CANACCORD Adams

Equity Research

Mark Thompson CFA
44.20.7050.6649
mark.thompson@canaccordadams.com

Sara Elford CFA
sara.elford@canaccordadams.com

Eric Glover CFA
eric.glover@canaccordadams.com

Eric Prouty
eric.prouty@canaccordadams.com

John Quealy
john.quealy@canaccordadams.com

Inside

The London Accord CO_2

Sustainability

Investing in renewable energy

Renewables – evolving into a carbon-constrained world

A secular shift to a carbon-constrained society is creating opportunities for excess returns across the renewable energy spectrum, ranging from high risk/reward technologies to low risk utility returns from operating plants. This report is part of the London Accord and highlights investment options in renewables, plus the effect of carbon constraints.

Why invest in renewables?

Climate change, energy security and economic development create demand for renewable energy – a demand mirrored by investors. While renewables have been around for many years, we have recently seen substantial growth in the sector as improvements in technology, rising power prices and government incentives have aligned. Subsidies are still required, but cost less than existing incentives for conventional generation.

The profound shift in political commitment to improve the economics of renewables suggests this support is unlikely to reverse in the medium term. Wind and solar have led news coverage: while many stocks look fully priced, even with a CAGR for wind power at ~32% and for solar power ~45%, we see numerous opportunities as the sector evolves.

Financial versus carbon

Investors still tend to ignore carbon risk for day to day portfolio construction, as it seems like a long-term factor that falls outside most investment horizons. However, we believe regulatory change and public opinion are moving the global economy to far-reaching and demanding carbon limits that make environmental sustainability a de facto necessity. As such, renewables should now form part of any investment style or portfolio.

Investment opportunities

We see the best opportunities in:

- Solar: thermal projects, PV cell production and concentrating solar;
- Wind power project development;
- Geothermal energy; and
- Wave and tidal power in the longer term.

19 November 2007 2007-217

INVESTMENT CASE

- The renewable energy industry has critical mass and is here to stay.
- Government incentives are unlikely to disappear. Public awareness of climate change and business's environmental impact will remain a key driver.
- Renewable energy accounts for ~14% of the world's *energy* consumption, but its technical potential is sufficient to cover many times current demand.
- Renewables are needed to de-carbonize electricity production, for capacity expansion and renewal, as global electricity demand doubles over the next 25 years.
- The industry is still at an early stage and substantial change is ongoing. Several technologies are already price competitive and others are close, when GHG emissions are priced in.
- Each resource (wind, solar, ocean etc) has unique characteristics that make company-specific, bottom-up analysis more effective than a sector basket approach.
- Public and private R&D funding could easily eclipse existing expectations and have already exceeded most forecasts, especially in the US.
- Our top picks are in: project developers, geothermal, solar thermal and wave power.

Figure 1: Top picks

Company	Ticker	Price	Target price	Rec	Mkt Cap (m)	Description
ARISE*	APV CN	C$2.35	C$3.75	BUY	US$229	Thin film on silicon wafer PV cell manufacturer
Canadian Hydro Developers*	KHD CN	C$6.50	C$7.01	BUY	C$893	Operator and developer of wind, hydro & biomass plants
EMCORE*	EMKR US	US$10.36	US$14.00	BUY	US$530	CPV cells and systems
Itron*	ITRI US	US$80.07	US$100.00	BUY	US$2,407	Intelligent metering
QuestAir*	QAR CN	C$0.35	C$1.90	BUY	C$25	PSA producer for gas purification

Source: Bloomberg, Canaccord Adams estimates as at close 151107.

Figure 2: Renewable energy companies of interest

Company	Ticker	Price	Target price	Rec	Mkt Cap	Description
Boralex	BLX TSX	C$16.82	NA	NR	C$630M	Growing renewable energy project developer
Environmental Power*	EPG US	US$4.33	US$8.00	BUY	US$45M	AD plant operator
Ormat	ORA US	US$49.08	NA	NR	US$2045M	Geothermal developer
Perfect Energy	PFEN US	US$1.79	NA	NR	US$212M	Small specialist mono-crystalline PV
PNOC	EDC PM	PHP7.20	NA	NR	PHP108B	Largest listed geothermal co
Renewable Energy Corp	REC NO	Nkr261.00	NA	NR	Nkr129B	Large vertically integrated PV producer
Q-Cells	QCE DE	€86.20	NA	NR	€9.4B	Large PV company
Theolia	TEO FP	€21.40	NA	NR	€816M	Large renewable energy project developer

Source: Bloomberg, Canaccord Adams estimates as at close 15 November 2007.

Renewable power covers hydro, wind, solar, ocean, biomass and geothermal, with each technology at a different stage of development and route to commercialisation. This creates many investment prospects: last year, US$70 billion was invested in sustainable energy[1] – a 43% increase on 2005 and we do not see this stopping for a decade.

The future has a way of arriving unannounced.
George Will

The London Accord

The London Accord is a cooperative research programme between the leading equity research houses in London to assess investment opportunities around climate change. The research is supported by BP and the City of London Corporation, with a core concept of "cash-in, carbon-out". The London Accord provides information for anyone that believes economics and investment in mitigation initiatives are central to solving the climate change challenge. Similarly, the Accord should highlight many investment opportunities created by the global focus on climate change.

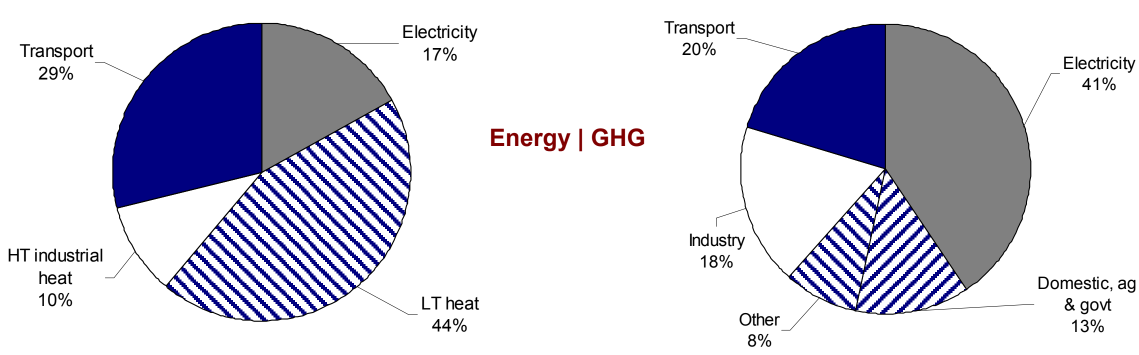
Renewables – part of the energy development continuum

A key factor in global economic development is energy and over the last 2,000 years the sources of energy have gradually evolved. Wood was the only source of energy for many years – even today a substantial proportion of the world's primary energy is still provided by wood. This evolved into charcoal to power the first part of the Industrial Revolution. Coal took industrial growth into the 20th Century, before oil carried the batten into the 21st. We believe renewable energy is set to continue this process and provide a growing proportion of the world's energy needs. As Amory Lovins wrote: "The stone age did not end because the world ran out of stones, and the oil age will not end because the world will run out of oil." (Source: The Economist, 1999).

Demand for power

Electricity provides ~17% of global energy. Demand has grown substantially over the last 20 years, as the energy intensity of the developed world increased, while the developing world grew wealthier and the population without access to electricity reduced.

Figure 3: Global final energy split and GHG emissions



Source: WBCSD and IEA World Energy Outlook 2006

[1] Source: Global Trends in Sustainable Energy Investment Report 2007.

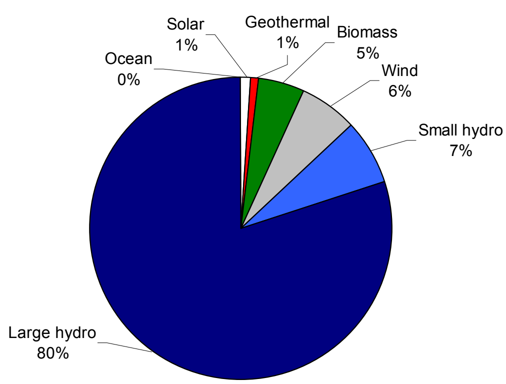
Over the same period, the symptoms of climate change were inescapable and policy makers turned to the huge sources of energy in nature. While there was never any doubt about their magnitude, the challenge had been harnessing them in a cost effective manner. Technical improvements have brought costs down and increasing recognition of the hidden costs of pollution has further narrowed the gap. This means several renewable technologies are now cost competitive and existing developments suggest these should get even cheaper.

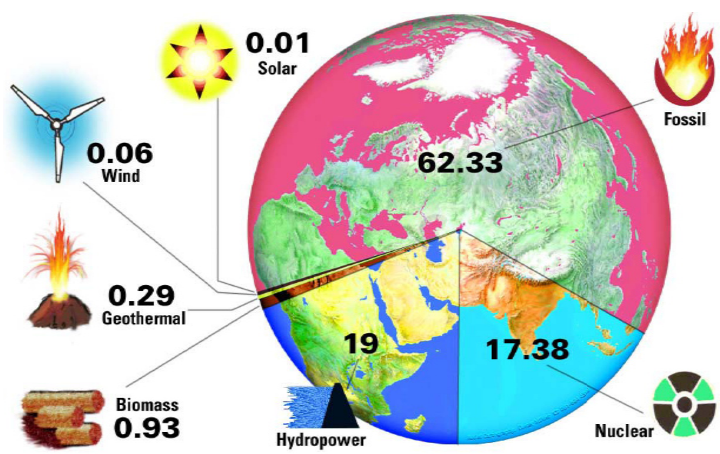
More importantly, an overwhelming global policy shift is explicitly stimulating investment in renewable power by improving its economics and educating the public. Even now, financial support for renewables is a fraction of the funds supporting conventional generation: in Europe ~€23.9 billion is spent annually on incentives for fossil fuels and nuclear, compared to €5.3 billion on renewables. Whatever the original motive – energy security, climate change or economic development – we consider it highly unlikely that this socio-economic shift is reversible in the next 20 years. For all the seeming climate change cynicism in the current White House, it's worth noting that Governor Bush put in the incentives for Texas to become one of the world's leading wind power centres. This economic paradigm creates investment opportunities for all technologies.

Which renewables?

In this report we look at all renewables: wind power, geothermal, wave and tidal, biomass (landfill gas, anaerobic digestion, gasification and mass burn), hydro power, earth energy, biofuels and solar (thermal and photovoltaic). For the purposes of the London Accord, we only touch lightly on solar and biofuels. Of the ~20% of world electricity that comes from renewables, most of the capacity is large hydro, with wind and solar exhibiting the highest growth rates.

Figure 4: Percentage power generation by type (~17,600 TWh global electricity consumption)





Source: Andritz AG, IHA/IEA, 2006/REN21

Our analysis shows that each technology has its own unique dynamics in terms of business model, economic concentration, value chain and generating profile. In our view, the best returns will come from technologies that are:

- Simple and reliable;
- Modular;

- Primarily made off-site;
- Produced in volume; and,
- Site agnostic.

On this basis, our preferences are for wind, solar, earth energy, HDR geothermal, plus some biomass and wave technologies. Technologies that require more customisation can still offer good returns, but these tend to offer fewer access points for the public markets. These include biomass, conventional geothermal and many tidal/wave technologies. In our view, small embedded generation that supplies a home or community is an important factor for reducing GHG, but for the listed markets we see the main upside from large, utility-scale projects, as these have the need and ability to use the public markets effectively.

The market is developing an understanding of quality. However, high growth rates in wind and solar have pushed up valuations across all sectors. In many cases these imply substantial market growth, flawless execution and a supply chain able to grow apace. In our view, this is unlikely, although near-term opportunities to go short are often difficult due to the substantial investment inflows that still tend to focus on a limited number of larger cap companies.

INVESTMENT BY TECHNOLOGY

Geothermal

Geothermal energy has long been viewed as a resource constrained option that only makes sense in limited areas. In our view, technical developments in the next five years could make geothermal one of the largest accessible sources of renewable energy – a recent report estimated that the extractable resource in the US is around 2,000 times its existing primary energy consumption.

Geothermal is reliable, scalable and cost competitive with conventional generation under most existing renewable energy mandates. With carbon pricing, it becomes easily competitive and able to provide reliable, base load power. Companies in this space include PNOC, Ormat and Geodynamics.

Earth energy

Earth energy is a geothermal variant that uses the earth as a heat sink and couples an efficient heat exchanger to move heat in or out of the earth. Earth energy can provide background heating or cooling for residential and commercial applications and typically produces ~3kW for each 1kW of input energy. This is a relatively new technology that is starting to penetrate the house builder and heating engineer market. However, it is already cost competitive and the only pure play in this sector is WFI Industries, with Nibe Industrier offering some exposure. LSB Industries also makes heat pumps and heat exchangers, as part of a broader HVAC business.

Hydro power

Hydro power is a relatively mature industry, with high up-front costs but negligible running costs. There is considerable scope for hydro power capacity expansion in most developed countries using existing dams and impoundments. However, outside of a few pumped storage projects, hydro power growth has been limited by environmental concerns to smaller run-of-river type projects.

Small hydro projects have been difficult to follow reliably, given their position in a larger, mature sector. However, we believe these offer the best investment opportunities, along with technology focused on micro hydro, low head hydro, improved efficiency and environmental integration (fish friendly). Companies developing small hydro projects include: Canadian Hydro Developers, Run of River Power and Plutonic Power.

Solar power

Solar power is one of the high profile ‘success’ stories for renewables. Although we only briefly look at solar in this report, our analysis suggests that:

- Solar thermal is unappreciated but can deliver good returns and significant GHG savings. However, truly proprietary technology appears scarce;
- Polysilicon supplies, or thin film technologies, offer a short-term attraction until the price of silicon falls as new capacity comes on line over the next couple of years. Thereafter, polysilicon producers will compete on product purity (F-Zone silicon) and energy intensity, while margins will migrate back to cell manufacturers;
- Cell production offers the most opportunities to create competitive advantage and cells will price on efficiency and life.
- The energy intensity of PV production carries some regulatory risk, compounded by the market’s dependence on a limited number of geographies (US and Spain) where the solar climate matches the incentives. We are concerned German incentives cannot keep driving the global market, given its relatively poor solar climate.
- Concentrating PV offers a scalable alternative to Si-based PV, reducing the amount of semiconducting material required.

Renewable Energy Corp, Q-Cells and ARISE Technologies offer good exposure to the PV market, with the potential for defendable margins.

Ocean power

Tidal and wave power are still in late stage development. Both resources offer relatively predictable outputs and water’s density means that vast amounts of energy are captured in a relatively small area. Only two technologies meet our investment criteria of simple, robust, scaleable and survivable. These are the pelamis and power buoy designs. We believe some tidal current designs are interesting, but are unsure of the scale of the opportunity. Other wave and tidal technologies that require substantial shore based infrastructure or civil engineering may be attractive on a case by case basis for infrastructure investors, but we consider these unlikely to appeal to the public markets. We believe that desalination is not a scaleable demand. We found four listed companies offering meaningful exposure to ocean power, but all appear highly speculative in our opinion, with several private companies seeming to offer better solutions.

Biomass

Biomass is one of the most challenging sources of renewable power, as projects are highly feedstock dependent. The four main options are:

- Anaerobic digestion (AD) treats wet waste and either burns the resulting methane to generate electricity or purifies it to feed into the natural gas grid. AD is currently only economic where waste regulations create gate fees or long-term natural gas prices are over US$5/mmbtu.

- Landfill gas (LFG) is created by the decomposition of the organic waste fraction in a landfill. Most countries require the gas to be captured and, as a minimum, flared. As the fuel and fuel infrastructure is effectively free, LFG as a source of renewable power is economic with an all-in power price of ~US$40/MWh.
- Incineration is often used in Energy from Waste (EfW) plants or dry biomass (wood chip, wood waste or poultry litter) plants. EfW usually requires substantial gate fees (>US$120/t) to be economic, while conventional biomass needs free fuel for the economics to work on a power price under ~US$120/MWh. Mass burn plants are complex and rarely achieve operational reliability until several years of operation.
- Pyrolysis and gasification are often a complex solution to the poor public image of mass burn. They tend to have low conversion efficiencies and rarely make economic sense without some form of waste regulations.

The investment routes for biomass include: QuestAir, Novera Energy, Environmental Power and AltNRG, as well as some of the carbon funds that are focusing on LFG projects under Kyoto's Clean Development Mechanism.

Wind power

After hydro power, wind is the most mature renewable technology and on good sites it is competitive with conventional generation. Over the last 10 years, installed capacity has had a 28% CAGR and costs have fallen ~90%. The sector has consolidated, although we believe a range of incremental technical developments are possible and new manufacturers are targeting utilities that are not dependent on bank debt. Demand for wind projects at all stages has grown, and many developers seem to attract a very high option value for their equity.

However, with current indications suggesting that a normal grid can cope with up to 20% wind capacity, we believe the industry still has substantial growth, even ignoring the off-shore opportunity. Wind offers three main investment routes: established turbine manufacturers, project developers and a small number of new turbine producers. Vestas and Canadian Hydro Developers offer good options for the first two routes respectively, while Clipper Wind would appear to have potential, but is yet to prove itself as a turbine producer.

Energy efficiency

The single biggest use of fossil fuels in Britain is for heat to warm buildings and use in industrial processes. So any solution to climate change needs to contribute to heating, as well as to electricity generation. Because of inefficient buildings and appliances, every year we throw away more than *eight times* the amount of energy supplied by all of the UK's nuclear power stations combined, according to Greenpeace.

Although not looking directly at energy efficiency, our analysis suggests that this remains one of the easiest and cheapest ways to reduce GHGs. For instance, China, the world's biggest user of coal for electricity, could use ~20% less coal if its power plants were as efficient as an average Japanese plant. Similarly, Russia, the world's biggest user of natural gas for electricity generation could use a third less gas, if its power plants were as efficient as the average European gas fired plant. Since coal and gas produce 60% of global electricity and the IEA's 2006 World Energy Outlook expects this to increase to 67%, we anticipate policies that make investment in efficient fossil fuel power plants, low energy devices and insulation more attractive, along with further development of green building regulations.

LIFE CYCLE ANALYSIS

We assessed various studies on the carbon intensity of different renewable technologies and compared these with conventional generation. While intellectually satisfying, we found that life cycle carbon analyses (CO_{2e} cost of plant construction, fuel cycle, operation and decommissioning) required such sweeping and subjective assessments to make it effectively unworkable as a basis for economic incentives, without risking significant market distortions.

Direct emissions are relatively easily measured (i.e. kg CO_{2e}/MWh). As a result, we expect this to remain the main metric and shape future renewable energy incentives. This suggests wind, wave, tidal, solar and geothermal should prosper, but biomass will come under greater scrutiny, especially when using dedicated energy crops.

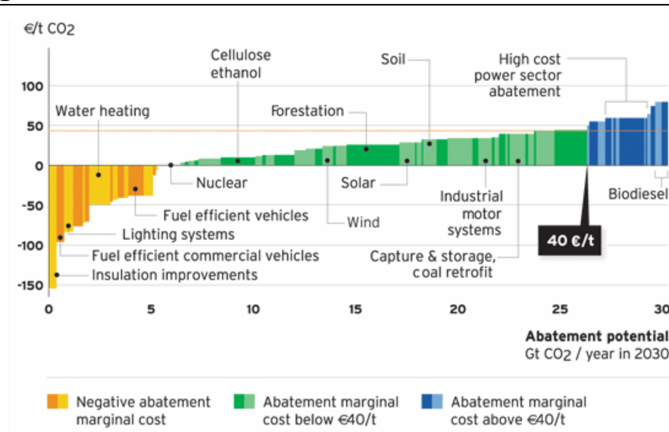
Carbon costs

A study by Vattenfall shows that any reasonable chance of keeping net global warming to 2^{O}C means limiting the content of GHG in the atmosphere to 450 $\pm$ 50ppm. In other words, annual emissions in 2030 must be limited to 31 billion tonnes CO_{2e} – a reduction of 27 billion tonnes compared to business-as usual. The marginal cost of this was estimated at ~€40/t CO_{2e}, and we calculate that the expected impact on the price of energy (using only CO_2) is:

- Coal fired – 994kg CO_2/MWh = €39.9/MWh carbon cost
- Gas fired – 550kg CO_2/MWh = €22.0/MWh carbon cost
- Oil fired – 758kg $_{CO}$ CO_2/MWh = €30.3/MWh carbon cost

Assuming a realistic generating mix[2], this suggests that carbon at €40/t gives renewable energy on average a €19.57/MWh cost advantage over the spot price. With coal providing most of the power in the US and China, renewables have an even bigger advantage in these markets, should carbon pricing be introduced. Estimating the cost to the global economy is obviously difficult. However, Vattenfall's figures give this as ~0.6% of global GDP in 2030: total insurance costs in 2005 were 3.3% of global GDP.

Figure 5: Marginal cost of abatement



Source: Vattenfall

[2] 25% renewable, 10% nuclear/large hydro, 25% coal, 30% gas and 10% oil.

MACRO INVESTMENT IDEAS

Apart from highlighting interesting companies, several broad investment ideas came out of this report:

- In future, renewable energy is likely to have its support mechanisms tempered by the carbon cost of each technology, while biofuels are likely to include an assessment of the feedstock's ecological and social impact.
- Carbon capture and storage is likely to play a growing role in the future; otherwise, the options to decarbonise existing generating assets are limited.
- Carbon trading may slow down carbon intensive industries, but it won't necessarily translate into accelerated growth for renewables.
- Asian energy policies need to move from grand targets to practical implementation, especially around the long-term frameworks needed for bankable projects. Similarly, the EU needs to simplify grid access and administrative procedures for renewables.
- We expect the wind turbine supply chain to clear its bottlenecks in 2009/10 and at that point prices should resume their downward trend.
- Heat exchangers are key enablers for several technologies: Earth Energy, Binary cycle geothermal, OTEC, distributed generation and some gasification/pyrolysis.
- Variable renewable energy generation (wind, solar and wave) is unlikely to provide much more than 20-30% of a grid's power, without energy storage or more sophisticated demand management.
- Geothermal, biomass and tidal could provide a substantial proportion of base load generation and, in the medium-term, there could attract a disproportionate interest from utilities.

SUMMARY

In our view, most renewable energy technologies have a realistic route to cost parity (or better) with conventional generation, given time and the right incentives. Adding a carbon cost brings this much closer. Finance is readily available and with the sector rapidly changing, there are many investment opportunities, although being clothed in green does not exempt any business from economic reality.

In our view, careful bottom-up analysis, grounded by pre-Kyoto sector experience, is the best way to build a successful portfolio. Growth rates could be phenomenal, provided (as expected) the political will is maintained and some existing structural barriers are removed.

Figure 6: Comparing generation – relative performance

	Time, years		Capex	Fuel cost	Cost curve potential	Scalable	GHG	Other pollution	Waste	Subsidy free
	Permits	Build								
Windpower	1-3	0.5-2	√√	√√√	√	√√√	√√√	√√√	√√√	2010
Solar PV	1-3	0.5-1	xxx	√√√	√√√	√√√	√	√√	√√√	2019
Solar thermal	1-3	0.5-2	√	√√√	√	√√	√√√	√√√	√√√	2009
Biomass – thermal	2-4	1-3	√	√	√	x	√	√	√	Now
Biomass – gas/pyr	1-3	1-3	√	√√	√	√	√	√	x	2012+
AD	1-3	0.5-1	X	√√	√	√	√√	√	√	2012
LFG	0.5-2	0.5-1	√√√	√√√	√	√	√√	√	√√	Now
Tidal	1-5	1-3	xxx	√√√	√	√	√√√	√√√	√√√	2017
Wave	1-3	1	xx	√√√	√√	√√√	√√√	√√√	√√√	2015
Geothermal – wet	1-3	1-2	√	√√√	√√	x	√√	√√√	√√√	Now
Geothermal - HDR	1-3	1-2	X	√√√	√	√√	√√√	√√√	√√√	2017
Earth energy	0	<0.5	√√√	√√	√√	√√√	√√	√√	√√√	Now
Hydro - ROR	2-4	1.5-3	√	√√√	√√	√	√√	√√√	√√√	Now
Hydro - large	5-6	4-10	√	√√√	√	√√	√	√√√	√√√	Now
Coal	2-5	2-3	√	√√	√	xx	xxx	xxx	x	?
Gas	1-3	1-2	√√√	√	√	x	xx	x	√√	Now

√√√ - best
xxx – worst
Cost curve potential – ability to reduce costs through economies of scale and technology development
Scaleable – potential across a range of capacities
GHG – emissions profile from a climate change perspective
Other pollution – emissions profile from a health/environmental permitting perspective
Waste – by products that attract a disposal cost

Source: MIT and Canaccord Adams estimates

RENEWABLE ENERGY

Renewable Energy is energy derived from resources that are regenerative, or for all practical purposes cannot be depleted. Not only does this make renewable energy fundamentally different from fossil fuels, it also produces less GHG or other pollutants per unit of energy, when measured on a whole life basis.

Wind, water and solar energy have been used for thousands of years. However, the mass production of electricity using renewables only recently became commonplace, as threats of climate change, energy security, ostensible exhaustion of fossil fuels and the social, environmental and political costs of fossil/nuclear fuels could no longer be ignored.

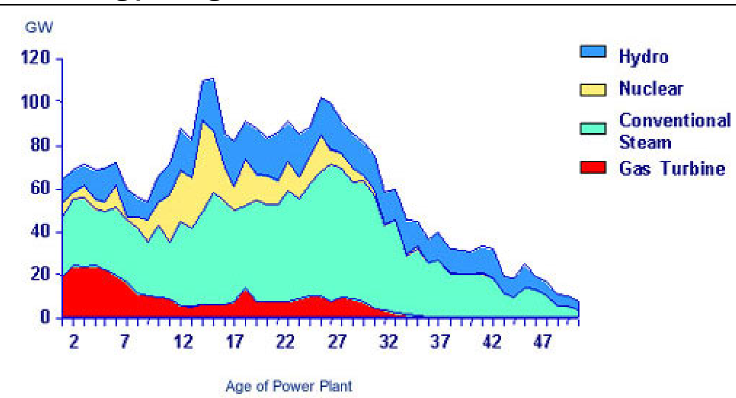
Renewable energy accounts for ~14% of the world's energy consumption, but its technical potential is sufficient to cover many times current and several times projected energy consumption in 2100. Some renewable technologies are economically viable without subsidies, such as geothermal, landfill gas and hydro power, while others such as wind power or biomass are viable on good sites, while other technologies such as solar, wind and wave still require substantial subsidies, but with costs that could realistically decline to a fraction of current levels.

The power sector is responsible for a large share of global emissions. In 2002, power and heat generation contributed ~40% of global GHG emissions. The IEA's 2006 World Energy Outlook reference scenario projects that power generation will contribute half of the increase in global CO_2 emissions between 2004-2030. Therefore, mitigation strategies that reduce GHG emissions from electricity generation may play a pivotal role in meeting countries' obligations under the Kyoto Protocol.

The demand for power

In the industrialised world, the existing installed base of power generation still meets the demand for electric power. Instead, modern, low-cost plant is being built to replace aging or less efficient plant and to cover increasing peak demand/lower reserve margins.

Figure 7: Generating plant age

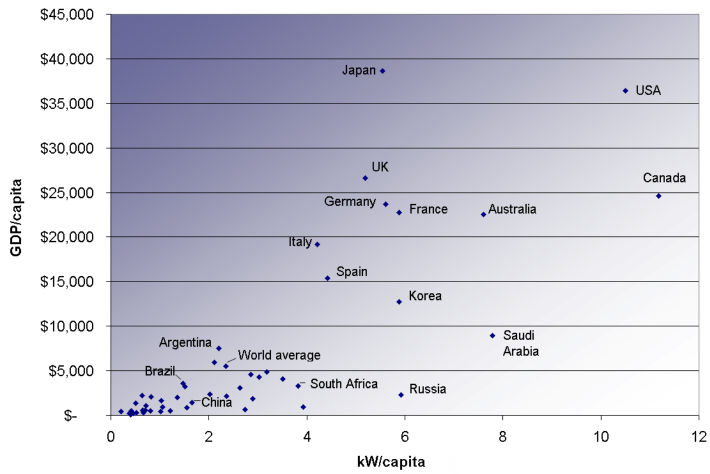


Source: Alstom

A large proportion of European generating capacity needs replacing in the next decade. Opposition to conventional generation should accelerate renewables. According to Platts, 169GW of generating capacity is currently planned for Europe: 50% gas fired 19% wind and 2% other renewables. This situation is reversed in the emerging markets, where the installed base is extremely small compared to their sizable, and growing, populations.

Figure 8: Access to electricity – millions of people

Region	Population	People w/out	Electrification
Africa	891	554	37.8%
China & East Asia	1,951	224	88.5%
South Asia	1,467	706	51.8%
Latin America	449	45	90.0%
Middle East	186	41	78.1%
Transition	1,510	8	99.5%
Total	6,452	1,577	75.6%



Source:: IEA – World Energy Outlook 2006 and Frank van Mierlo

In developing countries, it is expected that economic growth and an increase in per-capita electricity usage will significantly increase the demand for generating capacity. Asia and Latin America in particular should see strong growth. Globally, real demand is growing 1-2%/year, with the IEA forecasting total demand to double inside the next 25 years. Were China's population to match average US per capita consumption, this would require a 29-fold increase in its existing operating plant. However, demand and supply are not co-located, with all the major economies now having to import energy.

Figure 9: Electricity consumed - 2006

Country	GWh used	Population, M	MWh/person
Australia	236,775	20.4	11.59
China	2,824,800	1,320.0	2.14
Germany	576,771	82.4	7.00
France	485,977	63.7	7.63
United Kingdom	390,633	60.8	6.43
United States	4,110,252	301.1	13.65
Wyoming	*14*	*0.51*	*27.79*
California	*254*	*36.2*	*7.03*
World	9,627,230	6,602.2	1.46

Source: IEA and CIA World Fact Book

Capacity factors

Capacity factors are an important measure of the output of any generating plant, as no energy project – renewable or conventional – produces electricity at its full capacity all the time. The capacity factor measures the percentage of power generated or predicted to be generated during a given period of time, relative to how much would be generated had the plant run flat out. This captures both the mechanical reliability of the technology and the availability of the resource (fuel). A high capacity factor is not necessarily the most economic, as it often means the plant is undersized. In Figure 10, we summarise typical capacity factors found in economic projects – any projects with a figure substantially different probably needs careful scrutiny.

Figure 10: Technology assessments – current status

Technology	Capacity factor, %	Capex, $/kW	O&M, $/MWh	Heat rate, BTU/kWh
Biomass	80-94	1,500-3,500	15-25	8-12,000
Earth energy - small	95-99	NM	NM	~1,500
Geothermal	85-97	1,500-3,000	2-10	NM
Hydro - RoR	40-60	500-4,000	10-14	NM
Land fill gas	70-95	750-2,000	4-12	NM
Waste combustion	60-90	3-4,000	18-30	9-12,000
Solar PV	8-33	5-10,000	1-5	NM
Tidal (non-barrage)*	35-45	3,000+	NM	NM
Wave*	30-40	~6,000	NM	NM
Wind	24-40	1,600-2,000	12-18	NM
Nuclear	66-85	2,000-4,000	7-15	NM
IGCC - coal	60-85	1,600-4,000*	4-11	8,700
NGCC	70-90	500-1,400	2-7	7,200

* Estimate for commercial systems
Source: EWEA, EIA, EPRI, AEP, OECD, Canaccord Adams estimates

Our research revealed a wide range of capex costs and prices for all technologies appear to have increased substantially over the last few years, even though much of the literature still reports historic costs. This increase appears to be due to a mix of raw material costs, a shortage of construction capacity and higher development costs due to increasing environmental concerns. By way of example, an IGCC project in Canada was recently cancelled, as actual capex costs had reached C$8,000/kW, while a large combined cycle cogen plant using natural gas (Progress Energy) is reporting a cost of US$1,320/kW.

Resource base

All renewable energy, bar geothermal, is derived from the sun, which drives earth's wind systems (through thermal currents), rivers (through evaporation) and biomass (through photosynthesis), while with the moon it influences the tides and waves. Enough energy from the sun hits the earth in 20 minutes to power the planet for one year and this still represents only ~$2x10^{-9}$ of the sun's energy. Earth's albedo reflects back ~34% of the energy, 42% goes to warm the land and water, 23% is used in the water cycle, 1% is used by wind and ocean currents, with photosynthesis using 0.023%.

Total renewable resources compared to any hydrocarbon are disproportionately large: oil reserves are ~5.3×10^{12}boe, compared to geothermal crustal heat systems with 7.9 times 10^{16}boe. In our view, the renewable resource is so much larger than conventional energy resources that on a long-term view we expect hydro carbon resources to concentrate on high value end markets – with renewables filling most of the difference.

Learning curve effects

We generally assume a standard learning curve that has costs falling 20% for each doubling of production. On a 10-year view, this has important implications, as technologies with a small piece size (i.e. solar) should see more pronounced learning curve effects than, for instance, hydro power. In our view, this favours solar and some wave devices at the expense of biomass and shoreline ocean power, while wind power has already moved a long way down its curve.

What about nuclear?

While nuclear power's carbon footprint is low compared to all fossil fuels and most emissions occur outside actual power generation (i.e. during fuel processing, construction and decommissioning), it uses non-renewable[3] mineral fuels (uranium, plutonium or thorium). As such, it falls outside the scope of this report and, in our view, only offers a partial solution to climate change that does not offset the risks it creates.

Don't get me wrong: I love nuclear energy! It's just that I prefer fusion to fission. And it just so happens that there's an enormous fusion reactor safely banked a few million miles from us. It delivers more than we could ever use in just about 8 minutes. And it's wireless!

William McDonough, Fortune Brainstorm Conference, 2006

On a whole life basis, the CO_{2e} emissions from all stages of the nuclear fuel cycle create a material downside. With high-grade uranium ore, these emissions are small, but some studies suggest that low-grade ore will soon be needed, which means that the carbon emissions from its mining, milling and enrichment will be large enough to compare with emissions from a gas-fired power station. The only way to avoid low-grade uranium would be to return to the (dangerous and expensive) route of generating plutonium in fast-breeder reactors. So far, fast-breeders and reprocessing the spent fuel have been technological and economic failures, therefore nuclear power based on existing technologies does not appear to be a solution to climate change. However, new extraction techniques are being developed that should use less energy and allow access to lower grade resources. Whether the public in the developed world will support nuclear power after respective governments have made them more environmentally conscious and aware of renewables is another question.

Distributed generation

Centralised utilities focused on economies of scale often overlook the alternative model of decentralised generation: generation is on a smaller scale and close to demand. Higher generating costs are partially offset by reduced transmission losses and better reliability, especially where a grid is close to capacity. This model works well with many renewables (building PV, some biomass and earth energy). Where net metering exists, generators receive an 'at the meter' price which is often 2-3 times the wholesale price.

Offgrid power

Almost one-third of the world's population is not connected to an electricity grid. While India and China have focused on urban centers, rural locations have been neglected. The World Bank has in the past backed large scale power projects, but is now looking at smaller plants, such as wind, hydro and PV for rural electrification. While the cost per kWh is often above conventional technology, the fact that renewables can operate outside the grid and don't need fossil fuel (high logistical cost in rural locations), provides substantial economic and environmental advantages.

Modelling scenarios

The IEA Energy Scenarios are questioned by the GWEC, as they see the inputs being politically driven. GWEC projections show that wind capacity could reach 1,128-

[3] Breeder reactors improve fuel economy but do not create energy from nothing. The associated reprocessing demand also creates its own security, environmental and proliferation issues.

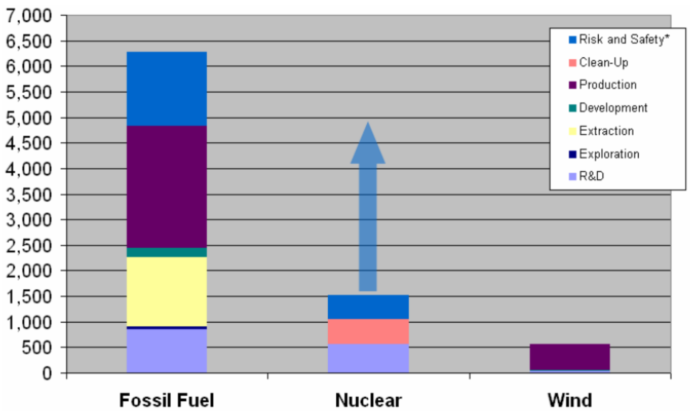
2,106GW by 2030, but the latest IEA Alternative Scenario is 538GW, mainly due to the IEA assumption that oil prices will fall to US$59/barrel by 2030, while GWEC assumes an increase to US$85/barrel by 2030. The IEA assumes fossil fuel use will double over the next 30 years and we find this difficult to accept, without CCS, given the current focus on climate change.

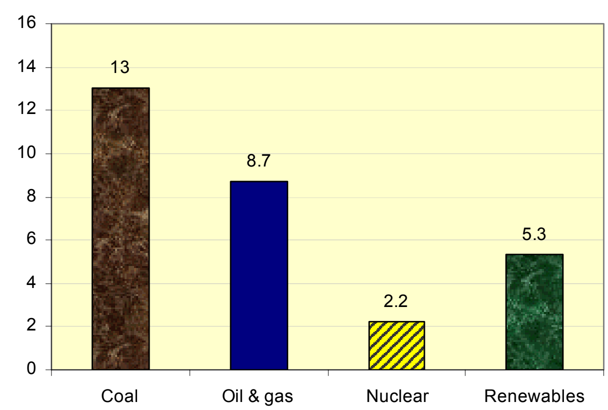
RENEWABLE ENERGY INCENTIVES

Renewable energy generally needs financial support as the technologies are relatively immature and have to overcome the status quo inertia. However, at a high level, we do not believe the need for subsidy is the fatal weakness that proponents of conventional power occasionally allege.

Every type of energy receives some form of aid and the European Environment Agency's figures in 2004 show that in the EU-15, renewables received substantially less aid than the supposedly low cost coal and gas sector and a similar story appears in the US when comparing wind power in 2006 with fossil fuel and nuclear. These figures also ignore the two largest invisible subsidies: the pollution cost not (yet) reflected in the energy price and the benefit of years of development funded by government-owned utilities.

Figure 11: Energy subsidies, US$ million and € billion





* The nuclear industry's limited liability under the Price Anderson Act had a wide range of reported values.
Source: EU, AWEA and Congressional Budget Office

There are few instances where renewable technologies don't require some form of public subsidy to attract private capital. On good sites, wind, hydro, geothermal, landfill gas and biomass are all cheaper than conventional generation, although landfill gas and biomass typically require some form of waste management regulations to make this work. Around 50 countries offer explicit direct subsidies, or instruments such as feed-in tariffs, quota obligations and energy tax exemptions, or in the other direction, taxes on particular energy sources (i.e. Sweden's nuclear power tax of ~€0.006/kWh).

In practise, we expect incentives will be needed for several more years, depending on the technology, until learning curve effects and economies of scales bring prices down to match new build, conventional generation. However, if direct carbon differences are factored in, then most renewable technologies are ~ €20/MWh closer to being competitive. Therefore, as the carbon market develops (probably post 2012), renewable subsidies could phase out more rapidly, or renewables grow faster.

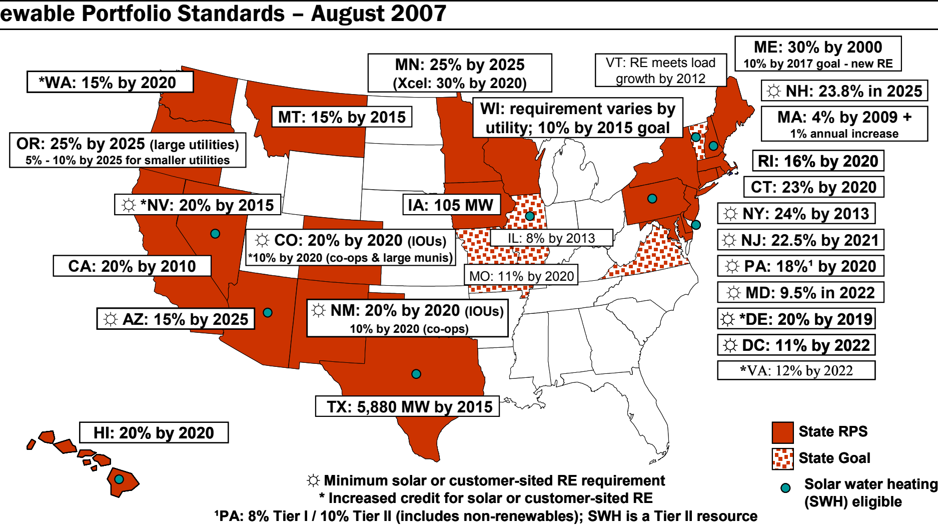
Incentive structures

There are five main types of incentives used for renewables. We briefly describe them, although detailed information is readily available on industry body websites.

- **Direct grants** are self-explanatory and in our view are most appropriate for technologies at the R&D or pre-commercial stage. We believe these need to be offered broadly and not shy away from funding quasi-commercial/pilot scale plants.
- **Feed-in tariffs** guarantee a payment for any renewable electricity fed into the grid. These sometimes have rates that vary by technology, but the main point is that these are readily available to any power plant. For these to work, government needs to set the rate to attract sufficient projects. As a result, some projects are highly profitable and issues around cost effectiveness and excess profits arise, although it is the quickest way to install substantial new capacity. The majority of Europe uses a feed in tariff structure, as does Ontario's standard offer programme.
- **Renewable portfolios standards** (RPS) require utilities to source a percentage of their power from renewables, typically through ownership of tradable renewable energy credits. This is relatively effective, provided the penalty for non-compliance is sufficient and it allows the market to source the most cost effective generation.
- **Production tax credits** are most widely known in the US, where the §45 tax credit is currently worth 2¢/kWh (US$20/MWh) for most technologies. It cuts the tax bill for renewable power in proportion to the power generated. This is an attractive option, as it is predictable and simple, provided sufficient investors with tax appetite exist[4].
- **Green certificates** are typically a voluntary system, whereby power is certified renewable and production is audited so that organisations or consumers wishing to support the environment pay a relatively modest premium to the brown power price. The market seems to be around US$2-5/MWh at present.

However, incentives alone are insufficient if the regulatory framework does not support a move to renewables. This means issues such as planning permission, environmental permits, access to the grid, land rights (especially offshore) or bureaucracy around PPAs all need adapting to ensure that the regulatory cost per MW capacity is reasonable.

Figure 12: US Renewable Portfolio Standards – August 2007



Source: DSIRE USA

[4] The US problem was uncertainty around PTC renewal, which causes peaks and troughs in development.

What makes a successful incentive?

In our view, an effective incentive should have the following attributes:

- Simple and predictable;
- Provide appropriate returns for the risk;
- Life to match the asset (finance) life;
- Protected from political tinkering;
- Economically sustainable for tax/rate payers.

In our view, feed-in tariffs are good for building installed capacity rapidly, but tend to be a blunt instrument due to the political process of price setting a fee that represents the marginal cost per kWh for conventional generation plus the external (pollution) cost of that generation. This tends to mean that the price of renewables does not reflect their true cost: in the late '90s, contract prices under Britain's auction process fell by ~40% in real terms but were stable in Germany and Spain.

RPS tends to be an effective method, but will bias towards the cheapest technologies and may not achieve the portfolio mix needed to meet energy security or economic development goals.

While we believe the fundamental shift towards renewables means that subsidies cannot be lightly removed, we remain concerned that the level for some technologies (notably solar) is not sustainable. Where these costs are directly picked up by rate payers, we believe there is less risk of political tinkering, unless they become an explicit cost. We believe the main risk lies where subsidies eat into an existing tax or excise base (as in the German B100 case) and would cost political capital by raising taxes elsewhere.

Regulatory uncertainty

The future supply of electricity cannot be assured without substantial investment and one critical uncertainty is the form and stringency of climate policy. A recent IEA report[5] estimated that over US$3.1 trillion needs to be invested in power plants to meet demand up to 2030. However, reports on climate change stress the need to reduce GHG emissions now, but the timing of policy measures remains unclear.

We believe that climate policy risk may be modest compared to other risks, if policy is set for a sufficiently long time. Longer commitment periods (beyond the current five-years) should lower the risks from climate policy and increase investment in climate-friendly technologies, which in our view also means reduced costs.

According to the IEA: "Our climate is changing; this is certain, less certain however, is the timing and magnitude of climate change, and the cost of transition to a low-carbon world. Therefore, many policies and programmes are still at a formative stage, and policy uncertainty is very high." As all power projects are capital intensive and long-lived, any policy risks create an incentive to delay investment. Investors routinely deal with uncertainty and risk is not inherently a bad thing - taking calculated risks allow companies to make profits in excess of their cost of capital. Even so, sustained policy risk raises the cost of capital, alters investment decisions and may weaken investment into low-carbon technologies, especially if it produces sub-optimal choices, such as extending the life of existing (dirty) plants.

---

[5] Climate Policy Uncertainty and Investment Risk

Policy uncertainty slows down the introduction of new technologies when compared to conventional ones because of the additional risk, with risk premiums for new technologies as high as 40% of capex for a power plant and 10% of price surcharges for electricity consumers. Even in an uncertain environment, companies are generally confident in committing capital to projects as long as they can establish a competitive advantage over other players. When it comes to regulatory risk, this means policy makers must establish clear rules that are applied consistently to all market players; then companies will feel more confident in power investment.

VOLUNTARY CREDITS

Green Credits are a way of buying the environmentally beneficial attributes of renewable energy plants, typically separate from the 'brown' power component. This is not yet a well established market and there is no generally accepted framework for the trading of such credits or proving their provenance. Yet, this market is gradually emerging, and transactions have grown substantially over the last three years. However, our experience of this market suggests that contracts rarely last more than three years; values are typically worth US$2-5/MWh, most PPAs include ownership of the green credits with the brown power (i.e. Ontario's standard offer contract) and that the process is more associated with the marketing cycle than energy demand. As a result, we believe green credits can add 'icing on the cake', but do not replace or mirror legislatively backed green programmes.

RENEWABLE ENERGY PROGRAMMES

There are six incentives that are worth highlighting, as they drive much of the world market:

- The **EU Renewables Directive** aims to increase the share of power from renewable sources in the EU from 13% in 2001 to 21% in 2010, which equates to around 237 TWh of additional production required. Each European country is responsible for meeting its own targets.
- The **Kyoto Protocol** is driving GHG cuts in Europe, with a cap and trade programme that lowers emission limits each year. Emission allowances were initially over allocated, although new limits from 2008 should keep credits at a more sustainable level. The forward market is around €15/tonne and most PPAs allocate carbon credits from a renewable plant to the utility buying the power.
- The **US Renewable Energy Production Incentive** (REPI) is targeted at not-for-profit electrical co-operatives, public utilities and state governments. This provides 1.5 cents/kWh for the first 10-years of operation and the programme runs until 2026.
- The **US Production Tax Credit** is aimed at independent power producers and gives a corporate tax credit worth 2cents/kWh for the first 10-years of operation. The credit is set to expire at the end of 2008, although we expect it to once again be extended.
- **Regional Greenhouse Gas Initiative** (RGGI) is a cooperative effort by the US north-eastern and mid-Atlantic states to reduce GHG emissions. This includes a multi-state cap and trade programme, similar to the EU. Instead of allocating credits to existing emitters, it is planned to auction credits and create an immediate pressure to reduce emissions. The region plans to cap emissions at 121.3Mt CO_2 to 2014 and reduce by 10% to 2018. The regulations are expected to come into force in 2009.

- The ecoENERGY Renewable Initiative in Canada has put aside C$1.5 billion to fund C$10/MWh for renewables for the first 10 years of operation and capped at 4GW of capacity coming on line in the next four years.

ENERGY SECURITY

The IEA considers energy supply to be "secure" if it is adequate, affordable and reliable. This is a major challenge for all economies, since prolonged disruptions would cause major economic upheaval. Security risks include the incapacity of an electricity infrastructure system to meet growing load demand; the threat of an attack on centralised production, transmission and distribution grids or pipelines; or global oil and gas supply restrictions due to political actions, or even just volatile prices.

In many circumstances diversifying supply, increasing domestic capacity using local energy sources to meet future energy demand growth, and demand reduction can all make positive contributions to energy security. Introducing a broad portfolio of renewable energy - hydro, geothermal, biomass, solar and wind energy - generating plants into the system, and establishing a decentralised power generation system can increase security, especially where many small to medium generating plants can be located close to the load. Renewables also reduce geopolitical security risks by contributing to fuel mix diversification. The risks are different from those of fossil fuel supply risks, and they can reduce the variability of generation costs. In addition, indigenous renewables reduce import dependency.

Renewable energy technologies such as hydro, wind, solar and tidal depend on different natural cycles that have low levels of correlation, which again helps energy security when considered as a portfolio. While large hydro, biomass, geothermal and concentrating solar power offer comparable levels of firm capacity to conventional fossil fuel plant, solar PV, wind, small hydro and wave energy are more variable. We discuss the issue of variability versus intermittency below, but options exist to balance the grid using a mix of renewable technologies with different natural cycles, reducing the need for back-up capacity. For instance, large hydro can complement wind power, which means more renewables can be built to meet increasing demand or replace end of life conventional plant. Nevertheless, appropriate grid management strategies and investments in back-up capacity and demand-side management may be necessary to absorb the grid integration of variable renewables.

VARIABLE OR INTERMITENT?

Ensuring both secure continuity of supply (reliably meeting peak demands) and power quality (no voltage drops etc) means that the actual potential for wind, ocean and solar input to a system is limited. It is clear that renewable energy sources have considerable potential to increase their contribution to meeting mainstream electricity needs. However, having solved problems of harnessing them there is the challenge of integrating them into the supply system. Obviously sun, wind, tides and waves cannot be controlled to provide continuous base-load power, or on demand peak-load power, so how can other, controllable sources be operated so as to complement them?

Intermittency issues require an understanding of *variability* and *predictability*. The variability of power output of a single turbine is small in the timescale of a few minutes and, for wind farms across a large area, is small in a timescale of hours. High-level data allow system operators to determine the level of reserve to maintain. Wind prediction techniques are still at an early stage and improvement could help firm up wind power for system operators by reducing forecast error. Solar and ocean power have similar issues, although they tend to have lower variability and better predictability.

Wind, wave and tidal energy are not intermittent, as at a system level they do not start or stop at irregular intervals, rather they have a variable output. In the case of wind energy, its output is smoothed by the thousands of units in operation, making it easier for the grid to manage changes. A single 1.5MW wind turbine tripping out is far easier to manage than a 1GW coal plant tripping out.

Looking at a single wind turbine might suggest the power system will be increasingly unreliable as more machines are built, while a large conventional power plant gives the impression of consistent reliability. In practice, the entire electricity system is variable, as supply and demand are influenced by many planned and unplanned factors. A change in the weather makes millions of people switch on or off their supply. However, transmission lines break down, trees fall on power lines and power stations break down.

No power station is totally reliable and large power stations going off-line, by accident or design, can immediately remove 250-4,000MW of power. However, power systems have always managed this real intermittency, as well as variable consumption. In our view, the existing network procedures are readily adaptable to renewable energy's variability.

The net output of all variable renewables on the grid is the issue, as obviously wind/waves do not occur continuously in one place, yet there is little overall impact as wind and waves are rarely not occurring somewhere else. As weather forecasting constantly improves, this is making it easier to predict what wind/waves can deliver, which to us means that these renewables can be harnessed to provide reliable power even if they are not available all the time at every site and, in theory, the more renewables added to a system, the easier it should be to reduce the average variability.

Separate reports from the EWEA and IEA conclude that the capacity of Europe's grid to absorb large amounts of wind power is set by economics and regulatory rules rather than technical or practical constraints. Currently, it is generally considered that wind energy can meet 20% of demand on a large network without material technical problems. In our view, the constraint is not technical problems but the requirement for regulatory, institutional and market modifications.

- A 2004 study for the Minnesota Department of Commerce found that adding 1,500MW of wind power to Xcel Energy's system would require only an additional 8MW of conventional generation to deal with the increased variability.
- In Germany, it is claimed that wind generation can be predicted with 90% certainty 24 hours ahead. This means that it is possible to deploy other plant more effectively so that the economic value of that wind contribution is increased.
- A 2006 report by the UK Energy Research Council looked at the system implications and costs of intermittent inputs from renewables whose variability was uncontrollable. It found that intermittent sources meeting up to 20% of electricity demand need not compromise reliability, but this was not cost free. The report looked at system balancing impacts and reliability impacts which affected ability to meet peak demand and also required a greater system margin (15-22% higher). It costed the former at £2-3/MWh and the latter at £3-5/MWh - total £5-8 (0.5-0.8p/kWh) with 20% wind input.

Figure 13: Case study – Jutland (Denmark) 2002

The most concentrated wind-turbine region of the world - 1.74 turbines/1,000 people

4,700 turbines totalling 2,315MW (including 1,800MW of priority dispatch)

Total system capacity of 6,850MW and max load 3,700MW:

- Peak wind output in one day averaged 1,813MW
- 54 days when the wind supplied <1% of demand and one cold calm week saw virtually no wind output.
- Two occasions when wind supplied more than total demand for a few hours.

Variability managed via interconnectors with Norway, Sweden and Germany (1GW, 0.6GW and 1.3GW respectively) and Norwegian hydro resources that can be called at short notice.

Source: Nuclear Energy Association

GEOTHERMAL ENERGY

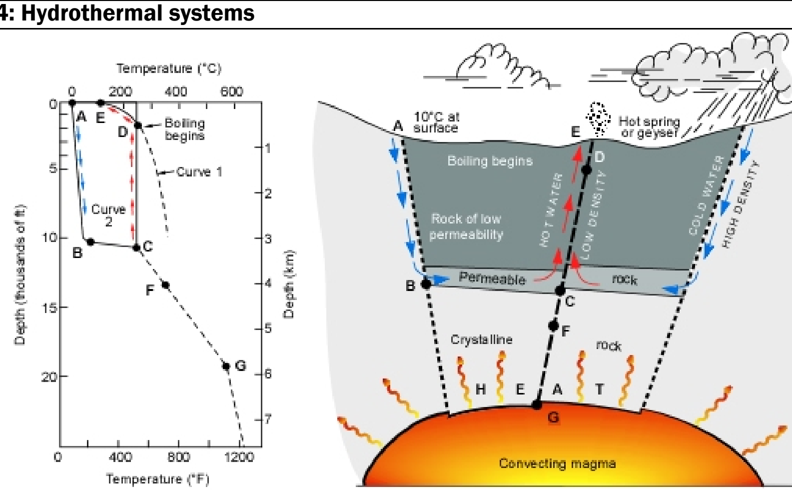
- Overlooked resource with reliable base load generation, with massive upside when hot dry rock potential is realised.
- Drilling technologies being developed for hydrocarbons should benefit geothermal.
- Limited quality investments, but several early stage companies with risky but potentially high reward development opportunities.
- Companies to consider: PNOC; Ormat; and Geodynamics.

Geothermal energy uses heat coming from the earth's molten interior that creates hot water or steam in reservoirs that are typically 500-2,000 meters below the surface. Drilling into these hydrothermal systems allows the pressurized hot water or steam to reach the surface and be used in steam turbines or for process heat. Although hydrothermal systems are widely used, they are relatively rare. Technology is now being developed to create artificial reservoirs in more common hot, but dry, rock formations and this could substantially increase the geothermal resource.

Background

Geothermal energy has been used for over a century, typically as base load energy. In the right locations, it is cost effective and reliable but this currently occurs in relatively few areas. Geothermal energy is most readily available along tectonic plate boundaries and in areas of recent igneous activity/volcanic events. As such, it is widely used in Iceland, the Philippines, Italy, Indonesia, Mexico, New Zealand, Japan and China.

Figure 14: Hydrothermal systems



Source: Geothermal Energy Association

Around 9GW of electrical and over 100GW of thermal capacity is on line: 75+ countries use geothermal heating and 24 use geothermal power. The International Geothermal Association expects electrical capacity to reach 13.5GW by 2010, with adequate funding and sustained policy support being more important than geotechnical factors.

The US is the world's largest producer of geothermal electricity with 2.8GW in service, while globally, more than 1GW of geothermal power was added between 2000-2004. At the end of May 2007, the US had ~60 projects representing ~2.5-2.9GW of power under development, with 251MW of this under construction across 11 projects. At the other end of the development spectrum, the African Rift Valley Geothermal (ARGeo) project involving six African countries has identified up to 7GW of geothermal power potential along the Rift Valley in a project sponsored by the World Bank.

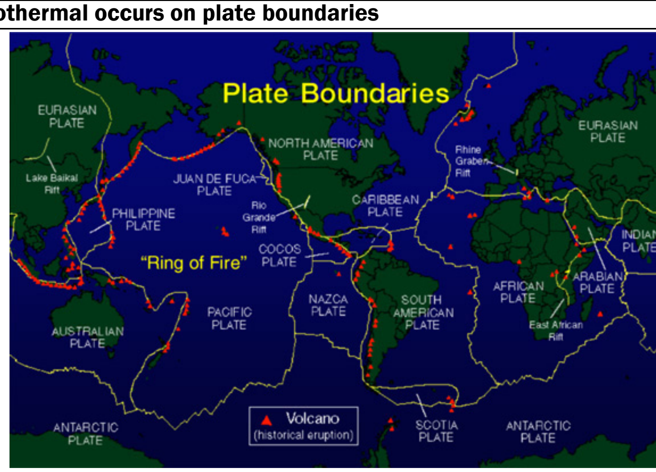
Although geothermal energy has provided commercial base-load power for many years, it is often overlooked, due to the widespread misconception that the total resource is limited to the obvious high grade hydrothermal systems. This in turn has caused a general under investment in technology, compared to higher profile resources such as solar and wind. However, many attributes of geothermal, such as its widespread distribution, base-load capability without storage, small footprint and low emissions, make it an ideal complement to any (renewable) energy portfolio.

Simplistically, the quality of a geothermal resource is measured by:

- its temperature-depth gradient;
- the rock's permeability and porosity; and,
- the amount of fluid saturation and reservoir for recharge.

Geothermal systems lacking one of these attributes are still theoretically viable with the addition of new enhancement techniques that are approaching commercialisation.

Figure 15: Geothermal occurs on plate boundaries



Source: Geothermal Energy Association

Existing technology

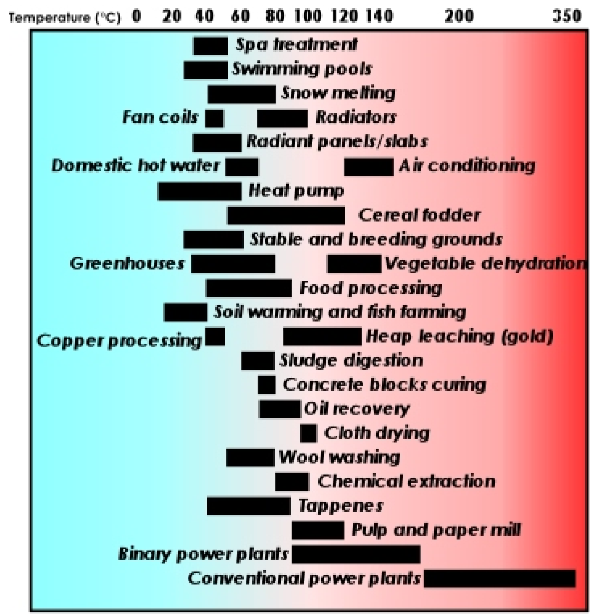
Current geothermal generation needs good quality hydrothermal systems, with high heat flows, significant permeability, high porosity and abundant water in order to drive one of three types of power plant:

- Dry steam plants are the rarest and best, as these produce steam directly from the resource and this goes straight to a turbine.
- Wet systems deliver high pressure water to the surface and this is turned into steam using a Flash Steam Plant that sprays the water into a low pressure tank that causes the water to vaporise, before it is used to drive a steam turbine.

- A binary cycle power plant is used for reservoirs where the water is under $175^{O}C$. It passes the water through a heat exchanger before returning it underground. A low boiling point fluid is used on the other side of the heat exchanger. This is vaporised to drive a turbine, before being condensed back and fed back to the heat exchanger.

The temperature of the resource dictates the type of use and only a few sites are 'dry' systems that provide steam at ground level. Most systems provide hot water and Figure 16 gives an indication of the temperatures needed for different applications.

Figure 16: Temperature profiles



Source: Geothermal Energy Association

Geothermal resource

There are five geothermal resource types:

- Hydrothermal systems are the main resource today. These are steam or water dominated and occur when heat is transferred upwards by the vertical circulation of water due to temperature differences. Most high temperature resources arise where magma has reached the Earth's upper crust.
- Direct use takes hot water from geothermal systems to heat buildings, provide drying, process heat or support agriculture. This typically uses lower grade heat than needed for generating electricity.
- Deep geothermal systems are hot dry rock/enhanced geothermal systems where a reservoir is engineered by creating subsurface fracture systems and water flows. Several projects are under development, although we believe these should still be considered demonstration stage.
- Geo-pressured resources are deep reservoirs of brine with dissolved methane. Such reservoirs are under lithostatic loads and occur along the Gulf of Mexico, Appalachia and in many deep sedimentary basins. The energy comes from the methane, heat and hydraulic pressure. We only know of one (US DoE sponsored) project to date.

- **Co-produced geothermal fluids** occur where oil and gas wells are in waterflood fields. Currently, the water is considered a nuisance and requires proper disposal, but developments in low-temperature power generation could use this heat, especially as the resource effectively has a negative cost and geothermal plant capex is ~60% spent on drilling. Existing geothermal fluids produced in the US could support up to 7.6GW of capacity[6].

There are many resource estimates available on a global basis, although the most reliable studies on a large scale have occurred in the US. As a result, we have used a recent study that updated a major report by the USGS in 1979 to show the potential scale of the opportunity in Figure 17. In this instance, we believe the absolute number is less important than the magnitude of the resource, compared to current demand, which could easily provide a substantial proportion of US primary energy. As such, we expect environmental and security concerns should drive a substantial increase in R&D, with re-engineering of existing resources to upgrade capacity in the near-term.

Figure 17: Resource estimate for the US - GWe

	Estimated accessible	Actual 2006	Estimated developable resource		
			2015	2025	2050
Shallow hydrothermal (identified) >90degC	30	2.8	10	20	30
Shallow hydrothermal (unidentified) >150degC	120	0	tbd	tbd	Tbd
Co-produced & geo-pressured	>100	2	10-15	70	>100
Deep geothermal	1,300-13,000	0	1	10	130

Source: NREL/TP-840-40665

Environmental impacts

Geothermal energy has exceptionally low emissions, especially compared to other base load generation. Emissions generally only occur where the geological fluid already has chemicals in solution and these are insignificant relative to most generating mixes. Geothermal also uses less land on a per MW basis than almost any other type of power plant.

Figure 18: Pollutants by generating plant type – kg/MWh

Type	CO_2	SO_2	NO_x	PM
Geothermal – wet	0-27	0.16	0	0
Geothermal - dry	0-40	0	0	0
Geothermal – binary	0	0	0	0
Coal	994	4.71	1.96	1.01
Oil	758	5.44	1.81	NA
Gas	550	0.10	1.34	0.06
US average (~9% RE)	632	2.73	1.34	NK

Source: MIT (Future of Geothermal Energy) and US EPA eGrid

[6] Source: Dr David Blackwell, Southern Methodist University.

HOT DRY ROCK

In general, temperature increases and moisture decreases the deeper you go. Subsurface granites can reach 250^{O}C (and higher) at depths of 3-5km. Typically, these granites are hot due to relatively high radioactive decay[7] and from the heat conducted from the earth's hot centre. In most cases (and preferably), the granites are buried beneath thick insulating sedimentary rocks.

The aim of hot dry rock (HDR) projects is to harness the energy in these granites by injecting water into a borehole and circulating it through a permeable reservoir created by hydraulically fracturing pre-existing, minute cracks in the rock. The injected water is heated as it passes through the hot rock and returns to the surface via adjacent boreholes, where it is used with conventional steam turbines.

HDR is the Holy Grail of geothermal power, as there are so many potential sites. Natural cracks and pores rarely allow economic flow rates, which means the permeability needs to be increased or stimulated by pumping cold water or water with acids and chemicals through the ground. Hydrofracturing and stimulation techniques are widely used in the oil and gas industry to extend production. These artificially created geothermal systems are sometimes called Enhanced Geothermal Systems (EGS). There are HDR/EGS systems being developed in France, Australia, Japan, the US and Switzerland.

A 2006 report by MIT that included EGS concluded that it would be affordable to generate 100GW of electricity by 2050, just in the US, for a maximum investment of US$1 billion in R&D over the next 15 years. The report also calculated the world's total EGS resources to be over 13,000 zettajoules of which 200+ ZJ (~55M TWh) would be extractable, with the potential to increase this to 2,000+ ZJ with technology improvements - sufficient to provide the world's energy for several millennia. At a 2% recovery of the estimated HDR/EGS resource, sufficient capacity exists to increase existing US geothermal production by a factor of ~400.

Figure 19: EGS/HDR potential in the US, with 2% recovery

Depth, km	Total power, MW	Power @150degC	Power @200degC	Power @250degC	Power @300degC	Power @350degC
3-4	12,200	12,000	90	70	40	
4-5	72,210	68,000	4,000	90	120	
5-6	154,160	124,000	28,000	1,100	60	
6-7	233,300	139,000	83,000	11,000	300	
7-8	324,120	154,000	124,000	41,000	5,000	120
8-10	451,000	187,000	119,000	110,000	30,000	5,000

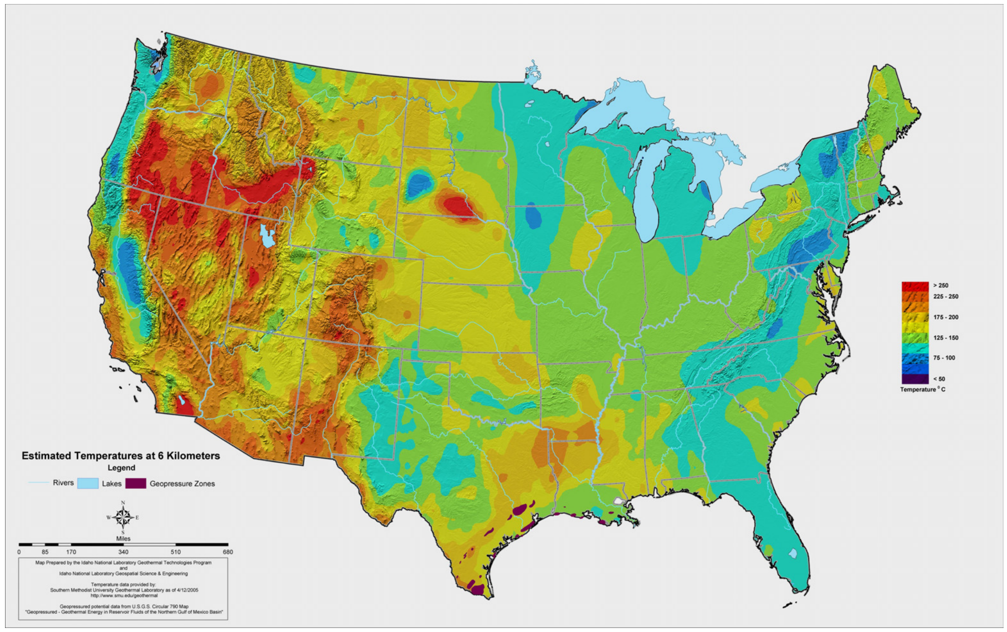
Source: MIT

HDR/EGS projects have so far been defeated by their inability to find natural fractures or create stable fracture zones that allow water permeation at the right rate to collect the heat, without excessive pumping costs or destabilising the fracture zone. Technical problems currently centre on the need for high pressure injection, flow short circuiting, water losses, geochemical impacts and induced seismic activity. Initial academic reports suggest that these are manageable with proper monitoring and operational changes, although we believe further field experience is still required. Currently, the main

[7] Typically, granite has a higher level of radioactivity than unprocessed uranium ore.

constraint is creating enough connectivity to allow high per-well production rates, without reducing reservoir life by rapid cooling.

Figure 20: Temperature at 6km



Source: SMU Geothermal Lab

Australia has an extensive HDR resource and the potential to generate electricity many times its current total power needs. A significant proportion of this resource resides in the Cooper Basin and as a result, Australia probably leads the world in support for HDR projects. A small number of Australian companies are currently targeting projects to prove the effectiveness of HDR technology. In theory, the world's first HDR project – the Habanero plant - could run its open circulation ('proof of concept') test by the year end.

ECONOMICS

Geothermal plants are economic at current power prices without subsidies, but the heavy up-front capex means that a long-term PPA is required to make the financing work. Capex spend per MW varies substantially, depending on the drilling programme (~60% of the cost), although US$2 million/MW is a reasonable baseline. Modern management techniques mean that geothermal resources used with care can last indefinitely. Valuation issues to consider include:

- Geothermal plants run 24/7 and are flexible; additional units can be installed as necessary.
- Upfront capex is relatively high.
- Geothermal energy currently can only be used in areas where the earth's crust is thin and the steam or hot water sources are relatively close to the surface.
- Geological risk can be hard to quantify reliably.

In our view, greenfield development and repowering existing projects offer the best returns, as the risks around HDR are still difficult to quantify. Management is a key resource, as controlling prospecting costs and managing the risk from surface surveys to exploratory drilling is the main differentiator.

Financial metrics

In our view, conventional geothermal is currently economic with limited options to cut costs further depending on improvements in prospecting and better heat management.

Figure 21: Geothermal financial summary

Performance	
Duty cycle	Base load
Typical capacity factor	85-97%
Economics	
Project costs (US$M/MW)	1.5-4
Variable O&M (US$/MWh)	2-10
Levelised cost (US$/MWh)	45-90
Commercial status	
Estimated time to commercial	Now

Source: Canaccord Adams

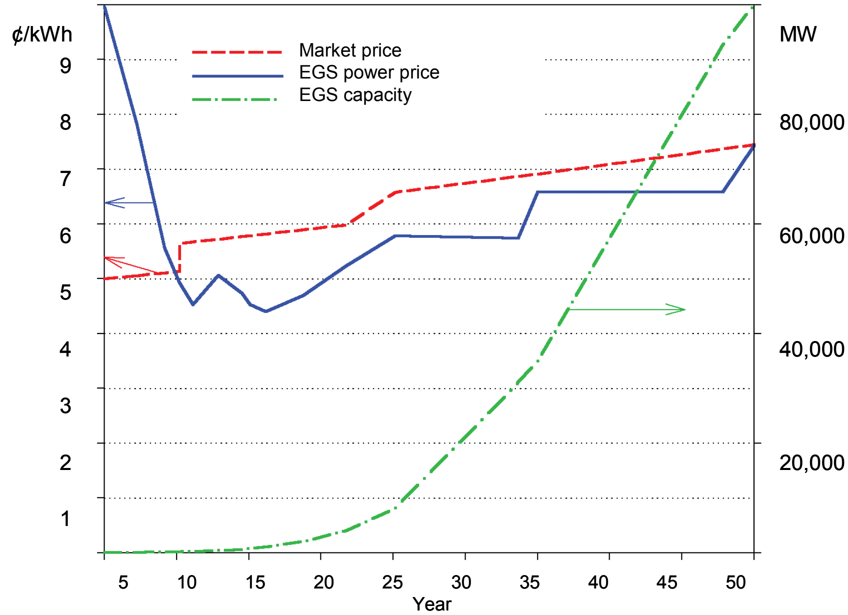
Investment enablers

In our view, the following changes could significantly improve the attractiveness of geothermal investments:

- Provision of consistent funding incentives that substantially match the asset life.
- Technical developments in:
  - New heat exchanger designs (fluidized bed exchangers and titanium heat exchangers).
  - Reservoir technology (enhancement, stimulation and heat transfer rates, graduated flow rates, use of supercritical CO_2[8] as a transfer fluid).
  - Drilling technology (drill bits, casing methods, cementing techniques, high temperature operation, sensors etc).
  - Power conversion technologies (heat transfer, low and high temperature and pressure fluid operating capabilities).

[8] A supercritical aqueous geofluid at 400^{O}C and 250 bar has five times the power producing potential of a hydrothermal liquid water geofluid at 225^{O}C. This creates a non-linear return for HDR/EGS systems.

Figure 22: Break-even price for EGS – MIT model



Source: MIT

COMPANIES

Investments tend to fall into two categories: project developers and technology developers. These occasionally overlap and we expect to see more companies emerge as HDR/EGS moves out of the R&D stage. We expect to see oil and gas exploration and drilling companies enter the market as their capabilities are suitable for developing HDR/EGS resources, although we caution that the skills are not directly transferable as drilling conditions are markedly different. Pure-play geothermal investments are limited in nature and Figure 23 is a brief summary of companies that can provide relatively direct exposure to the sector. Other companies offer tangential exposure, such as Graham Corp that makes heat exchangers for geothermal and other systems, Nabors that provides geothermal drilling services, as well as oil and gas drilling, or Borevind that plans unlisted investment into geothermal and other renewables.

Figure 23: Listed geothermal plays

Company	Ticker	EV, US$M	Description
Geodynamics Ltd	GDY AU	168	Developer of a HDR resource and owns rights to Kalina technology
Geothermal Resources Ltd	GHT AU	34	Developer of Australian HDR projects.
Nevada Geothermal	NGP : TSX.V NGLPF : OTCBB	30	Geothermal devco with a 35MW late stage development site in Nevada and 215MW of developments underway
Ormat	ORA US	2,110	Large geothermal operator, with plants in US, Israel, Philippines, Guatemala, Kenya and Nicaragua. Currently has 12 sites with 364MW operating and ~130MW under construction.
Petratherm	PTR AU	36	HDR developer in Australia and Spain, with unique heat exchanger exploration model.
PNOC Energy Dev Co	EDC PM	2,620	The largest producer of geothermal power in the Philippines and a leader in wet steam technology. It has 1,243MW of operational plant, ~350MW under development, ~60% of the country's geothermal capacity and 14% of its electricity supply.
Polaris Geothermal	GEO : TSX.V	49	Geothermal developer with 10MW of operating capacity and 340MW of potential.
Raser Technologies	RZ US	768	Technology licensing business with proprietary heat exchanger design for low temperature geothermal systems
Sierra Geothermal	SRA : TSX.V	26	A development stage company with leases on 15 properties and potential generation capacity of 250MW.
Torrens Energy Ltd	TEY AU	21	Developer of HDR technology/projects
US Geothermal Inc	GTH US	142	Development stage company in Idaho. Appears to have ~200MW of potential.
Western GeoPower	WGP : TSX.V	30	Developing Meager Creek in Canada and a 25MW project at the Geysers, California.

Source: Canaccord Adams research and Bloomberg

EARTH ENERGY[9]

- **Major growth potential, but modest barriers to entry.**
- **Economic now, but driven by new house builds in the near-term.**
- **Relatively simple, with excellent carbon savings.**
- **Companies to consider: WFI Industries; and Nibe Industrier.**

Earth Energy systems use a heat pump to extract energy from the temperature difference between the relatively constant temperature of the earth and the ambient temperature. The first 10km of the earth's surface (average radius ~6,373km) holds enough heat to provide 50,000 times the energy held by all the oil and natural gas resources in the world. This energy comes from the 51% of solar radiation that is absorbed by land and water. As this energy is effectively held at a constant temperature year round, just a few metres from the surface, it offers a vast source of renewable energy.

Earth Energy is used widely in northern Europe, especially in Scandinavia. It is also becoming more common in the southern US where it is used to cool buildings. North America appears to be leading the world market, with over 30,000 Earth Energy installations in Canada and 40,000 in the US.

BASICS

While outdoor air temperatures fluctuate throughout the year, the temperature just below the surface is a relatively constant 10-16^{O}C. Earth Energy systems use a heat pump and a network of buried plastic pipe (the loop) to harness this energy and deliver heating, air conditioning and hot water to homes and businesses.

During the heating season, fluid circulating through the buried loop absorbs heat from the earth and carries it to the heat pump. This unit extracts the heat, compresses it to a higher temperature and distributes it through standard ductwork. During the cooling season, the same unit extracts heat from the building and discharges it into the ground. Although an Earth Energy heat pump still needs electricity to run the unit's compressor and circulate the working fluid through the loop, the earth's stored energy does the rest and the net power requirement is far lower than the energy used by an equivalent fossil fuel system.

BENEFITS

Lower lifecycle costs

According to the US DoE, heating, cooling and hot water account for over two-thirds of the energy used in US homes. Geothermal systems offer much higher efficiency and much lower operating costs than competing systems. The US EPA has estimated that geothermal systems can save homeowners 30-70% on their heating and 20-50% on cooling, relative to conventional HVAC systems.

[9] The section on Earth Energy is substantially based on work completed by Sara Elford CFA for a report on Water Furnace International. Sara is contactable on +1 902 442 3161 for more information.

However, an Earth Energy system has a much higher upfront cost. A system for a typical new home (2,500 square feet) costs US$12-14,000 to install. This is ~50% more than other systems, due primarily to the cost of installing the earth loop, as well as the heat pump.

On a lifecycle basis, **and without any subsidies or incentives**, the payback on an Earth Energy system ranges between 2-7 years. The lower end of this range is becoming more common with the increase in energy prices.

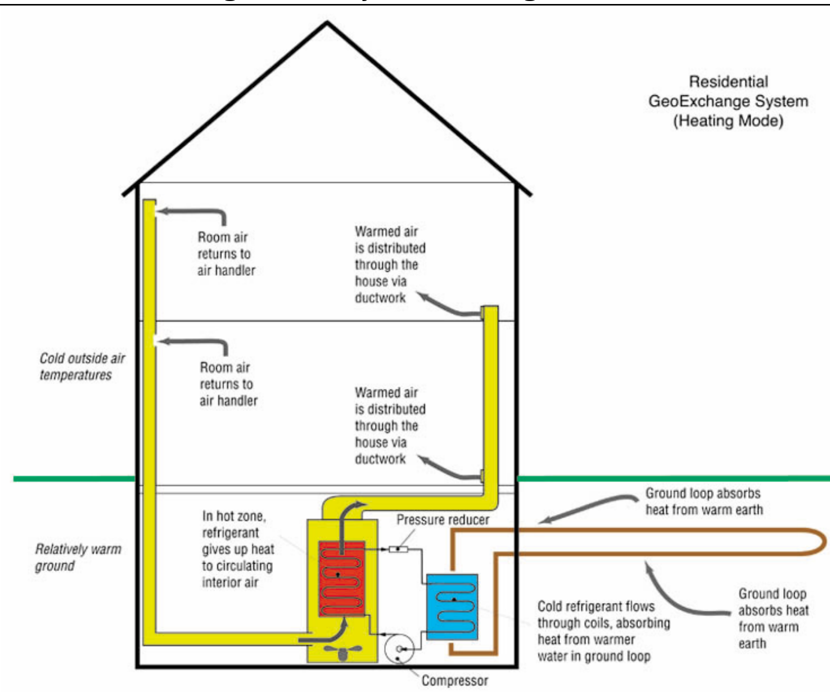
Better environmental solution

In heating mode Earth Energy systems work by moving and concentrating the earth's natural heat, rather than by producing heat through the combustion of fossil fuels. This makes them safer and cleaner than conventional equipment. Each kilowatt of electricity used to run a geothermal system produces at least three kilowatts of renewable energy. This translates into a significant reduction in energy consumption and a corresponding reduction in emissions.

Low maintenance and longer life

According to Natural Resources Canada (*Residential Earth Energy Systems: A Buyer's Guide*), studies have shown that Earth Energy heat pumps last longer than conventional HVAC equipment. They generally have a 20-year life and operate with little maintenance.

Figure 24: Illustration of a geothermal system in heating mode



Source: Geothermal Heat Pump Consortium

BARRIERS TO ADOPTION

Although Earth Energy systems are widely considered to be the most energy-efficient, environmentally clean and cost-effective heating and cooling systems available, they have only penetrated 1% of the HVAC market so far. We believe this is due to the upfront cost, the relative complexity and installers only gradually becoming aware of the opportunity.

The cost of the loop

Geothermal loops can be installed in various configurations. With limited space, the pipe is inserted into a series of vertical holes, drilled near the building. If space is available, the pipe can be laid horizontally in a series of trenches. Finally, coils of pipe can also be placed at the bottom of a pond or lake.

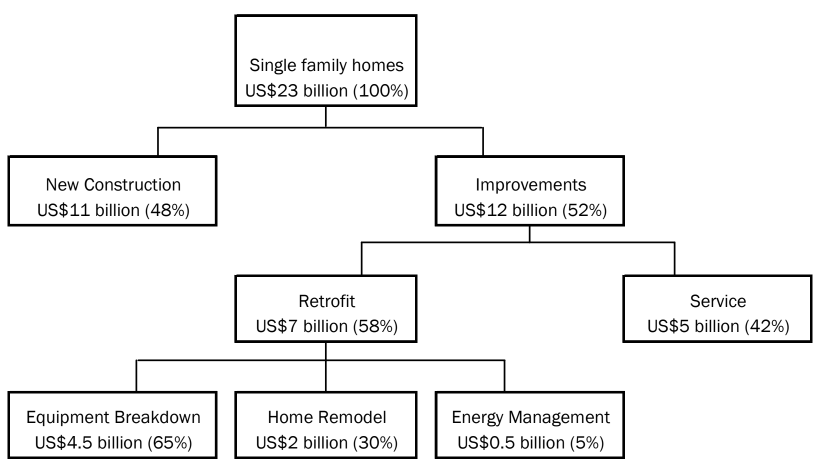
Typically, the loop adds ~US$1,500/tonne of capacity (one tonne ≡ 12,000 BTU/hour or 3.5kWh) to the cost of a geothermal system. For a 2,500 square foot home, this amounts to ~US$4,500. While this incremental cost is more than offset by lower monthly heating and cooling bills, it is an upfront expense that conventional systems do not require.

Longer lead time and mess

The retrofit segment of the US residential HVAC market is a US$7 billion industry (see Figure 25). Most of this opportunity is created when existing equipment breaks down and needs replacing, with work typically commissioned and completed in a matter of hours or days. Conversely, the installation of an Earth Energy loop takes time and is messy; especially in winter when most systems fail.

Not surprisingly, Earth Energy systems have had most success in new construction (a US$11 billion HVAC market in the US in 2003). For this market segment, the higher upfront cost, longer lead time and mess associated with installing the loop do not present the same challenges. Over the last few years, however, Earth Energy systems have started to increase their penetration of the DIY and energy management segments of the retrofit market due to the significant increase in energy prices.

Figure 25: US residential HVAC market (2003)



Source: National Energy Management Institute, Residential HVAC Market Research, Canaccord Adams

Selling an emerging technology

It takes a lot of "missionary work" to displace a conventional technology in any large and established market. Put simply, distributors, architects, dealers and contractors need to embrace a longer sales cycle (educate the market) and accept the technological and reputational risk of selling, designing and installing an emerging technology. It is a time consuming and long-term effort, although in the UK, Corgi fitters are now becoming more aware of the option, supported by growing interest in DIY and property development.

COMPANIES

The HVAC industry is well established, having experienced its primary growth during the post-World War II era with the introduction of affordable central heating and air conditioning systems for residential applications.

The HVAC market has recently been growing at an annual rate of ~6%, while the geothermal market has grown by 15-25%, with increasing momentum, over the last two years. Over the last 20 years, the HVAC market has grown at an average annual rate of about 3.5%; higher growth in recent years being a function of strength in new home construction and a growing replacement market (an aging installed base).

Conventional HVAC provides the main competition to Earth Energy and major manufacturers of HVAC include:

- Carrier Corporation (owned by United Technologies). 2005 revenue was US$12 billion;
- Trane Company (acquired by American Standard Companies Inc. 2005 revenue was US$6 billion;
- York International Corporation (acquired by Johnson Controls, Inc on 9 December 2005, for US$3.2 billion). 2005 revenue was US$5 billion;
- Lennox International, Inc. 2005 revenue was US$3.4 billion;
- Goodman Manufacturing Corporation (taken private on 23 December 2004, for US$1.43 billion). Recently went public again as Goodman Global Holdings, Inc. Current enterprise value is US$2.3 billion and 2005 revenue was US$1.6 billion;
- Rheem Manufacturing Company (private).

The only pure play listed Earth Energy company we know of is WFI Industries. Trane also makes Earth Energy heat pumps but only focuses on the commercial market at this time.

Other notable geothermal equipment manufacturers are ClimateMaster, FHP Manufacturing Company (known as Florida Heat Pump and recently acquired by Bosch), McQuay International, Mammoth Inc., Econar Energy Systems Corporation, Hydro Delta and Hydron Module. Other than ClimateMaster (a division of LSB Industries), all of these companies are privately held.

ClimateMaster and WFI Industries (their manufacturing division is called Water Furnace and their products are branded Water Furnace) are the two leading manufacturers serving the single-family residential market. Like Trane, McQuay and Mammoth are almost exclusively focused on the commercial market; Econar, Hydro Delta and Hydron Module are smaller, regional and primarily residential players. Finally, FHP Manufacturing is a leader in water source heat pumps for commercial and residential applications. Nibe Industrier is also active in the sector, but geothermal is a small part of its wider domestic heating business.

HYDRO POWER

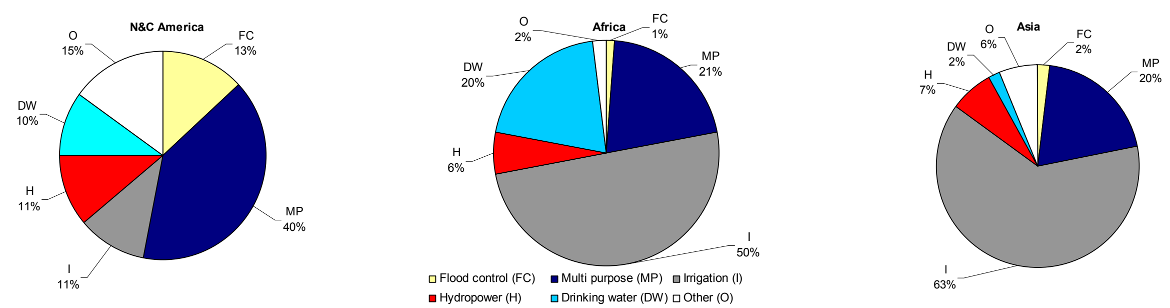
- Largest source of renewable energy, but most growth coming from small sites.
- Economically viable, with best returns from project development.
- Good carbon savings and long (50+ years) operating lives.
- Companies to consider: Canadian Hydro Developers; Boralex; Run of River Power; and Plutonic Power.

Hydro-power, using the potential energy of rivers, is by far the best-established means of renewable electricity generation. Energy is derived from flowing water in rivers or from man-made installations where water flows from a high-level reservoir down through a tunnel and through a turbine. Hydropower now supplies about 715,000MW or 19% of the world's electricity (99% in Norway, 58% in Canada, 55% in Switzerland, 45% in Sweden, 7% in USA, 6% in Australia). Apart from those four countries with an abundance of hydro, capacity is normally applied to peak-load demand, because it is so readily stopped and started. This also means that it is an ideal complement to intermittent generating plant (wind/wave/tidal/solar) in a grid system.

Hydro currently provides 87% of global renewable power generation; however, its share is declining as wind, biomass and solar capacity is developing much faster. In 2005, the total investment in hydro power was about €18 billion; the equipment component of this total was ~€7 billion and outside of China, the equipment market was about €4 billion.

Around 125 countries are using hydro power and, globally, only about a third of the realistic potential has been developed. Hydro is not a major option for the future in developed countries, as most major sites are either being exploited already or are unavailable for other reasons, such as environmental considerations. However, hydro power will be an important source of new generation in South America, China, the Indian Subcontinent and South-East Asia, especially in powering existing dams.

Figure 26: Main use of dams



Source: Andritz VA Tech

The World Hydro Association estimates that only one third of technically and economically feasible hydro power resources in the world have been developed to date. However, in the developed world, opportunities for low head or small run-of river type opportunities still exist. For instance, Canada is estimated to have ~2,500MW of economic small hydro sites available for development.

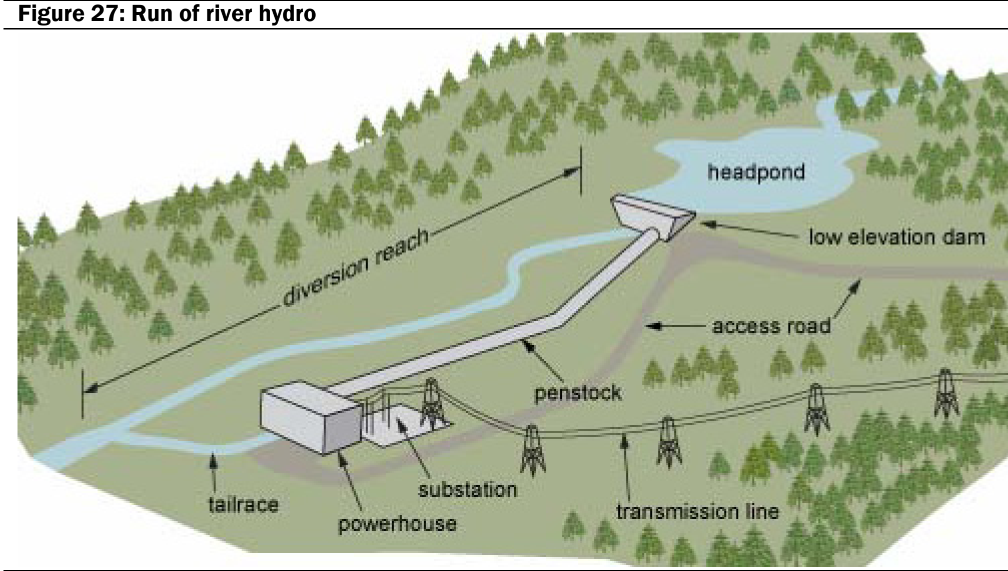
Power generation

Turbines placed within the flow of water extract its kinetic energy to drive a generator that converts the mechanical energy into electrical energy. The amount of hydroelectric power generated is related to the water flow and the vertical distance (known as 'head') through which the water has fallen[10].

There are three main types of hydroelectric scheme:

- Storage schemes use a dam to impound water in a reservoir that feeds the turbine and generator, usually located within the dam itself.
- Run-of-river schemes use the natural flow of a river, where the continuity of flow is enhanced by a weir. Both storage and run-of-river schemes can be diversion schemes where water is channelled to a remote powerhouse containing the turbine and generator. A canal or low-pressure tunnel transports the water to this end point and then back to the river, with most aiming to divert 20-50% of the river.
- Pumped storage uses two reservoirs - at times of low demand, electricity is used to pump water from the lower to the upper basin (i.e. using cheap base load power, often generated by nuclear plants). This water is then released to create power at a time when demand, and therefore price, is high. Use of abandoned mines can be considered, such as in the 2,000MW Mt. Hope in New Jersey and the 1,500MW Summit project in Ohio.

Figure 27: Run of river hydro



Source: Watershed Watch (T. Douglas)

Turbines

There are three basic turbine types: the Kaplan, Pelton and Francis[11]. Each design works best for a particular combination of flow rate and head (pressure). These turbines usually operate at 90+% efficiency and most sites apply a degree of customisation to improve

[10] The power in $1m^3/s$ of water falling 10m is the same as $10m^3/s$ of water falling 1m.
[11] Kaplan – low head, high flow, Pelton – low-med head, med-high flow, Francis – high head, low flow.

efficiency. Most turbines can run for several decades without major maintenance – the most common problem being water borne material that abrades the turbine blades, although these are relatively easily replaced.

Is large hydro renewable?

In the past, large hydro projects were considered renewable sources of energy. Negative publicity around their environmental and social damage – including possible climate change impacts, particularly in the tropics – now means few organisations consider them as clean energy. Indeed, the World Bank has decided that large dams should be excluded from its commitment to financing renewable energy. The World Bank appears to use a de facto limit of 50MW, although many organisations consider anything over 10MW to be large hydro. In our view, 50MW is a useful rule of thumb, although typically a large run-of-river project has far less impact than a smaller storage scheme.

Figure 28: Large versus small hydro

Small hydro:

- Fewer 'eggs in one basket'
- Power to remote communities
- Lower capital costs
- Increased private sector and local involvement/ownership
- Can assist in grid stability
- Greater political acceptability

Large-scale hydro:

- Most efficiently meets central needs
- Economy of scale (less $/kW)
- Security of supply, with storage
- Able to provide ancillary services
- Improves thermal generating performance and supports other renewables

Run-of-river

Most projects are now 'run-of-river' plants that extract water from a river at one point, feed it through a pipe into a turbine that sits below the intake and then return the water to the river. Run-of-river projects use little or no impoundment and the natural river flow is utilised with no seasonal regulation. Such projects are common for:

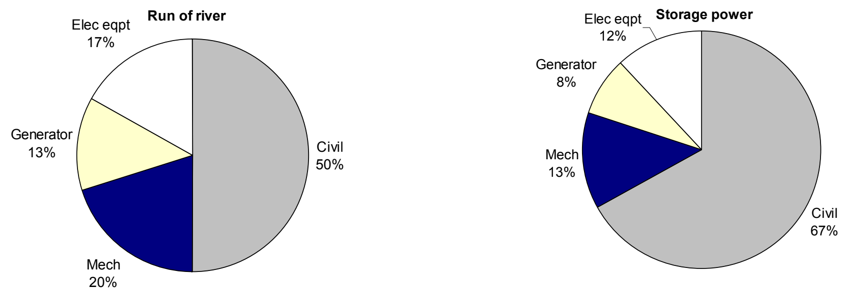
- large flows in flat river reaches;
- flows where a large head is obtainable;
- installed capacities below the maximum potential for the site;
- rivers with major sediment and/or bed loads and
- sites unsuitable for dam construction.

Run-of-river are typically characterised as either low head or high head. While no exact division is internationally recognised, low head schemes generally have a head of less than 30 metres. Around 75% of the capex is site specific and costs can easily range from US$1-3 million/MW.

Capacity factor

As a rule of thumb, a capacity factor of much greater than 50% in a run-of-river site suggests that the turbine is undersized, and less than 30% suggest the plant is bordering on uneconomic.

Figure 29: Construction cost split



Source: Andritz VA Tech

Risks

The main risk for hydro power occurs during the construction phase, when surprises in the geology can cause the biggest problems. Other than the usual timing risks associated with any large civil project, the only other risk is abnormal river levels that may cause temporary flooding ('overtopping') and thereby delay construction.

Technical operating risks are relatively minor and the plants can run with minimal supervision, although fluctuations in precipitation and seasonal runoff (glacier melt) can impact the flow and capacity utilisation of a site, which may impact revenues.

Financial metrics

In our view, run of river power is currently economic with some options to cut costs further through turbine improvements, better control systems, but potentially offset by increased environmental costs (fish ladders etc). Some of the most attractive projects are likely to be repowering existing sites or adding capacity to existing dams.

Figure 30: Run of river financial summary

Performance	New	Incremental
Duty cycle	Varies with resource	Varies with resource
Typical capacity factor	40-60%	40-60%
Economics		
Project costs (US$M/MW)	1-4	0.5-3
Fixed O&M (US$k/MW/yr)	5-25	5-25
Variable O&M (US$/MWh)	4-6	3-6
Levelised cost (US$/MWh)	40-120	5-90
Commercial status		
Estimated time to commercial	Now	Now

Source: Canaccord Adams

Investment opportunities

The large hydro sector is dominated by a four companies that are all subsidiaries of major corporations. As such, we found no pure play investments. Small hydro projects are difficult to follow reliably, given their position in the larger, mature sector. However, we believe these are the best investment opportunities, along with technology developers focused on micro hydro, low head hydro, improved efficiency and environmental integration (fish friendly).

Figure 31: Hydro power turbine market share

Alstom Power	35%
Andritz VA Tech Hydro	20%
Voith Siemens Hydro	15%
GE Energy	15%
Others	15%

Source: Companies and Canaccord Adams estimates

Companies developing small hydro projects include: Canadian Hydro Developers, Run of River Power and Plutonic Power.

SOLAR POWER

- One of the highest profile renewables, but most expensive although substantial cost reductions is possible.
- Many technical developments still possible and focus on polysilicon supplies likely to shift in the next two years back to cell efficiencies.
- Solar thermal is overlooked, but could offer major carbon savings.
- PV exposed to a few jurisdictions that offer large (expensive) incentive programmes.
- Companies to consider: ARISE; Carmanah Technologies; EMCORE; Renewable Energy Corp; Q-Cells; and Perfect Energy.

The solar market is one of the fastest growing and high profile parts of the renewable energy sector. For the purposes of the London Accord we are only briefly touching on solar, to keep the broader sector in context. For solar energy, there are two segments: photovoltaics (PV) convert sunlight to electricity and solar thermal, that converts sunlight into useable heat.

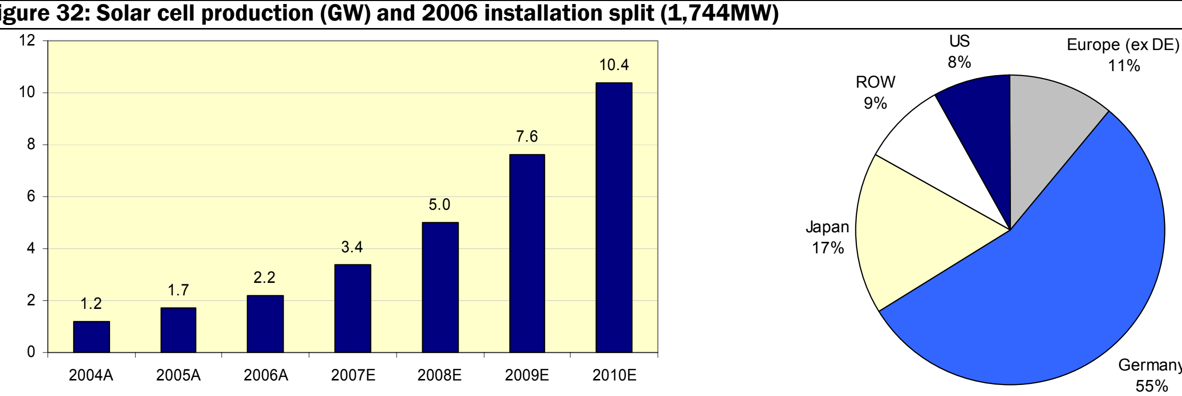
Photovoltaics

The PV market has grown rapidly, due to concerns over climate change, energy security and grid stability – installations increased 19% Y/Y in 2006 to reach 1.7GW. Most developed economies offer substantial incentives and the developing world also offers a growing market, since PV is competitive in most off-grid applications.

Polysilicon production rose 16% in 2006, which combined with aggressive PV industry procurement, allowed a marginally higher market growth rate than projected. Industry pricing went though a year of transition. In the first six months, prices rose through the PV chain in most markets, but by mid year customer push back had slowed price appreciation, particularly in European module prices.

Global PV revenues were US$10.6 billion in 2006, while capital investment across the PV value chain was US$2.8 billion. The industry raised US$4+ billion in equity and debt, up from US$1.8 billion the previous year and completed 11 IPOs. Photon Consulting predicts that PV production will grow at a CAGR of 43.7% from 2005-2010, driven largely by rising grid prices, government initiatives and new distribution channels.

Figure 32: Solar cell production (GW) and 2006 installation split (1,744MW)



Source: Marketbuzz 2007 and Photon Consulting

PV technologies

There are three main types of PV cell, with crystalline silicon technologies forming ~91% of all cells produced:

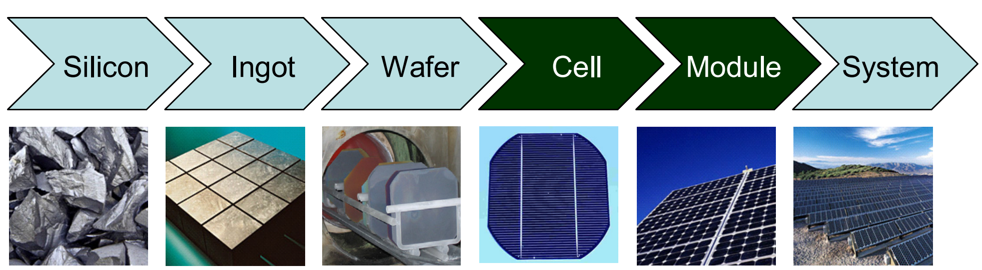
- **Monocrystalline** cells have a single and continuous crystal lattice with almost no defects or impurities. Monocrystalline cells have the highest conversion efficiencies, typically ~15%, although the manufacturing process is complicated, resulting in a slightly higher cost than other technologies.
- **Multicrystalline** cells use grains of monocrystalline silicon, which makes them cheaper to produce, due to simpler manufacturing. However, they tend to be slightly less efficient, with average efficiencies of ~11-14% and have shorter lives.
- **Thin film/amorphous silicon** cells use a thin layer of silicon atoms rather than a crystal structure, which is easier (cheaper) to produce. Amorphous silicon absorbs light more effectively than crystalline silicon, so the cells can be thinner and deposited on a range of rigid or flexible substrates. However, amorphous cells are less efficient, with typical efficiencies of ~5-7%. **Other thin film** materials include cadmium telluride (6-7.5% efficiency) and copper indium diselenide (~9% efficiency) that offer relatively inexpensive production processes and better efficiencies than amorphous silicon. However, the raw materials have limited availability, capex can be high and concerns exist over the environmental risk.

In our view, mono-crystalline silicon is the best long-term choice, due to its greater efficiency, although significant infrastructure as well as planned capacity for multi-crystalline silicon exists. Multi-crystalline and thin film technologies have applications where the additional space required does not impose excess costs. Short-term, the industry has focused on thin-film technologies, due to the high cost of polysilicon. However, we see significant polysilicon capacity increases occurring over the next three years that are likely to grow faster than demand and hence we believe that thin-film applications will remain in the minority.

PV value chain

The PV value chain consists of six steps and in normal market conditions; we expect cell production to offer the best margins. However, shortages of polysilicon have temporarily distorted the market in favour of raw material suppliers, although we expect this to reverse over the next 12-36 months, depending on market growth rates.

Figure 33: PV value chain



Source: Canaccord Adams

- Raw **silicon** is turned into metallurgical-grade silicon, which is then purified to semiconductor-grade or solar-grade polysilicon feedstock. While quartz sand forms over 25% of the Earth's crust, the standard "Siemens" purification process requires several costly steps and the time between planning new capacity and production is typically 1.5-2.5 years. PV and semiconductors are the main polysilicon users: in 2000 the PV industry used ~10% of global polysilicon supply, but by 2006 it used over 50%.

- An ingot is formed when polysilicon is converted into crystalline silicon, typically using high temperature furnaces. A monocrystalline ingot is one large crystal structure, while a multicrystalline ingot has many smaller silicon crystals that make it cheaper to produce. Monocrystalline ingots require precise specifications and careful monitoring to ensure uniform crystal growth and contaminant-free ingots. Completing a single cylindrical silicon crystal ingot takes between 36-40 hours and yields an ingot approximately two meters long and 15-20cm in diameter.
- Wafer sawing cuts the crystalline ingot into thin slices, ready for conversion into solar cells. Producing thinner wafers and reducing silicon waste is a major opportunity to reduce cost, as the saw grooves are approximately the same width as the wafers. Most of the industry uses 200-220µm micron wafers, but is testing thinner wafers.
- Solar cells are made from wafers through a manufacturing process that includes cleaning and texturing the wafer, doping, coating, applying anti-reflective coating and printing conductive metal grids to capture the electricity generated.
- A PV module is a finished product consisting of an array of solar cells that are electrically connected and laminated in a durable, weatherproof frame. Solar modules are the basic end-use product and are produced in various sizes and shapes. Module assembly involves electrically connecting strings of cells, laminating the strings in a durable, clear polymer material with special properties called EVA, and protecting the cells by enclosing the laminate in a frame with a glass front and normally with a backing material known as TPT.
- A PV system adds components, such as batteries and inverters to the modules, ready for installation in a range of applications, from utility-scale PV plants, to commercial and residential rooftops, to building integrated PV, to off-grid industrial and residential systems in rural areas.

In our view, the key position in the supply chain is cell manufacturing, as its efficiency and production costs are crucial for the efficiency of the entire solar module.

Market prices

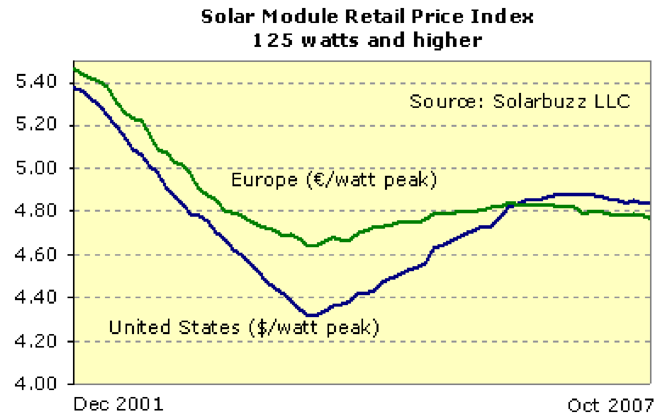
Solar modules are typically sold on the basis of cost per watt of power output. As a result, the industry is trying to increase conversion efficiencies while reducing material and assembly costs. In addition, increased conversion efficiency also reduces the space needed for a solar power system, thereby lowering installation costs.

Approximately 45% of a module’s cost comes from the silicon wafer used to make the cell and 35% comes from the materials used to make the module. As a guide, the industry is looking to drive module prices down to US$1.5-2/W over the next decade, if it is to make inroads in to the grid tied market, without subsidy. Current market prices are:

- Mono-crystalline module – US$4.30/W;

- Multi-crystalline module – US$4.07/W;
- Thin-film module – US$3.00/W.

Figure 34: Module prices (retail prices ex sales tax)



Source: Solarbuzz

More efficiency can be gained using concentrator PV (CPV), where some kind of parabolic mirror tracks the sun and increases the intensity of the solar radiation up to 1000-fold. Modules are typically 35-50 kW and some 18MWe of CPV capacity was installed in 2006.

Better efficiency and potential scalability can be gained using concentrator PV (CPV), where lenses or mirrors increase the intensity of the solar radiation from 200-1,000 times onto small, high-efficiency multi-junction cells. While the PV material itself is more expensive than silicon per unit area, the concentrating optics drastically reduce the amount required, leading to potentially lower costs. With a maximum conversion efficiency currently over 40% and a roadmap to 50% within the next 3–5 years, we believe costs can come down to sub-US$2.00/W levels in the future. Modules are typically 35-50 kW, and some 18MWe of CPV capacity was installed in 2006.

High upfront equipment and installation costs make solar power far more expensive than conventional alternatives for most applications. Unsurprisingly, the industry's goal is to reduce costs to a level that can compete on a non-subsidised basis with the price of electricity from the grid. As a guide, the industry is striving to drive solar module prices down to US$1.50-2.00/watt over the next decade. Even then, subsidies will still be required, especially with solar input being both diffuse and interrupted by night and by cloud cover, meaning capacity factors are typically less than 15%. Power costs are two to four times conventional sources, which still leaves it some way from being economically viable, even where the carbon differential is priced in.

PV financial metrics

In our view, PV is 10-14 years away from cost parity, depending on roll out rates and assuming incremental improvements in existing technology. However, the smaller piece size should amplify learning curve effects although we do not believe utility scale plants are likely in the next few years, unless supported by capital grants, other focused incentives or improvements in concentrator technology. Domestic and small commercial systems could be competitive within a few years, depending on local power rates, as these PV systems are generally competing with 'at the meter' prices, rather than wholesale power prices.

Figure 35: PV financial summary

Performance	Residential	Commercial	Utility
Duty cycle	Varies with resource	Varies with resource	Varies with resource
Typical capacity factor	12-20%	14-22%	14-24%
Economics			
Project costs (US$M/MW)	7-12	6-8	5-8
Fixed O&M (US$k/MW/yr)	50	30	25-30
Levelised cost (US$/MWh)	360-550	320-410	270-370
Commercial status			
Estimated time to commercial	5-10 years	8-12 years	8-14 years

Source: Canaccord Adams

SOLAR THERMAL

Solar energy is readily harnessed for low temperature heat, and in many places domestic hot water units (with storage) routinely use it. It is also used simply by sensible design of buildings and in many ways that are taken for granted. Industrially, probably the main use is in solar salt production - some 1,000 PJ per year in Australia (equivalent to two thirds of the nation's oil use). Solar thermal has not caught investors' imagination anything like PV. We believe this is mainly due to less obvious differentiation and a less obviously sophisticated IP offering.

In our view, the biggest role for solar energy in the future will be direct heating. Much of our energy need is for heat below 60°C. A lot more, particularly in industry, is for heat in the range 60-110°C. Together these account for a significant proportion of primary energy use in industrialised nations. The first need can readily be supplied by solar power much of the time and the second application is probably not far off commercially. Such uses will diminish to some extent both the demand for electricity and the consumption of fossil fuels, particularly if coupled with energy conservation measures such as insulation.

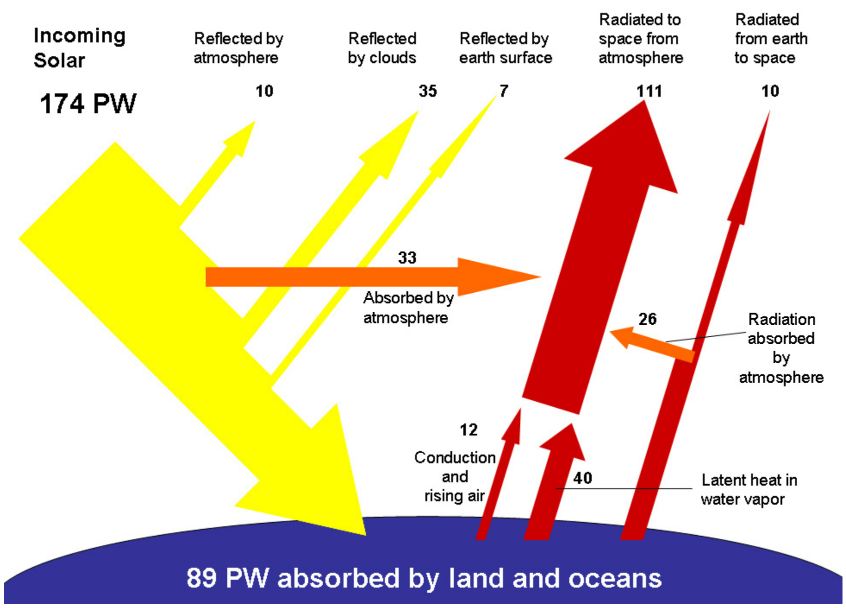
A solar thermal power plant has a system of mirrors to concentrate the sunlight on to an absorber, the energy then being used to drive turbines. The concentrator is usually a parabolic mirror trough, which tracks the sun's path. The absorber is at the focal point and converts the solar radiation to heat (~400°C) which is transferred into a fluid such as synthetic oil. The fluid drives a conventional turbine and generator. Several such installations in modules of 80MW are now operating. Each module requires about 50 hectares of land and needs precise engineering and control. These plants are supplemented by a gas-fired boiler to keep them warm overnight.

With adequate insulation, heat pumps using the conventional refrigeration cycle can be used to warm and cool buildings, with very little energy input other than from the sun. Eventually, up to 10% of total primary energy in industrialised countries may be supplied by direct solar thermal techniques, and to some extent this will substitute for base-load electrical energy.

Solar thermal concentrates heat from the sun using flat-plate, evacuated tubes or unglazed plastic collectors. According to the IEA:

- Installed capacity is ~115GW at the end of 2006 or 30 times the PV market.
- Solar thermal covers applications such as hot water and space heating.
- Flat-plate and evacuated tubes represent 78% of the market. China has ~half the thermal market (55GW), followed by Europe (13GW) and Japan (5GW).
- Unglazed plastic collectors represent 22% of the market, with the US providing the largest market with ~19GW, followed by Australia (2.5GW).

Figure 36: Breakdown of incoming solar energy



Source: Frank van Mierlo

Financial metrics

In our view, solar thermal is economic on good sites. There are many options to cut costs further through technology development and economies of scale.

Figure 37: Solar thermal financial summary

Performance	Parabolic trough	Parabolic dish
Duty cycle	Varies with resource	Varies with resource
Integrated storage	~6hrs	Nil
Typical capacity factor	30-45%	20-25%
Economics		
Project costs (US$M/MWe)	5.4-6.3	5.0-6.0
Variable O&M (US$/MWhe)	20-25	10-20
Levelised cost (US$/MWhe)	120-175	180-280
Commercial status		
Estimated time to commercial	Now	1-3 years

Source: Canaccord Adams

INVESTMENT OPPORTUNITIES

The solar sector offers a wide range of investment routes. We believe utility scale solar thermal projects offer large, relatively low risk projects that can approach cost parity when carbon prices are included. Most listed investments are in the PV segment and we believe:

- Polysilicon production is rapidly commoditising and most supply bottlenecks will have disappeared inside two years. Therefore, investments are best targeted at high purity/low energy producers, such as Renewable Energy Corp.
- High efficiency/low cost cell manufacturers offer the most opportunity in the medium-term, with several technologies offering enhanced efficiency. At opposite ends of the spectrum, Q-Cells and Perfect Energy offer good options here;
- Thin film is a niche product for applications where there are no space constraints. We believe its competitive advantage will diminish as the price of silicon falls, although specialist products (flexible cells, amorphous/monocrystalline mixes) are likely to retain a premium price. Arise appears to offer a compelling option in this segment.
- CPV offers a utility-scale alternative to traditional Si or thin-film technologies, reducing the amount of expensive materials required to provide a given amount of power. This under-appreciated PV technology is beginning to gain traction amid the Si shortage combined with its rapid technological improvements and scalability.

OCEAN POWER

- **High degree of predictability for wave and tidal power.**
- **Water's density creates a massive resource (IEA: 100,000 TWh/year or 5x current global electrical demand) of concentrated renewable energy.**
- **~60% of the world lives within 60km of the coast.**
- **All technologies are at a development stage, with no clear winners as yet, but indications are good that cost parity is achievable.**
- **Several companies offer exposure to ocean power, although none of them meet our current criteria for investment.**
- **We strongly recommend investors develop a familiarity with ocean power options, as we believe the sector is currently at the same stage wind power was 25 years ago.**

Tidal and wave power come the closest of all the intermittent renewables to providing a predictable output, while water's density means that lots of energy can be extracted from a relatively small area. In good locations the energy density of surface waves can average 40MW/km of coastline, sufficient for economic wave-generated energy. Over 1,000 patents exist for ocean power generators, although few designs have reached prototype stage, but despite this, capacity is forecast to increase from 1 TWh in 2002 to 35 TWh in 2030. By our estimate, tidal and wave power are at a similar stage in their development cycle to wind power 25-years ago. The main ocean power sources are:

- **Wave power** uses the energy in waves to move pontoons, buoys or columns of air/water up and down to generate electricity.
- **Tidal power** captures energy from the vertical change in tide height, typically by impounding the flow with a barrage – the incoming tide raises the water level and at low tide the water is released through a turbine.
- **Tidal stream** power captures energy from the flow of tides, often using the underwater equivalent of a small wind turbine.
- **Ocean thermal energy conversion** (OTEC) uses the temperature difference between the warm surface of the ocean and the cold depths to create power.
- **Blue energy** is the reverse of desalination, but is still in research.

What makes a good technology?

In our view, wave and tidal power offer substantial growth. We believe for a world class technology, any device should be:

- Scaleable and easy to fabricate or transport on-shore;
- Useable at any site, without customisation;
- Storm proof;
- Simple, with easy access for maintenance in all weathers.

Only two designs meet these criteria at the moment: the pelamis and power buoy designs. We believe some tidal current designs have great potential, but are unsure of the scale of the opportunity. Other wave and tidal technologies that require extensive shore based infrastructure or civil engineering may be attractive on a case by case basis for infrastructure investors, but these are unlikely to appeal in the public markets.

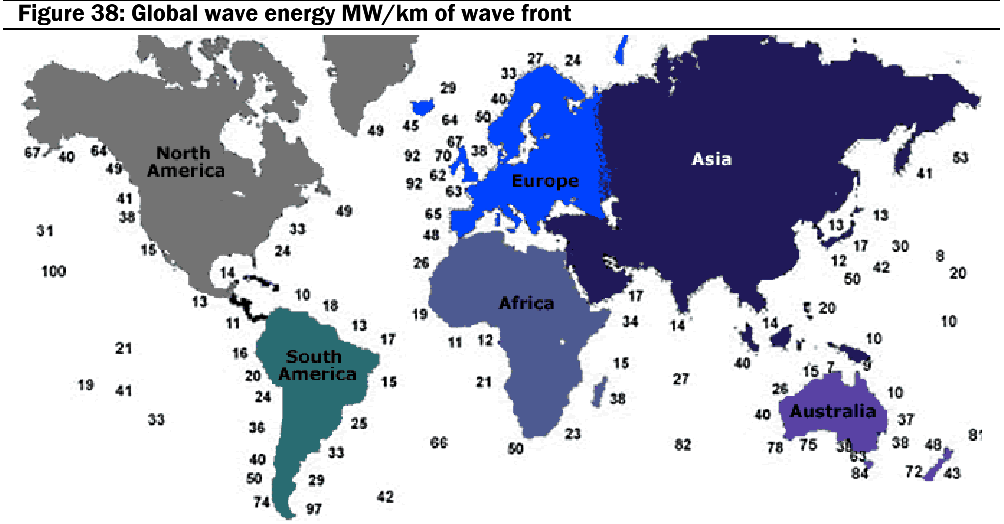
WAVE POWER

Waves are created by the interaction of wind with the surface of the sea. Wave size is determined by wind speed and fetch (the distance over which the wind excites the waves) and by the bathymetry and current of the seafloor (which can focus or disperse the energy of the waves). Waves have the potential to provide a completely sustainable source of energy, which can be captured by a wave energy converter. These can be deployed either on the shoreline, near the shore or in deeper waters offshore.

Massive energy resource

Figure 38 shows the average global wave energy available, which is a function of average wave height and average speed. In the US the lower 48 states have the potential for 860 TWh/year of capacity, while Alaska offers 1,250 TWh/year and the UK alone offers 58 TWh/year of capacity (Source: ETSU). Annual world electrical demand is ~17,000 TWh.

Figure 38: Global wave energy MW/km of wave front



Source: IMechE 1991

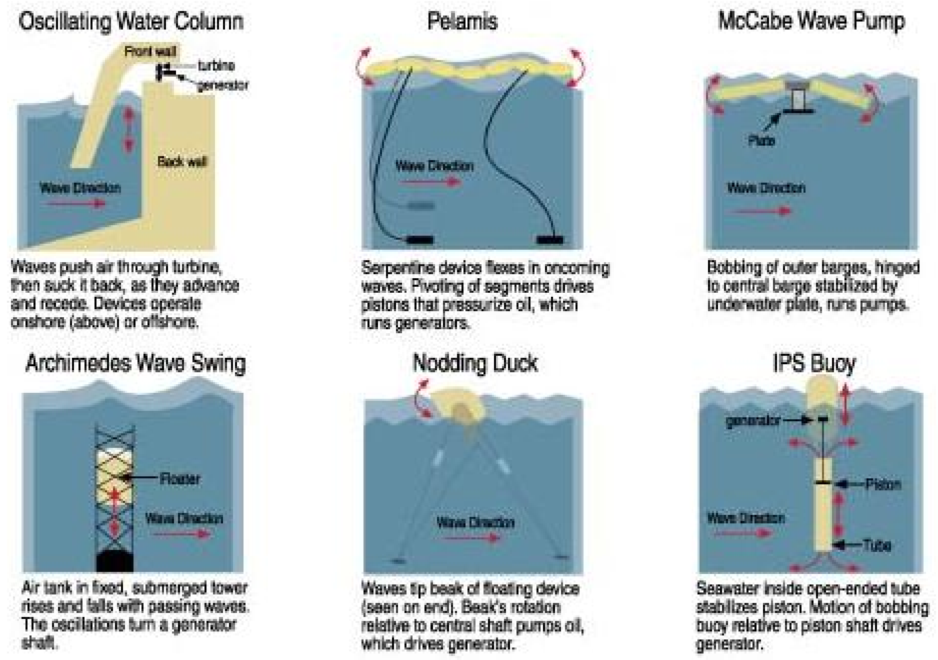
Wave Energy Converters

A wave power machine needs to resist the motion of the waves in order to generate power. There are five main designs:

- A floating device moored to the seabed that reacts to the change in water level. The floating part of the device can be either segmented with several components hinged together (i.e. Pelamis) or a single component that bobs up and down.
- An underwater buoyant device is rigidly moored to the seabed and reacts to the variations in the water pressure. The single moving part bobs up and down.
- A hinged flap device that is bottom mounted. The movement of the waves causes the buoyant paddle to oscillate, pushing hydraulic fluid through hydraulic pumps to generate electricity. The device reacts to variations in water velocity.

- An oscillating water column is a partially submerged, hollow structure that is open to the sea below the water line and enclosing a column of air on top of a column of water. Waves cause the water column to rise and fall, which in turn pushes the air to and fro through a turbine that spins in the same direction, regardless of the airflow direction.
- Overtopping devices physically capture water from waves and hold it in a reservoir above sea level, before being returned to the sea through conventional low-head turbines. The earliest example of this technology was the "Tapchan" system pioneered in Norway and is now seen in the "Wave Dragon" and the "Waveplane".

Figure 39: Wave power devices



Source: Peter Weiss / Science News online

TIDAL POWER

Tidal power typically uses a tidal 'dam' to trap the incoming tide and release it at low tide through a turbine. Harnessing the tides in a bay or estuary has been achieved in La Rance, France (where a 240MW plant has operated since 1966), Canada and Russia, and could be achieved in other areas where there is a large tidal range. The trapped water can be used to turn turbines as it is released through the tidal barrage in either direction, although power is generated primarily at ebb tides as the barrage creates a significant head of water, much like a hydroelectric dam.

However, estuaries are amongst the world's most productive and sensitive ecosystems, and the flooding by these barrages causes great disruption to their natural processes. As a result, this technology appears to have little global potential, largely due to environmental constraints and massive civil engineering costs, unless it is linked to existing construction plans.

TIDAL STREAM

Marine current turbines work much like submerged windmills, but driven by flowing water rather than air. They can be installed in the sea at places with high tidal current velocities, or in a few places with fast enough continuous ocean currents, to take out energy from these huge volumes of flowing water. These flows have the major advantage of being an energy resource which is as predictable as the tides that cause them, unlike wind or wave energy which respond to the more random whims of the weather.

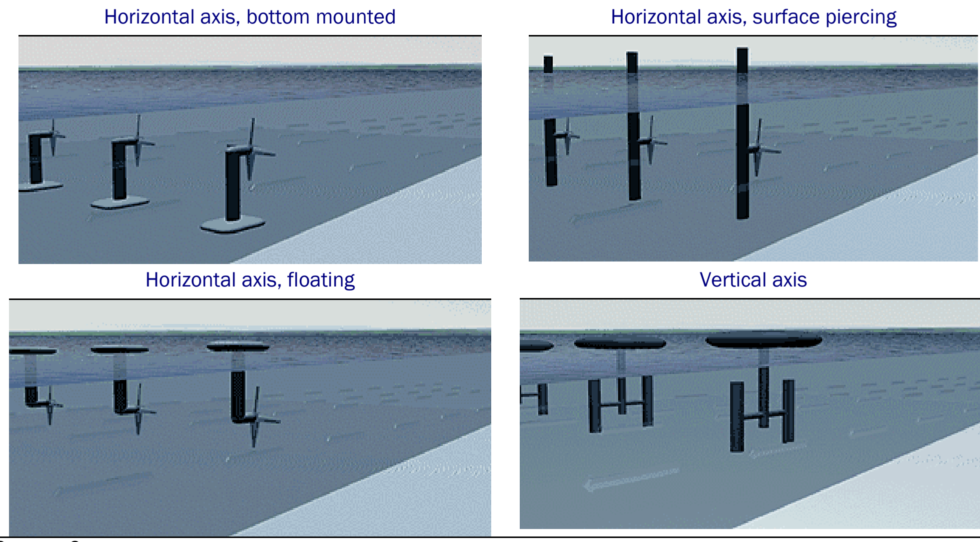
Figure 40: Tidal current options UK waters

Tidal streams with a mean spring peak velocity >4.5-5 knots and depth 20-30m.

Source: Marine Current Turbines

Fast sea currents created by the tides are often magnified by topographical features, such as headlands, inlets and straits, or by the shape of the seabed when water is forced through narrow channels. The UK and Canada have some of the largest potential resources in the world (Bay of Fundy and Pentland Firth): according to Natural Resources Canada, its tidal resources could supply two-thirds of the country's current electrical demand.

Figure 41: Tidal technologies



Source: Greenpeace

Compared to wind turbines, marine current turbines are smaller, (because water is 800 times denser than air) and they can be sited closer together (because tidal streams are normally bi-directional whereas wind tends to be multi-directional). Devices tend to be in one of four forms:

- Horizontal axis, bottom mounted. These turbines sit upon the seabed on either a plied or a gravity foundation.
- Horizontal axis surface piercing. These turbines are pile mounted to allow the turbine to be raised above the water level for maintenance.
- Horizontal axis, floating. The turbine is mounted under a floating structure, which is moored in the tidal stream.
- Vertical axis, floating/fixed. As before, but the turbine axis allows the generation equipment to be sited above the water level.

All tidal stream technologies appear to be at a development stage, with production models unlikely to appear for another 3-5 years. As such, we believe this is a promising area, but more suited to venture capital at this stage.

Figure 42: Ocean current projects

Location	Company/Uni	Project title	Project details
Lynmouth Coast, Devon	MCT	Seaflow	UK's first permanent marine current turbine to generate electricity, £3 million, 11 million blade, 300kW rated. Funds: DTI £0.96 million, EC£1 million
Kvalsund, Norway	Hammerfest Strøm/Statoil/ABB	Blue	First grid connected marine current turbine.
Italy, Straight of Messina	ENERMAR		Late 1990s, 130kW, crossflow Kobold turbine, max efficiency 42%
Yell Sound, Shetlands	Engineering Business	Stingray	150kW, Wing design
Loch Linnhe	IT Power		15kW moored, rotor suspended from floating buoy. In full operation would be anchored to the seabed by cables.
Orkney	Robert Gordon University / Prof. Bryden / AREG	SeaSnail	150kW, 30 tonne, £0.2 million Scottish Enterprise funding
Bluemull Sound, Shetlands	Seapower Scotland / Delta Marine	Exim	Ship-based prototype to measure energy produced at diff sites to find best site for full-scale tidal generator station for Shetland grid.
Grimsby/Iceland/Shetlands	RVco	Rochester/Hydro Venturi	Uses tidal flow to draw working fluid through turbines mounted onshore - hence has no moving parts under water. Expected to enter large-scale demonstration soon- commercial power station to be built in Iceland.

Source: Canaccord Adams research

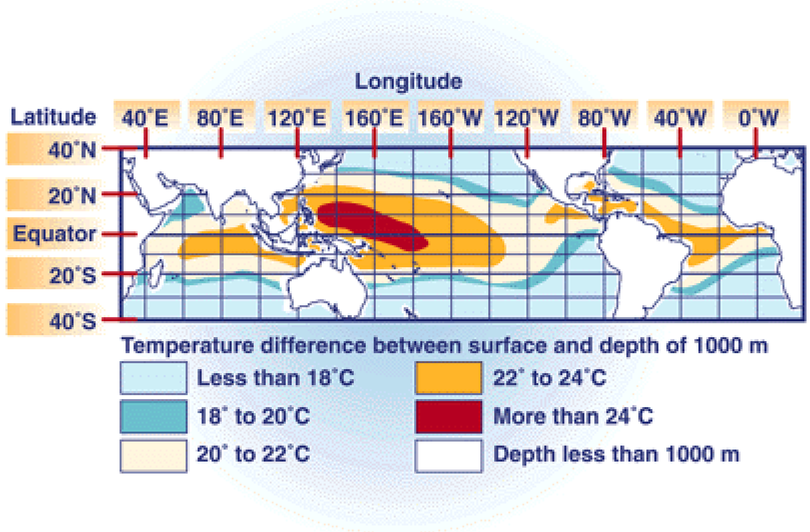
OCEAN THERMAL ENERGY CONVERSION

Ocean thermal energy conversion (OTEC) has long been an attractive idea that uses a temperature difference of at least 20°C between the warm, top layer of the ocean and the cold deep ocean water to create power. This differential typically exists in tropical areas. To bring the cold water to the surface, OTEC plants require a large (expensive) intake pipe, which is submerged a mile or more into the ocean. Theoretically, OTEC could produce vast amounts of power, but commericalisation remains some way off.

OTEC was first proposed in 1881 by Jacques Arsene d'Arsonval and the first plant was built in 1930 in Cuba. The system produced 22kW with a low-pressure turbine. In 1935, another plant was built on a 10,000-tonne cargo vessel moored off the coast of Brazil.

Poor weather destroyed both plants before they became net power generators (i.e. power generated was greater than the parasitic load). The US began OTEC research in 1974 at the Natural Energy Laboratory of Hawaii Authority. This is probably the leading repository of OTEC knowledge, although our research suggests this remains an academic pursuit and we were unable to discover any near-term commercial opportunities.

Figure 43: OTEC potential sites



Source: US DoE

Technologies

Two main OTEC designs exist:

- Closed-Cycle uses a low-boiling point fluid (eg ammonia) to rotate a turbine to generate electricity. Warm surface water is pumped through a heat exchanger to vaporise the low-boiling-point fluid, which expands and turns the turbine. Cold deep-seawater — pumped through a second heat exchanger — condenses the vapour back into a liquid ready for reuse. In 1979, the Natural Energy Laboratory and private-sector partners built the first successful at-sea closed-cycle OTEC generator, using a vessel moored 2.4km off the Hawaiian coast. This produced small amounts of power and in 1999; a 250kW pilot plant was successfully tested.
- Open-Cycle puts warm seawater in a low-pressure container, which causes it to boil and the steam drives a low-pressure turbine. The steam, which has left its salt behind in the low-pressure container, is almost pure water and is condensed back into a liquid in a heat exchanger with cold deep-ocean water. In 1984, NREL developed an evaporator with energy conversion efficiencies reaching 97%. In 1993, an experimental open-cycle OTEC plant at Keahole Point, Hawaii, produced 50kW.

Economics

OTEC has several spin offs that could improve its economics, such as:

- Using the cold sea water for chilled-soil agriculture that allows many plants that evolved in temperate climates to be grown in the subtropics.

- Aquaculture for cold-water delicacies, such as salmon and lobster, that thrive in the nutrient-rich, deep seawater.
- Open cycle OTEC plants produce fresh water and theoretically a plant producing 2MW of net electricity could produce ~4,300m3 of desalinated water/day.
- Mining the ocean water for its 57 dissolved trace elements, as OTEC already involves pumping large volumes of water.

OTEC power plants require substantial capex and it is unlikely that the private sector will fund this given the current level of technical uncertainty, unless fossil fuel prices continue to increase. There are also only a few hundred land-based sites in the tropics where deep-ocean water is close enough to shore to make OTEC plants feasible.

Researchers have tested aluminum heat exchangers that could reduce heat exchanger costs to US$1500/kW, however the cost/engineering of the pipe systems remains the challenge. Therefore, most research has focused on cold water pipe production processes, improved heat exchangers and low pressure turbines.

OCEAN POWER CHALLENGES

Transmission costs

Other than the technology itself required to capture the ocean energy, the biggest technological constraint is how to deliver the generated electricity to the customer. Many coastal areas with high-current velocities or good wave climates are in remote locations where no major transmission or distribution infrastructure exists. In this case, the sizes of schemes planned of around 30MW and greater will require direct connection to the 175kV transmission systems or significant reinforcement and up rating of the sub-transmission and distribution networks.

Therefore, the distance to the point of connection to the existing network will have major effects on the cost of grid connecting any marine current turbine scheme. This may involve installing sub-sea cables, underground cables, or overhead lines and the required transformer to up-rate the voltage to the current grid voltage level.

Government policy mixed

A lack of government policy around wave and tidal power is slowing the industry down. As governments become aware of the potential for wave power and regulations develop for the off-shore wind industry, we expect standards to develop and simplify commercial development.

Design standardisation

Unsurprisingly with a nascent industry, there is no agreement on the best design for wave or tidal power. This limits the industry's ability to focus its R&D money on driving costs down, although it does create more opportunities for investors.

INVESTMENT OPPORTUNITIES

Gaining investment exposure to ocean energy is difficult at the moment, as we are unconvinced by any of the listed technology options. A lower risk alternative might incorporate the two or three utilities that are actively engaged in wave power at the moment. Listed companies with some ocean power exposure include: Finavera, Ocean Power Technology, Renewable Energy Holdings and Oceanlinx, which has announced its intention to float on AIM.

BIOMASS

- **Massive resource that is 'carbon neutral' and can use waste products or be grown on marginal land.**
- **Able to deliver consistent base load power.**
- **Key issues are fuel logistics, managing a bulky and 'living' fuel.**
- **Competitive with conventional generation: LFG – now; direct combustion/AD – when waste regulations are supportive; advanced thermal treatment – development stage.**
- **Companies to consider: QuestAir; Novera Energy; Environmental Power; and Alter NRG.**

As plants grow they absorb CO_2 from the atmosphere. When this biomass material is used as a fuel, the CO_2 is returned to the atmosphere in a 'carbon neutral' cycle. If biomass displaces fossil fuels instead of decomposing naturally, it limits the emission of 'old' CO_2 and methane from decomposition.

Biomass is one of the largest sources of renewable energy and mainly uses direct combustion. Around 35GW of biomass power is operational worldwide, with 7GW in the US, according to the Sustainable Energy Coalition. In many ways biomass appears simple compared to other technologies, as it effectively uses conventional equipment and is not exposed to a variable resource. This is incorrect and biomass has probably been responsible for more economic problems than any other renewable energy technology. However, when done properly, it delivers substantial returns and its use as base load generation supplies an important component of any generating portfolio.

What is biomass?

A wide range of biomass can be turned into products such as heat; electricity; liquid, solid and gaseous fuels; and chemicals, which are all considered renewable. Biomass is derived from plant- or animal-based organic matter and may include:

- animal wastes;
- agricultural feed crops, waste and residues;
- aquatic plants;
- municipal and other organic waste materials;
- trees, wood waste and residues.

For this report, we are not considering transport biofuels, although the ability to concentrate biomass into a liquid fuel may make economic sense for power generation as a means to extend the feedstock collection area (i.e. lower transport costs/GJ). In our view, transport biofuels have a questionable environmental impact, mainly due to the feed stocks currently favoured, although the food versus fuel debate appears more down to an anti-globalisation agenda, than robust economics.

Resource base

The annual global primary production of bio-matter is ~220 billion oven dry tonnes, or 4,500EJ[12]. The theoretically harvestable bio-energy potential is estimated to be 2,900EJ, of which 270EJ (equivalent to ~2,300 GW of nameplate capacity) are considered technically available on a sustainable basis. We believe the challenge is not availability but logistics: sustainable management, conversion, and delivery to the market. As biomass resources can be converted to chemical fuels or electricity through several routes, its role in the future energy supply of industrialised countries is based on several considerations:

- The development of competitive production, collection, and conversion systems to create biomass-derived fuels that can substitute for fossil fuels in existing energy supply infrastructure.
- The potential resource base is substantial given the existence of land not needed or unsuitable for food production, as well as agricultural food yields that continue to rise faster than population growth.
- Biomass is bulky and often has a high water content. Fuel quality may be unpredictable, and physical handling of the material can be challenging. But technologies for biomass fuel upgrading (into pellets or briquettes, for example) are advancing, and the development of energy crops should improve standardisation.
- For biomass to become a major fuel, energy crops and plantations will have to become a significant land-use category. Land requirements depend on crop yields, water availability, and the efficiency of biomass conversion to usable fuel. Assuming 45% conversion efficiency and yields of 15 ODT/Ha/year, four square kilometres (400 Ha) are needed per installed megawatt of electrical capacity.

Technologies

There are several techniques for harnessing biomass to generate electricity. For the purposes of this report, we ignore ethanol and bio-diesel, but briefly touch on bio-oils. Instead, we focus on the production of electricity and divide this into three groups:

- Direct combustion – typically using mass burn processes and currently the largest source of biomass power.
- Advanced thermal treatment – typically using pyrolysis or gasification and currently at a development stage.
- Biogas – produced by anaerobic digestion (AD) or as landfill gas (LFG).

Apart from large conventional wood-chip plants, almost every other biomass technology has been developed as a waste treatment solution, with energy recovery used to reduce the cost. Waste regulations continue to be the main driver of biomass economics and if some of the proposed regulations for agricultural waste are ever enforced, this could substantially increase demand for biomass treatment.

---

[12] One exa joule is equivalent to 2.78 times 10^8 MWh

DIRECT COMBUSTION

Most biomass plants use traditional solid fuel technology (moving grate/steam boiler), with some additional equipment for fuel handling. This is used in Energy from Waste (EfW) plants and most large biomass plants using straw, wood or energy crops.

Biomass power

Most biomass capacity comes from large wood burning boilers that use waste wood products generated by the agriculture and wood-processing industries. These plants tend to be in the 10-50MW scale and use conventional solid fuel processing equipment, with specialised fuel handling equipment. These plants are usually one-offs and depend on the availability of sufficient fuel in the immediate area. Plants have been built to burn paper sludge, chicken litter and straw, amongst other fuels.

Energy from waste

EfW is a term describing the technologies used to recover energy in a carefully controlled combustion environment. The technologies are relatively well established and range from moving grate systems to circulating fluidised beds. EfW plants mirror conventional generation systems, along with pollution control system for the combustion gases.

EFW accounts for 8% of MSW treated in the UK and, in our view, it plays a crucial role at the end of the waste hierarchy. Currently, 210MW of electricity is generated in 15 EfW plants in the UK and incinerating 3.3 million tonnes of MSW. These facilities range from 26,000 tpa (Lerwick) to 600,000 tpa (Edmonton).

The potential health impacts of EfW have dominated the discussion on incineration. While public surveys have typically shown that the role of EfW is acknowledged when integrated into a balanced waste management strategy, individual applications to build such facilities are met with suspicion. Consequently, EfW is one of the most tightly regulated industrial processes, often with emission requirements that exceed comparable thermal processes in other industries.

Emissions

Emissions from mass burn/EfW are comparable with other solid fuels, although this depends heavily on the fuel mix: wood can burn very cleanly, while mixed waste with plastics included has high levels of dioxins, furans, mercury and other poisonous substances. However, abatement technology is readily available and some EfW plants release cleaner air than they take in, although this rarely prevents NIMBY opposition.

Co-firing

Some coal-fired power plants also add biomass to their coal-burning process (i.e. co-firing) to reduce the emissions produced by burning the coal. Co-firing biomass with coal may require a coal boiler to be modified and only a small amount of biomass is typically added (no more than 15% of the total amount of fuel going into the boiler) to maintain the boiler's efficiency. However, emissions are reduced, green credits are sometimes available on a pro-rata basis and thermal efficiency is not affected unduly.

Financial metrics

In our view, direct combustion biomass can be economic where the delivered fuel price is effectively zero and this only occurs where waste or environmental regulations dictate a disposal route and where long-term (15+year) PPAs are readily available. There are options to improve margins, although we see little opportunity for technology improvement or economies of scale. Most improvements are likely to come from operating experience or regulations changing the fuel supply dynamics.

Figure 44: Biomass direct combustion financial summary

Performance	Direct fired	Co-fired
Duty cycle	Base load	Base load
Typical capacity factor	60-90	60-85
Economics		
Project costs (US$M/MWe)	1.5-3.5	0.3-0.5
Fixed O&M (US$k/MW biomass/yr)	70-90	5-15
Variable O&M (US$/MWh biomass)	10-15	1-3
Levelised cost (US$/MWhe)	70-120	5-30
Commercial status		
Estimated time to commercial	Now	Regulatory driven

Source: Canaccord Adams

Investment routes

Most equipment providers for mass burn/EfW are part of larger engineering firms. We believe the only way investors can gain exposure to this market is through project developers (Novera or Verdant Energy), or fuel processors (Sterecycle).

ADVANCED THERMAL TECHNOLOGIES

Pyrolysis and gasification are widely proposed as alternative thermal treatment processes for biomass and MSW. In our experience, few examples of gasification or pyrolysis work effectively on large scale as reliability, efficiency and price are rarely competitive. However, their status as ‘advanced’ and ‘not incineration’ has given significant impetus to the sector.

Gasification

Gasification is a thermo-chemical process that heats biomass in a low oxygen environment to produce a low-energy gas (typically has under half the energy content of natural gas) containing hydrogen, carbon monoxide and methane. The gas can fuel a turbine, combustion engine or conventional steam boiler to generate electricity - or possibly get turned into ethanol or hydrogen.

Gasifiers using fossil fuels (typically coal) have been used for many years and are now being developed to accept more varied fuels. Gases generally burn cleaner and more efficiently than solids, which allows removal of toxic materials. New gas clean-up technology ensures that the resulting gas can be used in different gas engines, with a decent emissions profile. Gasifiers operate at a smaller scale than incineration plant and may work in modular form to provide scale.

Pyrolysis

Pyrolysis has many of the characteristics of gasification but instead of partial oxidation, pyrolysis heats the biomass in an oxygen free atmosphere to produce gas, olefin liquid and char. The gas and oil can be processed, stored and transported, if necessary and burnt in an engine, gas turbine or boiler. Char can be recovered from the residue and used as a fuel, or passed through a gasifier.

Technology trade-offs

Pyrolysis is always the first step in combustion and gasification processes where it is followed by total or partial oxidation of the primary products. Lower process temperature and longer vapour residence times favour the production of charcoal. High temperature and longer residence time increase the biomass conversion to gas and moderate temperature and short vapour residence time are optimum for producing liquids. Fast pyrolysis for liquids production is of particular interest as the liquids are transportable and easily stored. The product distribution obtained from different process modes are summarised in the table below.

Figure 45: Typical product yields by weight from dry wood

Mode	Temp, ºC	Residence time	Liquid	Char	Gas
Fast pyrolysis	500	~1 sec	75%	12%	13%
Pyrolysis	500	~10-20 sec	50%	20%	30%
Carbonisation	400	Very long	30%	35%	35%
Gasification	800	Long	5%	10%	85%

Source: Pyrolysis Network

Alternative products

Bio-oil can substitute for fuel oil or diesel in many static applications including boilers, furnaces, engines and turbines for electricity generation. There is also a range of chemicals that can be extracted or derived including food flavourings, resins, agri-chemicals, fertilisers, and emission control agents.

Upgrading bio-oil to transportation fuels is feasible but currently not economic, although most current research is looking at fuel applications. In our view, the near-term production of bio-oil will depend on its use as a chemical feedstock due to:

- Bio-oil being easier to transport than biomass, meaning that pyrolysis plants could be located near low-cost feedstock while reforming occurs at a site with existing hydrogen infrastructure.
- The production of higher value added co-products from bio-oil that could help the economics, with the lignin-derived fraction used as a phenol substitute in phenol-formaldehyde adhesives while the carbohydrate derived fraction is catalytically steam reformed to produce hydrogen. If the phenolic fraction could be sold for US$0.44/kg (approximately half of the price of phenol), the estimated cost of hydrogen would be US$7.7/GJ, which is at the low end of the current prices.

Advanced thermal treatment of waste

In our view, many of the perceived benefits of gasification and pyrolysis over combustion technology are unfounded. There is a real technology risk and, in our view, standalone gasification and pyrolysis plants are not commercially proven for residual MSW. These technologies might offer potential if:

- renewable incentives make the economics far more robust;
- a local authority is willing to take the technology risk to overcome the negative view on combustion; and
- the waste stream is homogenous or consists of small quantities of high value clinical/hazardous waste.

Investment routes

Several companies offer gasification and pyrolysis options. AltNRG provides exposure to this space, although its longer-term focus appears to be more on coal gasification than waste to energy.

BIOGAS

Biogas is primarily methane and CO_2 that occurs from the anaerobic decay of wet organic matter such as manure, sewage sludge, municipal solid waste, or any other (wet) biodegradable feedstock, under anaerobic (i.e. low oxygen) conditions. These conditions typically occur in a landfill or a purpose-made anaerobic digester.

The resulting biogas can be flared, used to power a gas engine that drives a turbine or, more recently, purified and sold to the natural gas grid. Since methane is a GHG that is ~21 times more powerful than CO_2, its recovery and use from landfills/digestors reduces GHG emissions, as well as off-setting electricity generated by other polluting sources.

Large amounts of biogas are produced globally. Historically, most of this has been flared or used to provide heat in sewage works. Over the last couple of decades, waste legislation and renewable energy incentives have increased the amount of biogas used for power. As it is a continuous process, AD and LFG can provide base load generation.

Figure 46: Biogas 2006 - GWh

Country	Total	Landfill	Sludge	Other	Electricity
Germany	22,370	6,670	4300	11400	7338
UK	19,720	17,620	2100	0	4997
Italy	4,110	3,610	10	490	1234
Spain	3,890	2,930	660	300	675
France	2,640	1,720	870	50	579
EU	62,200	36,250	11050	14900	17272

Source: Biogas barometre 2007 - EurObserver

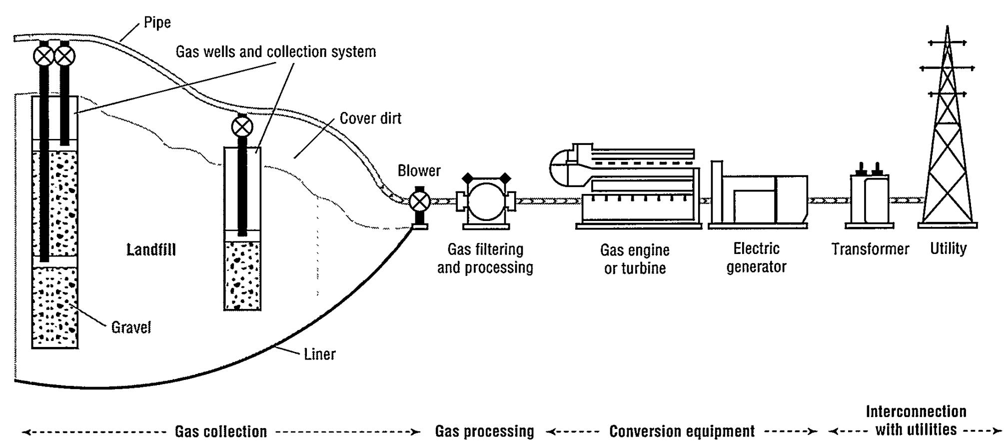
LANDFILL GAS

The capture and conversion of LFG into CO_2 is expected to produce around 10% of Kyoto's CERs in 2012, due to methane's GHG potency. Municipal solid waste typically contains a large proportion of biodegradable organic material, which produces LFG from anaerobic bacteria causing decay in the organic waste fraction amid the sub-optimal conditions of a landfill. This is a mature technology and it has been a major contributor to renewable energy generation.

Under ideal conditions, one tonne of waste produces 150-300m^3 of gas. Depending on the phase of the breakdown process, the gas is mainly methane (~60%) and CO_2 (~35%). These are the major constituents for most degradation and this process can continue at commercial rates for up to 30 years. A LFG system has three basic components:

- Gas Collection typically occurs via a series of wells, as gas from decomposing garbage exists at all levels of the landfill. The number and spacing of wells depends on landfill aspects such as volume, density, and geometry. Wells are made by drilling holes into the landfill, with perforated plastic pipes inserted and the area around the pipes filled with gravel to prevent refuse plugging. The wells are connected by a series of pipes leading to larger, header pipes that deliver the gas to the processing stations. The pipes are under partial vacuum created by blowers at the processing station, causing landfill gas to migrate toward the wells, while the landfill itself has an impermeable capping. Typically, a simple collection system captures ~10% of the gas generated, while modern systems capture up to 80%.
- Gas Processing occurs once blowers deliver the gas to a central point where it can be processed or converted. At a minimum, the gas needs to be filtered to remove any particles and condensate that may be suspended in the gas stream.
- Conversion Equipment such as internal combustion engines or turbines can be used to power on-site generators, which convert the gas into saleable electricity.

Figure 47: A typical landfill gas system



Source: Rhode Island Solid Waste Management Company

Biogas economics

Methane is flammable and an asphyxiant in confined spaces that also kills vegetation when it infiltrates the soil. It was the need to minimise these risks that led to the development of LFG control systems and recovery over the last 20 years. While some landfills simply flare LFG, more than 380 projects at 365 US landfills are collecting and using LFG to produce energy. Thirty additional projects are currently under construction. The US EPA estimates that more than 600 additional landfills could support landfill gas energy projects cost-effectively.

In many developing countries, general standards of solid waste management are low. Considerable amounts of methane continue to be released from dumps or poorly controlled landfills. Regulatory requirements do not normally require full control of LFG and therefore addition of gas destruction systems can be eligible for CDM emissions reductions.

Undiluted landfill gas has a calorific value of 15-21 MJ/m^3, and in the UK 357 plants generated 4.2 TWh in 2006, with an average capacity factor of 60-65%. LFG continues to be produced for 20-30 years after a landfill is closed. Therefore, as long as landfills continue to be used, LFG will continue to be a resource for producing electricity.

Since landfills are already obliged to capture biogas, the fuel supply is effectively free. This reduces the economic decision to a trade off between the returns from flaring, converting to electricity or purifying for the gas grid. This means that LFG has tended to be one of the cheapest sources of renewable power, and projects with long-term PPAs can make economic sense at prices of US$50/MWh.

Financial metrics

In our view, landfill gas is clearly economic where regulations require methane capture and, with a reasonable PPA term, it is economic where drilling is required, provided appropriate control over landfill operation is possible. There are some options to cut costs further, although the technology is effectively mature.

Figure 48: Landfill gas financial summary

Performance	
Duty cycle	Base load
Typical capacity factor	70-95%
Economics	
Project costs (US$M/MW)	0.75-2.0
Variable O&M (US$/MWh)	15-20
Levelised cost (US$/MWh)	40-80
Commercial status	
Estimated time to commercial	Now

Source: Canaccord Adams

Landfill gas investment

Most landfill gas technology is held as part of a large engineering concern, or as small private developers. The largest ‘pure play’ landfill gas operator in the UK is Novera, although utilities such as Scottish & Southern or RWE have much larger portfolios, this is hidden by their other generating capacity. In our view, landfill gas has investment interest when it is held as part of a wider renewable energy generating portfolio. In the UK, the industry is fragmented, divided largely between large waste management companies that manage generation at their own sites and numerous small independent operators. As a result, we believe opportunities for consolidation exist.

ANAEROBIC DIGESTION

The biological processes that take place in a landfill site can be harnessed in a specially designed vessel known as an anaerobic digester to accelerate the decomposition of wastes. Anaerobic digestion is typically used on wet wastes, such as sewage sludge or animal slurries but the biodegradable fraction of municipal wastes can be added to wetter wastes to increase the biogas output.

An anaerobic digester produces biogas that can be converted to heat and electricity, with the digestate creating a soil improving material. Anaerobic digestion is the preferred stabilisation process for wastewater sludges and organic wastes. The process provides volume, odour and mass reduction, renewable energy and predictable pathogen kills.

AD is primarily a waste treatment process, but as it is a living system, digestors require dedicated staff, meaning that farmer-run solutions tend to fail. As a result, a minimum scale is required in our view to make this investable (~ 100ktpa feedstock/3,600 dairy cattle) and the economics only make sense when natural gas is over US$5/mmbtu.

Small biogas plants are used by farmers in many developing countries to provide household gas and fertilizer from cattle manure. Larger anaerobic digestors are more common in Europe but are starting to appear in North America. Many of these digestion plants use manure from cattle feedlots or swine operations, as biogas plants provide an excellent method for disposing of waste that is becoming increasingly regulated.

The main issue for anaerobic digestion systems is the feedstock. Digesters typically can accept any biodegradable material; however, the level of putrescibility is key. Anaerobes can break down material to varying degrees: short chain hydrocarbons such as sugars are easily digested; more time is needed for cellulose and hemicellulose while long chain woody molecules such as lignin cannot generally be broken down. Anaerobic digesters were originally designed for use with sewage sludge and manures, although this is rarely the best material, as most of its energy content has already been extracted by the animal.

Two conventional operating temperatures exist for anaerobic digesters:

- **Mesophilic** takes place at 37-41°C. These microorganisms are relatively robust, but have slower digestions rates.
- **Thermophilic** takes place around 50°-52° and these microorganisms are more sensitive to their environment, but have higher digestion rates and meet the EU criteria for pathogen kill levels.

Financial metrics

In our view, anaerobic digestion is commercially viable if regulations constrain animal waste disposal. We believe projects are marginal if they must depend on power or gas sales alone, unless there is a reasonable renewable energy incentive. It is unlikely that farm scale projects are able to attract useful levels of debt. There are some options to cut costs with design standardization, although the technology is approaching maturity.

Figure 49: Landfill gas financial summary

Performance	
Duty cycle	Base load
Typical capacity factor	70-90%
Economics	
Project costs (US$M/MWe)	4-6
Variable O&M (US$/MWhe)	15-20
Levelised cost (US$/MWhe)	70-130
Commercial status	
Estimated time to commercial	Now

Source: Canaccord Adams

Biogas investment opportunities

Significant interest in AD has come from countries where intensive dairy and hog farming occurs, as manure disposal is becoming more difficult due to environmental regulations, or where land restrictions limit traditional disposal routes. To put the opportunity in context, the US hog and dairy industry produces ~1.5 million tonnes of manure/day. In other words, the power potential of one animal is:

- Dairy cow – 100W/head/day
- Hog – 28W/head/day
- Layer chickens – 1W/head/day

Global biogas development was led by Germany in 2006, following the introduction of favourable incentives. In that year, ~650 systems were installed, taking the total installed base to 3,500 plants and 1.1GW of capacity (i.e. average plant size of 0.3MW), although sales growth has subsequently slowed, following increases in commodity prices. In addition to Germany's renewable energy incentives, biogas receives a bonus for using renewable raw materials, for innovative technologies and using CHP. Companies active in this area include: Schmack Biogas, Biogas Nord, Archea Biogas NV, Environmental Power and Thenergo NV. QuestAir is also active in the market through the provision of PSA technology that cleans up biogas to pipeline grade.

BIOMASS ISSUES

Fuel supply

The key to any biomass project is the fuel supply, which is usually only economically sourced from a small area and exhibits substantial variation in its characteristics. This variation is partly a function of the inevitable differences in a natural material, partly the different collection/harvesting techniques used and partly due to seasonal variation.

Fuel is a major logistic challenge and it is rarely economic for a plant to source its fuel beyond a 50-mile radius. This exposes the plant (a 30-year asset) to changes in the local area, where biomass is often on a five-year cycle. Unlike coal, biomass is a living fuel that continually changes over time and significant variation can occur between batches. This requires careful fuel management and skilled operators.

Energy crops

Energy crops are a form of biomass that uses crops planted solely for energy production. This includes switch grass, high yield varieties of poplar and willow. Wood-based fuels are usually known as short rotation coppice (SRC), with saplings planted at a high density, of ~15,000/Ha for willow and 12,000/Ha for poplar.

Saplings are grown for a year before being coppiced. The first three years are part of the establishment phase and do not yield much biomass. After four years the plantation is ready for harvest on a two- to five-year cycle. It should yield 8-18 tonnes of dry woodchip per hectare per year and can be harvested for up to 30 years. The price of dry willow as a heating fuel is around €45/t in most of Europe. This is not a relatively high-return crop, but it is low-maintenance and is a way of using difficult fields. Correctly managed, SRC has little need for pesticides or treatments.

The carbon costs associated with SRC are: the planting, farming and chipping of the SRC plantation. However, energy from SRC provides 3-6 times the CO_2 reduction of bioethanol from cereal crops. A power station requires around 100 hectares (1 km²) of SRC for 1MW of capacity. The primary barrier to establishing plantations is the cost as there is no financial reward for four years from a large initial investment. The current nature of the power industry generally requires flexibility in energy supply, which is incompatible with the long-term commitment SRC requires.

In our view, direct investment into fuel crops is most effectively done on an unlisted basis, due to the long lead times, lumpy cash flows and the tax incentives available to forestry. However, a move to industrial crops is likely to be positive for compost producers such as TEG and Bioganix, as they source much of their product from mixed sources that are unsuitable for horticultural compost.

Commissioning risk

Compared to wind or hydro plants, biomass generators are more complex and only fabricated on site. A one-two year build period is usual and tends to be followed by a prolonged commissioning programme, as many issues can only be resolved sequentially. We expect most biomass plants to take at least one year post commissioning to achieve their full output and are aware of several that took over three years to resolve all issues.

Gas versus power

If biogas is suitably purified, the resulting methane can be sold to the natural gas grid, rather than being burnt to create power. Recent rises in natural gas prices have made this an attractive option and some jurisdictions attach green certificates to the gas, meaning a utility can claim a portion of renewable electricity generation at large CCGT plants (~50% efficient) rather than using on-site generation (20-30% efficient).

The economics are predicated on the availability of a gas grid and the price of local power. However, companies such as QuestAir that sell PSAs to purify biogas have indicated that on a small AD site, the gas engine and generator trade off typically occurs with gas at ~US$6/mmbtu Figure 50 gives an example using a current project:

Figure 50: Gas versus power sales trade off

AD and 600kW power		AD and PSA gas sales	
Total system cost:	US$1.6M	Total system cost:	US$1.45M
Gas engine & generator cost	US$700,000	Gas engine & generator cost	US$550,000
Local power price:	5.5¢/kWh	Local power price:	5.5¢/kWh
Local gas prices:	US$6-7/mmbtu	Local gas prices:	US$6-7/mmbtu
Annual revenue:	~US$300,000	Annual revenue:	~US$380,000

Source: QuestAir and Canaccord Adams estimates

Baseload generation

Biomass power is almost constant all year round. Wet weather can reduce output if the delivered fuel has increased moisture content, while cold dry weather can increase output as parasitic load falls, due to the cooling systems operating more efficiently. Biomass plants are exposed to hydrocarbon fuel price risk to a modest extent, as they often use gas or oil to help control the combustion process. In the worst cases, this can reach 10% of the energy content, although 1-3% is more usual.

Energy balances and biomass productivity

Biomass energy production depends on factors such as climate and agronomy. Examples of net energy yields—output minus energy inputs for agricultural operations, fertiliser, harvest, and the like—are given below. Generally, perennial crops perform better than annual crops, as perennials have lower inputs and thus lower production costs as well as lower ecological impacts. Different management situations— irrigation, fertiliser application, genetic plant improvements, or some combination of the three—can also increase biomass productivity, by a factor of up to 10. In addition to production and harvesting, biomass requires transportation to a conversion facility.

The energy used to transport biomass over land averages about 0.5 MJ/t/km, depending on infrastructure and vehicle type. This means that land transport of biomass can become a significant energy penalty for distances of more than 100km. But such a radius covers a surface of hundreds of thousands of hectares, and is sufficient to supply enough biomass for conversion facilities with hundreds of megawatts of thermal power.

Figure 51: Biomass productivity

	Yield, ODT/Ha/yr	Energy factor	Net energy yield, GJ/Ha/yr
Short rotation crops (willow, poplar)	10-12	10x	180-200
Tropical crops (eucalyptus etc)	2-10	10x	30-180
Miscanthus	10-12	12x	180-200
Sugarcane (Brazil, Zambia)	15-20	18x	400-500
Commercial wood	1-4	20-30x	30-80
Sugar beet - Europe	10-16	10x	30-100
Rapeseed – NW Europe	4-7	4x	50-90

Note assumes no genetic enhancement and standard agronomy
Source: UN World Energy Assessment

BIOMASS INVESTMENT SUMMARY

We are not great fans of biomass as an investment: the fuel is challenging, economies of scale are rare and few companies are consistently successful. However, its ability to provide baseload power and a wide range of potential locations means that it is likely to form a core component of any renewable energy portfolio.

In our view, landfill gas is the easiest and lowest risk option, with a substantial opportunity in the developing world to secure uncapped landfills, or improve in-situ operations. We like the concept of anaerobic digestion, but believe it needs to be run centrally and supported by robust waste disposal regulations that create gate fees, before it becomes an attractive investment. Wood and waste fired incineration can offer scale, but are probably better suited to infrastructure type funds initially. Advanced thermal treatment processes are some way off being commercial and we expect the most successful processes will be those that offer niche products, such as bio oil. We remain seriously concerned over the technical risks facing advanced thermal treatment when used for waste disposal or on a very large scale.

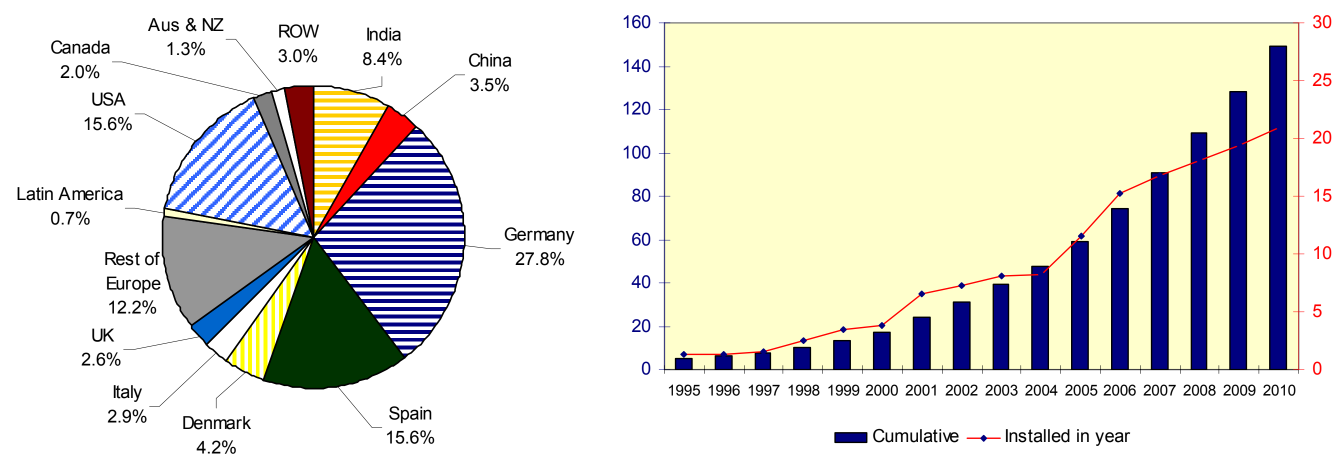
WIND POWER

- **Substantial growth likely for the next 10+ years and wind is competitive with conventional generation at good sites, with further cost reductions possible.**
- **Most investable sector – best risk-adjusted returns from developers with existing capacity, but some valuations looking stretched.**
- **Size is a competitive advantage in turbine production in order to manage warranty risk and R&D costs.**
- **Companies to consider: Vestas; Canadian Hydro Developers; and Hanwei.**

Wind represents a vast source of energy that has been harnessed for hundreds of years and should never run out, as it is constantly replenished by the sun. Most turbines start generating electricity at wind speeds of around 3-4m/s, generate maximum 'rated' power at around 15m/s and shut down to prevent damage at ~25m/s[13].

The use of wind energy has increased spectacularly in recent years, with a 25% increase in installed capacity during 2006 capping similar rises in previous years. This brought total world wind capacity to 74GW, with tens of thousands of turbines now operating.

Figure 52: Global installed base (74.2GW) and capacity installed (GW)



Source: GWEC

Globally, wind energy is expected to have grown to 560 GW of installed capacity by 2020, accounting for more than 7% of electricity demand. In Europe alone, 132 GW of new capacity is expected to be installed over the next 14 years, reaching 180 GW in 2020, or 13.4% of the electricity required for the continent (Source: EWEA).

The wind power market neatly divides into three investment categories:

- well established, existing turbine manufacturers such as Vestas or Gamesa;
- wind farm developers, owners and operators, such as Canadian Hydro Developers;

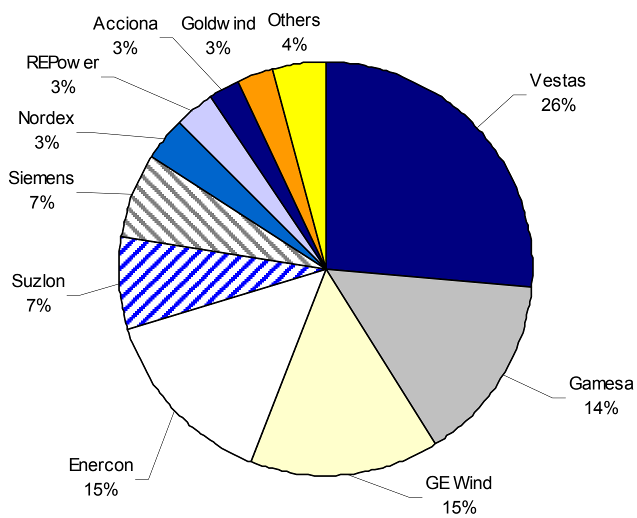
[13] Start at 7-9mph, maximum power at 33mph and shut down at 56mph.

- new turbine design companies, such as Clipper Wind Power.

TURBINE DESIGN AND PRODUCTION

Turbine manufacturing is a concentrated market. Six suppliers cover 84% of the market, with the four main listed manufacturers (Vestas, Gamesa, Suzlon and Nordex) attracting a reasonable scarcity premium as further M&A is still possible. These companies offer a well established 'pure play' exposure to the turbine market. In practice, there is little to differentiate them, although Vestas would appear to have one of the best technology portfolios and, with over 33,500 turbines operating, it is the most established supplier. In our view, turbine makers need a minimum size to provide the warranty protection required by the project finance market and to manage a substantial R&D spend.

Figure 53: Turbine manufacturers - 2006



Source: BTM Consult

Several new technology companies are trying to establish themselves in the turbine market, the most obvious being Clipper Wind Power, although others have attracted venture capital in the last couple of years. Most of these companies offer incremental improvements and an alternative to the dominant players. However, we have concerns over their ability to achieve scale, as:

- initial sales are only likely to developers (i.e. utilities) able to fund projects on their balance sheets, due to bankability issues for new technology; and
- technology development is not usually easy in the public gaze and normal engineering setbacks can have a disproportionate impact on a company's image in the financial markets.

In the past, we have seen companies trying to attract investor interest due to their position in the wind energy supply chain. In our view, there are few, if any, pure play suppliers to the wind market of any consequence. Most suppliers are part of larger industrial companies and tend to produce 'commoditised' goods, since the main turbine manufacturers tend to key IP-related production in-house.

Figure 54: Market position

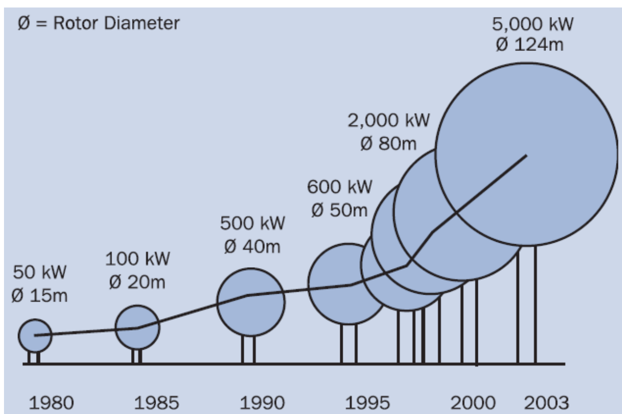
	'06 MW installed	No 1	No 2	No 3
US	2,454	GE	Vestas	Siemens
Germany	2,233	Enercon	Vestas	RePower
India	1,840	Suzlon	Enercon	Vestas
Spain	1,587	Gamesa	Acciona	Vestas
China	1,334	Goldwind	Vestas	Gamesa
France	810	Nordex	Vestas	RePower
Canada	776	GE	Vestas	Enercon
Britain	631	Vestas	Siemens	RePower
Portugal	629	Vestas	Gamesa	Enercon
Italy	417	Gamesa	Vestas	Enercon

Source: BTM Consult

Technology 101

Commercial wind turbines started in earnest in the 1980s, and in the last 20-years turbine power has increased by a factor of over 100, while costs have fallen over 90%. From units of 20-60kW in the early 1980s, with rotor diameters of around 20 metres, wind turbines have increased to 5MW, with rotor diameters of over 100m. The dramatic increase in size and technology know-how, coupled with economies of scale from fast-growing production volumes, have reduced the cost of wind power to the point at which good onshore wind farms are competitive with conventional generation.

Figure 55: Growth in wind technology

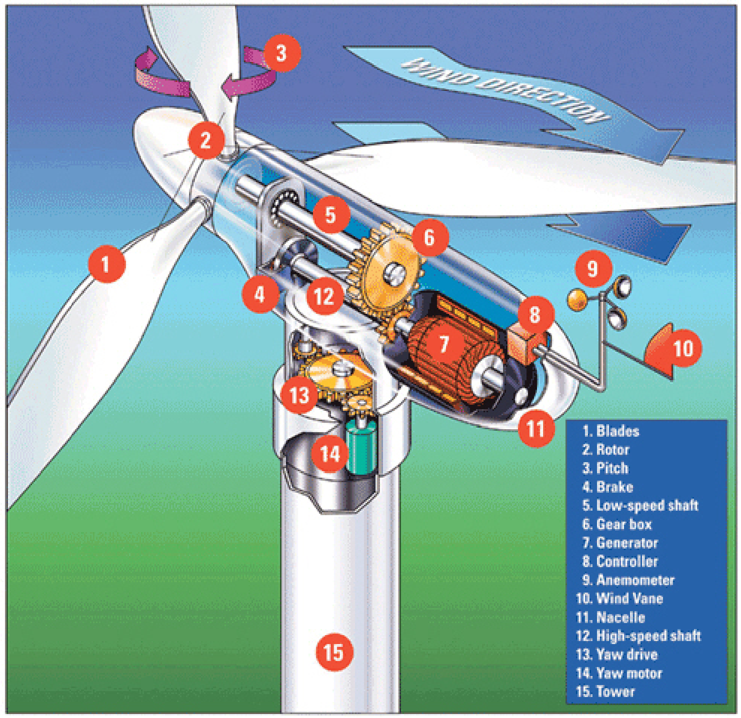


Source: EWEA

Wind turbines are a natural evolution from traditional windmills, but are now designed to generate high quality, network frequency electricity, and to operate continuously, unattended and with low maintenance, for more than 20-years. The rotors usually consist of three blades, with their speed and power controlled by stall or pitch regulation. The rotor may be attached to its generator via a gearbox and drive train, or directly to the rotor in an arrangement known as "direct drive". Turbines able to operate at varying speeds are becoming increasingly common as this improves their compatibility with the electricity grid. Rotor blades are typically made from glass polyester or glass epoxy, sometimes in combination with wood or carbon fibre.

The tubular towers supporting the nacelle and rotor are made of steel and taper from their base to the nacelle at the top. Wind turbines are mounted on high towers to optimise energy capture, as the wind is generally stronger, more consistent and less turbulent higher up.

Figure 56: Wind turbine schematic



Source: Alliant Energy

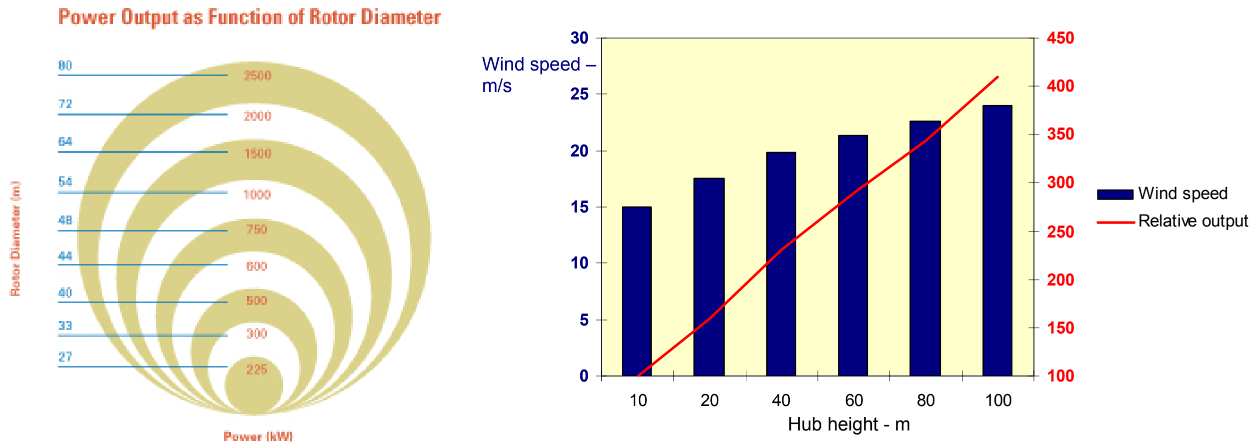
Instruments on top of the nacelle include anemometers and a wind vane, which respectively measure wind speed and direction. When the wind changes direction, motors turn the nacelle, and the blades along with it, to face the wind and extract as much energy as possible. All this information is recorded by computers and transmitted to a control centre, which can be many miles away, meaning that wind turbines are not physically staffed, although each has periodic mechanical checks. The onboard computers also monitor the performance of each turbine component, especially the blades, and automatically shut the turbine down if any problems are detected.

Turbine developments

The average wind turbine size has increased significantly, with most demand now for MW class machines. Wind turbines of up to 5MW are running, though most new turbines are still in the 1-2MW range. Larger machines bring economies of scale, plus for a given capacity, they are less visually intrusive than many smaller machines. Figure 57 illustrates the relationship between rotor size and power output: 40m rotors generate 0.5MW of power, while 80m rotors generate 2.5MW of power. It also shows the substantial difference an increase in hub height brings. The faster and less turbulent air exists further off the ground and the chart shows the output relative to a 10m hub height with a 15m/s wind.

The power output is a function of the cube of the wind speed, so doubling the wind speed gives eight times the energy potential.

Figure 57: Rotor size and height impact on output



Source: Airtricity

There are many turbine designs, with scope for innovation and technological development. The most common turbine design is the up-wind, three bladed, **stall controlled**, constant speed machine. However, the market is moving to the next most common design, which is **pitch controlled,** with variable speed machines growing in popularity, again with three blades. A smaller number of turbines have no gearboxes or two blades, or use other concepts, such as a vertical axis.

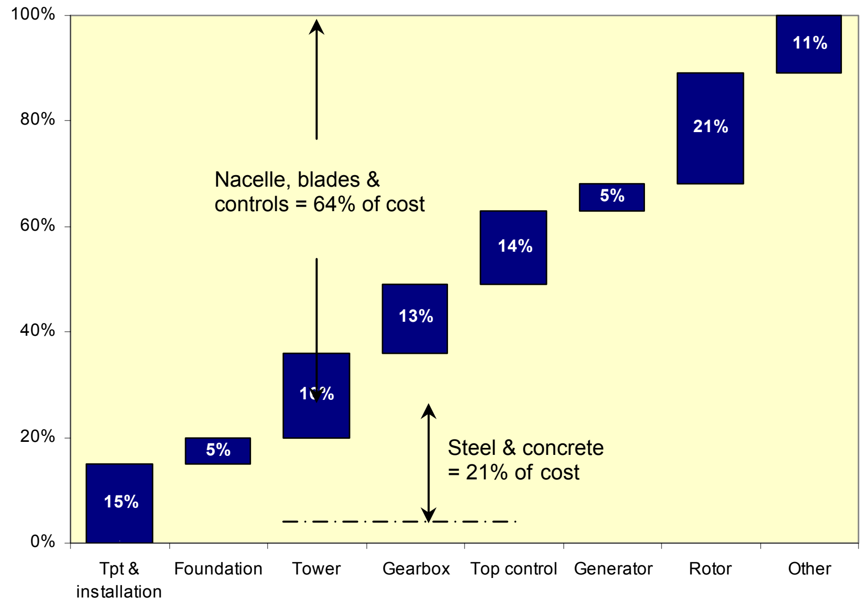
- **Pitch control** actively adjusts the angle of blades and has built-in braking, since the blades become stationary when they are fully feathered. The move to pitch control reflects the growth in utility scale plants.
- **Stall control** is a passive system where the blade's aerodynamic design determines the power output and uses no moving parts. The blade's twist and thickness vary along its length so that turbulence occurs behind the blade whenever the wind speed becomes too high and reduces the power transferred. Stall control machines also have brakes on the blade tips to bring the rotor to a standstill when needed.

We expect to see more variable speed machines. While the power electronics are more challenging, the machines tend to generate more power for a given wind speed, that output is relatively easily controlled and less system wear occurs. The cost of wind generation is mainly the upfront capital costs, plus relatively modest ongoing O&M costs. Turbines make up most of the capital cost (64% on shore and ~50% off shore), although civil works and grid connections are also significant.

Production costs and suppliers

With increased scale and numbers of units, generation costs have fallen substantially. They are still greater than those for a fully depreciated coal fired plant, and allowing for back-up capacity and grid connection complexities adds to this. However, we expect the recent trend of increased prices (due to supply constraints and steel costs) to reverse in the next couple of years and within a relatively short time, on-shore wind could be competitive at many sites. Last year, US wind farms produced ~31TWh/year at an average capacity factor of 30.5%, using a relatively small production tax credit and a range of renewable portfolio standards.

Figure 58: Turbine cost breakdown



Source: Gamesa

Material costs – steel and concrete – have increased substantially over the last few years, reversing the long-term trend of falling real prices. More significant has been the increase in turbine demand that has allowed manufacturers to raise prices and increase margins. Prices have tended to increase more than margins, as substantial supply chain investment is required.

Figure 59: Component supply

Manufacturer	Blades	Gearboxes	Generators	Controllers	Towers
Vestas	IH, LM Glasfiber	Bosch, Hansen, Winergy, Moventas	IH	IH	IH
GE	LM Glasfiber, Tecsis	IH, Winergy, Bosch, Eickhoff	IH	IH	DMI, Omnical, Siag
Gamesa	IH, LM Glasfiber	IH, Winergy, Hansen	IH	IH	IH
Enercon	IH	N/A	IH	IH	KGW, SAM
Siemens	IH, LM Glasfiber	Winergy	IH, ABB	IH, KK Electronic	Roug, KGW
Suzlon	IH	Hansen, Winergy	IH, Siemens	IH, Mita Teknik	IH
Nordex	IH, LM Glasfiber	Winergy, Eickhoff, Maag	VEM, Loher	IH, Mita Teknik	IH, Omnical
Clipper	Tecsis	IH	Potencia	IH	Emerson, Anston

I

IH – In-house
Winergy – Siemens owned
Hansen – now owned by Suzlon, but about to be IPO'd on the LSE
Source: BTM Consult

Blades and control systems are typically produced in-house, while generators, gearboxes and inverters are sourced externally. We believe the problem the whole industry faced with gearboxes, and the relatively high perceived risk, has tended to keep this contracted to a few major providers, with most bottlenecks occurring in the specialist bearing industry (SKF and FAG Kugelfischer). Overall, we expect to see a move to more in-house production, as manufacturers seek to control quality and internalise margins. We not convinced that specialist component manufacturers are good investments, unless there is substantial IP that the rest of the industry cannot readily replicate.

Despite these cost pressures, we expect wind energy prices to continue their long-term decline as the technology improves. Turbine manufacturing is relatively concentrated and several new entrants have struggled to achieve the scale needed to run an effective product development process or provide the project finance warranties.

When increasing the size of the turbine, blade size is the main limiting factor today. With blades commonly in the 40-50m bracket, each additional metre of blade length on average doubles the pressure on the hub, as well as making transport more difficult and expensive.

New entrants

We see limited risk from new entrants to the global market, as most clients need proven technology, a good operating history and the capacity to support warranties. Several small companies are on the fringes and only Clipper Wind Power appears to be on the verge of real scale. Likewise, in the supply chain there are few new entrants as most turbine manufacturers keep strategic manufacturing in-house, with the vast number (~8,000) of smaller components meaning little pricing power exists. However, China has seen a surge of new manufacturers straight into MW class machines, with some licensing European designs. We believe real quality risks exist, as this is a sector where know-how and experience play a role that goes beyond the information in a blueprint. However, with China requiring 70% domestic content, we expect more manufacturers to appear on the market.

Most new entrants have targeted the blade supply sector, which is dominated by LM Glasfiber, with a 27% market share. The only direct listed play on blades is Hanwei Energy Services, which is developing a business that expands its existing experience in GRP pipe in China to produce blades (first deliveries expected in December), although Zoltek provides carbon fibre for many industries, including wind turbine blades. However, the major manufacturers, apart from GE and Clipper, produce most of their blades in-house, using LM as surge capacity. We believe there is limited IP in blade production per se, although the relative cost savings are unlikely to justify the increased warranty risk by moving to junior suppliers.

Technology differentiation

Wind turbines are highly reliable, with operating availabilities of ~98% (i.e. they are available to run 98% of the hours in a year) – no conventional generating technology can better this. Most technical developments are focused on incremental improvements to reduce weight and vibration or improve blade aerodynamics, monitoring systems or drive train efficiency.

PROJECT DEVELOPMENT

There are numerous developers and operators of wind farms now listed, although utilities and large IPPs are now starting to dominate the market. Development is an area that the public market finds difficult to value sensibly, partly due to a lack of experience plus the inevitably limited disclosure possible on projects that are still in development. As a result, we believe private equity firms have a material advantage in their ability to due diligence a development portfolio far more thoroughly than the public markets.

While the development process offers some of the best returns in the sector, the quality of corporate disclosure varies substantially and the headline figures for different development portfolios are not comparable. In our view, Canadian Hydro Developers sets the benchmark, as its mix between operating and development assets reduces the asymmetric risk facing many smaller developers. We are also unconvinced of the development value in many turbine manufacturers' land banks, in isolation. However, as a means to optimising the use of their production capacity, this offers upside.

Figure 60: Selected wind power developers and operators

Company	Ticker	EV, US$M	Description
Boralex	BLX CN	834	26MW hydro, 14MW gas cogen, 204MW biomass, 103MW wind
Canadian Hydro Developers	KHD CN	1,162	86MW hydro, 26MW biomass, 154MW wind, 2+GW development potential
Creststreet Power & Income Funds	CRS-U CN	117	85MW of wind, 1+GW of development potential
EDF Energies Nouvelles	EEN FP	5,642	128MW hydro, 26MW biomass, 964MW wind, further development potential
Finavera Renewables	FVR CN	75	Development options on 325MW wind plus wave technology
Greentech Energy Systems	GES DC	973	208MW wind, 0.9GW wind development portfolio
Naikun Wind Energy	NKW CN	121	Single 1.7GW development project
Novera	NVE LN	159	16MW hydro, 15MW wind, 87MW LFG, 0.3+GW development portfolio
Renewable Energy Holdings	REH LN	92	47MW wind, 2MW LFG, wave technology
Renewable Energy Generation	RWE LN	240	66MW wind, large development portfolio
Shear Wind	SWX CN	59	0.7GW wind development portfolio
Theolia	TEO FP	1,177	495MW wind, 2GW development portfolio

Source: Bloomberg as at 30/10/07, companies and Canaccord Adams estimates

Valuing development portfolios

According to New Energy Finance, US$19.7 billion was spent on acquiring wind power assets from 2001 to 2006. Most of this was in Europe, with large utilities starting to dominate the market as time progressed. The Horizon transaction has put a figure of US$80,000/MW as a benchmark for development portfolios. However, we believe this is fundamentally misleading, as developers report widely differing figures for what they consider is in a development pipeline. We use a risk-adjusted approach to assess Canadian Hydro Developers' portfolio and in our current valuation, this equates to ~US$64,000/MW on an unrisked basis. In our view, the company provides relatively full disclosure of its development assets.

Figure 61: Asset transactions

Date	Seller	Buyer	MW	Implied €M/MW
Q3/07	Dong Energy	EON	260	2,776
Q3/07	Trinergy	International Power	648	2,387
Q2/07	Alinta	ANZ	91	1,524
Q1/07	Horizon	EDP	1,324	1,318
Q4/06	Agupa Eolica	EDP	207	1,981
Q4/06	Gamesa	BabcockEDP & Brown	231	1,141
Q4/06	CRC Levanto	International Power	412	1,376
Q1/06	MCC	Elecnor	111	1,351
Q1/06	Bridgepoint	Acciona	770	1,871
Q1/06	RWE	Beaufort Wind	140	1,711

Source: Canaccord Adams

The development process

Project development has several well defined steps that include prospecting, optioning land, wind and environmental studies, securing a PPA, finance and construction. The main responsibility lies with the developer and taking a greenfield site through to being construction-ready typically offers the greatest returns.

- Prospecting involves finding a site with good wind resources. Over the last few years, many wind atlases have been created to help developers. In more detail, prospecting requires a topographical assessment to identify features that might reduce the resource (woods, towns) or cause planning problems (airfields, TV masts). Once the site is identified, it is typically secured by option for 3-4 years.

- A detailed wind study usually requires several measurement devices (wind speed, direction, temperature, humidity) installed at the site. Measurements usually run for at least one full year and preferably longer. These measurements are then correlated with local data (such as from an airport) going back 20+ years, to assess the long-term potential of the site. Poor measurement and modelling has been one of the main causes of the few wind farms that have underperformed.

- Environmental studies include the effects on local wild life, noise and vibration. Visual impacts are often a complaint of NIMBY groups. Over the last few years, environmental assessments have tended to delay, rather than stop, wind farm development.

- The most economic projects are those able to secure long-term PPAs, as these can often attract project debt finance up to 80%. This will depend on the site quality and the turbine provider.

- The final step is construction, typically via an EPC contract, although some developers, such as Canadian Hydro Developers, do their own project management and save ~10% from the EPC cost. Typically, a 20-100MW wind farm can be built in nine months, depending on the availability of cranes.

Once the farm is running, O&M costs are relatively low and design lives of ~25 years are normal. In our view, the real life of a wind farm is much longer, as repowering turbines can significantly extend the economic operation. Once operating, a wind farm can be monitored and controlled remotely with roughly two maintenance people for every 20-30 turbines.

Framework agreements

There is currently a shortage of turbines and the relationship between suppliers and developers is now crucial. This has resulted in framework agreements being signed to 'secure' future turbine supplies and increasing demand for deposits. This has provided the manufacturers with greater clarity and most are fully booked until early 2009. This has also changed the nature of the industry: developers are placing larger orders but in return are expecting much tighter commercial terms. This tends to bias against the likes of Clipper Wind Power.

What happens when the wind stops?

Electricity is not generated when there is no wind. This means that there are some technical challenges with incorporating it into the electricity grid. However, recent studies show that up to 20% of grid power can come from wind power using current techniques. In the following pages we discuss options to extend this further and a recent study in Minnesota found that adding 1.5GW of wind power to Xcel Energy's system only needed an additional 8MW of conventional generation to deal with the increased variability.

This factor of intermittent generation is often cited as a disadvantage, with a popular question being "what happens when the wind stops blowing". Not a lot really, as electricity continues to be provided by other forms of generation. The electricity system is mostly made up of large power stations, and the system has to be able to cope when one of these large plants goes off line unexpectedly. Equally, the system is well used to dealing with fluctuations in demand throughout the day and the fluctuations caused by non-firm generation from wind turbines is not noticeable above the normal rises and falls in demand on the system.

Capacity factor

Wind turbines generate electricity for approximately 80% of the year, although not always at full output. They tend to operate at a high output when demand is greatest. Over the whole of 2003, the average capacity factor of UK wind farms was 31%. Over the summer, the capacity factor was 17%, but during the winter it was 45%. In broad terms for onshore wind, a capacity factor under 25% is rarely economic, 32% is reasonable and better than 38% is good.

Resource optimisation

The amount of electricity produced from a wind turbine depends on three factors:

- Windiness of the site – the power available from the wind is a function of the cube of its speed. Therefore, if the wind blows at twice the speed, its energy content increases eight-fold. A wind farm with an average wind speed of 7m/s produces around 30% more power than a 6m/s site, as not all the extra energy can be harvested. Careful location can substantially change the site's effectiveness and experience often plays a major role.
- Equipment availability is the ability to operate when the wind is blowing - an indication of the turbine's reliability. This is typically 98% or above for modern machines.

- Site layout is important, so that one turbine doesn't take the wind away from another. The ideal position for a wind turbine is a smooth hill top, with a flat clear fetch, at least in the prevailing wind direction.

A number of constraints affect the site of a wind farm, such as land ownership, positioning in relation to roads or overhead lines, the location of inhabited buildings and avoidance of sites of environmental importance. Once these constraints have been determined, the layout of the wind turbines themselves can be set to maximise electricity production while minimising infrastructure and O&M costs. Specialist software has been developed to produce visualisations of how the turbines may appear in the landscape, enabling developers and planners to choose the best visual impact solutions before the project is constructed and model the potential output. Aside from the turbines, the other principal components of a wind farm are: foundations for the turbine towers, access roads, and the electrical infrastructure to connect with the grid.

Bird strikes and noise

Mechanical noise has been practically eliminated and aerodynamic noise vastly reduced, meaning that most objections to a wind farm now centre on the visual impact and the potential to kill birds. We believe this is a solvable issue, provided a wind farm is not sited on key flight paths. To put the problem in context, for each 1,000 birds killed per year due to anthropogenic causes, 550 are killed by buildings, 100 by domestic cats, 70 by each of pesticides and cars, while wind turbines are responsible for less than one fatality on average (Source: BWE – Erickson et al 2002). Poorly sited wind farms with lattice towers (i.e. Altamont Pass) originally got the industry a bad name; however, modern wind farms with relatively slow-moving blades and better environmental screening have reduced the scale of the problem dramatically – as such, we believe this is a function of effective planning, rather than real regulatory risk.

How much land is needed?

Even though a wind farm only uses a fraction (3-5%) of its total land area, wind dynamics and equipment size mean that turbines need to be well spaced. Depending on the wind regime, topography and other structures in the area, turbines are typically placed 3-5 rotor diameters apart (300-500m). This makes wind farms attractive to many land owners, as livestock can continue using the land, while the rental income amply offsets the small loss of grazing. Put another way, an area of 20x50km could have enough turbines to provide 25% of Britain's nameplate capacity, assuming a 5MW machine. This is a large land area for Britain, but relatively small in an off-shore context.

WIND ECONOMICS

The economics of wind energy have changed dramatically over the past 20 years, as the cost of wind power has fallen ~90% over that period. Despite the progress, the industry is relatively immature, with production volumes that pale in comparison to what they could be two decades from now. Thus, the factors affecting the cost of wind energy are still rapidly changing, and wind energy's costs should continue to decline as the industry grows.

A number of factors determine the economics of utility-scale wind energy and its competitiveness in the energy marketplace:

- **The cost of wind energy depends on the wind speed at a given project site**. The energy that can be tapped from the wind is proportional to the cube of the wind speed, so a slight increase in wind speed results in a large increase in electricity generation. Consider two sites, one with an average wind speed of 14 mph and the other with average winds of 16 mph. All other things being equal, a wind turbine at the second site will generate nearly 50% more electricity than at the first location.
- **Turbine design improvements bring down costs**. The taller the turbine tower and the larger the area swept by the blades, the more powerful and productive the turbine. The swept area of a turbine rotor (a circle) is a function of the square of the blade length (the circle's radius).
- **A large wind farm is more economical than a small one**. Assuming the same average wind speed of 18 mph and identical wind turbine sizes, a 3–MW wind project delivers electricity at a cost of $0.059/kWh and a 51-MW project delivers electricity at $0.036/kWh - a drop of nearly 40%. This is mainly due to spreading the fixed costs (grid connection, transaction costs, O&M fee) across a larger revenue base.

Portfolio impact of wind

Studies are showing that the cost of wind power is often less than expected, since adding wind power to the grid can reduce the overall cost of power. On a windy day, the marginal cost of wind power is almost zero, since there is no fuel cost. That power displaces generation from other sources and usually it is the highest cost power that is switched off first. Nuon has calculated that in 2005 the average spot price was €45/MWh when there was no wind and €30/MWh when the average wind speed exceeded 13m/s. This year the Danish Wind Energy Association expects wind power to give consumers a net saving, for the first time.

Financial metrics

In our view, wind power is economic on good sites and has the ability to further reduce costs – we estimate another 30% over the next 15 years – through incremental technology improvements. This should increase the range of sites that are commercially viable without subsidies to capacity factors of ~30% or better, provided long term PPAs are available.

Figure 62: Wind power financial summary

Performance	
Duty cycle	Varies with resource
Typical capacity factor	24-40%
Economics	
Project costs (US$M/MWe)	1.6-2.1
Fixed O&M (US$k/MW/year)	25-30
Variable O&M (US$/MWhe)	5-10
Levelised cost (US$/MWhe)	50-90
Commercial status	
Estimated time to commercial	Now onwards

Source: Canaccord Adams

OFFSHORE WIND

Wind turbines can be sited offshore, where the wind blows harder and larger turbines can be installed. Many offshore wind farms are being proposed and developed today in Europe, where there is limited space on land and relatively large offshore areas with shallow water.

For several years, the offshore market has been expected to drive wind market growth. So far, expansion has been much slower than forecast and several companies remain sceptical of any major off-shore impact until the many unknown costs are better quantified. Offshore wind needs to achieve a 35% CAGR over the next 14 years to hit the EWEA's 60GW target for 2020. While hard, this is not impossible, as onshore wind has achieved a 33% CAGR over the past 14 years.

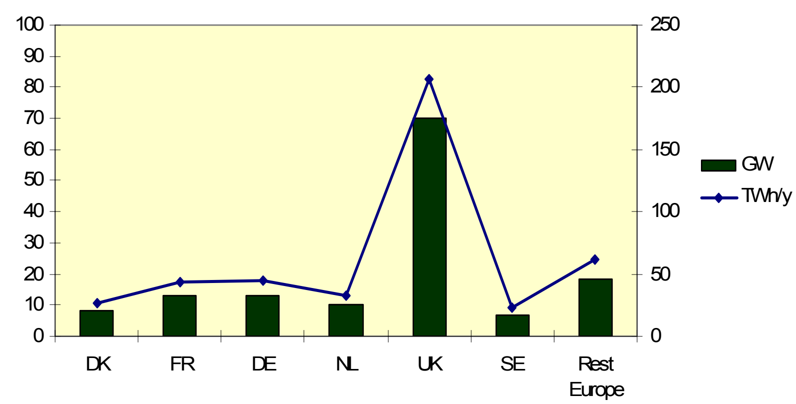
Reducing costs is the main target, with current estimates around €1,800/kW. The key lies in economies of scale that can reduce fixed costs – a crane barge costs ~€15 million, or €25-30,000/day, but with the ability to install 80+ turbines/year. Other cost factors are foundations and grid connections, which should reduce with scale and learning curve effects.

There are several reasons for the interest in offshore wind development that offset the increased cost of operating in a marine environment:

- better capacity factors occur as it tends to be windier at sea and the quality of the wind is far better, as it has not picked up the same level of turbulence as occurs over the land. Offshore capacity factors are typically around 40%;
- no visual and space less of an issue; and
- no noise

The offshore potential is substantial. Figure 63 shows the opportunity around Europe, with the UK unsurprisingly having a disproportionate resource. Around the US, there is ~90GW of capacity in 30m or less of water and ~273GW in less than 60m.

Figure 63: European offshore wind potential



Source: EU

CHINA

China relies on high sulphur coal for ~75% of its total energy and, in 2002 hydrocarbon power provided ~82% of its electricity, hydro accounted for ~15%, nuclear 2% and less than 1% from renewables. Twenty years ago, China was the largest oil exporter in East Asia. Now, it is the second-largest importer in the world (after the US) and looks likely to surpass the US by 2030 – in 2004, it accounted for 31% of the global growth in oil demand. China is expected to have 900GW of energy capacity by 2020 – double that of 2003 (Source: GWEC). However, China uses three times the energy to produce $1 of GDP as the world average, 4.7 times the US average and 11.5 times the Japanese average. China is estimated to have ~250GW of potential wind capacity.

In 2005, the Chinese Government set a target of 5 GW of wind energy capacity to be installed by 2010, and 30 GW by 2020. At first sight, the targets seem ambitious. However, recognising that China's installed capacity at the end of 2006 was 2,600MW and given the current growth rate, it becomes obvious that the 2010 target could be met much earlier. Moreover, given current demand trends, a wind capacity of 30 GW in 2020 would still merely represent about 1% of the around 6,000 TWh of electricity expected to be needed in China at that time.

In the EU, where average wind speeds are considerably lower than in China, wind power capacity increased from 2,500MW in 1995 to 48,000MW at the end of 2006, currently accounting for around 3% of the EU's electricity demand. The EU governments have just set a binding target of 20% of energy demand to be covered by renewable energy sources by 2020. In China, the current capacity stands at 2,600MW. Given the good wind resources, the need for new generation capacity to fuel the growing Chinese economy, and the advances in turbine technology and size, there is every reason to assume that the Chinese wind market could grow at an even faster rate over the next 10-15 years.

China is embarking on one of the largest investments in grid capacity in the world with a new high voltage system the scale of which has not been seen before. The country is thus in a position to lead the world in the integration of wind energy into the net. To achieve this, it is important for upgrades in China's transmission networks to be coordinated with approvals for new wind projects to ensure that infrastructure, grid access and substations are available where the projects are being built. This will avoid delays and complications in connecting new wind farms to the grid because of insufficient connection capacity.

For a wind energy target to be effective, it would make sense to base this on the electricity production rather that the installed capacity, similar to what has been introduced by other countries. Such a national target for China could be in the region of 5%, or ~300 TWh of electricity generated in China in 2020. Based on a sensible capacity factor of 28.5%, this would translate into 120 GW of installed capacity, rather than the 30 GW that the government is currently aiming for.

In our view, the Chinese market can be accessed, in order of increasing risk/return, via:

- existing leading global manufacturers due to their sales into China;
- Suzlon due to its relative pricing power and developing world application;
- Goldwind or Hanwei as direct exposure to China.

SUMMARY

In our view, wind energy is one of the most attractive areas of the renewable market, as it offers scale, near cost parity and a range of investment models. The flood of money coming into the sustainability sector has skewed some wind power valuations and we believe this creates many options for alpha generation.

INVESTMENT SPIN-OFFS

Other technologies could benefit – and be required – if a significant shift to renewables occurs. In this section we highlight some of these opportunities.

ENERGY STORAGE

Power markets operate on a "just-in-time" system. If there were some way that electricity from intermittent producers such as solar and wind could be stored efficiently, the potential contribution of these technologies would be much greater. Already in some places pumped storage is used to even out the daily generating load by pumping water to a high storage dam during off-peak hours and weekends, using the excess base-load capacity from low-cost coal or nuclear sources. During peak hours this water can be used for hydro-electric generation. Relatively few places have scope for pumped storage dams close to where the power is needed, and overall efficiency is low.

We believe energy storage is a potential key enabler for renewable power, as this could remove the penalty for variable generation. While electricity itself cannot be stored, it is easy to store energy in other forms and convert it to electricity when needed. Advanced storage technologies for electricity applications include, but are not limited to, batteries, electro-mechanical, and chemical and thermal storage technologies in either on-grid or off-grid situations. This cuts the need for new generating and transmission capacity by allowing power stations to run more efficiently, while also significantly improving grid reliability and reducing the small variations in power output that can trigger disruption to machinery and plant.

Wind is the most developed renewable energy, but it does not blow all the time and often blows in inverse relation to peak power demand so wind generators get a lower price for their electricity than companies able to sell power at peak times. To a lesser extent, hydro, solar, wave and tidal suffer from the same problem, which means extra capacity is needed to compensate for periods of low output, while conversely, if the resource exceeds forecasts and more power is generated than predicted, it is often just discarded to maintain system stability. If the power can be stored and sold at peak times, making the energy "dispatchable", the economics of renewables become much more attractive.

Transmission systems can cope with very little variation in power output from second to second, and wind cannot be forecast with any great degree of accuracy and if you put more wind on to the system, it increases frequency variations, which are bad for power quality. As a result, certain markets cannot fully exploit their wind resources. These are often islands with lots of wind but weak grid connections to other markets and few other power generating resources, such as New Zealand, the Shetlands, the Faroe Isles and the Canary Islands. In the Shetlands, for example, they could generate wind for under £30/MWh against the £100/MWh paid to meet their power needs with diesel (Source: BWEA).

There are four existing technologies that currently offer some form of energy storage and, longer term, hydrogen offers a fifth alternative.

Pumped storage

Pumped hydro storage is the largest and oldest large-scale technology. Water is pumped from a hydro-electric plant's lower reservoir to the upper reservoir in off-peak hours to be released at peak times. This is the most developed and best value proposition, but most available sites have been developed or have high environmental and financial costs, long lead times and must be in remote areas, given their size.

Compressed air energy systems

Compressed air energy systems (CAES) can provide big efficiency gains for gas turbines. About two-thirds of the energy produced in a gas turbine is used to pressurise the air for combustion, according to the US DoE. CAES systems use off-peak electricity to pre-compress the air, which is then stored in an underground reservoir and released at peak times to feed the turbine. Decoupling air compression from turbines increases the amount of power that can be produced per unit of fuel by two or three times.

Currently there are only two CAES plants in the world (the US and Germany), although both were designed as peaking plants, rather than support for wind/wave energy. CAES are inefficient, so they only work where there are big variations in power prices. As a result, a group of municipal power companies is considering a site in Iowa to take advantage of the windy Great Plains, with a target operational date of 2011. General Compression Inc (Private) has developed a wind turbine that puts a compressor into the nacelle to pump air into underground storage, where it can then be called on demand to generate power. While we are yet to be convinced that conversion losses will be offset by the power price, with a first prototype expected in 2009, this is an innovative solution to an industry-wide issue.

Hydrogen

Hydrogen may provide an energy storage medium for variable renewable power, by electrolysing water into hydrogen, especially if fuel cell vehicles become common. With electrolysis, the GHG burden depends on the source of the power, but if renewables are used to make hydrogen, they can be opportunistically used whenever they are available, since the hydrogen is stored and used as required.

A similar rationale applies to base-load power from geothermal, LFG or AD, which could allow the plant to run continuously at full capacity, with all the output supplied to the grid in peak periods and any excess capacity being used to make hydrogen at other times. This would mean maximized plant efficiency and a similar argument applies to nuclear power.

An NREL report[14] published in 2006 claims that wind turbines could produce delivered hydrogen for under US$3/kg. Near-term, the report expects hydrogen could be produced at a wind farm for US$5.55/kg and US$2.27/kg long-term. This is a relatively simple calculation, as basic physics shows that electrolysis needs 39 kWh of electricity to produce one kilogram of hydrogen and each kilogram of hydrogen has approximately the same energy content as one US gallon of petrol.

---

[14] Wind Energy & Production of Hydrogen & Electricity - Opportunities for Renewable Hydrogen' prepared by J Levene for DOE's National Renewable Energy Laboratory.

The production of distributed hydrogen using a centrally sited electrolyser is probably the most efficient method, as different wind farms could support a centralised electrolyser, lifting its capacity factor. The report estimated that hydrogen could be produced at the point of use for US$4.03/kg near-term, to US$2.33/kg in the long-term, with an electrolyser located at the filling station.

The US DOE has a 2015 goal of delivering hydrogen at US$2-3/kg plus US$1/kg for delivery and dispensing. Generating hydrogen at a wind farm means it must be produced for US$1-2/kg, while generating it at a central location allows US$2-3/kg due to the saving on delivery costs. The report's long-term price for wind-produced hydrogen was US$2.70-2.27/kg which, when added to delivery costs, was slightly higher than the DOE's targets. If aggregate wind electricity is available at the filling station for US$0.038/kWh, it is possible for production, compression and storage to meet the target of US$2-3/kg of delivered hydrogen.

We believe this report has important implications for ITM as it sets a clear benchmark for its aspirations in the electrolyser market, although it seems that a substantive market is at least five years away. We think a shift to on-site hydrogen production could also be positive for QuestAir as it has already supplied several hydrogen refuelling stations.

Chemical storage

Broadly speaking, storage comes in two varieties: batteries and capacitors. Batteries contain lots of incipient electricity in the form of chemicals that, when they react, generate an electric current. Such "high energy-density" devices, however, release their potential slowly. For a short, sharp shock a capacitor is better. This is a low energy-density device, which stores electricity directly by charging two conductive plates with static. When the two plates are connected as part of a circuit, the charge flows rapidly between them and produces a far more powerful current than a battery can.

Conventional batteries rarely make sense to smooth grid fluctuations, other than a route to providing emergency back up until a generator can start up. Several new developments may give the power storage needed to make variable renewables more attractive. These include zinc bromine batteries (ZBB Technologies), vanadium redox batteries (VRB) and vanadium flow batteries (V-Fuel). Flywheel technologies may offer another route forward, although power levels are still relatively low. LiOn and A123 are developing innovative solutions, primarily for the transport market, while Atraverda's bipolar plate lead acid batteries may also offer options for power generation.

INVERTERS

Most electrical equipment and the main grid run on alternating current (AC), while most renewable energy technologies produce direct current (DC), which means it must be converted to AC using inverters and related power conditioning equipment. This has four main elements:

- conversion — of constant DC power to oscillating AC power;
- frequency of the AC cycles — should be 60 cycles per second;
- voltage consistency — extent to which the output voltage fluctuates; and
- quality of the AC sine curve — whether the AC wave is jagged or smooth.

Simple electric devices, such as incandescent lights, can run on fairly low-quality electricity. A consistent voltage and smooth sine curve are more important for sensitive electronic equipment, such as computers. Inverters condition electricity so that it matches the requirements of the load or the power grid (i.e. voltage, phase, frequency and sine wave profile). Inverters are required for many renewable energy applications, such as wind and solar, with efficiency, reliability and cost being the main metrics. Only Xantrex Technology offers a relatively pure play exposure to the inverter/power electronics market, as its main competitors are subsidiaries of larger companies. At this stage, we are unconvinced of the differentiation between manufacturers to advocate exposure to the sector, as we believe the telecoms sector tends to have a greater impact on valuation.

NEW TRANSMISSION SYSTEMS

The best wind, wave and tidal regimes are typically located far away from the centres of population that need the power. Unavoidable transmission losses occur that are in proportion to the distance the power is transmitted and inversely proportional to the voltage. All major power grids use AC, as this is more effective over the relatively short distances that national grids were originally designed to manage. However, over long distances DC is more efficiently transmitted than AC.

Recent proposals have been put forward for a European-wide DC transmission grid that could link the large pumped storage hydro sites in Norway, with wind farms across Europe. This would provide power storage and help manage generation that is not correlated with demand.

Recent advances in power electronics have enabled the economic use of power semi-conductors in high capacity inverters. These devices, known as IGBTs[15], are being used more widely in transmission grids and even hybrid vehicles (Toyota's latest Prius uses a 50kW IGBT to control two AC motors/generators linked to a DC battery). IGBTs allow AC to be stepped up to high voltage DC for transmission and allow better power management, as well as easier interfacing with weak grids. The two main suppliers of IGBTs for transmission applications are ABB and Siemens.

Several high voltage DC transmission lines have been installed or ordered over the last few years, such as a 5GW DC 1,400km transmission line in China due in service mid-2010 to carry power from hydro power plants in Yunnan to the industrialized area of Guangzhou, or the following links with Denmark - 1GW to Norway, 0.6GW to Sweden and 1.2GW to Germany sponsored by the TSO Energinet.dk. Although the Danish links are mainly aimed at selling Norwegian power, rather than managing renewable loads, this provides a good demonstration of the potential. In our view, the most attractive near-term use of a DC grid would be to provide an offshore backbone to which wind and wave power stations could connect.

SUPERCONDUCTORS

Superconductors are electrical conductors with zero resistance to DC and exceptional current carrying density, which effectively makes them 100% efficient. The original low temperature superconductors (LTS) were cooled to almost absolute zero, using liquid

[15] Insulated Gate Bipolar Transistor.

helium, while more recent high temperature superconductors (HTS) can operate at 77K, using much cheaper liquid nitrogen cooling. This now creates the potential to use HTS in:

- **Transmission cables** with low power loss, and increased current capacity that allow utilities to increase power in urban areas by using existing cable ducts.
- Efficient, light and compact **transformers** with lower life cycle costs, no dangerous materials and the ability to operate above rated power without degradation.
- **Superconducting fault current limiters** that protect against transient high currents (e.g. due to lightning) to improve grid safety, as there is no corresponding conventional device today.
- **Motors and generators** that are more efficient, smaller and lighter to provide energy savings.
- **Voltage regulation and power factor correction**.

Current applications of HTS technology in renewables include power factor regulation and early stage design of smaller fixed drive generators for wind turbines (saving on tower and foundation costs). More than 7% of the energy generated in the US is lost during transmission and distribution. The US Department of Energy estimates that half of this loss could be eliminated by the application of HTS. This saving could amount to $16 billion per year.

Companies active in the HTS space include Philips (via its SuperPower Inc/Intermagnetics subsidiary), American Superconductor, International Superconductor, Finetec Corp, Zenergy Power and Superconductive Components.

Voltage regulation

Many wind turbines use induction or asynchronous generators that draw reactive power[16] from the grid and this fluctuates with the output of the turbine. Uncompensated, these variations in reactive power cause voltage fluctuations that impact power quality, as well as grid reliability. Traditionally, switched capacitors are used to compensate, but with a typical wind farm easily experiencing 50-100 switching events/day, this can rapidly reduce capacitor life and capacitors often need several minutes before re-energisation is possible. In addition, some wind turbine generator gearboxes are sensitive to large step changes in voltage associated with normal capacitor switching, which can overstress the gearbox, which is already one of the most maintenance intensive components. Capacitor banks are the cheapest option, but these will not necessarily work where there is a weak grid or poor interconnection. In these instances, alternative solutions are required.

Keeping wind turbines online under low voltage conditions is also a problem, as transient voltage events that drop voltages below turbine tolerance levels can cause generators to trip offline. Most interconnection standards today require wind farms to have the ability to ride through faults that can be accomplished in the turbine or with a centralized solution at the wind substation.

[16] Pure reactive power occurs in inductive/capacitive circuits, which put voltage & current 90 degrees out of phase.

OFF GRID POWER

A large proportion of the world's population is not connected to an electricity grid. In these instances, power is typically provided by petrol or diesel generators. This is financially and environmentally costly, as a genset can easily cost US$1,500/kW, efficiencies are typically poor, and fuel transport costs are relatively high. Isolated communities have similar problems where they are at the end of the grid infrastructure and suffer a disproportionate number of brown outs and high transmission costs.

CARBON CAPTURE AND STORAGE (CCS)

In our view, CCS will be needed to achieve the GHG reductions necessary to stabilise the climate, as we do not believe renewable generation can replace enough of the existing generating plant in time. One option is to capture and store CO_2 from fossil fuel combustion. For now, CO_2 can already be removed from industrial facilities producing concentrated CO_2 streams that are vented to the atmosphere, such as natural gas treatment facilities, refineries, and ammonia plants. CO_2 can also be removed from power plants using several options:

- chemical adsorption
- fossil fuel combustion in an O2/ CO_2 atmosphere producing a flue gas mainly consisting of CO_2 that can be stored.
- conversion of fossil fuels into CO_2 and hydrogen using steam reformation or partial oxidation followed by a water-gas shift reaction. The CO_2 is separated from the hydrogen using membranes or absorption, with the hydrogen burnt in a power plant or purified to fuel cars or supply energy to the domestic sector.

CCS has an energy and cost penalty. In the case of a power plant, it can reduce CO_2 emissions by 90-100%, but at the expense of increasing primary energy consumption by 15-40% and electricity production costs by 30-100%. Capture, compression, transport, and storage of CO_2 are already used for many related applications. CO_2 can be stored in depleted oil and natural gas reservoirs, deep saline aquifers, and unmineable coal seams. The capacity of safe CO_2 storage underground is believed to be thousands of Gt of CO_2. In addition, it may be possible to store CO_2 in deep oceans, if the associated environmental concerns can be addressed. Early options for CO_2 storage include Enhanced Oil Recovery and Enhanced Coal Bed Methane production using CO_2. Currently, most attention is given to the potential, costs, impacts, reliability, and acceptance of underground CO_2 storage. In the US, there are ~70 CO_2 EOR operations underway which, in total, inject ~33 Mt of CO_2 annually.

Current cost estimates suggest that CCS will cost US$40-$55/ton of CO_2 captured. If this is an accurate estimate, CCS is economic if Vattenfall's €40/ton is the real clearing cost. In practice, a much higher price is probably needed to stimulate the long-term investment required in CCS, or the development of a market-based 10-year price curve: unlikely until a post-2012 Kyoto agreement occurs.

ACTUS ET POTENTIA

A range of technical and policy changes could significantly accelerate the deployment of renewables, beyond actual technology developments. Some of these include:

- Extend the life of all incentive schemes to give greater predictability, especially post 2012 Kyoto.
- Subsidies to competitive and polluting technologies are unproductive, distort markets and increase the need to support renewables. Removing subsidies to conventional electricity would save taxpayers' money and reduce current market distortions in the electricity market, while dramatically reducing the need for renewables support.
- Making power plant owners, especially utility shareholders, pay for the pollution caused would focus efforts on renewables, rather than allowing the carbon cost to be passed straight through to customers.
- Introduce real net metering for all small scale generation, not just a two way metre (payback domestic 7-21 years if 4p to 12p).
- Continue improvements in wind prediction techniques and modelling, to reduce the level of variability.
- Simplify planning permission and grid access for all renewables, with transparent pricing incentives for embedded generation. Current energy legislation on planning, certification and grid access assumes the existence of large centralised power plants and represents a significant market barrier to renewables.

UNEXPECTED CONSEQUENCES

Assuming some degree of climate change, some unexpected consequences are likely. Those that we have identified include:

- If average humidity increases due to warmer air, its average density falls (water has a lower molecular mass than air and warmer air is less dense), then the average output from a wind turbine will fall, since power is proportional to air density.
- If average sea levels rise, what does this mean for:
    - access to offshore wind turbines;
    - shore-based wave power generators (i.e. oscillating water column designs); and
    - nuclear power plants that are located next to the sea?
- If the hydrogen economy creates home based generation (i.e. your fuel cell powered car runs the power for the home at night or the office during the day), what happens to peaking power?
- Does the emergence of plug in hybrids (currently only via hacked Prius) change the demand for power and oil?

- A more unpredictable climate, means less land can be depended on to be productive (as in Australia at the moment) and this may create issues for biomass and biofuels.
- Hydro plants that depend on spring melt or glacier run-off could be impacted if average temperatures rise: short term this would increase flow rates, but long term it could reduce flow rates substantially.

LIFE CYCLE ANALYSIS

Throughout this report, we have considered the emissions resulting from the direct operation of a particular technology. We expect this to remain the main comparator between technologies, as these emissions are easily measured and provide a robust figure. However, all energy systems emit GHGs and contribute to anthropogenic climate change when measured over the full life cycle of the technology and its fuel. Therefore, we expect policy makers to consider life cycle emissions when framing incentives, but consider it unlikely that anything other than direct emissions will be affected in a carbon constrained world. Our analysis shows that the most significant GHG avoidance (in absolute terms) is made by technology substitution.

Terminology

In this report, the GHG emissions from the entire life-cycle of a technology are *cumulative emissions* or its life cycle analysis (LCA) emissions. Emissions during power generation are *direct emissions*. All processes and associated emissions other than direct emissions are *upstream* (fuel exploration, mining, transport etc) or *downstream* (decommissioning, waste management and disposal etc) emissions. However, different studies apply different boundaries to the energy chain and this can cause substantial variation in the data.

The LCA process

Analysing up- and downstream GHG emissions, which occur outside a plant's direct emissions, is important; otherwise, the GHG emissions of the various fuel options are underestimated. For fossil fuels, upstream GHG emission rates can be up to 25% of the direct emissions, while most renewable power and nuclear plant GHG upstream emissions account for over 90% of cumulative emissions. Typically, LCA accounts for GHG emissions from:

- energy resource exploration, extraction and processing;
- raw material extraction for technology and infrastructure;
- production of infrastructure and fuels;
- production and construction of technology;
- transport of fuel and other activity (e.g. during construction, decommissioning);
- conversion to electricity or heat or mechanical energy (heat rate); and,
- waste management and infrastructure (i.e. radioactive waste depositories, ash disposal etc).

In this report, we have focused on GHGs, although in practice a full LCA also includes other categories that can have a material impact on the deployment rate for a technology. These factors may include:

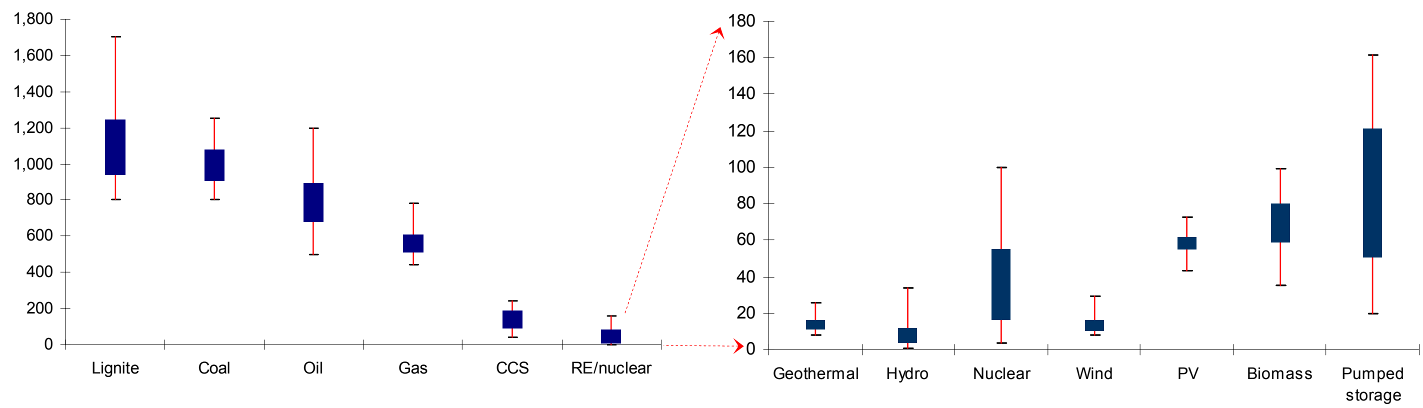
- stratospheric ozone depletion;
- acidification or eutrophication;
- photochemical smog;

- terrestrial or aquatic toxicity;
- human health; and,
- resource depletion and land use.

In contrast to fossil fuel technologies, most GHG emissions from renewables occur upstream of the plant in the construction of the technology, although biomass does have emissions due to the fuel-cycle. Figure 64 summarises the results for different studies.

LCA gives a wide range of results and is, at best, an imprecise science. However, the results clearly show that whatever methodology is used, renewable energy (and nuclear power) all have substantially lower GHG emissions than any hydro-carbon fuel, even compared to the, as yet unproven, Carbon Capture and Storage.

Figure 64: Summary of LCA power plant emissions – kg CO_2e / MWh – min/max and standard deviation



Source: Weiser (Energy 2007) and Fthenakis and Kim (Energy 2006)

LCA weaknesses

The LCA we considered gave widely varying results. We highlight some inconsistencies by technology, although the reasons common to all, are:

- different methodologies (economic input/output or process chain analysis);
- the need for subjective judgments (where is the boundary for construction and decommissioning, or technology life, load factor influences efficiency etc);
- the existing generating mix; and
- unreliable data for rapidly developing technologies (i.e. the per MWh steel and concrete content of modern large wind turbines is far less than smaller, older models).

Other issues that could impact the policy-making process include:

- Technology options may not be true alternatives, since services provided by some energy technologies such as irrigation and flood control, reliability of supply, voltage control and regulation, operating reserve, load-following and system black-start capability are not available with every technology.

- Significant upstream emissions may occur beyond the borders of many national GHG programmes, meaning that power generated in one country may cause GHG releases in another. Clearly, this could be an advantage for technologies with a relatively high proportion of upstream emissions, if these can be produced in an economy without carbon constraints or with lower carbon costs.
- All the LCA ignores the benefits of embedded generation. Many renewable energy technologies are viable on a relatively small scale that often generates power close to the demand. This means transmission losses are reduced, compared to large centralised power plants (nuclear or coal), typically built away from centres of population. Transmission losses can range from 1-7% of the power produced.

Nuclear

We include a brief analysis of nuclear power, as this is often wrapped in with renewables as a route to reducing GHG. However, the data are highly subjective and emissions vary widely on a LCA basis from 3.5-100kg CO_{2e}/MWh, mainly due to assumptions on enrichment, production and operation (centrifugal enrichment in Sweden uses far less power than gaseous diffusion enrichment in the US, with Sweden using hydro power and the US mainly coal fired). The industry is generally moving away from gaseous diffusion and starting to look at laser enrichment to reduce costs further. However, even greater uncertainty occurs with assumptions on decommissioning, where no actual data exist yet.

A recent report[17] also showed that uranium ore of 0.01% or lower could be valueless from a LCA perspective, although this ignores possible improvements in mining/milling efficiency, or an increase in price leading to increased exploration that delays the need to mine low-grade ores.

Photovoltaics

GHG emissions for PV on a LCA basis are 43-73 kg CO_2e/MWh. Four systems are usually included: mono-crystalline, multicrystalline, amorphous and CIGS. Unsurprisingly, most GHG emissions occur upstream and during cell production (50-80%). Other material GHG releases occur with the balance-of-plant and the inverter.

Of the four technologies, mono-crystalline plants appear to emit the least GHGs (43-62 kg CO_{2e} /MWh) and the other technologies emit 50-73 kg CO_{2e}/MWh, which reflects the differences in efficiency. The breadth of results comes from variations in lifetime assumptions (lower for amorphous), limited data (CIGS) and different insolation / installation assumptions. GHG emissions are likely to reduce as conversion efficiencies are rising, although new polysilicon production methods may increase the energy used in production.

Wind

Around 72-90% of cumulative emissions for a wind farm occur when the turbine is made and the farm is built. The remainder occurs during O&M, decommissioning and equipment transport. The main variance depends on assumptions on foundations and turbine size: offshore turbines use more steel and cement than on-shore (i.e. more GHGs) but should offer better capacity factors.

---

[17] Storm van Leeuwen and Smith (2005)

Wind farm LCA is very site specific and sensitive to capacity factor assumptions, due to the cubic relationship of wind speed to power. Since wind regimes vary significantly, even within a locality, this causes major discrepancies between studies. Turbine technology is also improving rapidly, which limits the relevance of many studies and the larger a turbine – given similar wind conditions – the lower the life-cycle GHGs. Lifetime assumptions are also significant and relatively thin on real data, with studies ignoring the recent practice of repowering wind farms after a few years, while often keeping the same foundations and towers.

Hydro

Most GHG emissions occur during plant construction (especially for reservoir dams). In the studies reviewed, construction emissions are 2-9kg CO_{2e}/MWh. However, hydro power plants that use reservoirs can emit significant quantities of GHGs due to land-clearance before construction, or flooding that produces CO_2 and methane as the sub-surface biomass decays. These releases vary considerably depending on the specific characteristics and cover a wide range of 0.35-30kg CO_{2e}/MWh. Overall, the life-cycle GHG emissions for the assessed cases ranged from 1-34 kg CO_{2e}/MWh, depending on the type of plant (run-of-river or reservoir), its size and usage (eg pumped hydro), as well as the electricity mix (and hence emissions) used for its operation. The studies also tend to ignore the common practice of repowering hydro plants or adapting existing infrastructure (such as irrigation dams) to produce hydro power.

Biomass

Life-cycle GHG emissions from biomass power depend primarily on the fuel used and the generating plant's thermal efficiency. GHG emissions range from 35-99 g CO_{2e} /kWh. Most emissions occur at the fuel-cycle stage, while GHG emissions during the other stages of the life-cycle are negligible. Biogenic GHG emissions (emissions due to the combustion of biofuel) are excluded, since they are assumed to be carbon neutral, as the CO_2 released during combustion was recently absorbed during (fuel) plant growth. Life-cycle emissions for biomass systems vary substantially depending on the combustion efficiency, power rate and the type of feed.

POLICY IMPLICATIONS

Most policy makers cover GHG emissions by focusing on large-scale stationary point-sources. This risks missing significant up- and downstream emissions. However, accurate calculation of GHG emissions per MWh is difficult across the whole life cycle and, in a free power market, we expect regulations to fall on direct emissions that are readily measured and controlled.

There appears to be substantial academic interest in the idea of LCA, and in a perfect world, all emissions should be accounted for on an LCA basis. However, there is a risk of double counting if all industry operates on a carbon constrained basis – does a coal miner account for its GHGs or does the end customer account for them in its upstream analysis? As a result, we believe LCA is useful for broad policy guidance and as a factor in creating a generating portfolio. However, there is such a range of results that we think it is unlikely that LCA will be used for selecting between technologies, other than the obvious renewables versus conventional decision.

APPENDIX 1 - RENEWABLES 101

In this section we run through some of the basic renewable energy concepts and issues facing each technology. We consider four issues common to all technologies that form a core component in project development:

1. the resource assessment;
2. the grid connection;
3. permitting; and
4. the capacity factor.

Resource assessment

The resource assessment is one of the most important steps in the development phase of a project. Robust data are needed to ensure that, once built, a project can generate sufficient power to be economic. For wind and hydro power, this involves measuring flow rates at the site for at least 12-months, if not longer, to span more than one full set of seasonal variation. This data are then correlated with historic data from nearby sites, such as airports or hydrological stations, and adjusted for local topography to give a long-term mean output.

Wind farms typically need to set up several anemometres at the site, often at different heights to gather sufficient data. Ideally, these are located in the same place as the turbines will go. This is an expensive process, as it requires a cash cost early on in the development cycle and there is a risk of skimping on the research. Several correlation methods exist for the data and the longer the data can be gathered, the more accurate the result. Therefore, building out existing operating sites is one of the most effective ways of adding new capacity.

Once the resource is established, the challenge is to harness the energy and convert it into electricity.

Grid connection

A major potential cost for renewable power is the grid connection. Developers usually have to pay the cost of connecting to the grid and running the wires from the plant to the grid. While running an (overhead) cable is relatively straightforward, projects are usually sited near the grid to minimise the cost, and reduce the chances of subsequent problems and the level of transmission loss.

While agreeing a grid connection is relatively straightforward, the challenge occurs in grid-constrained locations, or where a major upgrade is required to the existing grid. However, grid connections are a function of cost.

Permitting

One of the major challenges facing any power project is the permitting process. With relatively small power projects, permitting costs can form a large proportion of the development cost. Careful siting, good local research and an active PR process can reduce the risk, while rural areas are often keen to attract projects due to the impact on the local economy. This remains a challenging area for investors to assess objectively, as government officials are usually involved and unable to offer objective advice.

Capacity factor, efficiency and availability

The capacity factor is an important statistic used to assess the economic viability of a power plant, as it gives a quick measure of the amount of saleable electricity that can be produced. It is often confused with availability and efficiency.

A conventional power plant uses fuel, so it normally runs most of the time, unless it is idled by equipment problems or for maintenance. This typically gives capacity factors of 40-80%. Wind turbines generate electricity for approximately 80% of the year, biomass for up to 95% and a small hydro from 40-99%, although not necessarily at full output, which means for a wind turbine, an *annual* capacity factor of 25-40% is common.

In fact, no energy technology can be relied on 100% of the time and all power plants are unavailable at times, whether for routine maintenance or unexpected reasons, such as component failure or lightning striking a power line. An availability figure measures the proportion of a year for which a turbine is available to generate.

It is important to note that, while capacity factor is almost entirely a matter of reliability for a fuelled power plant, it is not for a wind/wave/hydro plant, where it is a matter of economics. A wind turbine with a very large rotor and a very small generator could run at full capacity whenever the wind blew, giving a 60-80% capacity factor, but it would produce very little power. The most power per investment dollar is achieved with a larger generator and accepting that the capacity factor will be lower as a result. Renewable power plants are fundamentally different from fuelled power plants in this respect.

The capacity factor measures the average saleable power over a year compared to the maximum theoretical generation if the plant operated at full capacity for the entire year. It includes an allowance for availability (i.e. can the plant run) and the available resource (i.e. how much power can be extracted when it is running).

$$Capacity\_factor = \frac{MWh\_produced}{Capacity(MW) \times 8760} \times 100\%$$

Capacity factors vary by technology and site. Efficiency is different to capacity factor and measures the amount of potential fuel energy that is converted to electrical energy. In gas-fired plants, this is related to the heat rate and can be up to 54%. A hydro power site often runs at 90+%, a wind turbine has a maximum theoretical efficiency of 56%, and biomass often runs at 25-30%.

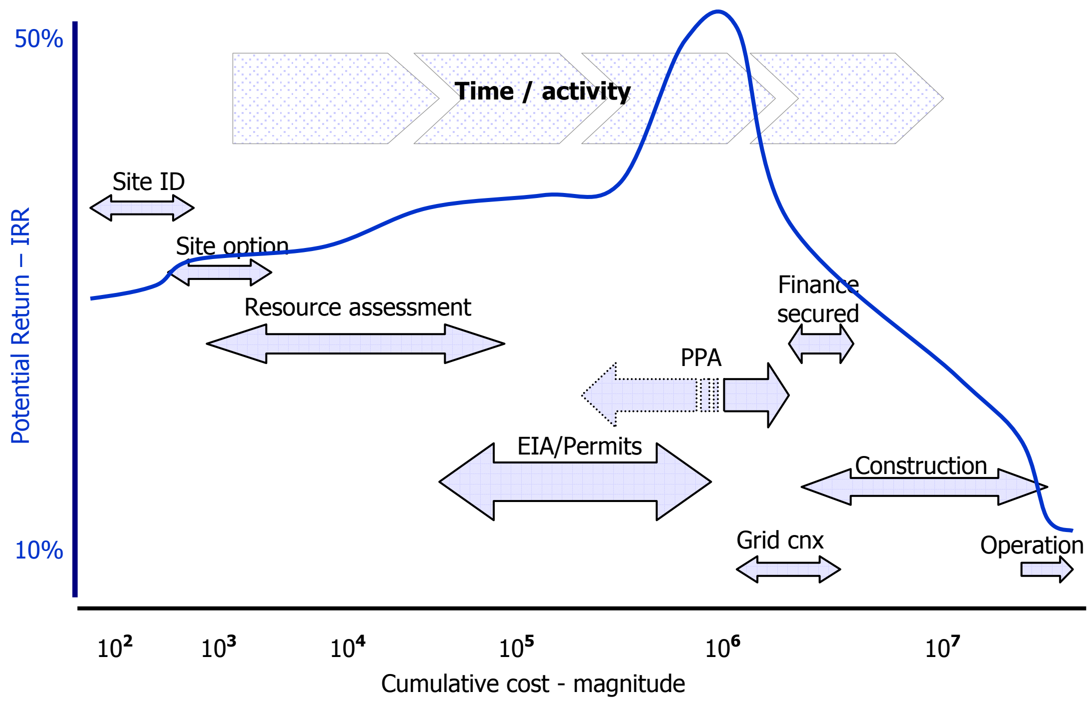
Carbon dioxide equivalence

CO_{2e} is an internationally accepted measure that expresses the amount of global warming of GHGs in terms of the amount of carbon dioxide (CO_2) that would have the same global warming potential. The CO_{2e} compares the emissions from various GHG based upon the amount of CO_2 that would have the same global warming potential measured over a specified timescale (generally 100 years) for emissions. In this report, we use CO_{2e} and carbon interchangeably.

Development process

The following diagram shows a simplified development process and the key activities required. The best developers tend to operate a large project pipeline, as substantial drop out rates occur and project timings often shift unexpectedly (forwards and backwards). The process calls for a careful allocation of resources in terms of manpower and cash, in order to ensure a consistent stream of construction-ready projects. Typically, the greatest uncertainty occurs around the permitting process and PPA, as these depend on third parties – often government approvals. With most renewable energy projects being relatively small compared to conventional plants, the developer can tolerate a lower failure rate, as the costs of unsuccessful projects are spread over a smaller asset base.

Figure 65: Development process



Source: Canaccord Adams

INVESTMENT RISKS

There are numerous investment risks facing the sector. We have identified some of the main ones investors should consider during portfolio construction:

- Many technologies are still immature and there are several paths to success.
- Standards are still in development; there is significant misinformation in the market, which affects decisions and regulatory requirements.
- Infrastructure needs further development to cope with intermittent power. It is unclear when this might occur.
- Most renewable power plants benefit from some form of government incentive. In our view, there is little risk of these being removed, although we believe there is a chance of the emphasis changing, to focus on lower carbon solutions or solutions nearer to commercialisation. In reality, the impact of a subsidy reduction is more likely to be on growth rates, rather than to a go/no go basis.

- There are pre-commercial advanced solar technologies that may reduce the cost of solar energy, such as concentrating solar photovoltaic (CPV) and parabolic dish engines. We assume advances in CPV will not make that technology competitive with conventional solar parabolic trough technologies for utility scale applications. However, there does appear to be potential for dish engine technologies to become competitive with solar trough technology.
- Advances are expected in wind and solar technologies, resulting in lower costs and higher capacity factors. However, there is a risk that such advancement may be delayed or not realized. When technology advances are delayed, wind and solar thermal projects may have lower capacity factors and increase levelised costs, which in turn makes other technologies (biomass and geothermal) comparatively more attractive.
- Capital costs have recently increased faster than general inflation, due to a tight market for materials and labour. As this applies across all industries, we believe it may slow down all new build, but won't change the relative attraction of renewables compared to conventional generation.
- Manufacturing and supply chain constraints are likely to impacted solar and wind, due to their rapid growth and changing technology. If these increase, capacity may be delayed and costs reduce more slowly as a result.
- In the near-term, projects may under-deliver renewable energy as they gain experience during the initial operational and development learning period. Projects may also fail outright, and not supply any renewable energy. If lower-priced projects fail, utilities will be forced to contract with more expensive renewable projects and it also risks sending the wrong message to policy makers or the media that occasionally seem to have naïve expectations on the roll out of a new technology.
- Oil and energy prices impact the relative attraction of renewables. If oil prices were to substantially fall, then we believe the deployment rate for renewables would slow down, although wider energy security and climate change issues are likely to ensure a core demand remains.

VALUATIONS AND INVESTMENT RISKS

Arise Technologies Corporation (APV : TSX V: C$2.71 | BUY, C$3.75 target price)

Our target price is based on our DCF model (18% discount rate; 3.5% terminal growth rate). On a P/E basis, our target price equates to 15 times our 2009 EPS estimate. Key risks include, but are not limited to: technology risk, expansion and manufacturing risk, silicon supply (price and volume), government policy risk, FX risk, dependence on key personnel, financing risk and competition.

Canadian Hydro Developers (KHD : TSX: C$6.6 | BUY, C$7.01 target price)

To derive our target price, we value the operating assets using a DCF with a 9.5% discount rate and add a probability-weighted development portfolio DCF. Risks associated with the share price achieving our target price and our forecasts include delays in securing permits, variability of wind and water resources, plus uncertainty over the development of early stage projects.

QuestAir (QAR : TSX : C$0.42 | BUY, C$1.90 target price)

We value QuestAir using a 10-year DCF and terminal growth rate of 3%, with a WACC of 15.2%. Risks associated with the company achieving our target price and rating include the inherent uncertainty of any early stage company, where operating results are hard to predict, and reliance on strategic partners to leverage resources and provide access to key markets is uncertain.

EMCORE (EMKR : NASDAQ : US$8.86 | BUY, US$12.50 target price)

We derive our target price using a sum-of-the-parts analysis. Risks to the company meeting our target price include: 1) typical end market cyclicality caused by supply and demand issues, which could adversely affect revenues and gross margins; 2) order push-outs or cancellations; and 3) technological innovation that could result in obsolescence and cause loss of market share. In addition to the general risks, company-specific risks include: a relatively high concentration of revenue from Motorola and an inconsistent record of profitability (the company is currently unprofitable).

Environmental Power (EPG : AMEX : US$4.38 | BUY, US$8.00 target price)

We apply a 14x EV/EBITDA premium multiple on our base-year 2011E EBITDA of $19 million (assuming $136 million in debt) and discounting the product back three years by 15% (above the estimated WACC of 11%) to derive our US$8.00 price target. Risks associated with the company meeting our target price include, EPG has had no previous experience of operating a large-scale biogas producing facility. Although anaerobic digestion technology used by EPG has been successfully tested in Europe, it was applied on a smaller basis and was sold as capital equipment versus a long-term service. The company is a speculative investment, in our opinion. EPG’s overall size, stage of its current cash flow profile generating ability and recent management turnover are risks, in our opinion. In particular, availability and price of substrate as a main component in the anaerobic digestion requires stable "tipping fees" to offset transportation costs. The company's BOO model is highly capital intensive and usually has a lumpy pattern for project developers, with unexpected delays.

Figure 66: Companies mentioned in the report

Stock	Ticker	Exchange	Recommendation	Share Price
ARISE Technologies	APV	TSX-V	BUY	C$2.35
Alter NRG	NRG	TSX	NR	C$2.00
American Superconductor	AMSC	NASDAQ	NR	US$24.93
American Standard Companies Inc	ASD	NYSE	NR	US$36.17
Archea Biogas NV	3AB	F	NR	€0.29
Biogas Nord	BG8	F	NR	€19.59
Boralex	BLX	TSX	NR	C$16.82
Borevind	BORE	SS	NR	SEK13.00
Canadian Hydro Developers	KHD	TSX	BUY	C$6.55
Carmanah Technologies	CMH	TSX	HOLD	C$1.23
Carrier Corporation	UTX	NYSE	NR	US$73.99
Clipper Wind	CWP	AIM	NR	627p
EMCORE	EMKR	NASDAQ	BUY	US$8.59
Environmental Power	EPG	AMEX	BUY	US$4.33
Finetec Corp	033500	KS	NR	KRW15500
Geodynamics	GDY	AU	NR	AS$1.83
Goodman Global Holdings Inc	GGL	NYSE	NR	US$23.88
Graham Corp	GHM	AMEX	NR	US$58.88
Hanwei Energy Services	HE	TSX	BUY	C$5.11
ITM	ITM	LSE	NR	105p
International Superconductor	PATS	NYSE	NR	NA
Johnson Controls Inc	JCI	NYSE	NR	US$38.52
LSB Industries	LXU	AMEX	NR	US$22.44
Lennox International Inc	LII	NYSE	NR	US$35.77
Nabors	NBR	NYSE	NR	US$27.65
Nibe Industrier	NIBE-B	SS	NR	SEK61.0
Novera Energy	NVE	LSE	NR	64.5p
Ormat	ORA	NYSE	NR	US$49.08
Perfect Energy	PFEN	NASDAQ	NR	US$1.79
PNOC	EDC	PM	NR	PHP7.20
Plutonic Power	PCC	TSX	NR	C$8.73
Q-Cells	QCE	DE	NR	€86.20
QuestAir	QAR	TSX	BUY	C$0.48
Renewable Energy Corp	REC	NO	NR	Nkr261.00
Run of River Power	ROR	TSX-V	NR	C$0.44
Schmack Biogas	SB1	F	NR	€24.08
Superconductive Components	SCCI	OB	NR	US$5.75
Thenergo NV	ALTHE	FP	NR	€8.49
Theolia	TEO	FP	NR	€21.40
Vestas	VWS	DC	NR	DKK446
WFI Industries	WFI	TSX	HOLD	C$28.86
Xantrex Technology	XTX	TSX	NR	C$10.07
Zenergy Power	ZEN	LSE	NR	288p
Zoltek	ZOLT	NASDAQ	NR	US$37.16

NR = not rated.
Source: Bloomberg, Canaccord Adams estimates. Share price data COB 15 November 2007

ENERGY READY RECKONER - APPENDIX II

Figure 67: Energy ready reckoner

Energy consumption	
Annual US energy consumption	~100 quads
Annual US electrical production	~40 quads
Daily US petroleum demand	~21M bbl
Daily global petroleum demand	~84M bbl

Resource base	
Total US energy resource base =	0.65M bboe
	3.8M quads
US resource base made up of:	
Geothermal	258,000 bboe
Solar (PV & biomass)	178,000 bboe
Wind	177,000 bboe
Shale oil	27,000 bboe
Coal	15,000 bboe
Petroleum	480 bboe
Natural gas	294 bboe
Uranium	203 bboe
Hydropower	170 bboe

Conversion factors	
One quad =	170M boe
	45M tons coal
	1 tcf natural gas
	288 TWh
	10^15 BTU
	1.06 EJ
One MWh =	0.59 boe
	34.7 M BTU

Emissions	
US CO2 emissions (2005)	5945Mt
Global warming potential	
CO2	1
Methane (CH4)	21
Nitrous oxide	310
Sulphur hexafluoride	23,900
HFC	650-11,700
PFC	6,500-9,200

Source: EWEA, EIA, EPRI, AEP, Canaccord Adams estimates

GLOSSARY - APPENDIX III

Autogeneration	Generation of electricity by companies for their own use, where their main business is not power generation.
Baseload Capacity	The power output that generating equipment could continuously produce.
Baseload Demand	The minimum demand experienced by an electric utility, usually around 30 ~ 40% of the peak demand.
Baseload Plant	The generating plant normally operated to meet requirements for energy on a round-the-clock basis.
Carbon Cycle	The process of removal and uptake of carbon on a global scale. This involves components in food chains, in the atmosphere as carbon dioxide, in the hydrosphere and in the geosphere. The major movement of carbon results from photosynthesis and respiration.
Carbon dioxide (CO_2)	A colourless, odourless, incombustible gas present in the atmosphere and formed during the decomposition of organic compounds e.g. burning of fossil fuels.
Carbon monoxide (CO)	A colourless and poisonous gas, produced by incomplete burning of carbon-based fuels, or many natural and synthetic products.
Carbon Sink	A pool (reservoir) that absorbs or takes up released carbon from another part of the carbon cycle. For example, if the net exchange between the biosphere and the atmosphere is towards the atmosphere, the biosphere is the source, and the atmosphere is the sink.
Chlorofluorocarbons (CFCs)	Synthetically produced compounds containing varying amounts of chlorine, fluorine and carbon. Used in industrial processes, refrigeration and as a propellant for gases and sprays. In the atmosphere they are responsible for the depletion of ozone and can destroy as many as 10,000 molecules of ozone in their long lifetime. Their use is now currently restricted under the Montreal Protocol.
Climate Change	The long-term fluctuations in temperature, precipitation, wind, and all other aspects of the Earth's climate which is attributed directly or indirectly to human activity.
Combined Cycle Gas Turbine Plant	Power plant which combines gas and steam turbines in the same operation. The gas turbine produces mechanical power to drive the generator and heat in the form of hot exhaust gases that are fed to a boiler, where steam is raised to drive a conventional steam turbine also connected to the generator. Uses gas as the primary fuel with heat recovered from the turbine exhaust utilised in a steam turbine.
Combined Heat and Power	Simultaneous generation of usable heat and electrical power in a single process. A generating facility that produces electricity and another form of useful thermal energy (such as heat or steam) used for industrial, commercial, heating, or cooling purposes.
Computational Fluid Dynamics (CFD)	CFD is the broad topic encompassing the numerical solution, by computational methods, of the governing equations which describe fluid flow, the set of the Navier-Stokes equations, continuity and any additional conservation equations, for example energy or species concentrations.
Conventional Thermal Power Station	Power station generating electricity by burning fossil fuel to produce heat to convert water into steam, which then powers steam turbine.
Declared Net Capacity	The maximum power available from generating a station on a continuous basis less any power from the network used to run the station.
Demand	The country's requirement for power.
Demand-Side Management	The planning, implementation, and monitoring of activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand.
Density	The mass per unit volume (kg/m3) of a substance under specified conditions of pressure and temperature.
Distributed Generation	Generation by a plant connected to a distribution system rather than to a transmission system.
Distribution System	The local wires, transformers, substations and other equipment used to distribute and deliver energy to end-use consumers.
Energy	A measure of the amount of 'work' that can be done by, or is needed to operate, an energy conversion system, sometimes measured in 'joules' (J) or 'kilowatt hours' (kWh).
Embedded generation	Generation that is connected to the local (distribution) grid, rather than the national (transmission) grid. This locates supply closer to demand, which reduces transmission losses and can make the grid more robust.
Emissions Trading	A system that would allow countries that have committed to targets to "buy" or "sell" emissions permits among themselves as detailed by the Kyoto Protocol. It provides participating parties with the opportunity to reduce emissions where it is most cost-effective to do so.
Environmental Impact Assessment (EIA)	A process for identifying the potential impacts of development and communication of these to the competent authority prior to a decision being made on development.
EPC	Equip, procure & construct. A contract for the delivery of a major construction project that specifies the results and not necessarily the process.
Fossil Fuel	A collective term for coal, petroleum and natural gas, which are used for energy production through combustion. They are called fossil fuels because they are made of fossilized, carbon-rich plant and animal remains. These remains were buried in sediments millions of years ago and, over geological time, have been converted to their current state. Fossil fuels can be extracted from the sediments by humans millions of years after their deposition and their stored energy can be used as fuel when it is burned.
Gigawatt (GW)	A unit of power equal to 1 billion watts; 1 million kilowatts, or 1,000 megawatts.
Gigawatt-hour (GWhr)	A unit of energy equal to million kilowatt-hours. 1 GWhr is equivalent to the total electricity typically used by

	250 homes in one year. Equal to 1000 megawatt-hours.
Global Warming	Strictly speaking, the natural warming and cooling trends that the Earth has experienced through its history. However, the term global warming has become popularized as the term that encompasses all aspects of the global warming problem, including the potential climate changes that will be brought about by an increase in global temperatures.
Global Warming Potential (GWP)	The concept has been developed to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas.
Greenhouse Effect	Warming of the atmosphere due to the reduction in outgoing solar radiation caused by greenhouse gases.
Greenhouse Gases (GHGs)	Carbon dioxide (CO_2), methane (CH4), nitrous oxide (N2O), perfluorocarbons (PFCs), sulphur hexafluoride (SF6) and hydrofluorocarbons (HFCs). These gases absorb the earth's radiation and warm the atmosphere. Some greenhouse gases occur naturally but are also produced by human activities, particularly the burning of fossil fuels. When greenhouse gases build up in the atmosphere, they have an impact on climate and weather patterns. They are usually measured in carbon dioxide equivalents.
Grid Supply Point	A point of supply from the national transmission system to the local system of the distribution network operator.
Hydro-Electric Power Plant	A plant that uses natural water flows to turn turbines.
Hydro-Electric Pumped Storage	A plant generating electricity during peak loads by using water previously pumped into an elevated storage reservoir during off-peak periods when excess generating capacity is available to do so.
Hydroflurocarbon (HFC)	A compound consisting of hydrogen, fluorine and carbon, which is used as a replacement for CFCs. Because the compound does not contain chlorine or bromine, it does not deplete the ozone layer and has an ODP of 0. Some HFCs have a high GWP.
Installed Capacity	The total capacity of generation units installed at a power station.
Interconnector	A connection or link between power systems that enables them to draw on each other's reserve capacity in time of need.
Intergovernmental Panel on Climate Change (IPCC)	Established in 1988 by the World Meteorological Organization and the United Nations Environment Program (UNEP), the IPCC is the authoritative international body charged with studying climate change. The IPCC surveys the worldwide technical and scientific literature on climate change and publishes assessment reports. Its widely quoted 1995 report found that "the balance of evidence suggests that there is a discernible human influence on global climate."
Joint Implementation (JI)	The concept that, through the Framework Convention on Climate Change, a developed country is involved in emissions projects that result in a real, measurable and long-term reduction in net greenhouse gas emissions in a developing country.
Kilowatt (kW)	A standard unit of electrical power equal to 1000 watts, or to the energy consumption at a rate of 1000 joules per second.
Kilowatt-hour (kWhr)	A unit of energy. A typical home uses around 3,300 kWh of electricity per year.
Kinetic Energy	The energy possessed by a body because of its motion, equal to one half the mass of the body times the square of its speed.
Kyoto Protocol	Legally binding agreement between developed countries to reduce emissions of six greenhouse gases to tackle the threat of climate change.
Load (Electric)	The amount of electric power delivered or required at any specific point or points on an electric system. The requirement originates at the energy-consuming equipment of the consumer.
Load Factor	The ratio of the actual energy output of a generating plant to the maximum possible energy output over a time period.
Megatonne of Carbon (MtC)	One million tonnes of carbon. Emissions of carbon dioxide are often expressed in terms of their carbon content. 1 MtC is equivalent to 3.67 million tonnes of carbon dioxide.
Megawatt (MW)	Standard measure of generating plant capacity equal to one thousand kilowatts, or one million watts. Medium to large power stations have capacity typically in the range of 500-2,000MW.
Megawatt Hour (MWhr)	A unit of energy. Used to measure usable or "active" power. Equal to 1000 kilowatt-hours.
Mitigation	The term used to cover measures that seek to avoid, reduce or delay global warming by reducing those emissions of atmospheric gases that are of human origin or within human control
Peak demand	The highest level of demand recorded on the transmission system.
Power	The rate at which energy is produced or consumed.
PPA	Power purchase agreement – a (typically) long term contract to buy power.
PV	Photovoltaic – the use of semi-conductor material to produce electricity
Registered Capacity	Full load capability of a generating unit as declared by the generator, less the energy consumed through the unit transformer.
Renewable Energy	Energy derived from resources that are regenerative. This includes solar power, wind, wave and tide and hydroelectricity. Wood, straw and waste are often called solid renewable energy, while landfill gas and sewage gas can be described as gaseous renewable.
Sinks	Natural systems such as forests and wetlands that absorb and store greenhouse gases.
Turbine	Any of various machines in which the kinetic energy of a moving fluid is converted to mechanical power by the impulse or reaction of the fluid with a series of blades arrayed about the circumference of a wheel or cylinder.

NOTES

NOTES

CANACCORD Adams

NOTES

APPENDIX: IMPORTANT DISCLOSURES

Analyst Certification: Each authoring analyst of Canaccord Adams whose name appears on the front page of this investment research hereby certifies that (i) the recommendations and opinions expressed in this investment research accurately reflect the authoring analyst's personal, independent and objective views about any and all of the designated investments or relevant issuers discussed herein that are within such authoring analyst's coverage universe and (ii) no part of the authoring analyst's compensation was, is, or will be, directly or indirectly, related to the specific recommendations or views expressed by the authoring analyst in the investment research.

Price Chart:* In order to obtain these (6 or more) stock price charts or additional applicable disclosures and information concerning Canaccord Capital's recommendations of companies under coverage mentioned in this report, please contact Canaccord Capital at 1-800-382-9280 or visit www.canaccord.com.

* Price charts assume event 1 indicates initiation of coverage or the beginning of the measurement period.

Distribution of Ratings:
Global Stock Ratings
(as of 1 November 2007)

	Coverage Universe		IB Clients
Rating	#	%	%
Buy	301	57.6%	42.5%
Speculative Buy	55	10.5%	69.1%
Hold	149	28.5%	30.9%
Sell	18	3.4%	5.6%
	523	100.0%	

Canaccord Ratings System:

BUY: The stock is expected to generate risk-adjusted returns of over 10% during the next 12 months.
HOLD: The stock is expected to generate risk-adjusted returns of 0-10% during the next 12 months.
SELL: The stock is expected to generate negative risk-adjusted returns during the next 12 months.
NOT RATED: Canaccord Adams does not provide research coverage of the relevant issuer.

"Risk-adjusted return" refers to the expected return in relation to the amount of risk associated with the designated investment or the relevant issuer.

Risk Qualifier: SPECULATIVE: Stocks bear significantly higher risk that typically cannot be valued by normal fundamental criteria. Investments in the stock may result in material loss.

Canaccord Adams is the business name used by certain subsidiaries of Canaccord Capital Inc., including Canaccord Adams Inc., Canaccord Adams Limited, and Canaccord Adams, a division of Canaccord Capital Corporation. Clients of Canaccord Adams, in the past 12 months, may have been clients of Canaccord Capital Corporation, Canaccord Capital (Europe) Limited, Canaccord Capital Corporation USA Inc., and/or Adams Harkness Financial Group Ltd.

The authoring analysts who are responsible for the preparation of this investment research are employed by Canaccord Adams, a securities broker-dealer with principal offices located in Vancouver, Calgary, Toronto, Montreal (all Canada), Boston, New York, San Francisco (all US) and London (UK).

In the event that this is compendium investment research (covering six or more relevant issuers), Canaccord Adams and its affiliated companies may choose to provide specific disclosures of the subject companies by reference, as well as its policies and procedures regarding the dissemination of investment research. To access this material or for more information, please send a request to Canaccord Adams Research, Attn: Disclosures, P.O. Box 10337 Pacific Centre, 2200-609 Granville Street, Vancouver, BC, Canada V7Y 1H2 or disclosures@canaccordadams.com.

The authoring analysts who are responsible for the preparation of this investment research have received (or will receive) compensation based upon (among other factors) the Corporate Finance/Investment Banking revenues and general profits of Canaccord Adams. However, such authoring analysts have not received, and will not receive, compensation that is directly based upon or linked to one or more specific Corporate Finance/Investment Banking activities, or to recommendations contained in the investment research.

Canaccord Adams and its affiliated companies may have a Corporate Finance/Investment Banking or other relationship with the company that is the subject of this investment research and may trade in any of the designated investments mentioned herein either for their own account or the accounts of their customers, in good faith or in the normal course of market making. Accordingly, Canaccord Adams or their affiliated companies, principals or employees (other than the authoring analyst(s) who prepared this investment research) may at any time have a long or short position in any such designated investments, Related designated investments or in options, futures or other derivative instruments based thereon.

Some regulators require that a firm must establish, implement and make available a policy for managing conflicts of interest arising as a result of publication or distribution of investment research. This investment research has been prepared in accordance with Canaccord Adams' policy on managing conflicts of interest, and information barriers or firewalls have been used where appropriate. Canaccord Adams' policy is available upon request.

The information contained in this investment research has been compiled by Canaccord Adams from sources believed to be reliable, but (with the exception of the information about Canaccord Adams) no representation or warranty, express or implied, is made by Canaccord Adams, its affiliated companies or any other person as to its fairness, accuracy, completeness or correctness. Canaccord Adams has not independently verified the facts, assumptions, and estimates contained herein. All estimates, opinions and other information contained in this investment research constitute Canaccord Adams' judgement as of the date of this investment research, are subject to change without notice and are provided in good faith but without legal responsibility or liability.

Canaccord Adams salespeople, traders, and other professionals may provide oral or written market commentary or trading strategies to our clients and our proprietary trading desk that reflect opinions that are contrary to the opinions expressed in this investment research. Canaccord Adams' affiliates, proprietary trading desk, and investing businesses may make investment decisions that are inconsistent with the recommendations or views expressed in this investment research.

This investment research is provided for information purposes only and does not constitute an offer or solicitation to buy or sell any designated investments discussed herein in any jurisdiction where such offer or solicitation would be prohibited. As a result, the designated investments discussed in this investment research may not be eligible for sale in some jurisdictions. This investment research is not, and under no circumstances should be construed as, a solicitation to act as a securities broker or dealer in any jurisdiction by any person or company that is not legally permitted to carry on the business of a securities broker or dealer in that jurisdiction. This material is prepared for general circulation to clients and does not have regard to the investment objectives, financial situation or particular needs of any particular person. Investors should obtain advice based on their own individual circumstances before making an investment decision. To the fullest extent permitted by law, none of Canaccord Adams, its affiliated companies or any other person accepts any liability whatsoever for any direct or consequential loss arising from or relating to any use of the information contained in this investment research.

For Canadian Residents: This investment research has been approved by Canaccord Adams, a division of Canaccord Capital Corporation, which accepts responsibility for this investment research and its dissemination in Canada. Canadian clients wishing to effect transactions in any Designated Investment discussed should do so through a qualified salesperson of Canaccord Adams, a division of Canaccord Capital Corporation in their particular jurisdiction.

For United Kingdom Residents: This investment research complies with the Financial Services Authority's Conduct of Business Sourcebook and is approved by Canaccord Adams Limited, which is authorized and regulated by the Financial Services Authority, in connection with its distribution in the United Kingdom. This material is not for distribution in the United Kingdom to private customers, as defined under the rules of the Financial Services Authority. Canaccord Adams Limited accepts responsibility for this investment research and its dissemination in the United Kingdom. The information contained in this investment research is only intended for distribution in the UK to persons who qualify as intermediate customers or market counterparties, as defined under the rules of the Financial Services Authority.

For United States Residents: Canaccord Adams Inc., a US registered broker-dealer, accepts responsibility for this Investment Research and its dissemination in the United States. This Investment Research is intended for distribution in the United States only to certain US institutional investors. US clients wishing to effect transactions in any Designated Investment discussed should do so through a qualified salesperson of Canaccord Adams Inc.

For European Residents: If this Investment Research is intended for disclosure in any jurisdiction other than the United Kingdom, the US or Canada, then the relevant rules and regulatory requirements of that jurisdiction will apply.

Additional information is available on request.

CANACCORD Adams

Sales and Trading

Toronto 1.800.810.8051 London 44.20.7050.6505 Boston 1.800.343.7096 Vancouver 1.604.643.7052

Calgary 1.403.508.3826 Montreal 1.514.284.1476 San Francisco 1.800.830.2608 New York 1.800.818.2196 www.canaccordadams.com

Mark Maybank, CA, CBV Director of Research (Global), Toronto	1.416.869.7922
Peter Misek, CA, CPA, CFA Head of Research (Canada), Toronto	1.416.869.7920
Karl Keegan, MPhil, PhD Head of Research (UK), London	44.20.7050.6633
Eric Ross, MS Head of Research (US), New York	1.212.849.3970

Mining and Metals

Damien Hackett, London	44.20.7050.6641
Steven Butler, MBA, Toronto	1.416.869.7918
Scott Finlay, London	44.20.7050.6651
Gary Lampard, Toronto	1.416.867.6020
Jim Taylor, London	44.20.7050.6648
Toni Wallis, PGeo, Vancouver	1.604.643.7551
Orest Wowkodaw, CA, CFA, Toronto	1.416.869.3092
Wendell Zerb, PGeol, Vancouver	1.604.643.7485
Nick Chalmers, Associate, London	44.20.7050.6636
Christopher Chang, Associate, Toronto	1.416.869.7299
Gary Hon, CFA, Associate, Toronto	1.416.869.7376
John Vinnai, Associate, Toronto	1.416.869.7289

Energy

Andrew Bradford, CFA, MA, Calgary	1.403.781.1611
Michael Deng, MBA, Calgary	1.403.508.3804
Irene Haas, MS, MBA, Houston	1.713.331.9443
Rafi Khouri, MBA, London	44.20.7050.6645
Frederick Kozak, Calgary	1.403.508.3836
Wendy Liu, CFA, Calgary	1.403.508.3890
Terry Peters, MBA, Toronto	1.416.869.6597
Curtis Trimble, MBA, Houston	1.713.331.9447
Richard Wyman, MBA, Calgary	1.403.508.3886
Jeff Barber, CFA, MA, Associate, Calgary	1.403.781.1620
Amy Chan, Associate, Calgary	1.403.508.3854
Timothy Clark, Associate, Calgary	1.403.508.3824
Bill Cruise, MBA, Sr. Associate, Houston	1.713.331.9446
Stephanie Joe, Associate, Houston	1.713.331.9444
Asad Rawra, CA, CPA, Associate, Toronto	1.416.869.7397
Lindsay Wheeler, Associate, Calgary	1.403.508.3862

Technology

Jeff Rath, CFA, Boston	1.617.371.3891
Richard Baldry, CFA, Boston	1.617.371.3862
Dushan Batrovic, MBA, Toronto	1.416.869.7399
Anthony Chow, MBA, London	44.20.7050.6637
Jonathan Dorsheimer, Boston	1.617.371.3875
Steven Frankel, MBA, Boston	1.617.371.3711
Colin Gillis, MBA, New York	1.212.849.3914
Catriona Hamilton, MBA, London	44.20.7050.6642
Alan Howard, CFA, MA, London	44.20.7050.6644
Mark Kelleher, MBA, Boston	1.617.371.3726
David Lambert, CFA, Toronto	1.416.869.6592
Bob Liao, CFA, London	44.20.7050.6654
Peter Misek, CA, CPA, CFA, Toronto	1.416.869.7920
Dennis C. Wassung, Jr., CFA, MBA, Boston	1.617.788.1510
Josh Baribeau, Associate, Boston	1.617.371.3892
May Giang, Associate, Montreal	1.514.284.1593
Neal Gilmer, Associate, Toronto	1.416.869.7294
Aron Honig, Associate, Boston	1.617.371.3728
Andrew Jardine, Associate, Boston	1.617.371.3779
Domenic LaCava, Sr. Associate, Boston	1.617.371.3817
Shannon Lynch, Associate, Toronto	1.416.869.7344
Chip Moore, CFA, Sr. Associate, Boston	1.617.371.3879
Eyal Ofir, CFA, Associate, Toronto	1.416.869.7215

Life Sciences

Karl Keegan, MPhil, PhD, London	44.20.7050.6633
Adam Cutler, New York	1.212.849.3907
Jason Mills, San Francisco	1.415.229.7166
Neil Maruoka, Toronto	1.416.869.3073
Joseph Pantginis, PhD, New York	1.212.849.3921
William Plovanic, CFA, Chicago	1.312.674.4836
Matthew Scalo, San Francisco	1.415.229.0649
Ritu Baral, Sr. Associate, New York	1.212.849.3917
Theresa Chu, Associate, San Francisco	1.415.299.0699
Lala Gregorek, Associate, London	44.20.7050.6635
Jamar Ismail, Associate, San Francisco	1.415.229.0683
Anup Mehta, Associate, Chicago	1.312.674.4989
Mark Mitchell, Associate, Toronto	1.416.869.3894
Ben Sun, PhD, Sr. Associate, Boston	1.617.788.1595
Guillaume van Renterghem, MSc, Assoc. London	44.20.7050.6650

Real Estate

Jonathan Kelcher, CFA, MBA, Toronto	1.416.869.3260
Shant Poladian, CA, CPA, Toronto	1.416.869.6595
Yashwant Sankpal, Associate, Toronto	1.416.869.3643
John Travaglini, Associate, Toronto	1.416.869.3650

Consumer

Robert J. Hastings, CFA, Vancouver	1.604.643.0177
Stephen Colbert, Boston	1.617.788.1573
Chris Rankin, CFA, MBA, Toronto	1.416.869.7325
Scott Van Winkle, CFA, Boston	1.617.371.3759
Diederik Basch, CFA, Sr. Associate, Boston	1.617.371.3764
Catherine Siu, CFA, Associate, Montréal	1.514.844.3108

Industrial Growth

Robert J. Hastings, CFA, Vancouver	1.604.643.0177
Sara Elford, CFA, Halifax	1.902.442.3161
Robert Fay, MBA, Toronto	1.416.869.3028
Eric Glover, CFA, San Francisco	1.415.229.0669
Mark Thompson, MSc, CFA, London	44.20.7050.6649
Eric Prouty, Boston	1.617.371.3729
John Quealy, CPA, Boston	1.617.371.3837
Chris Rankin, CFA, MBA, Toronto	1.416.869.7325
Jeffrey Leung, Associate, Vancouver	1.604.661.7861
Juan Plessis, MBA, CFA, Associate, Vancouver	1.604.643.0181
Mark Sigal, Associate, Boston	1.617.788.1591
Christy Taylor, Associate, Vancouver	1.604.643.7034
Tom Varesh, MBA, Associate, Toronto	1.416.869.3189
Max Vichniakov, MBA, Associate, Toronto	1.416.869.7284

Investment Companies

Stephen Davis, London	44.20.7050.6653

Portfolio Strategy

Nick Majendie, CA, MA, Vancouver	1.604.643.7005
Michael Rudd, CFA, Associate, Vancouver	1.604.643.7421

Vancouver Head Office
P.O. Box 10337 Pacific Centre
2200 – 609 Granville Street
Vancouver, British Columbia
V7Y 1H2
1.604.643.7000

Toronto
BCE Place, 161 Bay Street
Suite 3000, P.O. Box 516
Toronto, Ontario
M5J 2S1
1.416.869.7368

Calgary
TransCanada Tower
450 1st Street SW Suite 2200
Calgary, Alberta
T2P 5P8
1.403.508.3800

Montréal
1010, rue Sherbrooke ouest
Bureau 1100
Montréal, Québec
H3A 2R7
1.514.844.5443

London
7th Floor, Cardinal Place
80 Victoria Street,
London, SW1E 5JL
44.20.7050.6500

Boston
99 High Street
Suite 1200
Boston, MA
02110
1.617.371.3900

New York
535 Madison Avenue
2nd Floor
New York, NY
10022
1.212.849.3900

San Francisco
101 Montgomery Street
Suite 2000
San Francisco, CA
94104
1.415.229.7171