oil industry subsidiary, becoming part of Shell Solar in 2001. Today, Shell Solar produces PV products in Japan, USA, and Germany, and also has PV research laboratories around the world. Oil Companies are also starting to install PV in their facilities (e.g., Shell's Cutter Platform in the Southern North Sea, Fig. 1). However, in early 2006, Shell Solar's silicon production and R&D units

were bought by German start-up company Deutsche Cell (part of SolarWorld), and it has also been mentioned in trade magazines that Shell Solar is trying to sell their CIS thin-film technology that they purchased from Siemens in 1990 despite significant recent improvements in efficiency.

Total's involvement in solar energy dates back to 1983 and the creation of Total Energie, renamed Tenesol in 2005. This is now a 50/50 joint venture between Total and Electricité de France (EDF). Total's involvement in PV spans solar cell manufacture (through 47.8%-owned Belgian subsidiary Photovoltech), system design and rural electrification programmes.

The UK-based company BP Solar has been a major player in the PV industry for many years, and BP relied on its PV involvement heavily for green advertising and marketing. It installed PV panels on the curved roofs of its petrol stations, which attracted significant interest due to the attractive design. In addition, the BP Institute at Cambridge University is a high-profile, solar-powered installation (http://www.BPi.cam.ac.uk/). However, BP Solar's previous share of PV cell production of 12.6% in 2002 has now been reduced to 5.3% in 2005 due to aggressive expansion from German and Japanese companies. Even so, BP Solar was increasing significantly its capacity in crystalline silicon at its US, Spain, Australia, and India facilities over these years, but the net capacity expansion including the closure of thin-film resulted in slower expansion overall than today's crystalline silicon cell production volume leaders Sharp Solar (Japan), Kyocera Solar (Japan), and Q-Cells (Germany).

In addition, as mentioned above, several decisions by the company (or mother company) primarily the closure of the thin film plants, reduced the growth of the company during these years. Firstly, after BP merged with Amoco, BP Solar acquired one of America's largest PV manufacturers, Solarex. (Solarex had previously bought Exxon's solar energy division in 1984). This led to BP Solar manufacturing five different PV technologies (three crystalline silicon and two thin films) at the time (1999-2002). Perhaps surprisingly, they decided to exit the two thin film technologies and kept the standard mono and multi crystalline screen print cell lines as well as their proprietary high efficiency 'Saturn' line which uses laser grooving to produce a premium cell. As part of the 2003 consolidation, BP Solar closed its separate UK-based research facilities transferring that work to other facilities in the U.S. and Spain.

More recently it has announced (BP, 2006b) a multi-million dollar link-up between BP Solar and California Institute of Technology (Caltech) to grow silicon in arrays of nanorods which could open the way to a radical new way of producing solar cells. This follows on an earlier link-up with the University of Lisbon to grow silicon crystals directly in the form of a ribbon (BP, 2006b). These developments show BP's commitment to cutting the cost of silicon wafer production.

The approach taken by BP Solar is the opposite to that of the start-up PV companies (such as Q-Cells). Five years ago they didn't exist, now, they are making so much money producing silicon solar cells that they are purchasing thin-film technologies to ensure their place in PV industry in the future.

The Italian oil company Eni also has a long involvement in the PV industry. For many years, Eurosolare (now renamed EniTechnologie) was one of the leading European PV manufacturers. However it has now slipped far behind the newer start-up companies like Q-Cells and Solar World (Germany).

Mobil Solar Energy Corporation was bought out by ASE, which is now part of RWE Schott Solar.

PV manufacturing has now moved out of its 'cottage industry' shell, and is now much more than a green marketing machine. Today, the PV industry uses more silicon than the whole microelectronics industry and more glass than the automobile industry. The current electricity prices in California are making PV an economically viable option! The dominance of the PV industry by oil-owned companies in the 1980s and early 1990s is no longer apparent. BP and Shell appear in the top 10 of worldwide PV producers still, however they have been rapidly being overtaken by aggressive expansion from Japanese electronics companies and German start-up companies. In addition, there are several Chinese manufacturers who will also soon have a greater production capacity than BP or Shell.

In a Credit-Lyonnaise Report, identifying the 15 best PV manufacturing and installation companies to invest in (Rogol, 2004), none of these were owned by oil companies. Therefore, it is interesting to ask 'what is the long-term commitment of the oil industry to PV?' In an earlier report, in the late 1990s, Shell predicted that 50% of the world's energy supply will come from renewables (Van Der Veer, 1997). It remains to be seen how involved the oil industry of today will be in the energy industry of tomorrow without significant investment in solar.

Wind

The development of the wind energy sector is at a more advanced stage than other 'new' renewable technologies. Early technological development in the 1970s and 80s has resulted in a fully commercial wind sector, so much so that

Figure 2 *BP Solar PV panels installed on the roof of the Olympic Village in Sydney, Australia. Grid-connected PV, feeds energy back into the electricity grid during the day, and is taken from the grid at night m making it is the most rapidly growing PV market.*

Company	2000	2001	2002	2003	2004	2005	Rank
Sharp	50	75	123	198	324	428	1
Q-Cells	-	-	-	28	75	166	2
Kyocera	42	54	60	72	105	142	3
Sanyo	17	19	35	35	65	125	4
Mitsubishi	12	14	24	40	75	100	5
Schott Solar	14	23	30	42	63	95	6
BP Solar	**42**	**54**	**74**	**70**	**85**	**88**	**7**
Suntech	-	-	-	-	28	82	8
Motech	-	-	-	-	35	60	9
Shell Solar	**28**	**39**	**58**	**73**	**72**	**59**	**10**

Table 2 *Top PV cell/module producers (MW), see* PV news, *25, 3, March 2006 (from Maycock and Bradford, 2006). Note how the positions of BP Solar and Shell Solar have slipped down the table in the last few years.*

wind turbines are now a familiar part of our landscape. By 2005, there was nearly 60,000 MW of installed capacity worldwide, of which more than half was in the EU (Cameron 2006). Average annual growth in installed capacity is 28%, with €8 billion capital expenditure in 2004 (GWEC 2005). The sector is fast becoming a major employer. By 2002 there were 31,000 people directly employed in the manufacture of wind turbines (over 80% of this in Germany, Spain, and Denmark) (Jacobsen 2004). Estimates suggest that by 2020 there will be 1250 GW installed globally (GWEC 2005).

The basic technology for extracting energy from wind is well understood. Consequently research and development is now focusing on optimizing technology, in particular improving efficiency through economies of scale and improved reliability. This drive for efficiency halved the cost of producing electricity from wind over the 1990s (Neij et al., 2003). In contrast to the development of ever-larger commercial devices there is an increasing interest in small-scale devices. In many situations small-scale devices present an effective *in situ* source of power for both industrial and domestic use.

Petroleum industry engagement with wind energy can be broadly divided into three categories.

- The installation of wind energy devices as sources of power for installations particularly offshore platforms.
- Investment in commercial wind farm developments.
- Investment in commercial wind developments linked with existing oil or gas infrastructure.

Shell's new Cutter platform, mentioned above, is a good example of wind energy providing electrical power for petroleum production. This type of activity can make good commercial sense achieving cost-effective reductions carbon emissions. This is particularly the case since the introduction of the EU emission trading scheme and where gas turbines are the only alternative power source. This may represent good practice, within the context of oil and gas production, but it is not evidence of a strategic shift into the renewable energy sector.

Petroleum companies investing in commercial wind energy development provide evidence of more significant involvement in wind energy. For example, Total is developing a 90 MW 30 turbine offshore wind project in the Aveyron region of France. Norsk-Hydro has established a separate wind energy company Sarepta Energi. Shell currently operates over 350 MW of wind capacity, and this is expected to reach approximately 500 MW in 2007. While this investment is growing rapidly it is still modest in relation to oil production. For example, 500 MW of wind turbines will produce electricity equivalent to 800,000 barrels of oil per annum. In 2005, Shell produced 3.52 million barrels of oil per day.

A third level of engagement is emerging in the form of wind developments that make use of oil and gas infrastructure. Electrical grid connections in particular are often a limiting factor for new commercial wind developments. Many locations with a good wind resource are distant from existing electricity grid infrastructure. In such cases grid strengthening and cable costs may only be economically justifiable for very large developments. Land availability and planning constraints also limit development, particularly when the wind resource is at locations with high conservation value or close to habitation.

Many oil and gas installations have existing high voltage grid connections and offer brown field (or offshore) sites with fewer planning constraints. In 2003 Total commissioned the 12 MW Mardyck wind development adjacent to Total's refinery at Le Flanders in northern France. The development exploits the availability of a brownfield site and the refinery's electrical connection. Other industrial sectors have similar opportunities. Port operators in particular have been quick to develop wind turbines on breakwaters, harbour walls and adjacent land.

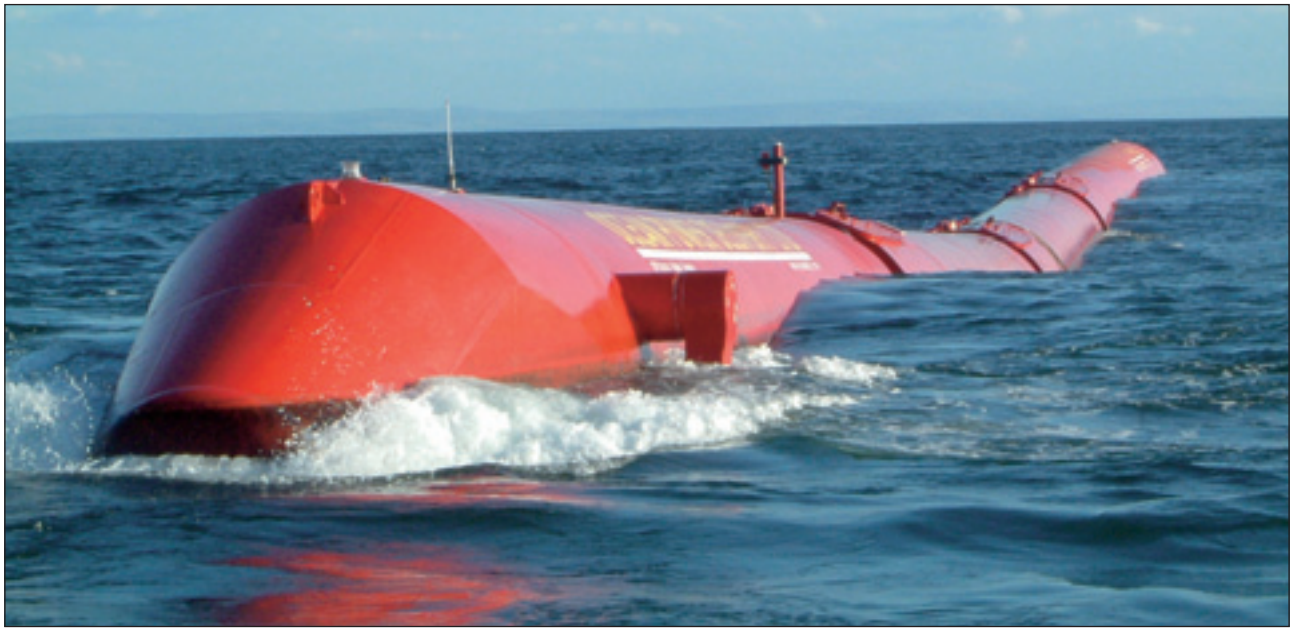

Figure 3 *Ocean Power Delivery's Pelamis wave power device undergoing sea trials. Pelamis is supported by Norsk Hydro. (Photo reproduced by permission of Ocean Power Delivery Ltd.).*

The offshore wind development by Talisman around its North Sea Beatrice oil field is a significant new development. Beatrice Field lies approximately 12 miles offshore to the east of northern Scotland in 45 m of water. The field is both relatively close inshore and shallow compared to many other northern North Sea developments. Production commenced in September 1981. Oil is exported via a 87 km pipeline south to Nigg on the Scottish mainland. The crude oil from the field has a low GOR which necessitated the use of electrical submersible pumps. This also means there was limited gas available for *in situ* electricity generation. As a consequence the Beatrice AP platform is connected to the UK Electricity grid via a 33KV subsea electricity cable. At the time of writing (August 2006) Talisman is in the process of installing two 5 MW wind turbines as a demonstration project which will tie in to the existing 33 KV connection. These wind turbines are the largest commercially available turbines in the world at the deepest offshore wind site in the world. If the demonstration is successful Talisman has plans for a 1000 MW development involving $1.6 bn of investment.

Wind energy offers many opportunities for the petroleum industry. These range from the adoption of wind technology as *in situ* power generators for oil and gas production facilities to full scale commercial developments. Existing oil and gas infrastructure may offer exciting opportunities. Brownfield sites and existing electrical connections are now being exploited. However, more innovative opportunities, such as hydrogen production from offshore wind, may provide further synergies between petroleum and renewables.

Marine

The marine energy industry is less well developed than either the solar or wind industries and the role of a number of pioneering petroleum companies (e.g., Total, Norsk-Hydro), represents an important measure of the potential. The offshore experience of the petroleum industry is also a key aspect of support to the younger industry, although the competition for offshore support facilities (e.g., boats) is providing additional challenges for the marine renewable industry.

Hydroelectric

Total of the majors mentions investments in a hydro electric scheme, the Piedra de Aguila plant in Argentina. Norsk Hydro is a significant producer of hydro-electric in Norway with 9TWh.

Conclusions

- The petroleum industry is a significant player in the renewables industry, with growth in wind and marine activity, although in solar, where it had been a dominant player, it has slipped from its once leading role
- Many petroleum companies are investing in broader energy sources that include renewables. There is also evidence that companies are withdrawing in some sectors
- The petroleum industry is increasing the use of renewable energy in oilfield operations
- The international operations of the major oil companies give them the opportunity to develop world-wide renewables industry
- Given the current high oil prices and the focus of the companies of securing oil and gas supplies at reasonable cost, it might be questioned whether the oil majors have the organizational structure to effectively adopt these newer industries

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