GUINNESS ATKINSON FUNDS

# The Dawn of the Alternative Energy Age

## THE 20TH CENTURY

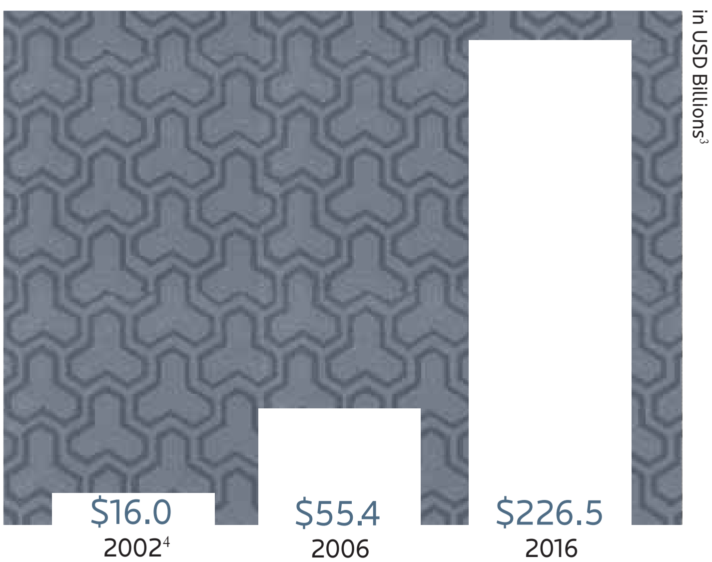
In the 20th century, mankind's massive material and financial progress were only made possible by the exploitation of oil. Oil was a main force in global geopolitics and the driving force behind unprecedented industrialization. Oil has been such a powerful lynch pin that it is hard to believe that its days of prominence may be waning. But as demand for oil steadily increases and reserves are consumed, oil is in the autumn of its life. In its place will increasingly emerge an array of alternative—non-fossil-fuel—energy technologies, both high tech and old tech. This is the dawn of the alternative energy age.

Today, a powerful new synergy of fast-rising global demand for energy, dwindling oil supplies and concern around energy security and climate change are driving the rapid adoption of alternative energy. For wind, solar, geothermal, bio-based energy, energy efficiency and the emerging associated technologies of fuel cells and energy storage, the prospects over the long-term appear bright.

## INCREASING ENERGY DEMAND

Worldwide economic growth is creating new pressures on conventional fuels that can't possibly be met entirely by traditional energy sources. It's hard to argue with the data. Oil consumption was running at a new high in 2006; 83.7M barrels per day[1] while global electricity generation grew by 4.2%. And 2006 was no freak occurrence. In fact, since the launch of the BP Statistical Review of World Energy in 1965, global energy consumption has on an annual basis only dipped three times—during the downturn of 1980-1982. Today, global GDP per capita is still very low at just over $7,400[2] and it is the developing nations led by China and India that are driving demand.[5] From 2000 to 2006, Chinese oil consumption grew a staggering 56%[6] and there's no let-up in sight. Some 2 billion[7] of the world's 6.5 billion citizens[8] still do not have access to electricity, and in China in 2007, there were just 14.1 cars on the road for every 1000 people versus 474.0 in the U.S.A.[9] Such low living standards cannot endure in the face of a global economy growing between 4% and 5% per annum. Between 2000 and 2030, global GDP is expected to more than double from $31.5 trillion to $70 trillion.[10] Some in China anticipate vehicle ownership rising to 600 per 1000 citizens by 2050[11]—an astonishing 40-fold increase.

### Combined Projected Annual Sales Growth: Solar, Biofuels, Wind, Fuel Cells & Distributed Hydrogen

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The International Energy Agency (IEA) recently revised upwards its annual forecast of worldwide energy demand in 2030[12] to 129.7 billion barrels of oil equivalent—nearly 50 billion more than today. Further out in 2050, with an extra 2.8 billion added to the earth's population[13] and assuming continued annual energy consumption growth of 1.8%[14] that may result in demand over two times higher than it is today. No one is predicting a lower consumption of energy. When broken down by region, it becomes clear just how much more the developing world will need.[15]

## A WORD OF CAUTION

As optimistic as we are about the prospects for the alternative energy industry, we caution investors regarding three issues related to alternative energy investing. First, a large percentage of alternative energy companies are thinly traded small cap stocks. Second, many of these companies are loss making or just beginning to produce profits. Third, many alternative energy stocks have appreciated significantly recently as a result of increased energy prices. In short, investing in alternative energy stocks should be seen as a long-term investment and investors should expect the sector to be volatile.

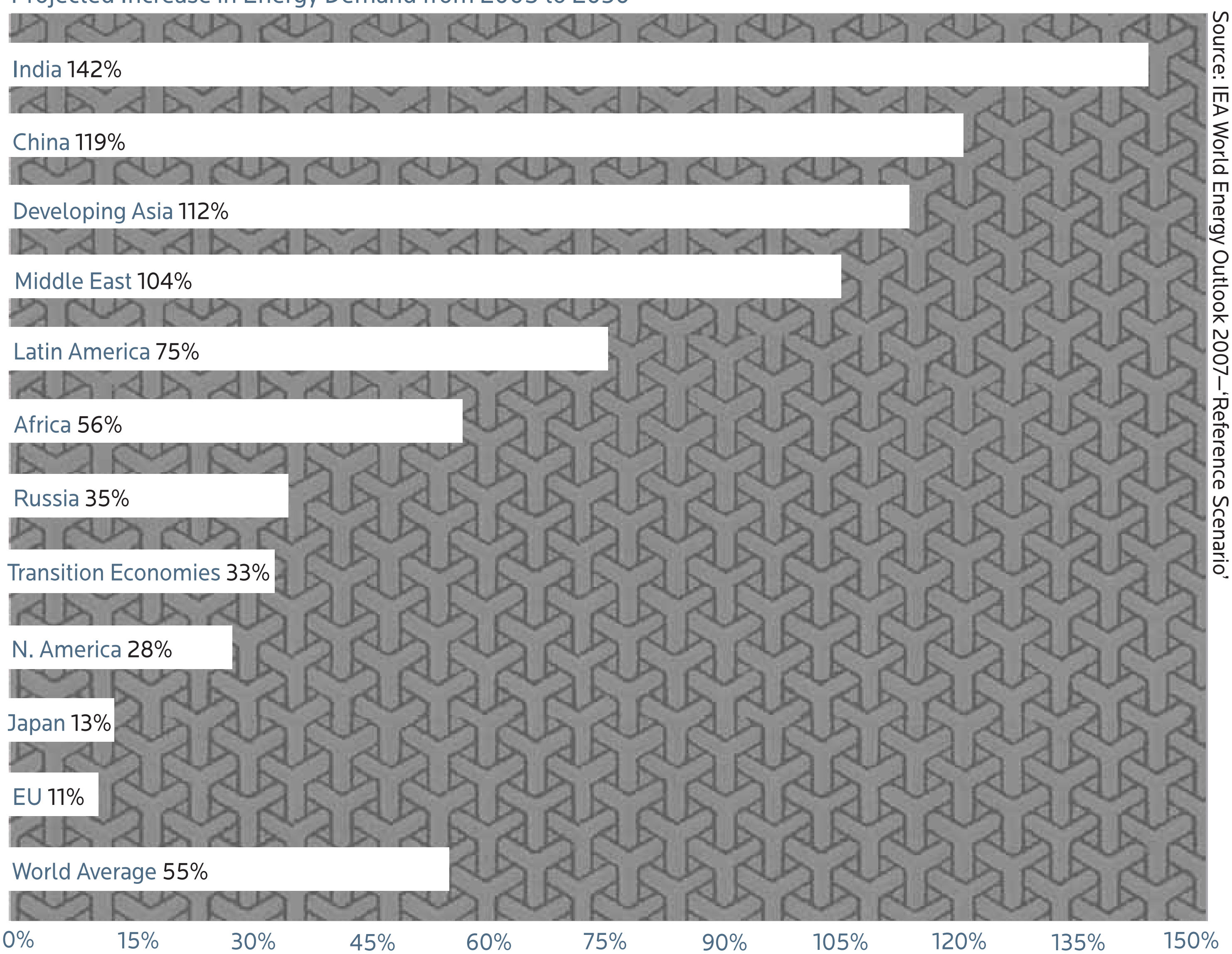
There's a clear link between development and soaring global energy demand. But where will this energy come from? No one seriously suggests that fossil fuels can provide all of the answers. That's why alternative energy is destined to receive a much, much bigger slice of the pie than it does today.

## SUPPLY CONSTRAINTS

Just as world growth in energy demand is accelerating, the world is starting to face the prospects of limited production capacity. While much can be said about the future of fossil fuel production, several facts are increasingly clear. First, much of the world's major oil fields are experiencing declining production. The North Sea, for example, has begun to experience year over year production declines since 1999/2000.[16] Kuwait's Burgan field—the world's second largest—is now in decline, ditto for Cantarell, the biggest in Mexico. Some experts believe that Saudi Arabia, which is home to the world's largest oil field, may also be experiencing problems as it tries to keep pace with world oil demand.

We have written in the past about the concept of Peak Oil. This concept, pioneered by former Shell Oil geologist M. King Hubbert uses a statistical analysis to project the moment in time that oil production from a well, region or indeed the world as a whole will reach its peak production year. Conceptually, once this year is reached output will begin to decline. In 1956 Hubbert predicted the U.S. would reach its peak oil year in 1970. He was correct. Hubbert's methodology is simple but quite prescient: the peak year is reached once one-half of the economically

Projected Increase in Energy Demand from 2005 to 2030



> "Just as growth in energy demand is accelerating, the world is starting to face the prospects of limited production capacity."

exploitable oil is gone. By 1970 the U.S. had produced one-half of its reserves and production began to decline. For the North Sea the peak year was 1999/2000.[17] Predicting the peak year for the earth has become an industry-wide debate. Our view is that it is some time off, say 2015 to 2020. Colin Campbell of the Association for the Study of Peak Oil believes the peak may have occurred in 2005. He appears to be a little early; according to the *BP 2007 Statistical Review of World Energy*, oil production was 0.4% higher in 2006 than 2005 at 81.6M barrels per day. Granted, a higher oil price effectively creates larger economically exploitable reserves and the world's proven reserves are still rising. Yet what matters far more is at what price that oil can be exploited and how quickly it can be brought to market. Oil worth extracting at say, more than $300 a barrel over the next century, will probably stay undisturbed. And with a 10-year lead time between seismic discovery and its appearance in the marketplace, it's hard to see how oil investment can cater to future demand—which could total 32 million additional barrels per day by 2030.[18] That's equal to finding and bringing on stream another three new Saudi Arabias. Peak production may well be just 100 million barrels per day. In the next 10 years, demand should continue to outstrip supply and this would lead to further price rises fuelling the shift to alternatives.

But this must be understood within context of what is happening to the oil markets at the moment. Even with oil above $90 a barrel, the Western oil Majors who typically make profit when oil is above $15 to $20 per barrel are very nervous about a repeat of the investment boom of the 1980s and 1990s. Then, the investment boom led to over production and a subsequent collapse of the oil price to $9 a barrel. In 2003, the IEA calculated that to meet future demand in 2030, the Oil Industry would have to invest $16 trillion, yet there is little sign of this happening.[19] In fact, British Petroleum (BP) advised soon after announcing record profits in 2006 that it planned to make record shareholder distributions[20] should the price of oil stay high. Apart from the industry's caution over increasing investment and the declining exploitability of non-OPEC oil, there are other constraints.

In 2005, American universities produced only 200 petrochemical engineers compared to thousands per year during the 1970s.[21] This shortage of skilled manpower does not bode well for future investment. The average salary for a petroleum geologist jumped 23% in the past three years, whilst the relatively unskilled job of rig-controller has seen a pay rise of over 60%[22] in the same period to $58,000. Add to that the shortage of deep-water drilling rigs[23] and the difficulty of expanding into increasingly inhospitable terrain and the long-term future of the oil industry is by no means certain, less still, predictable.

Over the next 30 years as alternative energy starts to make its mark, there will most likely be a major shift in financing from government subsidies—worth $20 billion in 2006[24]— to Western capital markets, which can better quantify the risks and raise additional long-term investment capital. The recent emergence of carbon trading is one unknown quantity, which just might be a critical breakthrough in alternative energy financing. The current price at the Chicago Climate Exchange is just under $2 per ton,[25] compared to a Kyoto-compliant Europe where the price is some 18 times higher at around EUR 24 per ton.[26]

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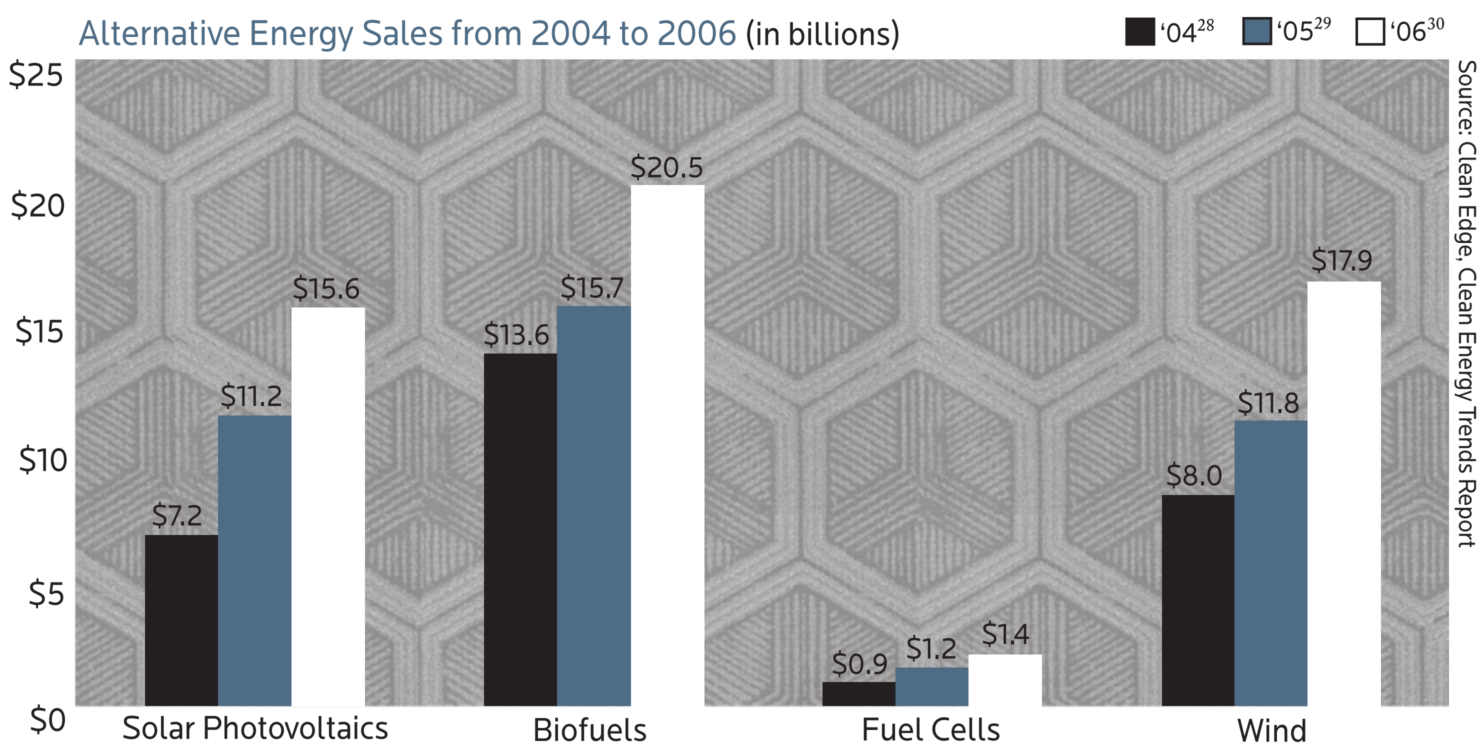
In a post-Kyoto world, it's quite possible that carbon markets will price forward at least 15 years instead of just three to five years and there will be a global market, which should result in a much higher and less volatile carbon price. Certainly, the carbon market is growing very fast, helped by new signatories to the Kyoto Protocol like Australia and ten U.S. states, who are choosing independently of the federal government to enact their own cap-and-trade schemes, with possibly many more on the way.[27] Such trading volume-enhancements could well accelerate investment in alternative energy technologies at the lower cost, shorter payback period part of the market.

Aided by rising incomes, new and evolving technologies should mature and achieve grid-parity in electricity. And eventually, in transport, other sources will displace oil as the main source of fuel. Conventional fossil fuel energy is getting more expensive, not just in terms of the price of gas, coal or oil, but also at the regulatory and plant and facility construction level. Consequently, alternative energy is closing the price gap with its conventional rivals. And governments are taking a closer note of voters' fears surrounding energy security and climate change.

Indeed the growth we have seen in the number and market capitalization of companies in the alternative energy sector over the last five years means a universe of publicly quoted companies now exists from which an attractive portfolio can be selected. The market capitalization of such companies (excluding hydropower utilities) has grown from $19 billion at the end of 2002 to $380 billion at the end of 2007. And the increasing attractiveness of the sector has been reflected in rising stock prices. The Wilderhill Clean Energy Index has, for example, risen by 17.68% per annum (130.36% compound from December 31, 2002 to February 14, 2008) versus a return of 10.70% per annum (68.40%) by the S&P 500. Of course, because the companies are very long-term growth stories, investors in the sector have to accept above average volatility and are well advised to take a very long-term view of their investment.

Alternative Energy will not provide 100% of our needs for heating, electricity and transport fuel in the foreseeable future. But the enormous expansion required to meet a meaningful fraction of that demand suggests that this industry is at the beginning of a steep growth curve. Alternative energy is coming of age.



## So, what do the alternatives have to offer and at what price and with what technology can they start to add to and replace the world's energy infrastructure?

### THE RISE OF THE SOLAR PHOTOVOLTAIC INDUSTRY

The solar industry can be considered in three sectors. Solar photovoltaic (PV) cells, which convert sunlight to electricity, solar thermal power stations (also known as Concentrated Solar Power or CSP) for electricity production from the thermal energy of the sun, and solar collectors to generate heat and hot water. Solar PV offers the investor an abundant universe of stocks to pick from. Despite being the most expensive method of producing electricity, the solar photovoltaic cell industry has grown in leaps and bounds in the last few years[31]—a 44% jump in production in 2006 alone. According to Solarbuzz—a leading industry portal—solar power modules, which are about 50%-60% of the fully installed cost, have priced in the last four years between $4 and $5 per watt. To be directly competitive with grid-generated wholesale electricity, these prices would have to fall to between $1 and $2 per watt. Yet retail-priced solar power, currently costing between USD 0.25-.50 per kilowatt hour[32] in the U.S.A. does not compete in the market with grid-generated wholesale electricity which is typically USD 0.05-0.10 per kilowatt hour.[33] Instead it competes with retail prices, which range from USD 0.08-0.15 per kilowatt hour in mainland U.S.A.[34] In addition, solar power is typically installed at point of use, so it requires no distribution infrastructure. That's why, married with the rising cost of conventional power, some observers forecast grid-parity[35] will be reached in the U.S.A. between 2010 and 2015—at a cost of USD 0.15 per kilowatt hour or better. That would mean take-off for the solar industry.

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In recent times, production has been doubling every few years, typically yielding an annual fall in production costs of 15%. This has been negated by rising demand and the increasing cost of high-grade polysilicon, which has kept prices stable.

In 2006, the total output of solar grade polysilicon was 21,000 tons but the demand was 28,000 tons.[36] This excess demand has translated into a price increase from $25 per kilo in 2000 to $70-$80 by the end of 2006. The polysilicon shortage is forecast to last until at least 2009. This may well lead to a fall in the price of silicon by 2010. In the meantime, demand for solar power remains incredibly strong.

Thin film solar cell manufacturers—who use less or no silicon in cells and can achieve much lower costs per watt—have been emerging and are expected to gain a market share of up to 20% by 2010, up from 5.8% in 2005.[37] However, these cells are constrained by having lower efficiencies than silicon-based photovoltaics—12% or less versus 22% for the best silicon-based photovoltaic.

The outlook for silicon-based PV is for steady ongoing cost reduction of 7%-10% per annum for the next 5-10 years. These cost reductions will be derived from increasing cell efficiency from an average of 15% today towards a lab achieved maximum of nearly 43%,[38] improved design, further development of the manufacturing process and scaled up-production. These improvements, coupled with ongoing government support and regulation should price solar photovoltaics into everyday life for well-resourced Western consumers in the foreseeable future.

Solar collectors, although vital in developing countries like China, where it provides over 90% of domestic hot water, offer virtually no opportunities to the stock investor. Almost the same can be said of Concentrated Solar Power, although we expect to see more opportunities in this space going forward.

## WIND

The big picture economics of wind power remain strong and appear destined to improve. It is the least expensive by far of the modern renewables and comes closest to competing with fossil fuels and nuclear by providing gigawatt quantities of mainstream power.

In 2006, the wind industry—measured as new installation capital costs—amounted to just under $18 billion.[39]

## CASE STUDY: DENMARK'S WIND POWER

At 20%,[40] Denmark has the highest penetration of wind power in the world, when measured by annual consumption by the source of electricity. As well as the deployment of many turbines, this is ultimately only made possible by its high interconnectivity to the more powerful grids of larger neighbors—Norway, Sweden and Germany—and access to the most advanced electricity markets in the world. That enables Denmark to accommodate exceptionally large amounts of fluctuating wind power more easily than other nations. In the first ten months of 2007, the proportion of Denmark's electricity generated from wind, on occasion, reached as high as 90%, and on some very calm days, fell almost to zero. Indeed, with wind electricity production sometimes reaching 125% of Danish demand, the difficulty has sometimes been exporting the electricity surplus rather than not having enough. That excess supply has lowered the price of electricity on the spot market and 2007 is forecast to be Denmark's first year where the subsidies cost less for wind than the reduced costs of electricity it has delivered[41] to the consumer. Other countries that are either larger than their neighbors or have a lower interconnectivity could safely integrate an annual average of 10% windpower—a proportion very few countries have yet to achieve—into their electricity supply. To expand beyond 10%, significant improvements to the transmission grid infrastructure and scalable energy storage technologies are needed.

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## WINDPOWER COSTS

Installed cost per megawatt — onshore

**$2 million**[42]

Installed cost per megawatt — offshore

**$3 million**

Typical cost of wind in U.S.

**<5¢ per kilowatt hour**

Typical European cost

**6–7.5 euro ¢ per kilowatt hour**[43]

Wind power costs have fallen so dramatically over the years because they have followed the same material design trajectory as aircraft; from wood to metal to carbon fibers. As with aircraft, these new materials have paved the way for larger, stronger turbines that can generate more power. And automated electronics and software are boosting their ability to produce reliable and consistent power by controlling the pitch of the blades in more demanding weather conditions. Larger turbines, of 5 MW capacity and above, will lower costs. The average size of an installed wind turbine in the U.S.A. was 1.6 MW in 2006,[44] and elsewhere 2.5 MW is nearer the average. Further improvements will come from increased production runs, more reliable components and the greater availability of the cranes, lorries and balance of systems parts that are so vital to the final cost of wind farms. Some studies suggest a fall in costs of 40% over the next 15 years, which would eliminate all need for direct subsidies in most locations.

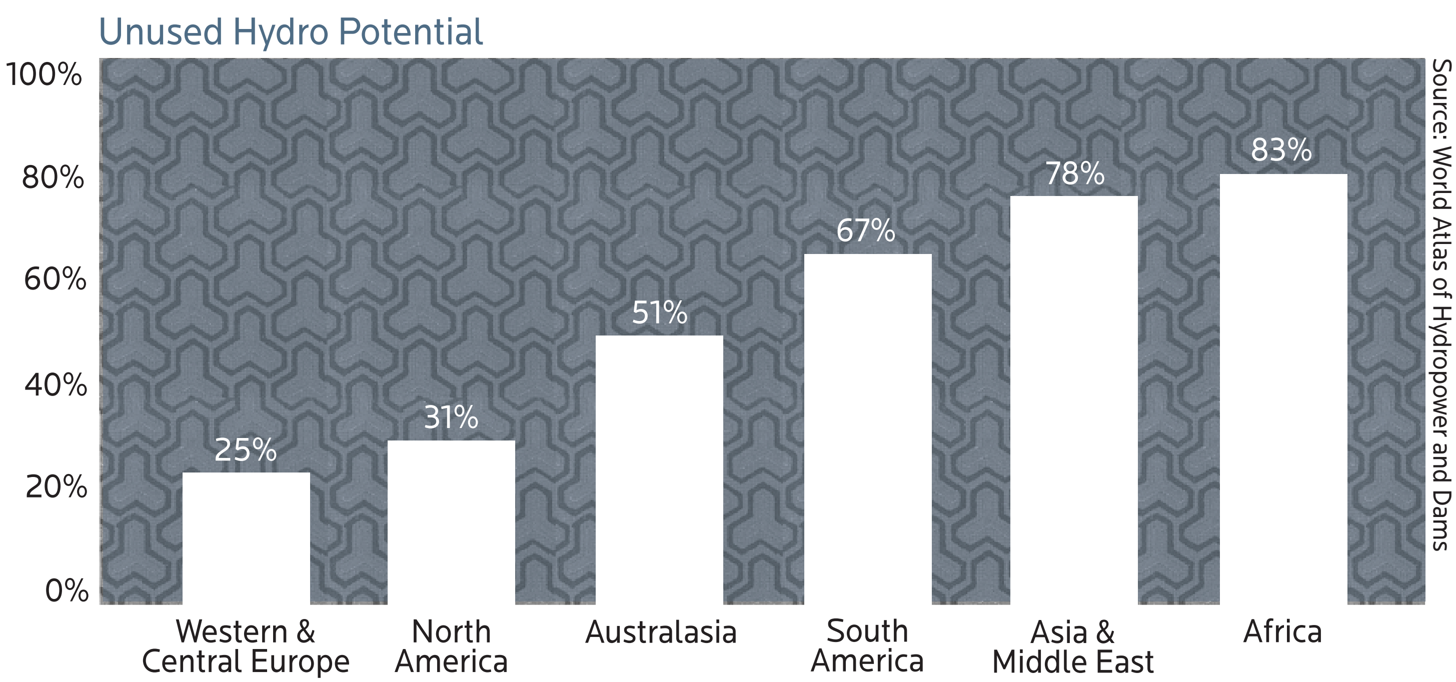
This is still a fast-growing industry. One market forecast put the size of the wind market at $60.8 billion in 2016.[45] Yet the location of this growth and its manufacturing base is set to change. Previously, most of the growth has taken place in Germany, Denmark and Spain. Now we are seeing a seismic shift to the developing world and the U.S.A. Thanks to the extended renewal of the Production Tax Credit, American wind power grew by 35%[46] in 2005, by 27% in 2006 and was already up by 20% at the end of September 2007.[47] Add to this the awakening of the sleeping giant, China, which plans for up to 30 gigawatts by 2020[48] from a standing start of around 500 megawatts in 2005. India, meanwhile, already has an established wind industry and manufacturing base that appears well placed to expand.

This is, though, an industry that is not short of its critics. They are right to point out its shortcomings of availability, the difficulty in locating wind farms near to demand and the visual and environmental impact of turbines on unspoilt landscapes. And whilst overall construction costs have risen for wind since 2002, those of its conventional competitors for power have risen too, so the affordability rankings have not changed. That's why even in Texas, wind power has since 2005 delivered lower costs to the consumer than natural gas or coal.[49]

Offshore wind farms have been held out as a solution to onshore planning delays and costs. Investors, though, have shown themselves to be much less enthusiastic than governments about their prospects. A 2005 study[50] anticipated that the offshore wind industry would need to invest $115 billion in European waters until 2030 in order to meet offshore wind targets. This is only now starting to materialize, with EUR 11.1[51] billion of investment secured for the period 2007-2012. Offshore wind, with its higher wind speeds and potentially much larger wind turbines, has the potential to yield the lowest costs of all in perhaps 20 years.[52] But until the industry matures, it will remain more expensive than onshore wind power and in need of significant government support.

## HYDRO

The hydro industry is the giant of the renewable energy sector. In 2006 it accounted for more than 19% of global electricity generation capacity—more than nuclear power. Just as with oil, the growth appears to be coming from the Pacific Basin and the developing world in general. Last year, hydroelectric power consumption grew in the Asia-Pacific region by 7.5%[53] and China has set a target of an additional 170 GW of hydroelectricity plant by 2020.[54] Hydropower has a head start, the technology is at least 100 years old. And when the cost is calculated over a potentially



200-year lifespan, it is by far the cheapest form of electricity generation. Post-amortization, most figures come in at 2 U.S. cents a kilowatt hour and sometimes half that. Not only is it a proven technology, but it provides other benefits, such as water supply, flood control and irrigation.

The potential for hydro systems remains huge, estimated at 3,000 gigawatts[55] around the earth. According to the World Atlas of Hydropower and Dams, it is particularly in the developing world where these resources are least exploited[56] as the table opposite shows.

But hydropower stations take a long time to build, operate at a lower load factor than a gigawatt-scale conventional power plant, and have in recent years run into much environmental opposition, delaying construction.

That's why there may be substantial opportunities in small hydro. For small hydro plants of less than 30 MW in size, there is a more easily exploitable potential resource from an environmental and political perspective. Small run of river schemes, which use a percentage of the waterflow, have a particularly low environmental impact and can be repeated over the length of a watercourse. The technology is proven and inexpensive and as a result global small hydro capacity is expected to double by 2020,[57] much of which will be in China and other developing economies, where there has been less capital for such projects previously.

All in all, the clear benefits of hydro's low-cost, long-life technology will continue to outweigh the negatives and the industry is expected to benefit as higher electricity prices translate directly into profits for hydroelectric power companies.

## GEOTHERMAL

Geothermal power—from the Greek words *geo*, meaning earth, and *therme* meaning heat—is the capture of heat from deep under the earth to generate steam either for industrial use or to generate electricity.

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Compared to other fast-expanding alternative energy technologies, the growth rate for geothermal electric power has been relatively slow. According to the International Geothermal Association, since 1990, the generation capacity of geothermal electric power has grown at 3% per annum to approximately 9 GW in 2006. The largest concentration of this power, 40%, resides in the Philippines and the U.S.A. The untapped global potential, however, remains huge. The world's theoretical geothermal capacity is estimated using existing current technology as between 35 GW and 72 GW[58] and using enhanced technology, as much as 138 GW. In spite of relatively low capital costs, high availability and long plant lifetime, it's nevertheless unlikely that this capacity will be exploited in scale for some time. Future growth of geothermal electric power will primarily be located in developing countries on the Pacific Rim. These nations tend to not only have a more suitable geothermal gradient—the relative increase in temperature the deeper into the earth's crust—but also a more urgent impetus to develop it. They have growing populations, an unsatiated thirst for electricity and, typically, fewer planning constraints.

## EFFICIENCY

Reduction in energy demand from improvements in efficiency are the easiest way for the tight global demand for energy to be eased, but most energy efficiencies face the uphill battle of requiring individual effort. We have been used to cheap energy for so long that persuading people to change their habits will take time. Energy efficiency is an area where most of the benefits will not directly be captured by companies but by energy consumers themselves. However, products that enable consumers to improve their efficiency provide a fertile ground for investments.

One example of where there is clear evidence and legislative pressure for a step change in efficiency is in the miles per gallon achieved by conventional vehicles. America's fleet of cars and light trucks achieve an average of 25 mpg today. Several factors will emerge over the next decade which will boost that significantly and not just legislation. Ten years hence, a 60-mpg vehicle should be very commonplace—this will be achieved by reducing the weight of the vehicle, using hybrid motors and achieving still greater efficiencies from internal combustion engines.

In buildings, particularly factories, there are also many off-the-shelf, less glamorous efficiency solutions to be exploited. For example, there are quick and easy efficiency gains that result from a substitution of high intensity discharge lamps for low energy use light bulbs.

From a residential point of view, improved insulation provides the biggest gains, and new-build property is able to benefit from improved efficiency heating appliances, including ground source heat pumps, which have been used successfully in Scandinavia for over fifty years.

## WAVE & TIDAL

Both wave and tidal have tremendous long-term potential—the earth is, after all, two-thirds covered by water. Trying to capture the kinetic energy from the movement of water is not new, but making it commercially viable is not quite within reach yet. Of all the technologies in this sector, today, wave power is in the lead. The most exploitable waves—those with the greatest energy density expressed in kilowatts per meter of wavefront—tend to be located on coastlines with the longest ocean fetches, ideally more than 400 km. This suits much of Europe's Atlantic coastline. Worldwide, tidal resources remain almost entirely untapped and

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could be easily exploited, if environmental and planning concerns are allayed, with largely off-the-shelf hydropower components. Another candidate for near-future success could be tidal stream—turbines that exploit the movement of currents on the sea floor. Currently for the investor, there are only a handful of stocks with exposure to the potential of wave power. In the years to come, there will be more as other technologies come to the fore.

## BIOMASS AND BIOFUELS

Energy derived from living matter is the oldest form of renewable energy of all. Biomass means renewable organic material, such as wood, agricultural crops or wastes, and municipal wastes, and it can be burned directly or processed into biofuels such as ethanol or biodiesel. Each year, 100 billion tons of biomass are produced on Earth.[59] The energy content of this is equivalent to five times current global energy production. As a source of energy for the future, biomass' advantage lies in the fact that it is carbon neutral and renewable apart from the energy used in collecting and processing the fuel.

Investors are principally concerned with biofuels for transport and biomass for electricity generation. Whilst the process of refining crops such as corn to produce ethanol is an old, established technology that has been used as far back as in the Ford Model T, the most exciting prospects are the emerging technologies of new biofuels processes, biogas from agricultural wastes and landfill for electricity production. Modern bioenergy technologies can produce electricity, heat, and liquid, gas or solid fuels. This variety of energy carriers is a specific and unique characteristic of bioenergy, making it the only renewable energy source with this versatility.

In all of these processes, a key determinant in the final price is the cost of the fuel feedstock. The cheapest commercially used ethanol feedstock is sugarcane produced in Brazil. Corn in the American Midwest and sugarbeet[60] are more expensive, but are the prevalent feedstocks in the U.S. and Europe. A recent development has been the oversupply of U.S.-based ethanol leading to ethanol trading at a high discount to gasoline. There has also been a displacement effect on food production, as crops are used for fuel production rather than food. This has led to unpopular food price inflation, which can be seen as a growing pain of first generation biofuels. For those involved in refining, this has led to low margins and a marked slowdown in investment in new refining capacity. Second generation biofuels, however, promise to overcome the food versus fuel conundrum. In the not too distant future, genetically modified enzymes will facilitate the fermentation of the entire crop into greater quantities of biofuels rather than conventional ethanol refining, which can only make use of the edible part of the plant. Further out on the horizon, some believe that farmed ponds of algae, which has a higher energy density than crude oil and, theoretically, could be refined into petrol, diesel or jet fuel, may well be the defining breakthrough for biofuels.

In 2006, global production in ethanol was 13.5 billion gallons, which is just 4% of global gasoline consumption. For biodiesel, global production was 1.6 billion gallons, which is less than 0.5% of global diesel consumption. The total level of biofuel production is, however, more than 10 times where it was just five years ago.

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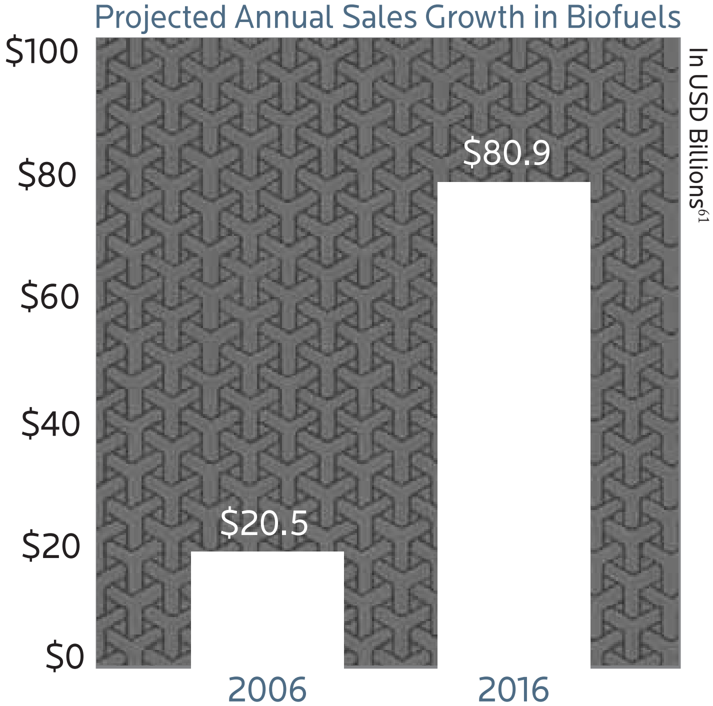
Projected Annual Sales Growth in Biofuels




Growth in biofuel production is today largely driven by government mandates, which should enable the industry to develop strong economic fundamentals. Existing EU targets for biofuels as a share of transport energy are at 5.75% by 2010, rising to 10% by 2020. In the U.S.A., the Energy Policy Act of 2005 mandated 7.5 billion gallons of annual domestic fuel production by 2012, and this has taken U.S. production to circa 6.5 billion gallons in 2007.[62] The Bush administration has now mandated the use of 36 billion gallons of alternative fuels by 2022.

With over 40% of European cars running on diesel and vehicles able to run on higher concentrations of biodiesel than ethanol without undergoing any alteration to engines, it has made the most sense for the European market to focus on biodiesel instead of ethanol so far. Biodiesel feedstocks are principally vegetable oils produced from rapeseed and soybean. A future biodiesel feedstock that promises much lower raw material costs is the jatropha curcas plant, which can grow, albeit with lower yields, in reclaimed and non-agricultural lands.

The greatest issue for biofuels is logistical. To produce meaningful quantities of biofuels, large tracts of land need to be turned over to biofuel feedstock production, which would place significant pressure on global food production and prices. As an example of the scale of the potential increase in land needed, according to the World Bank, a full tank of biofuel for an SUV requires as much grain as would feed a person for a whole year. For biofuels to fulfil their potential, the agricultural resources of the developing not the developed world will have to be harnessed to modern agricultural technology. U.S. and European government policy today, however, imposes import tariffs on biofuels to protect national farming interests rather than encouraging the world's lowest-cost ethanol producers.

> "In the long run the **best hope** is for **cheap electricity** from **renewable sources** to be harnessed to provide the transport **fuel of the future** as well as to keep the lights on."

Brazil has been the world's leader in ethanol and is one of the few large economies which is almost energy independent. Today Brazil devotes 5.3M hectares of land to sugarcane plantations but could easily expand into 320M hectares of unused (non rainforest) arable land given increased foreign demand.

## FUEL CELLS

Fuel cells are electrochemical conversion devices that convert hydrogen and oxygen into water and in the process create electricity. Thus far, they have been very long on promises and short on delivery. The forecast is that this industry is about to enter into a major growth stage from a turnover of $0.9 billion in 2004 to $15.6 billion in 2016.[63] However, most of fuel cell products today are in small niche markets and the holy grail of mass adoption of fuel cell vehicles is still at least ten years away. An internal combustion engine delivers 1.3 horsepower for $50 and an equivalent fuel cell costs $3000. That's why we do not see fuel cell vehicles any time soon and expect them to remain an experimental curiosity for the next few years.

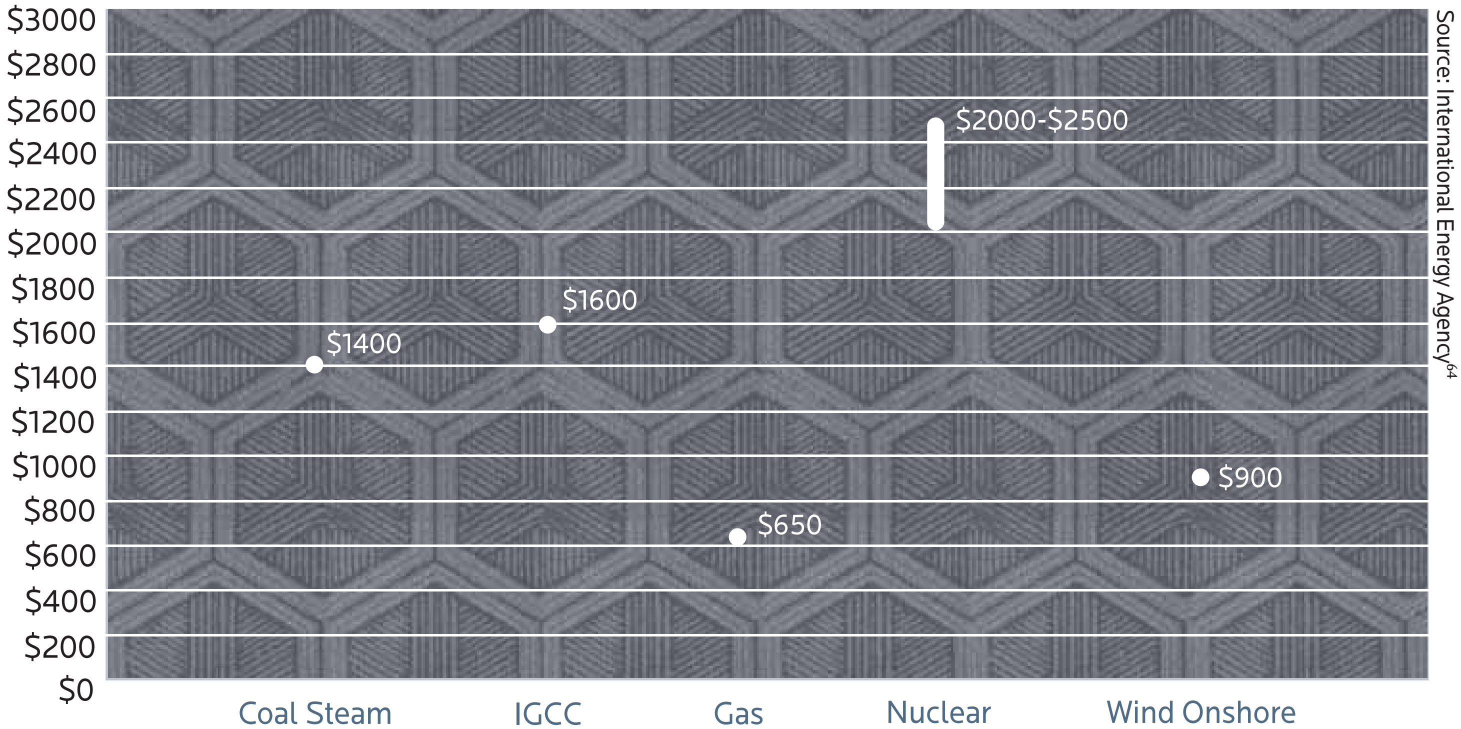
## HYDROGEN

Hydrogen has the potential to solve the world's energy problems in the long term, but is a long way away today. Hydrogen is in plentiful supply (as one of the two elements that make up water) and the main emissions from using hydrogen are water or steam. It would be possible to convert combustion engines to run on hydrogen at little extra manufacturing cost and hydrogen can be used to generate electricity in any number of ways.

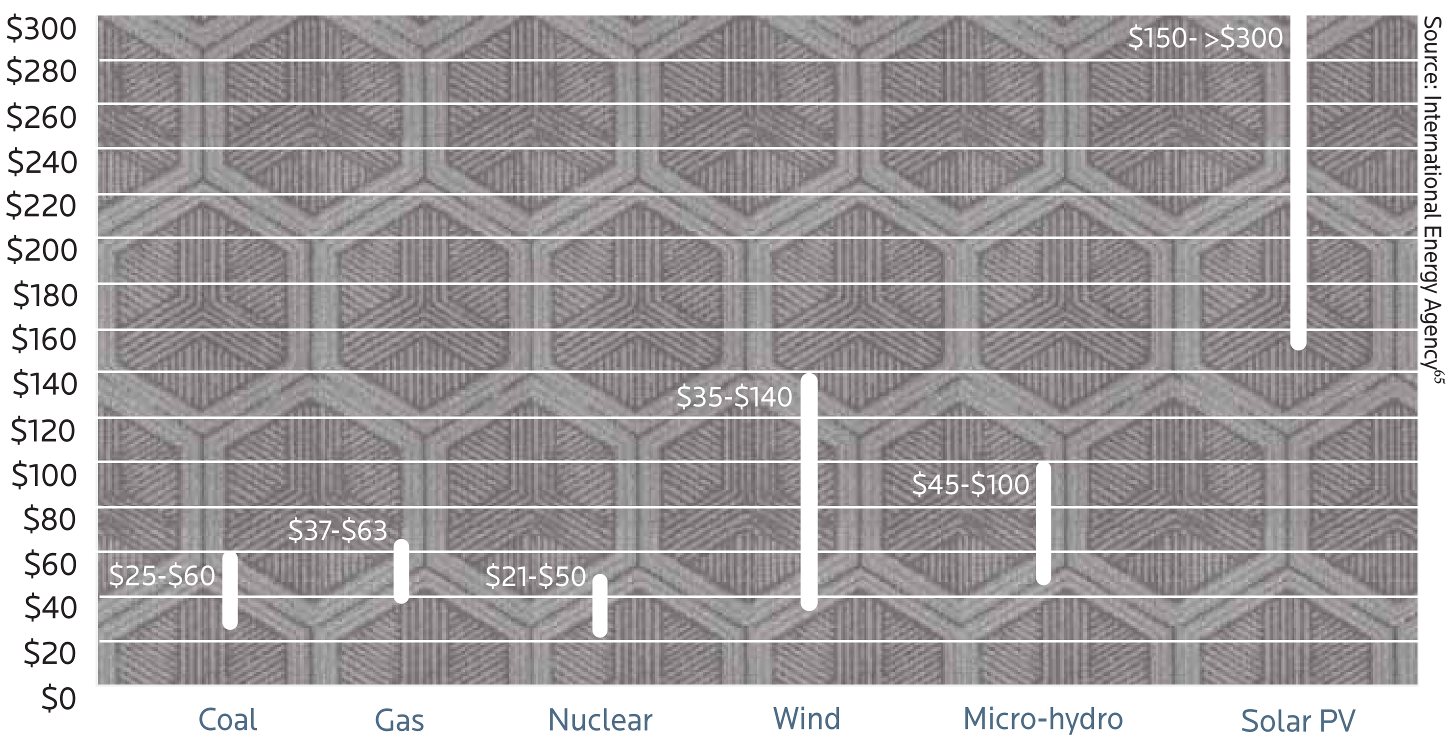
A critical issue is how to create and store large amounts of hydrogen, both environmentally and economically. The cleanest way to create "green hydrogen" is via the electrolysis of water, powered by a renewable resource. However, electrolysis equipment is expensive, and then one has to pay for the electricity as well. Ninety-six percent of today's hydrogen is produced by steam reforming or oxidization of fossil fuels like natural gas, which is considerably less expensive and is hoped to provide a bridging technology. That's why ironically the emerging hydrogen economy will at first be highly dependent on finite fossil fuels.

In the long run the best hope is for cheap electricity from renewable sources to be harnessed to provide the transport fuel of the future as well as to keep the lights on.

## Projected Investment Cost by Technology (cost per installed kilowatt in USD)




## Current Levelised Cost by Technology (cost per megawatt hour in USD)




All energy prices are highly sensitive to government policy frameworks and national economic systems. This leads to wide differentials for the same energy technologies in different countries. The range in the above tables produced by the IEA is also due to the variance of the discount rate from 5% to 10%. They do not include transmission, distribution or greenhouse gas emission costs.

1. See BP 2007 Statistical Review of World Energy http://www.earthscan.co.uk/news/article/mps/UAN/469/v/4/sp/332445698713342712230

2. The actual figure is $7,438.6 as at 2006, according to the World Bank measured as GNI per capita, Atlas method (current U.S.$) - see http://devdata.worldbank.org/external/CPProfile.asp?PTYPE=CP&CCODE=WLD

3. See http://www.cleanedge.com/reports/trends2006.pdf 2006 report by Clean Edge and http://www.cleanedge.com/reports/Trends2007.pdf March 2007 report

4. http://www.cleanedge.com/reports/Trends2007.pdf March 2007 report by Clean Edge combined with Guinness Asset Management estimate for biofuels in 2002

5. In the 3 years to 2004, Chinese energy demand grew by 65%, accounting for half the increase in global energy demand – see http://www.earthscan.co.uk/news/article/mps/UAN/469/v/4/sp/332445698713342712230 sourced from BP Statistical Review 2005

6. Chinese oil consumption was 4.7m barrels per day in 2000, in 2006, 7.4m. BP Statistical Review 2007.

7. See http://www.solarenergy.org/resources/energyfacts.html

8. See http://geography.about.com/od/obtainpopulationdata/a/worldpopulation.htm

9. The Economist Intelligence Unit 2008

10. See http://www.exxonmobil.com/corporate/Citizenship/Imports/EnergyOutlook05/slide_5.html

11. See 2006 IBM Report on the Chinese Motor Industry http://www-03.ibm.com/industries/automotive/doc/content/bin/ge510-6229-inside-china.pdf -Figure 5, page 5.

12. IEA World Energy Outlook 2007

13. See http://www.census.gov/ipc/www/idb/worldpop.html 2050, 9.4 billion

14. See speech by the then Australian Prime Minister, John Howard, January 2006 -http://www.pm.gov.au/news/speeches/speech1741.html

15. IEA World Energy Outlook 2007 – 'Reference Scenario'

16. Energy Bulletin, 2 December 2005. North Sea oil and gas peaked in 1999 for the UK and in 2000 for Norway.

17. See http://www.energybulletin.net/11370.html UK North Sea peaked 1999 and Norway 2000

18. See IEA World Energy Outlook 2007

19. See http://news.ft.com/cms/s/3864eadc-bc04-11d9-817e-00000e2511c8.html

20. See http://business.scotsman.com/index.cfm?id=196882006

21. See "Oil giants can't drill fast enough" http://www.timesonline.co.uk/article/0,,2095-2024984,00.html

22. See Oil Field Workers striking it rich http://www.chron.com/disp/story.mpl/headline/biz/4767136.html

23. Fewer than 100 in the world – see http://www.timesonline.co.uk/article/0,,2095-2024984,00.html

24. See Eric Martinot – Renewables 2007 Global Status Report http://www.martinot.info/Martinot_WREA2007.pdf

25. As at COB, November 23rd it was $1.75 for Vintage 2008 – see http://www.chicagoclimateexchange.com/market/data/daily.jsf

26. As at COB, November 23rd it was EUR 23.69 for December '08 see http://www.europeanclimateexchange.com/index_flash.php

27. This include the nine East Coast signatories to the Regional Greenhouse Gas Initiative (RGGI) and California will have a state-wide cap-and-trade mechanism in place by 2012.

28. Clean Edge, Clean Energy Trends 2005

29. Clean Edge, Clean Energy Trends 2006

30. Clean Edge, Clean Energy Trends 2007

31. See http://www.solarbuzz.com/StatsGrowth.htm

32. See chart from BP Plc, "The Path to Grid Parity," in "Gaining on the grid," measured in 2005 constant U.S. Dollars

33. EIA – U.S. wholesale electricity prices 2007

34. EIA – U.S. retail electricity prices (Year to Date, November 2007)
35. See report from BP Plc, "Gaining on the Grid" http://www.bp.com/sectiongenericarticle.do?categoryId=9019305&contentId=7035199
36. See Global & China Solar Polysilicon Industry Chain Report http://www.businesswire.com/portal/site/google/index.jsp?ndmViewId=news_view&newsId=20071203005525&newsLang=en
37. See "Solar Energy Report 2007" Banque Sarasin & Cie
38. See "From 40.7 to 42.8% Solar Cell Efficiency" from Renewable Energy Access, 30th July 2007.
39. See Clean Edge 2007 report
40. See Danish Wind Industry Association - http://www.windpower.org/en/futuresupply.htm
41. See The Economist "Cheap Alternatives"
http://www.economist.com/finance/displaystory.cfm?story_id=9447965&CFID=520113&CFTOKEN=d47d15a2f5ebb137-9FFC2210-B27C-BB00-01295E6A022F9760 July 5th, 2007.
42. See British Wind Energy Association figures as at December 2007 – as converted at GBP1: USD2
43. See http://www.westminsterenergy.org/events_archive/downloads/nuclear20060119/Peek_ABN_AMRO.pdf
44. See American Wind Energy Association's Annual Rankings of Wind Energy Developments April 2007
http://www.awea.org/newsroom/releases/Annual_US_Wind_Power_Rankings_041107.html
45. See Clean Edge – Clean Energy Trends 2007
46. See http://www.awea.org/news/US_Wind_Industry_Ends_Most_Productive_Year_012406.html
47. See AWEA and IEA Wind Energy Annual Report 2006
http://www.ieawind.org/AnnualReports_PDF/2006%20AR%20IEA%20Wind/2006%20IEAWind%20AR.indd.pdf
48. See http://english.people.com.cn/90001/90776/90881/6314349.html People's Daily "Six major bases for wind-power generation to be built"
49. See "The Clean Tech Revolution" by Ron Pernick and Clint Wilder, pages 59-60.
50. See New Energy Finance White Paper July 2005 "Offshore Wind: Europe's EUR 90 Billion Funding Requirement"
51. See http://www.mgn.com/news/newsreleasedetails.cfm?id=6460&type=
52. See http://www.offshoresea.org.uk/site/scripts/documents_info.php?documentID=6&pageNumber=2 underfuture costs
53. See BP Statistical Review 2007
54. See Eric Martinot 2007 report – 2006 130 GW, target for 2020, 300 GW
55. See http://www.eurorex.com/ugtoges/Glossary/smhypage.htm
56. See http://www.hydropower.org/downloads/Hydro-Worldwide.pdf
57. See http://www.iash.info/worldpotential2020.htm
58. The Geothermal Energy Association cites a 1999 study http://www.geoenergy.org/aboutGE/potentialUse.asp#world
59. See "Encyclopedia of agricultural, food, and biological engineering" – edited by Dennis R. Heldman , an estimate of total global annual net photosynthetic biomass production -http://books.google.com/books?id=fCRpUZzT2hMC&pg=PA86&lpg=PA86&dq=%22annual+biomass+production%22+world&source=web&ots=vCWgc0S4lz&sig=aAzOoqKbDlwvxNU01SZIXIdi9DU
60. See http://www.stockholm-network.org/downloads/media/8f2df869-Petroleum%20Economist%20-%20August%202005.pdf
61. See Cleanedge 2007 Report
62. See www.ethanolrfa.org
63. See Clean Edge 2007 Report
64. See IEA World Energy Outlook 2006
65. See http://www.iea.org/textbase/npsum/ElecCostSUM.pdf

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