Grant Thornton

Clean Technology Report 2009

In association with new energy finance

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Introduction

Today, clean energy is anything but alternative. The sector made up around 10% of global energy infrastructure investment, with a global transaction value of $213 billion in 2008, and with strong underlying fundamentals – energy security, fossil fuel depletion, climate change, aging infrastructure – we believe there are significant opportunities emerging in the sector.

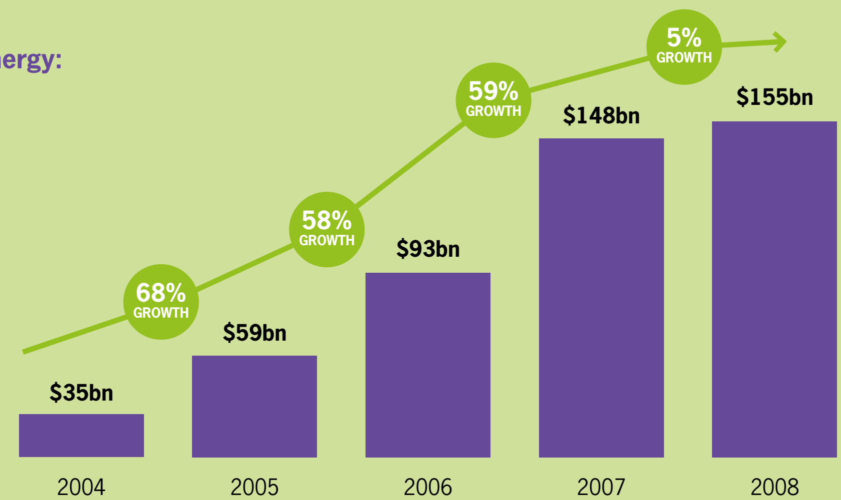
The sector does show signs of slowing its high double-digit growth: global investment increased from $148 billion in 2007 to just $155 billion in 2008 (see Figure 1). Yet interest from institutional investors, corporates and utilities remains strong. Opportunities span the clean energy subsectors and various geographies.

The goal of this report is to provide a concise summary of the clean energy sector and where its opportunities lie. The report is divided into three parts: Renewable Energy & Bioenergy; Energy Efficiency; and Low Carbon Technologies. Each component plays a critical role in sustainably meeting growing energy demand and lowering the carbon footprint of energy production. Renewable Energy is made up of the different clean energy sub-sectors such as wind, solar, biomass and geothermal. Energy Efficiency focuses on more effectively producing and consuming each unit of energy. Low Carbon Technologies focus on the technologies that will help to decarbonise the global energy portfolio through cleaner energy generation and the store of carbon dioxide.

Each part is made up of individual technology sections, which detail the leading emerging technologies and what is driving their innovation. The sections then close with the relevant opportunities within each sub-sector. Thus, each section can be read by itself, or as a component of the greater clean energy sector.

Looking to the future, clean energy will become a crucial component of our global energy infrastructure and portfolio. Expect to see plenty of opportunity in this exciting and dynamic industry.

Figure 1
Total global new investment in clean energy: 2004-2008 ($billions)



Note: Adjusted for reinvestment. Geared re-investment assumes a one year lag between VC/PE/Public Markets funds raised and re-investment in projects. Grossed-up and buffered values are based on disclosed deals from the New Energy Finance Industry Intelligence Desktop

Source: New Energy Finance.

Section 1: Renewable energy and bioenergy

A confluence of political, economic, security and environmental factors is driving the development of renewable energy. The rise and fall in the price of conventional energy sources points to the need to create a new kind of energy economy; political impetus comes from the potential impacts of climate change and worries about energy security.

The global renewable energy sector is composed of several distinct sub-sectors. While wind energy generation is by far the most developed – reaching 100GW of installed capacity mid-way through 2008 (see Figure 3) – rising investment activity in renewable energy has been fuelled by more than just increases in installed wind capacity. Solar energy has commanded the attention of investors from the newest venture-backed technology to the largest publicly traded solar companies; geothermal has nearly the same installed capacity but is less well known. Biomass and waste-to-energy have grown steadily, albeit at a lower rate of 5%. With many resources fully developed, mini-hydro offers the greatest expansion into the developed world. In contrast, marine energy has yet to be commercially developed, although may be close to a breakthrough.

The world's insatiable demand for transportation fuel has driven continued investment into first and second generation biofuels. Installed capacity has grown, with double-digit compounded growth rates (see Figure 4) driving the prices of bioenergy feedstocks to record highs in the first half of 2008. While feed and foodstuff use for fuel feedstock is controversial, New Energy Finance analysis suggests that, at a maximum, biofuels accounted for 8% of the increase in price for grains and 17% of the increase in price for oils.

The industry is still in its early stages, so there are many areas for growth and improvement. The greatest opportunities, in our view, stem from the potential gains in second generation technologies. Within each renewable energy sector, various technologies are vying for the top spot, each trying to reach cost parity with its conventional energy resource counterpart. However, as the technology range in each sub-sector differs, so does the investment risk. Within some sectors, the leading technologies will depend on where they are deployed (on-grid, building integrated, distributed), while in others consolidation to one main technology will prove inevitable.

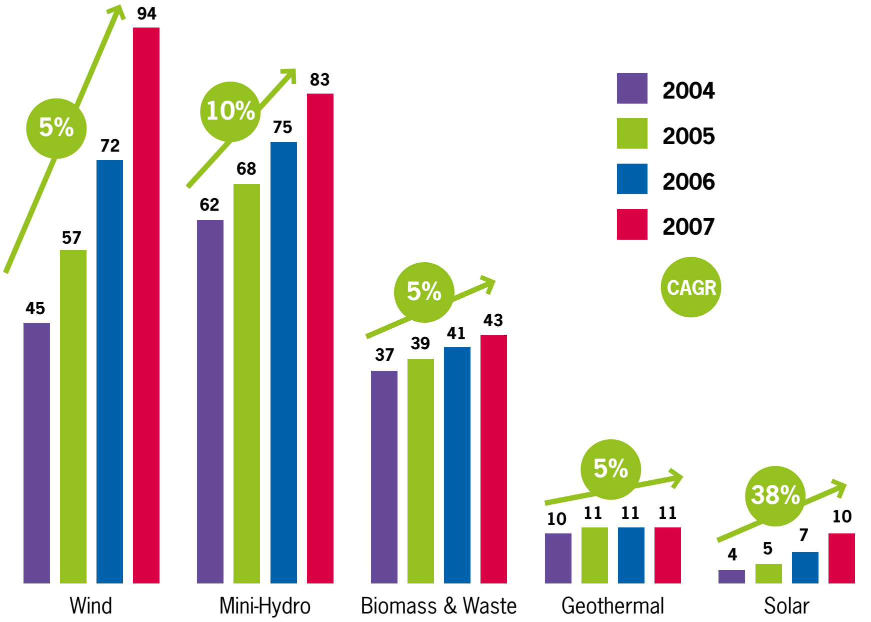
While renewable energy has many environmental and security benefits, in most cases it still requires government incentives in order to be economically viable. A plethora of subsidies, tax incentives, financing mechanism programs, and regulatory change across the globe has underpinned growth in the clean energy sector. However, whether measured in dollar per watt of electricity or dollar per gallon of fuel, the race to parity with conventional fossil fuels will ultimately be decided by the technologies that prove commercially viable and offer economically sustainable profits in the absence of longer-term governmental support.

We expect the sector to move towards commercial parity with conventional fossil fuels – driven by supply concerns, an increased awareness of global climate change (which is starting to become monetised), technology maturity and increased scale. Renewable energy will continue to demand an increasing share of the world's energy investment and represent a greater share of the world energy's mix.

The key sub-sectors are described below – in alphabetical order rather than perceived order of importance.

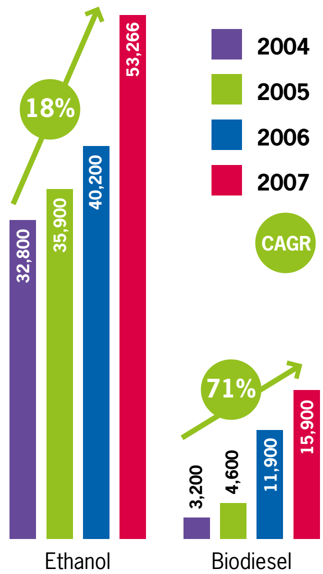
The industry is still in its early stages, so there are many areas for growth and improvement.

Figure 3 Installed renewable energy capacity 2004-2007 (GW) & CAGR (%)



Source: New Energy Finance

Figure 4 Bioenergy installed capacity 2004-2007 (mLpa) and CAGR (%)



Source: New Energy Finance

Biofuels

Senior description and drivers

The key drivers for the biofuels industry are environmental, petroleum fuel substitution and the ease of conversion. The days of cheap feedstocks are temporarily over – with the sustained exception of sugar cane.

The issues of environmentalism and energy security have become blurred, but the results are the same – governments have put in place significant support for biofuels. Support mechanisms are evolving from tax breaks for biofuel production to more commonly blending mandates, which provide biofuel producers with a valuable, guaranteed market. However, the UK has recently scaled back its biofuel production tax breaks. Although it introduced its renewable transport fuels obligation in April 2008, which requires fuel suppliers to sell 2.5% biofuels per annum, it has recently proposed that the 5% biofuels blend obligation be postponed for three years until 2013-14. Politically, this sector has lost its attractiveness as the world has seen food shortages and price inflation recently, exacerbated by poor weather conditions in many places.

With the exception of sugar cane ethanol in certain parts of the globe, the economics of biofuel production currently requires either guaranteed markets or subsidies. In Brazil and the US, the two largest ethanol producers, there is discretionary blending. Supportive biofuel market conditions have seen fuel suppliers using ethanol as a petrol substitute when the price of crude oil is high. Brazilian sugar cane ethanol is competitive at an oil price of $50 a barrel without subsidies.

Technologies and market development

Converting sugars, grains and oilseeds into fuel has been proven on a commercial scale since 2004. The ease of conversion means first generation biofuel technology, in its renewable energy context, is relatively low risk. Biofuel facilities have now settled on their optimum capacity and take between 18 months and 24 months to construct once ground has been broken.

First generation biofuels use food sources as feedstock; the challenge is to now convert other types of biomass, like cellulose, into transport fuels. The technologies and feedstocks for doing this are in an early stage of development and are considered second generation biofuel technologies.

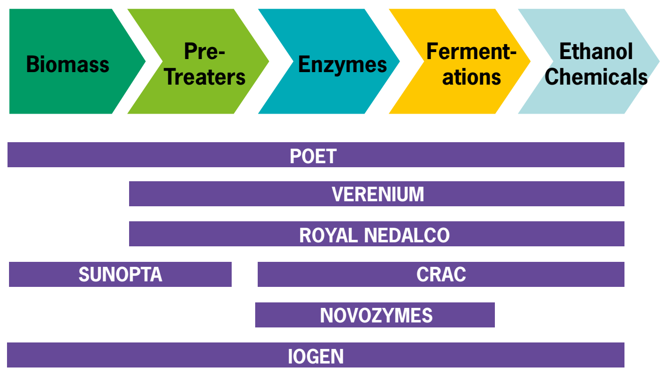
Opportunities

US maize ethanol, Brazilian sugar cane ethanol, and European biodiesel production assets are available in adundance. In the past year, there has been consolidation in the US and Brazilian ethanol markets. The high price of maize means some US ethanol assets are not operating at full capacity, which will increase the likelihood of the facility being available for acquisition. VeraSun's purchase of US BioEnergy is a recent high-profile example of consolidation. Brazilian ethanol assets are being scrutinised by foreign investors and domestic sugar and energy companies. The rush to enter the Brazilian sugar cane industry suggests there will be further consolidation – but at the right price.

The European biodiesel industry is suffering from low demand and cheaper imports from the US. Production facilities in Germany have been dismantled, and companies in the UK have sought alternative means of making biodiesel. Biofuels Corporation is processing cheaper, difficult-to-digest waste and crude vegetable oils in an attempt to reduce production costs, and making glycerine refining a core part of its business to compensate for the low sales price of biodiesel. The promise of being able to convert non-food stuffs into transport fuel at lower costs and greater volumes continues to draw investors into second generation biofuels: US cellulosic developer Mascoma recently closed an $81 million funding round while Sapphire Energy raised $50 million to further fund its development of bio-gasoline using algae.

There are second generation opportunities in developing new feedstocks; finding the appropriate infrastructure to transport it to the biorefinery gate; and in new technologies to convert it into fuel. However, developers that can then select one area in the value chain will be well served (see Figure 5). Opportunities also exist for waste companies as the waste and biofuel value chains converge – enabled by production technologies that can process a wide range of feedstocks.

Figure 5 Hypothetical value chain: enzymatic hydrolysis



Source: New Energy Finance.

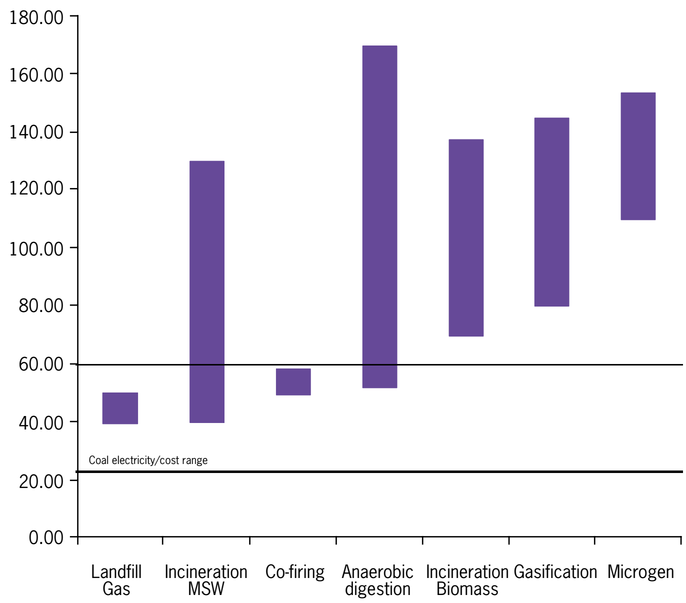
Biomass and Waste-to-Energy

Sector description and drivers

The greatest advantage of biomass is the availability of widespread resources to generate base-load power. But that is also its greatest challenge: how to secure long-term fuel supply at a stable price. Projects are developed most successfully where cheap residues are accessible, such as from the wood processing industry. Another driver is the availability of proven technologies at relatively low costs. Currently, there is an estimated 40GW of biomass and waste electricity generation capacity worldwide, with most of the resources used for heating. Overall, biomass contributes to 80% of the global renewable energy supply. In countries with less favourable conditions, governmental support is the most important driver for the industry. Due to high feed-in tariffs, Germany has seen a spectacular increase in biogas investments in 2006 and German companies are recognised as technology leaders by far. Finland generates 13% of its electricity from biomass.

Waste-to-Energy (WtE) on the other hand is driven by the need to dispose of municipal solid waste (MSW). Typically around 70% of the revenues come from the gate fee paid by local authorities and waste collection companies for disposing of the waste, and not from electricity generation. In Europe, the Landfill Directive (1999/31/EC) is also moving the sector forward as it stipulates that member countries must reduce the amount of biodegradable waste going to landfill to 35% of 1995 levels by 2020. In a few countries, WtE receives similar financial support as renewable energy.

Figure 6: Generation costs of bioelectricity compared to conventional electricity generation: $/MWh



Note: Based on a biomass feedstock priceof $11/MWh except for digestion and landfill gas plants where fuel cost assumed to be zero.

Source: IEA, Eubia, New Energy Finance.

For instance, in the UK the biodegradable part of MSW is eligible for Renewable Obligation Certificate (ROCs)[1] . However, the verification process is quite complicated. In the UK, government is ambivalent towards WtE and the policy approach varies across the country and according to the level of government involved in the permitting process. This, added to the often arcane and unpredictable planning regime, creates significant development challenges.

Technologies and market development

Most of the various technologies within the biomass & WtE sectors are well developed and field-tested for many years. Currently, the easiest, fastest and most cost-efficient way to increase the share of energy generated from biomass is via co-firing in existing power plants. For example, in the UK Drax, owner of the giant 4GW coal-fired power station, is targeting 10% biomass co-firing by 2011, and has recently awarded a £50 million ($97 million) contract to Alstom to provide a 1.5m-tonne-per-year biomass-processing plant. However, under the UK's renewable support regime, the level of subsidy available for co-firing is limited.

Electricity generation from landfill gas is competitive with fossil fuel plants even before subsidies are factored in (see Figure 6) but is expected to diminish in the longer term as organic matter is diverted away from landfill and older landfills naturally stop producing gas. Anaerobic digestion can be competitive in some projects but the wide range of generation costs is caused by project-to-project variations in feedstock cost and plant performance. Biomass gasification offers the largest potential for both development and the reduction of capital costs – expected to be up to 60% in the next ten years. Plasma gasification is still an early stage technology with only a few pilot plants in operation.

Biomass and Waste-to-Energy (continued).

Opportunities

The wood/paper industry and utilities have typically invested in biomass electricity generation assets, whereas local authorities and waste management companies (such as Biffa) have invested in WtE assets. This situation has begun to change as more independent power producers and financial investors discover this market. Private equity investment volume quintupled in 2007 compared to 2006 and reached $1.2 billion globally (20% of which went to gasification projects). Geographically, the UK dominated 2007 private equity activity, with six deals completed for a total of $275 million. The largest deal was the divestiture of landfill gas generation assets owned by CLP Envirogas to Macquarie Bank for $230 million. The UK also saw significant M&A activity such as RWE Innogy's recent acquisition of Helius Energy's Stallingborough Biomass Plant.

We do not expect to see growth rates in biomass comparable to those of the wind or solar energy sectors – the fragmented nature of the industry and the issues of feedstock supply limit investment opportunities at scale. But opportunities do exist, especially where favourable legislation is in place and feedstock supply can be secured. Fuel trade is a nascent business and there are efforts to create greater transparency on fuel prices, available quantities and locations. In the UK, the increasing demand for biomass for co-firing will see supply chain opportunities in trading and logistics. Opportunities will continue in the development of projects especially with the intent of selling a portfolio of projects to financial institutions. Energy consumers will also be able to develop biomass and WtE projects – particularly where they have access to a large supply of biomass or waste.

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[1] The Renewables Obligation (RO) is designed to incentivise the generation of electricity from eligible renewable sources in the United Kingdom. The RO places an obligation on licensed electricity suppliers to source an increasing proportion of electricity from renewable sources: initially 3% for the period 2002/03, rising to 10.4% by the period 2011-12, then by 1% annually for the five years.
Suppliers meet their obligations by presenting Renewables Obligation Certificates (ROCs). ROCs are issued for each MWh of renewable electricity that is produced (under updated arrangements from April 2009, some technologies will receive more than one ROC per MWh).
Where suppliers do not have sufficient ROCs to cover their obligation, they must make a payment into a buy-out fund, at a fixed price per MWh.
The proceeds of the buy-out fund are paid back to suppliers in proportion to how many ROCs they have presented.

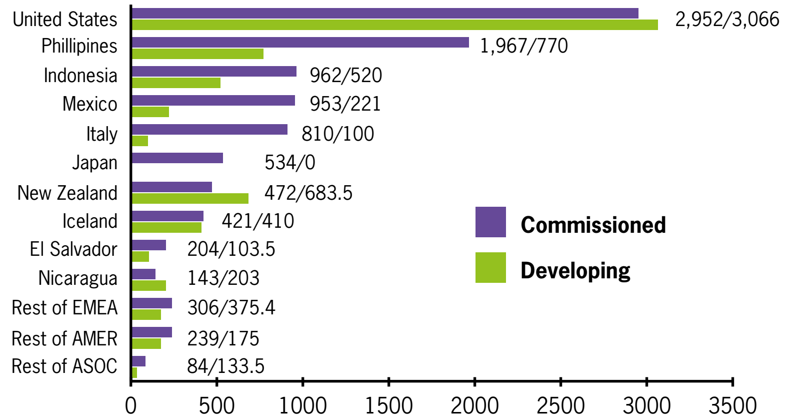
Geothermal

Sector description and drivers

The geothermal power sector aims to draw on the naturally-occurring heat stored in rock up to several miles below the surface of the earth. This extraction process is relatively simple in theory: drill a series of holes into the ground and capture the subterranean heat by circulating a thermal-transfer fluid through minute cracks in the rock. The injected fluid returns to the surface superheated, where it is converted to carbon-free electricity using conventional steam turbines.

Notable production advances are taking place in the US, the Philippines, Indonesia, Iceland, New Zealand, Australia, Turkey, and Germany. With an estimated 10GW of capacity online worldwide at the end of 2007, and new investments exceeding $3 billion in the same year, geothermal has made significant inroads towards the mainstream. Favourable policy frameworks, including feed-in tariffs and national targets – the US Production Tax Credit (PTC) being one such notable catalyst – have helped investors overcome the associated high up-front capital investment and financial risks.

Figure 7: Global commissioned and developing Geothermal capacity, Jan 2008: MW



Source: New Energy Finance. Note: Labels denote installed/developing capacity in MW.

Technologies and market development

Most large companies within the geothermal market are focused on developing conventional high-grade resources, relying on proven production techniques and resources capable of radiating temperatures upwards of 200ºC. More common resources with comparably lower temperatures and/or flow rates are becoming economically viable with the help of recent advances in technology. One company that sees potential in developing this type of low-grade resource is Raser Technologies Inc, which received $44 million in project financing from Merrill Lynch in January of 2008 to support the development of at least 100MW per year going forward. Another promising but as yet unproven play in this sector is enhanced geothermal systems (EGS), which seeks to engineer increased permeability within rock types possessing superior heat-capacity.

The growth of an industry also increases the demand for equipment and support services. A handful of companies are now marketing new drilling equipment – items like expandable tubulars and downhole vibration dampers – designed to improve efficiency and decrease the cost of drilling. Others are developing new tools for downhole data collection using high temperature electronics that have improved longevity. Manufacturers like United Technologies Corporation, UK-based Exorka, and Ormat Technologies are working to build efficient, small power plants useful in low-grade geothermal and EGS, as well as conventional applications. Consultancies, drilling contractors, compressed-air contractors, and mud contractors (mud is used to cool drill bits), among others, are also turning their attention towards the geothermal sector. The UK has significant exploration experience – albeit mostly offshore – which could be exported to countries with proven geothermal resources.

Opportunities

Financial muscle driving the geothermal sector has strengthened appreciably since 2006, spurred in part by regulatory support. The recent support explains the large development pipeline, especially in the United States (see Figure 7). Going forward, there will be many investment opportunities in next-generation drilling technologies, well-testing instruments, and advancements in exploration research as developers of geothermal-centric technologies look for additional funding and/or partnerships to continue commercialisation. While several companies are poised to expand their geothermal development portfolios, others are looking to gain entry into the market with hopes of buyout, and others still are hoping to gain revenues simply from the sale of geothermal lands acquired at the lease sales. For all but a handful of companies developing ground source heat pumps for heating and cooling, the opportunities to invest in geothermal activity in the UK are minimal. However, should ground source heat pumps take off; there will also be a demand for geothermal services and support.

Mini-hydro

Sector description and drivers

Hydropower was one of the first forms of renewable energy developed and ranges in size from kilowatts to tens of gigawatts – but it can create environmental issues and displace population. Small hydro avoids many of these issues by using a river's energy directly or smaller dams than those required for large hydro. The key advantages of small hydro are high efficiency (70% to 90%), high capacity factor (+50%), high predictability and durability, and reduced environmental impact.

Like most other renewable energy resources, the cost of small hydro has not yet reached grid parity. Nevertheless, the economics can be attractive where government support regimes exist. Capital requirements for small hydro plants depend on the effective head (the height difference between up- and downstream water), water flow rate, turbine efficiency, and site preparation requirements. Combining generation and irrigation, for example, can yield increased rates of return.

Technologies and market development

Hydropower is generated as turbines use water flow to turn a shaft that is connected to a generator. Available power is proportional to the head, the flow rate and turbine efficiency.

Minimally invasive underwater hydro systems can avoid many of the difficulties of traditional hydro facilities. However, these systems require high levels of efficiency, which can be difficult to reach due to the complex nature of fluid dynamics. GCK Technology's Gorlov helical turbine is an example of a revolutionary innovation in this space.

As of 2007, most European small hydro capacity (10.8 of 12.9GW) was located in seven countries: Italy, France, Spain, Germany, Austria, Norway, and Sweden. According to the European Small Hydropower Association, 65% of small hydro potential in the EU-15 countries has been exploited so far. Remaining economically feasible potential includes 20TWh/year in the EU-15 and 27TWh/year in new member states and candidate countries. Much of the European potential lies in refurbishing old plants or low-head sites. In early 2008, Alcan Aluminium UK, part of the giant international mining group Rio Tinto, applied for Scottish Parliament approval for a 5MW mini-hydro project it plans to develop at Loch Eilde Mor in Loch Leven.

The UK has existing hydropower and pumped storage capacity, but the extent of mini-hydro capacity is not clear. However, the Scottish Government recently commissioned a report ('Scottish Hydro Resource Study', August 2008) which identified 1,019 financially viable schemes and 657 MW of financially viable energy.

Opportunities

Investors will find prime opportunities in developing countries, notably China, India and Brazil, which each have a number of small hydro projects (see Table 1). According to the IEA's World Energy Outlook, one-third of China's counties rely on small hydro power as their main source of power generation, and the International Network on Small Hydro Power calculates that China has small hydro potential of 120GW; only a quarter of which has been exploited. Additionally, the Chinese government backs a small hydropower-based primary rural electrification program.

India, Vietnam, Thailand, and the Philippines are also rich in hydrological resources and open to foreign investors. Small hydro in these places is used to provide electricity to remote, isolated areas while also providing the opportunity to earn and sell Carbon Credits.

Table 1: Notable small hydro projects, recently completed or announced

Country	Developer	Investment Costs (USDm)	Total Capacity (MW)	Completion Date
Brazil	CPFL Energia	175	76	2012
China	Yuming Development	22	14	2007
China	Guangdong Shaoneng Group	26.7	14.1	2007
India	Kerala State Electricity Board	10.5	25	2008
India	National Thermal Power Corp.	15	8	N/A
Phillipines	Aboitiz Power Corp.	114	42.5	2009
Russia	Rika Grupp	158	800	2013

Source: New Energy Finance.

Marine

Sector description and drivers

The marine sector harnesses the energy of tides or waves. Tidal energy comes from tidal currents and uses water motion to directly drive turbines. Wave energy is drawn primarily from movement of the ocean surface created by wind-driven swell. The major drivers of the marine industry in a given location are the availability of good wave or tidal resources and strong government support. The UK and Portugal are arguably the strongest locations for marine projects, while Ireland, North America, South Africa, Australia, and China have all announced projects. The UK is also home to many marine companies, such as Pelamis and Marine Current Turbines.

Technologies and market development

To date, the marine sector has focused on developing and testing prototype devices. The number of tidal and marine devices actually in the water remains modest though many marine projects have been announced. The UK's Severn Estuary Marine Project is the largest proposed marine project, with a peak capacity of 8.6GW and an average capacity of 1.0GW. Like all marine projects, it must first pass environmental impact studies and the planning process.

The industry is still at an early stage, with many young technology-driven companies developing promising wave and tidal technologies (see Table 2 for a selection of marine technologies). More than fifty technologies are competing for pole position in this segment of the renewable energy industry. Experience from the wind industry, where three-bladed turbines on vertical towers have become standard, would suggest that only a few technologies will capture significant market share. The marine environment is more diverse than wind, due to its on, near and off-shore environment, so as many as four of these technologies may become established as industry standards in the next decade.

Opportunities

Investment interest in marine opportunities ranges from government support to strategic investments by major utilities, to VC/PE investments. Due to its early stage, there remain many hurdles to the successful commercialisation of marine technologies and the development of utility-scale projects. These include proving device reliability, reducing costs and creating a navigable permitting process. Investment opportunities will come in the continued development of technology, the deployment of full-scale devices and the ultimate financing of commercial-scale wave and tidal farms.

As commercial-scale projects take off, opportunities will increase for suppliers to the industry. Experience from the wind industry has shown that rapid demand growth can lead to supply bottlenecks, for example in gear boxes. Similar bottlenecks are likely to occur, for example, in the supply of power take-offs such as linear generators. However, since different technologies use different components, the precise bottlenecks will not be known until it becomes clear as to which marine technologies are becoming dominant.

However, some components are more common across the various devices, such as mooring systems, control electronics, power electronics, and steel and concrete fabrication. Current suppliers of these components have the opportunity to seek strategic relationships with device developers and thereby capture future potential sales.

Table 1: Notable small hydro projects, recently completed or announced

Wave Technologies		Tidal Technologies	
Bouyant Moored Device	Floats on or just below the surface of water and is moored to the seabed. One part of the machine remains still while the other is moved by waves, generating electricity.	**Tidal Turbines**	A horizontal axis turbine (MCT's SeaGen, for example) uses tidal currents to generate electricity.
Oscillating Water Column	A hollow structure partially submerged in the ocean. Waves cause the water column to compress and depress the air column. The trapped air helps rotate a turbine to generate electricity.	**Tidal Lagoons**	An adaptation of the bigger barrage technology. A rubble mound impoundment structure built to temporarily trap tidal flows. Uses low-head hydroelectric equipment to generate electricity.
Hinged Contour Device	Similar to a buoyant device. Waves raise and lower different sections of the machine relative to each other, pushing hydraulic fluid through pumps to generate electricity.	**Tidal Fences**	A vertical axis turbine mounted within a fence structure which forces all the water through it.

Source: UK Department for Business, Enterprise and Regulatory Reform.

Solar

Sector description and drivers

Most solar electricity generation technology is photovoltaic (PV) – it uses layered semiconductors with differing electrical properties. There is also growing interest in Solar Thermal Electricity Generation (STEG) which uses concentrated solar heat to vaporise a fluid and drive a turbine for electricity generation.

Subsidies represent by far the most significant driver of the solar market. Solar power is the most expensive energy source in nearly all applications, even with oil prices over $130/barrel. While it is the best option in a few niches, such as power for grid-isolated telecommunications towers and calculators, these markets are tiny. The growth markets are for grid-connected power plants supported by large subsidies. A somewhat cloudy Germany has built a strong domestic manufacturing industry and hopes generous domestic subsidies will be recouped via increased corporate profits.

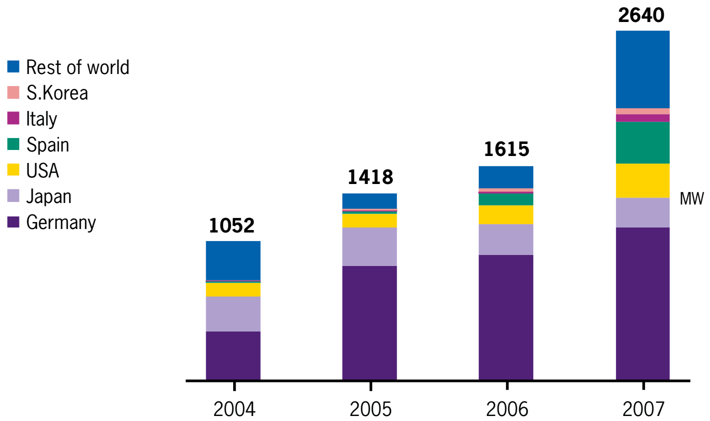
Technological improvements developed in response to subsidy-driven demand have already dramatically cut the cost of PV power, and will reduce it much further over the next five years. PV will eventually become cost-competitive in some non-niche markets, and this will unlock substantial additional demand, but expect the industry to depend heavily on government generosity for another three or four years.

Technologies and market development

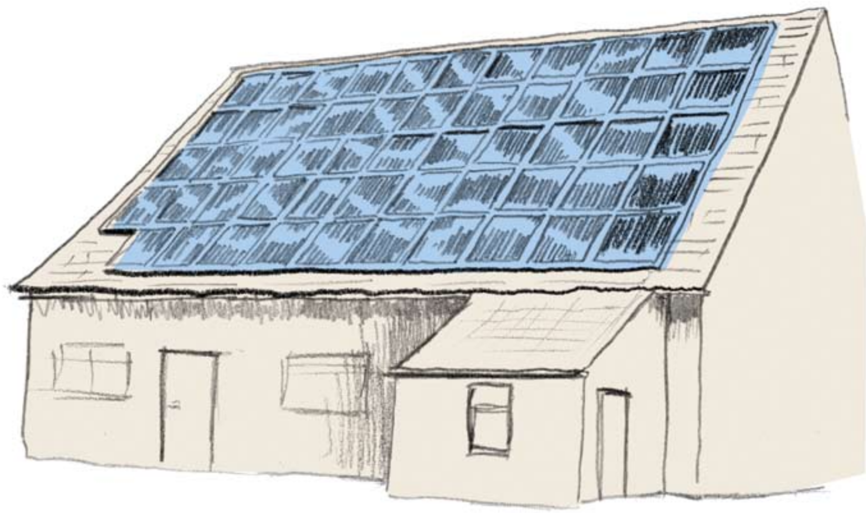
The conventional PV technology is 'crystalline silicon', which involves manufacturing silicon of at least 99.9999% purity – a technologically challenging and capital-intensive process – then slicing it into wafers, processing into cells and assembling into modules. Challengers include thin film PV processes, which could skip several stages and save expensive material by depositing semiconductor directly onto substrates. Thin film offers much lower cost modules, but would take up more space per W and have a lower efficiency. Only a few companies have managed thin-film manufacturing at scale, notably First Solar and their products are in great demand for large-scale projects.

There are also attempts to produce more power from the PV cell, which is currently the most expensive component of a PV system, by using mirrors or lenses to concentrate more light onto it. This is called concentrated photovoltaics (CPV), and incurs substantial additional balance of plant costs, as well as proving technically challenging. Most VC- which is developing specialised cells for CPV.

Figure 8: New PV installations each year 2004 - 2007: MW



Source: New Energy Finance.



…Subsidies represent by far the most significant driver of the solar market. Solar power is the most expensive energy source in nearly all applications, even with oil prices over $130/barrel.

Table 3: Selected UK VC/PE Funded Solar Companies

Country	Technology	Amount raised	Investment Rounds
Whitfield Solar	CPV	>$2m	4
Quanta Sol	CPV cells	$3.3m	2
Helio Dynamics	CPV	$6.4m	4 (exited for $10.4m)
G24i	Thin Film	>$50m	2 first informal
Solarcentury	Installation	$59.3m	6

Source: New Energy Finance.

The PV market is likely to develop along a horses-for-courses model, with high-efficiency crystalline silicon used in space-constrained applications, and thin film taking up to 50% of the market, dominating in large-scale installations. CPV may also find a niche in large-scale installations, if the technical hurdles can be surmounted before the cell cost falls significantly.

Opportunities

Much capital has already been invested in the value chain for module manufacturing, both thin film (such as UK-based G24i) and crystalline silicon (such as silicon and ingot maker PV Crystalox). This should drive cost reduction over time. Prime opportunities for investment are those which will benefit from a discontinuous fall in module price due to impending module oversupply, but which have some barriers to entry – for example, producers of inverters, monitoring systems, and innovations to make installation and maintenance easier are all potential targets. Installers and project developers will see short-term gains, but VC investors should be aware that barriers to entry here are small.

Manufacturers of specialised products for building integrated PV – like Romag Holdings – may also benefit from specific tariffs for this product in France, and steel manufacturer Corus is developing a rolled steel product with built-in dye sensitised PV, in collaboration with Australian technology developer Dyesol.

The leading solar markets, such as Spain and the US, have seen an increasing number of project acquisitions as developers and investors seek to benefit from the support structures and subsidies currently in place in these countries. Industrial companies are also entering the sector through the acquisition of specialist players - for example Bosch Group's purchase of ErSol Solar Energy, a Germany-based PV maker, for €1.2 billion ($1.8 billion) in August 2008.

Wind

Sector description and drivers

Wind energy harnesses the movement of air caused by temperature changes in the atmosphere. Technology has focused on three bladed upwind turbines whose design was popularised and commercialised by Danish companies in the late 1990s. The technology is considered mature and certified turbines have little difficulty attracting commercial insurance underwriters and project finance debt. Accurate assessment of wind resources is critical to the planning and financing of wind farms as well as their long-term integration into electricity networks.

Wind power is increasingly seen as a means to hedge against rising fossil fuelled power prices and stabilise electricity prices in countries with both fossil and hydro generation assets. As such, it has emerged as the leading renewable energy technology after hydro-electricity. Total installed capacity reached 91GW around the world at the end of 2007 with concentrations in Western Europe, USA, India and China.

Technologies and market development

After the first oil shock in the 1970s, California began developing wind capacity. In the 1980s, Denmark and Germany created markets through various regulatory mechanisms which supported the installation of domestic made turbines. Noise and aesthetic considerations, as well as the success of companies focused on three-bladed upwind turbines, led to this becoming the first design to gain widespread acceptance. Burgeoning growth in the market, initially driven by concerns over energy security and environmental impacts of fossil-fuelled power generation, has been further advanced by rising oil prices.

Growth in demand has been so high that market incumbents have been unable to keep pace and the industry is seeing the re-emergence of older technologies and new manufacturers to commercialise them. This includes simplified two-bladed turbines, downwind twobladed turbines and major innovations in offshore wind systems. The UK government has placed rising emphasis on offshore wind to meet its long-term targets and offset rising gas imports. Impatience with project approval processes onshore has led to an increasing emphasis on offshore wind farms – the UK's offshore wind potential is estimated at 25GW.

Opportunities

There are several key opportunity areas in the wind industry, the majority predicated on the high growth and the need for incumbent players to capture market share and balance sustainable growth. In the area of asset development, the need to meet government targets and to develop pipeline wind projects in markets where IRRs present attractive opportunities to investors. In the UK, hampered by restrictive planning regulations, opportunities for wind farm construction are few and far between, and acquisitions are taking place, as evidenced by Savill's recent sale of its 322MW pipeline for £23 million. SSE has also acquired Airtricity for a total cash consideration of total cash consideration $3.2 billion. There is M&A activity in offshore wind as existing players redefine their strategies. Shell, for instance, has sold its stake in the UK's London Array offshore project to E.on and Dong Energy.

Opportunities abound across the supply chain too. A global shortage of turbines has allowed incumbent turbine manufacturers to acquire competitors (Suzlon has acquired Repower, for example) while also presenting an opportunity for new players to emerge. In operations and maintenance, marked improvements in existing asset management techniques are being pioneered through scale and closer inventory and technical team management. Innovative technologies are reducing the cost of generation, the exposure to volatile commodities (steel/copper) or system design for complex issues such as offshore wind. The supporting infrastructure required for wind farms both in resource forecasting and grid expansion offer high technology and capital intensive investment opportunities, respectively. Several M&A opportunities should emerge as the sector consolidates.

Table 4: Top wind markets by capacity YE 2007

Market	Capacity (GW)
Germany	22.7
United States	16.9
Spain	15.1
India	8.3
China	5.9
Denmark	3.1
United Kingdom	2.8
Italy	2.7
France	2.4
Portugal	2.1
Other	9.4
Total	**91 GW**

Source: New Energy Finance, GWEC.

Section 2: Energy efficiency

Energy efficiency is a vast topic that affects all industries, businesses, and consumers. Covering such a broad spectrum, it is often difficult to define the opportunities driven by energy efficiency improvements. Opportunities in energy efficiency can be loosely grouped into four areas: buildings, industry, power, and transportation (see Figure 9). Within these four areas, we see the biggest future opportunities in generation efficiency, power storage, buildings, and lighting.

Financing energy efficiency projects represents a vast opportunity for financial institutions. Current projects have barely scratched the surface of the worldwide potential, leaving plenty of room for a great variety of institutions to have a piece of the action. However, fast payback periods are often overshadowed by both up-front capital costs and 'principal agent barrier', in which those making the investment decisions (such as house builders) are not the ones with the incentive to invest (such as home owners). A great opportunity lies in overcoming the various barriers to financing energy efficiency improvements.

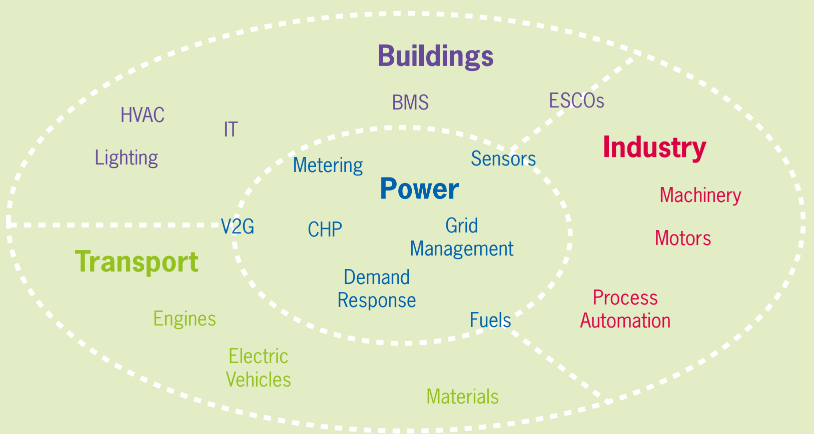
With regard to emissions abatement, the largest opportunity lies in the building sector. Key technologies used to enhance a building's energy efficiency focus on lighting, heating ventilation and air conditioning, insulation, windows, and a range of power management services and electronics. Specifically, energy used for lighting – responsible for nearly a fifth of current worldwide electric demand – can be slashed through the use of innovative lighting technologies, LEDs and OLEDs in particular. Small and medium-sized developers in this space will be prime targets for consolidation.

The power sector also presents significant business potential to reduce losses in transmission and distribution, and realise improvements in generation efficiency. Companies like Baxi-SenerTec and WhisperGen are developing distributed generation initiatives to create power, as well as useable heat and cooling, as close as possible to the end-user. Making best use of centrally-generated power is also vital – such as changing to high voltage direct current (HVDC) power lines, which exhibit less power loss over long transmission distances than conventional AC power lines. Smart grid technology developers like UK-based BGlobal and RLtec are helping create a real-time feedback loop between customers and suppliers in order to optimise consumption during peak power events.

Power storage is also a hot area of development. Closely tied to transportation efficiency on the small-scale, the proliferation of electric vehicles is driving development of nickel metal hydride (NiMH) and lithium ion (Li-ion) automotive batteries. In utility-scale applications, power storage technologies can be used for load-shifting and peak shaving, helping extend the capacity factor of intermittent renewables such as wind or solar.

Whether due to the economic benefits of reducing energy costs or the potential of regulated minimum efficiency standards and emissions-reduction targets, there are plenty of direct drivers for increased development within energy efficiency.

Figure 9: Energy efficiency sector road map



Source: New Energy Finance.

Buildings

Sector description and drivers

Buildings account for 30% of end-use energy so the potential to reduce energy use through energy efficiency technologies and services is significant. However, homeowners, builders and business are often reluctant to implement changes even though lower use of energy translates into lower energy bills – fast payback periods are overshadowed by upfront capital costs. Government legislation can be an effective tool in spurring energy efficiency improvements. The Energy Performance Buildings Directive (EPBD) sets out a framework for monitoring and implementing changes in the EU. Under the directive, minimum efficiency standards must be met on all new buildings and large buildings subject to major renovations.

In October 2006, the European Commission set forward the Energy Efficiency Action Plan which called for a 20% increase in energy efficiency by 2020. However, unlike some of the other 20/20 targets Europe has set out for renewable energy these are non-binding. The European Union seems to be quietly putting this recommendation to one side as it was not mentioned in the European Commission's climate change package released at the end of January 2008. This may be due to the lack of appetite for energy efficiency improvements among.

Technologies and market development

Several technologies can increase a building's energy efficiency: lighting; heating ventilation and air conditioning; heat pumps; sensors and controls; building management systems (BMS); windows; insulation; plus green electronics and IT. The majority of these are supplied by large integrated energy control companies such as Siemens, Honeywell, Trane and Johnson Controls. However, independent start-up companies are developing interesting technologies.

Window technologies such as electrochromic glass are being developed. Using an electric current to turn transparent window glass opaque, the technology eliminates the solar gain caused by sun light. Swedish VC/PE-backed start-up Chromogenics is active in eletrochromic window market with technology that can be applied to existing window panes. They have raised a total of $10.5m since 2006. Other applications include eye-wear and semistatic displays. Two UK-based insulation companies are Warmroof and EAGA Partnership. Warmroof specialises in spray loft insulation and, in December 2007, underwent a buy-in management buy-out (BIMBO) led by Barclays Capital and supported by Innovex Capital. EAGA Partnership carries out wall cavity and loft insulation retrofits. It floated on the London Stock Exchange in June 2007 for $438 million, raising $60 million in new equity.

Power electronics is an energy efficiency subsector of growing importance since it modulates electrical energy use of devices. Power electronics technology involves everything from inverters to integrated circuits. Cambridge University spin-out, CamSemi, is developing highly efficient power electronics having raised a total of $48 million from 3i, BankInvest and Carbon Trust Investment Partners.

Opportunities

Consolidation will undoubtedly take place as traditional energy control suppliers – such as Siemens, Honeywell, Trane and Johnson Controls – acquire interesting new technology companies. The most challenging aspect will be keeping track of myriad technologies and companies. In the UK, we will probably see both the creation and growth of energy service companies (ESCOs). However, these companies may struggle to raise funding as the lack of tangible assets in their business models make it difficult to attract conventional equity and debt investment. ESCOs that combine their service offering with some unique technology or product are likely to be more attractive. This area offers great potential for existing companies to add an ESCO business model to help rollout of their existing energy efficient product. Companies can also add an energy efficiency performance attribute to existing products via new product development or acquisition of new technologies/companies.

Table 5: Selected UK Buildings Efficiency Companies

Company	Ownership	Application
CamSemi	VC/PE funded	Control Electronics
EAGA Partnership	Quoted: LSE (EAGA)	Insulation
Camfridge	VC/PE funded	Refrigeration
Vibrant Energy	VC/PE funded	EPC provider
Warmroof	VC/PE funded	Insulation

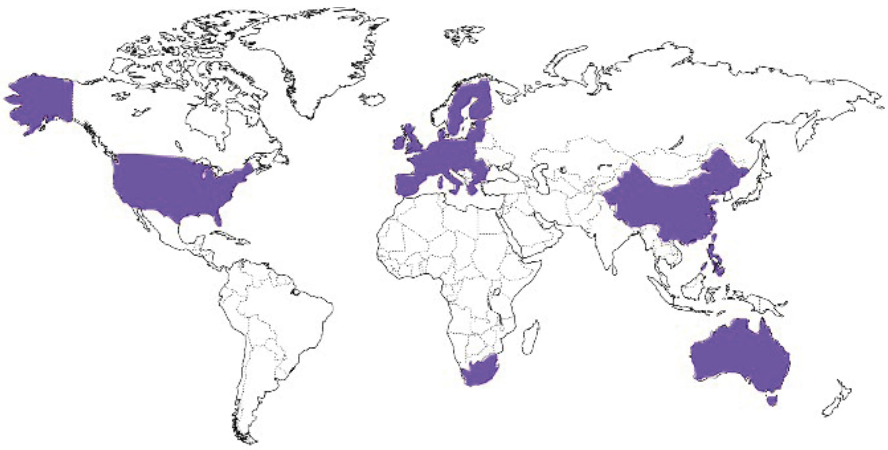
Source: New Energy Finance.

Lighting

Sector description and drivers

Energy efficient lighting is one of the most attractive efficiency products. It is easy to implement, available globally and offers typical return on investment of 35%. Lighting currently accounts for 19% of world electricity demand and therefore low energy lighting, in particular LEDs, are very important in the drive towards a low carbon economy. Incumbents in the lighting space have begun buying promising LED (and other efficient lighting) companies to protect and increase market share.

The combination of political action, increased consumer interest and the rapid maturing of technologies has driven consolidation. This creates the opportunity for good returns in all asset classes. In 2007, $1.4 billion was spent on the acquisition of energy efficient lighting companies – an increase of 532% over 2006.



Technologies and market development

The drivers for low energy lighting are very strong with legislation and high levels of public awareness driving sales. Many countries, including the UK, are in the process of banning incandescent lighting (see Figure 10). The most prominent energy efficient technology is light emitting diodes (LEDs) which provide up to ten times the efficiency of incandescent light bulbs, and a lifetime of 100,000 hours (11 years).

Energy efficient lighting has been well funded by VC/PE investors, with $359 million invested between 2005 and March 2008. Exits are also starting occur: in September 2007, UK-based Cambridge Display Technology was acquired for $285 million by Sumitomo Chemical. However, the subjects of recent acquisitions have tended to be established lighting companies that made big R&D investments in efficient technologies.

Table 6: Selected VC/PE Funded Lighting Companies

Company	Technology	Amount raised	Investment Rounds
Luminus Devices	LED	$139m	5 rounds, 2003
BridgeLux	LED	$61.5m*	3 rounds, 2006
Renaissance Lighting Inc	LED	$13.9m	1 round, 2007
Topanga Technologies	HID**	$1.5m	1 round, 2007
Novaled	OLED	$24.2m	2 rounds, 2003

Source: New Energy Finance. Note: *excluding series A. **High intensity discharge

Opportunities

Further consolidation will continue with big corporates vying for dominance in the expanding efficient lighting space, estimated to be worth $1.37 billion by 2012. IP-heavy companies will be especially important as established players rely upon new innovation to maintain market share.

The development of LEDs and other energy efficient lighting has left a fragmented value chain with many small to medium-sized companies providing ample pickings for traditional industry giants such as Philips, GE and Siemens/Osram Sylvania. Consolidation has also started to occur in earnest and it is likely to continue. Lighting giants will need to ensure they are able to provide new technologies to consumers or risk losing market share. As such, companies with innovative technologies that are IP heavy will continue to be prime targets.

Plenty of public and private companies, some with VC/PE backing, are continuing to develop technology (see Table 6). LED and OLED companies will continue to come through the investment chain.

Generation efficiency

Sector description and drivers

A third of primary energy supply is used to produce energy or conserve feedstock. And while energy production is inefficient, the transmission and distribution (T&D) of the generated energy is also subject to large losses. In developed countries, roughly 6-7% of energy is lost in T&D and in developing countries such as India losses can be as high as 30%. Although improvements often rely on regulation or governmental encouragement, economic reasons are driving the development of efficiency-improving technologies such as distributed generation with combined heat and power (CHP) or fuel transformation.

Technologies and market development

Technologies for distributed generation and CHP are internal combustion engines, microturbines, Stirling engines or fuel cells. Waste heat from electricity production is captured and utilised for heat or hot water. CHP is much more effectively utilised close to the point of use as it is hard to store electricity. Using trigeneration technology, waste heat can be used for cooling through absorption cooling methodologies. European companies involved in CHP are Baxi-SenerTec, Disenco, Frichs, Vaillant, WhisperGen and CFC Solutions.

T&D technologies include distribution infrastructure improvements such as high voltage direct current (HVDC) power lines. DC does not have the distance-dependent losses associated with AC power lines. However, infrastructure technologies are still widely developed and sold through multinational corporations such as ABB. Smart Grid technologies use several different technologies to optimise energy supply and demand networks. Metering technologies can be used to monitor overall energy usage in homes and offices, or that of individual appliances and devices. This data both encourages owners to reduce energy use and helps the utility to help optimise supply and demand. In the UK, metering company BGlobal has partnered with Bizz Energy to provide energy use data. Bizz Energy then uses the data to optimise energy purchases.

Demand response – in which companies install controlling meters on the air conditioning or lighting systems of large energy users – is helping grids to cope with peak power events and the integration of intermittent renewables, such as wind. The demand response company can then slightly turn down lights or aircon to reduce overall energy consumption and create extra capacity for the utility.

Opportunities

Because generation efficiency technologies are of such benefit to utilities, the technology companies that develop them are attractive investments for utility companies. Consolidation is likely to occur in the medium term for smart grid and metering companies as utilities seek to control the technology rather than license it. However, the market dynamics will largely depend on upcoming regulation or government incentives as there is still a large amount of uncertainty.

CHP companies meanwhile will likely be looking for expansion capital for installation roll-outs. There may also be consolidation within the sector, and some utilities will get involved with distributed generation – Centrica's £20 million investment in, and purchase contract with, Ceres Power is one example.

Table 7: Selected UK Efficiency Generation Companies

Company	Ownership	Application
Sabien Technology	Quoted AIM (SNT)	Boiler efficiency controls
2D Heat Ltd	Pre-institutional funding	Efficient heating elements
Disenco Energy	OTC Quoted: TSX (DIS)	Stirling engines for CHP
BGlobal	Quoted AIM (BGBL)	Smart metering

Source: New Energy Finance.

Power storage and transportation efficiency

Sector description and drivers

Power storage and transportation efficiency are very closely related. The major form of power storage – batteries – are frequently used by electric vehicles, the most common form of transportation efficiency. Whether hybrid (HEV), plug-in hybrid (PHEV) or battery electric vehicles (BEV), electric vehicles (EVs) have shown promise in reducing emissions and dependence on oil. In recent years, these vehicles have made great strides in consumer acceptance and desirability. However, questions remain about the impact on electricity grids, cost and the ability to achieve the performance of traditional internal combustion engine vehicles.

Other power storage opportunities will occur with companies involved in utility scale electricity storage which may be used to increase the capacity of intermittent renewables such as wind or solar. Load shifting and peak shaving are other large scale applications for which battery power storage is important. Peak shaving provides supplemental energy at peak energy times so that dirty and expensive forms of energy, such as diesel generators, are not required.

Table 8: Selected Battery and EV Companies

Company	Ownership	Application
Axeon Holdings	Quoted AIM (AXE)	Li-Batteries
Modec	Pre-institutional funding	Electric delivery vehicles
Plurion Ltd	VC/PE funded	Large scale power storage
Th!nk Global	VC/PE funded	Electric vehicles
Allied Vehicles	Private/familly controlled	Electric delivery vehicles

Source: New Energy Finance.

Technologies and market development

The two main battery technologies are nickel metal hydride (NiMH) and lithium ion (Li-ion). NiMH is used for hybrid electric vehicles and is the technology currently used in the Toyota Prius. Li-ion batteries are the emerging technology used for plug-in hybrid vehicles or battery electric vehicles. The major obstacles for Li-ion batteries are cost and safety concerns. Siemens/ Osram Sylvania .Lithium-iron-phosphate technology does not share the same thermal runway (ie, explosion) issues of traditional Li-ion technology.

Currently available vehicles range from the tiny G-Wiz (actually a quad rather than a car) to the recently released sports car, the Tesla Roadster, to the range of cars from Norwegian firm Th!nk Global. Tesla has partnered with Lotus to provide engineering for a car with a range of 240 miles. UK-based Modec develops electric delivery vans and has partnered with GE Financial Services to provide lease financing opportunities for customers. Allied Vehicles based in Scotland is also developing electric delivery vehicles and minivans in collaboration with Peugeot.

Opportunities

We believe that rising oil prices will continue to fuel growth in the power storage sector. This will require capital for increased battery manufacturing capacity and, in the medium term, consolidation is likely. As successful battery and electric vehicle developers appear, they will acquire less successful companies with useful technologies or acquired themselves by large battery OEMS.

Expect fuel prices to climb further, government incentives to increase and legislation to become tighter. As a consequence, sales of EVs will shift to PHEVs and BEVs, which will create opportunities for Lithiium-ion battery manufacturers and other component suppliers. Consolidation could occur as vehicle manufacturers seek to protect their supply chain. For instance, Toyota took an increased stake in its battery supplier for HEVs, Panasonic EV Energy. Other major auto manufacturers without substantial electric vehicle capabilities may find themselves in need of rapid market entry by acquiring existing independent players. Overall, the market for vehicles and batteries looks set to grow driven by increasing petrol prices and legislative pressures.

Section 3: Low carbon technologies

Climate change is now an important global issue – and policy makers have responded with various attempts to internalise the cost of green house gas emissions. The creation of a voluntary market through the Kyoto Protocol was the world's first serious attempt to price the cost of carbon emissions. Among conventional energy sources, it is the combustion of coal that yields the largest carbon emissions. As discussed in previous sections, one of the attractions of renewable energy and energy efficiency technologies is their zero emissions profile. While energy efficiency and renewable technologies are steps toward decarbonising the world's energy profile, the world's enormous reserves of coal means that many countries will continue to rely on coal as a major part of their energy supply for decades to come. If the world is serious about curbing greenhouse gas emissions, then clean coal and carbon capture and sequestration (CCS) technologies must be implemented.

Fundamentally, opportunities in clean coal and carbon capture and sequestration (CCS) sectors are quite different from that of the renewable energy and energy efficiency technologies. While the other sectors have the potential to be economically viable through technology breakthroughs and cost reduction, there is no potential technology breakthrough that will make a coal-fired power station with carbon capture cheaper to build or operate than one without. A long-term support mechanism of some sort is therefore essential, even for clean coal that can also rely on pressure for improved local air quality. Given current regulatory and market conditions, it is no surprise that there is no global carbon capture and sequestration industry yet. Opportunities in CCS and clean coal will become more accessible once a credible and robust carbon market has been created. Only then will a carbon price make coal plants with CCS able to compete economically with those without. Of course, just like other industries, there will need to be an economic stimulus provided by governments to encourage relevant market participants to experiment with new technologies and go beyond demonstration plants.

Fuel cells hold the promise of a cheap and abundant energy source for applications across markets; however, fuel cell and hydrogen companies suffer from the exact opposite challenge facing the more mature clean energy sectors. Investors have been waiting for their technologies to gain market traction for decades so they approach both with a sense of wariness. Indeed, fuel cells and hydrogen represent just about the only area where VCs have become less interested in recent years.

Potential opportunities in the fuel cell sector exist in niche applications: specifically, recreational vehicles, mid-sized distributed generation and telecoms backup. In Europe, interest has grown around UK-based companies that are actively developing fuel cells for residential combined heat and power.

Carbon capture and sequestration

Sector description and drivers

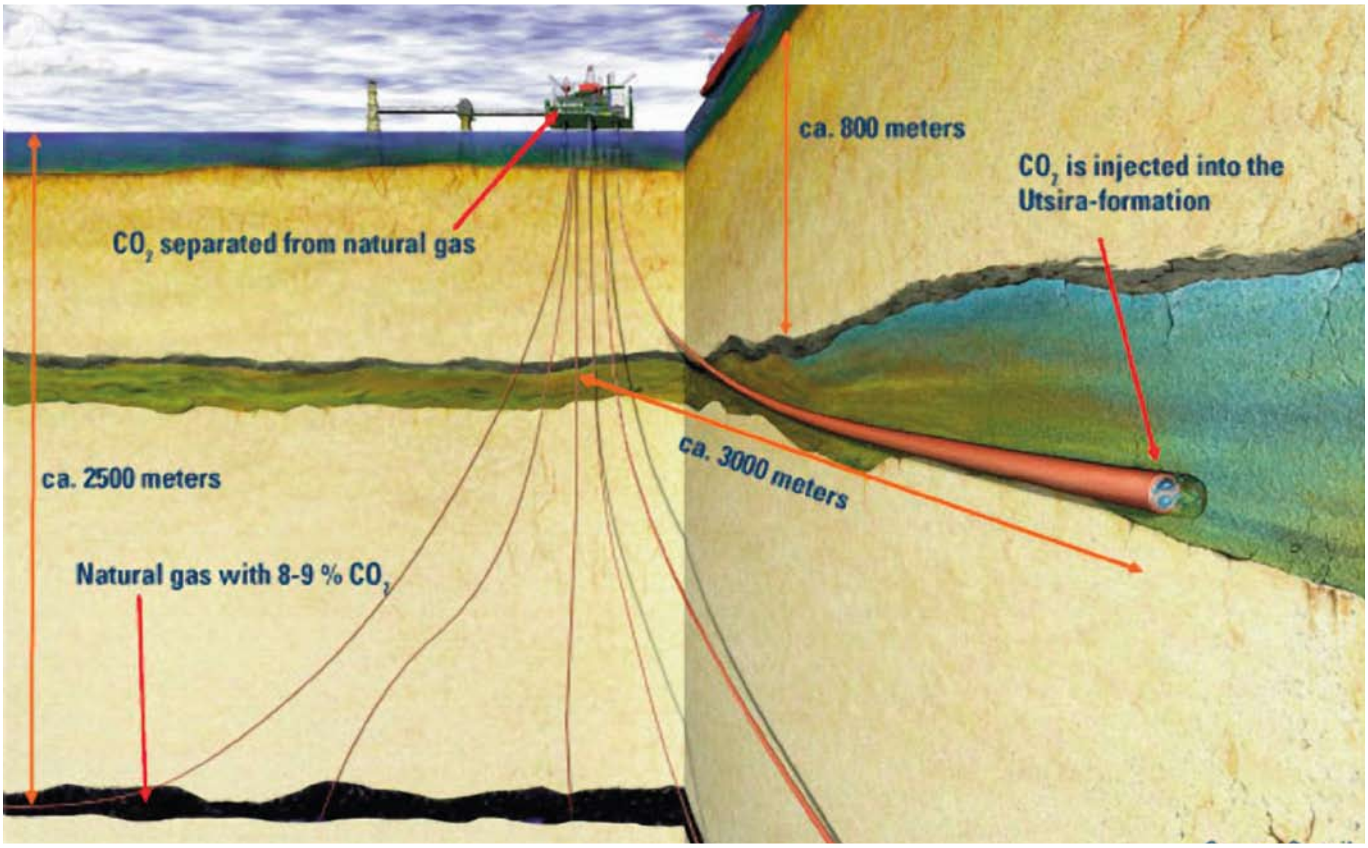
A global carbon capture and sequestration (CCS) industry does not yet exist. Of course, it can be a profitable endeavour in some instances, such as when it can be coupled with enhanced oil recovery (EOR) or in Norway where a levy on CO2 emissions has been established. But adding a CCS component to a power project is economically unfeasible in the current marketplace. Using technology available today, CCS operations cause substantial decreases in plant efficiency owing to the extra energy required to run the capture equipment. This can increase overall plant costs by up to 85%. While it is commonly known that CCS can reduce fossil fuel emissions, the substantial direct or indirect costs of CCS projects have so far deterred large emitters from developing large-scale CCS projects. Instead, investment has gone toward smaller scale projects that will serve as a springboard for development if carbon reduction policy makes CCS economically viable.

Technologies and market development

Several governments talk of the need to develop tens of utility-scale CCS projects that will drive regional and global commercial CCS industries. However, not one of these utility-scale projects has yet been built. The first project will provide empirical data regarding the actual cost of a CCS project of that size. And as well as probably gaining public acceptance for CCS as a carbon dioxide mitigation option, it will help to refine regulatory and legal definitions, prove technical and logistical feasibility and build investor confidence.

Notable among regional efforts to build the first utility-scale project is a contest set up by the UK government which will fund up to 100% of CCS retrofit to capture at least 90% of emissions on 300 MW of an existing coal-fired power plant. Bids have been submitted and are currently under review.

Another step in enabling commercially viable CCS is the development of functional technologies that carry less of an energy penalty and bring down the overall cost of CCS implementation. As it is the most expensive segment of the CCS value chain, efforts tend to be focused on advancing carbon capture technologies. There are currently nearly 200 CO_2 capture technology development projects globally, across approximately 100 organisations including national labs, large multinational corporations, universities, research institutions, and a growing number of pure play CCS technology start-up companies.



Source: ioc.unesco.org

Clean coal

Sector description and drivers

Given its abundance, location, and low-cost potential, coal will continue to play a significant role in the global energy profile. Coal accounts for approximately one-quarter of the world's energy consumption and one-third of its generating capacity. However, coal is also one of the dirtiest sources of energy: toxic by-products of coal-fired power such as particulate matter, NOx, SOx, and mercury pollute air quality. Additionally, by 2010, carbon dioxide emissions from coal will reach 40% of total carbon dixoide emissions worldwide.

Public outcry and uncertainty around future carbon policy have caused growth in new coal generation capacity to drop to its lowest levels in decades. But clean coal technologies are effective in eliminating many emissions from coal-fired generation and offer an opportunity to maintain coal's position in the global energy mix. That position is important, as most renewables fail to offer the base load power that clean coal can provide.

Technologies and market development

There are several technologies for burning coal cleanly, each with their own impact on cost and efficiency. The vast majority of coal-fired electricity (over 90%) is generated from plants using a pulverised coal combustion process (PCCC) in which coal is washed, crushed into fine particles, and incinerated to create steam, which then turns a turbine. Electrostatic filters, wet flue-gas desulphurisation, and selective catalytic reduction can be used to effectively eliminate toxic particulates, nitrogen and sulphur oxide, and mercury in post-combustion capture. Likewise, oxy-fuel combustion and amine technology can be used to reduce and separate carbon dioxide emissions. Note, however, that carbon dioxide capture processes typically reduce efficiency by one quarter, from approximately 40% to 30%. Fluid-bed combustion (FBC) and biomass co-firing can also be used to reduce sulphur dioxide and carbon dioxide emissions. The relative costs of each technology are illustrated in Table 9.

Integrated gasification combined cycle (IGCC) systems convert coal into syngas that can be burned to power a turbine. Residual heat is then converted to steam to power a second turbine, generating additional electricity. Carbon dioxide is separated in a pre-combustion capture process. Only four government-supported IGCC plants operate todayin the US and Europe.

Opportunities

Companies offering the relevant equipment, expertise, and construction services are likely to gain from the eventual incorporation of clean coal technologies. Building-out new IGCC systems, retrofitting of existing PCC plants, and developing infrastructure necessary to transport carbon dioxide to its sequestration destination will require significant amounts of capital. Owners of easily accessed, high quality coal are positioned to capitalise on the likely increase in demand for burning higher efficiency coal, plus the carbon offset costs of incorporating capture technologies.

Certain players are more likely to face substantial risks. Incorporating new capture and sequestration processes and negotiating new and old purchase contracts will likely be costly for producers. Sequestration firms will face the risks of maintaining reservoirs as well as certain liability issues. And ultimately, consumers will bear the brunt of higher coal generation costs through higher prices.

Table 9: Estimated cost of electricity by technology type

	Cost (USD cents/kWH)		CO_2 Avoidance Cost
	w/o CO_2 Capture	w CO_2 Capture	($/ton)
Subcritical PCC	4.84	8.16	41.3
Supercritical PCC	4.78	7.69	40.4
with Oxy-fuel	n/a	6.98	30
Ultra-supercritical PCC	4.69	7.34	41.1
FBC	4.68	7.79	39.7
IGCC	5.13	6.52	19.3

Source: MT Study on the Future of Coal, 2007.   Note: New build costs. Retrofits are similar as the plant is off-line for up to 12 months.

Fuel cells

Sector description and drivers

Fuel cells have long held the promise of revolutionising power generation in nearly every application from mobile phones to vehicles and distributed generation. However, they have been plagued with technical flaws that have caused delays and disappointed investors. The hot topic of the early 2000s, the share prices of fuel cell companies have now declined and investment volumes have slowed. Fuel cells may still provide benefits in niche market applications in which the price is less sensitive and the benefits of the fuel cell technology will enhance the value proposition. The key areas to watch will be recreational vehicles, mid-sized distributed generation and telecoms backup.

Technologies and market development

There are many different types of fuel cell technologies. Broadly speaking, they are either low temperature or high temperature. High temperature technologies such as solid-oxide (SOFC) and molten carbonate (MCFC) are used in stationary systems for distributed generation and residential combined heat and power. Low temperature technologies such as proton exchange membrane (PEMFC) and direct methanol (DMFC) are used for transportation application and recreational vehicles Auxillary Power Units (APUs).

Early in 2008, there was a flurry of excitement around several UK-based companies actively developing fuel cells for residential combined heat and power. Ceres Power announced that development partner Centrica was to acquire 10% of the company for $40 million and sign a provisional contract for 37,500 units over four years beginning in 2009. Ceramic Fuel Cells reached an agreement with Dutch utility Nuon for a provisional order of 50,000 over five years starting in 2009.

Intelligent Energy agreed to form a joint venture with Scottish and Southern Energy to develop residential CHP systems. But despite what appear to be promising signs out of a dormant industry, there remain concerns. The cost of these systems is still several times higher than the cost of a traditional condensing boiler - approximately $6,000 against $1,000. It is also questionable if these fuel cell systems achieve the correct heat to power ratios suitable for UK/EU residential use.

Opportunities

Companies will soon have to show results or give up. Some signs of decline have been seen with Hydrogen Corp in the US recently having to cut 64% of it workforce and considering selling the business. Plug Power, a US manufacturer of systems for materials handling and telecoms back-up power announced at the end of May 2008 that it would be cutting just over 20% of its workforce in an attempt to achieve profitability – the company lost $60 million in 2007. On the positive side, if commercial sales do take off there is likely to be consolidation as the winners acquire weaker competitors.

In the UK, opportunities may be found in residential CHP where, if the technology catches on, the winner may benefit from acquiring other players for their intellectual property and distribution networks. Alternatively, the successful technology company could be a prime target for acquisition by a utility, either by purchasing a partial stake similar to the Centrica deal, or by achieving a complete buy-out.

Table 10: Notable small hydro projects, recently completed or announced

Company	Ownership	Technology	Application
Ceres Power	Quoted: AIM (CWR)	SOFC	Residential CHP
Ceramic Fuel Cells	Quoted: AIM (CFU)	SOFC	Residential CHP
Intelligent Energy	VC/PE Funded	PEMFC	Motorcycles, planes, residential CHP
CMR Fuel Cells	Quoted: AIM (CMF)	DMFC	Mobile Electronics

Source: New Energy Finance.

About us

We are working with a wide variety of organisations to help them harness the opportunities presented by the move towards adopting clean energy technologies in the full range of sub-sectors and across geographic boundaries. Our clients include companies, investors and government bodies; projects range from fund raising and strategic business advice for start ups, advising investors on planning, regulation and investment strategies through to help in tendering for government projects and advising on floatation.

Company	Transaction	Sector	Amount / Date	Role
Nviro Cleantech plc	AIM flotation	Clean technologies	£7.5 million August 2007	Grant Thornton acted as nominated adviser
Renewable Power & Light Plc	AIM flotation	Power plants	£40.0 million raised December 2006	Grant Thornton acted as nominated adviser
Energetix Group	AIM flotation	Energy solutions products	£6.0 million raised August 2006	Grant Thornton acted as reporting accountant
Renova Energy plc	AIM flotation	Renewable energy	£7.0 million raised March 2005	Grant Thornton acted as reporting accountant
Bluewater Bio International	AIM flotation	Waste water management	£2.78 million funds raised £26.91 million market cap December 2007	Grant Thornton acted as reporting accountant
The TEG Group plc	Fundraising	Waste management	£11.0 million March 2007	Grant Thornton provided due diligence services
TEG Environmental plc	Placing	Waste management	£7.5 million raised April 2006	Grant Thornton provided due diligence services
Biofutures International	AIM flotation	Renewable fuels	£37.0 million raised November 2006	Grant Thornton acted as reporting accountant
ZincOx Resources plc	Fund raising	Recycling plant	£13.0 million raised December 2005	Grant Thornton acted as reporting accountant

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