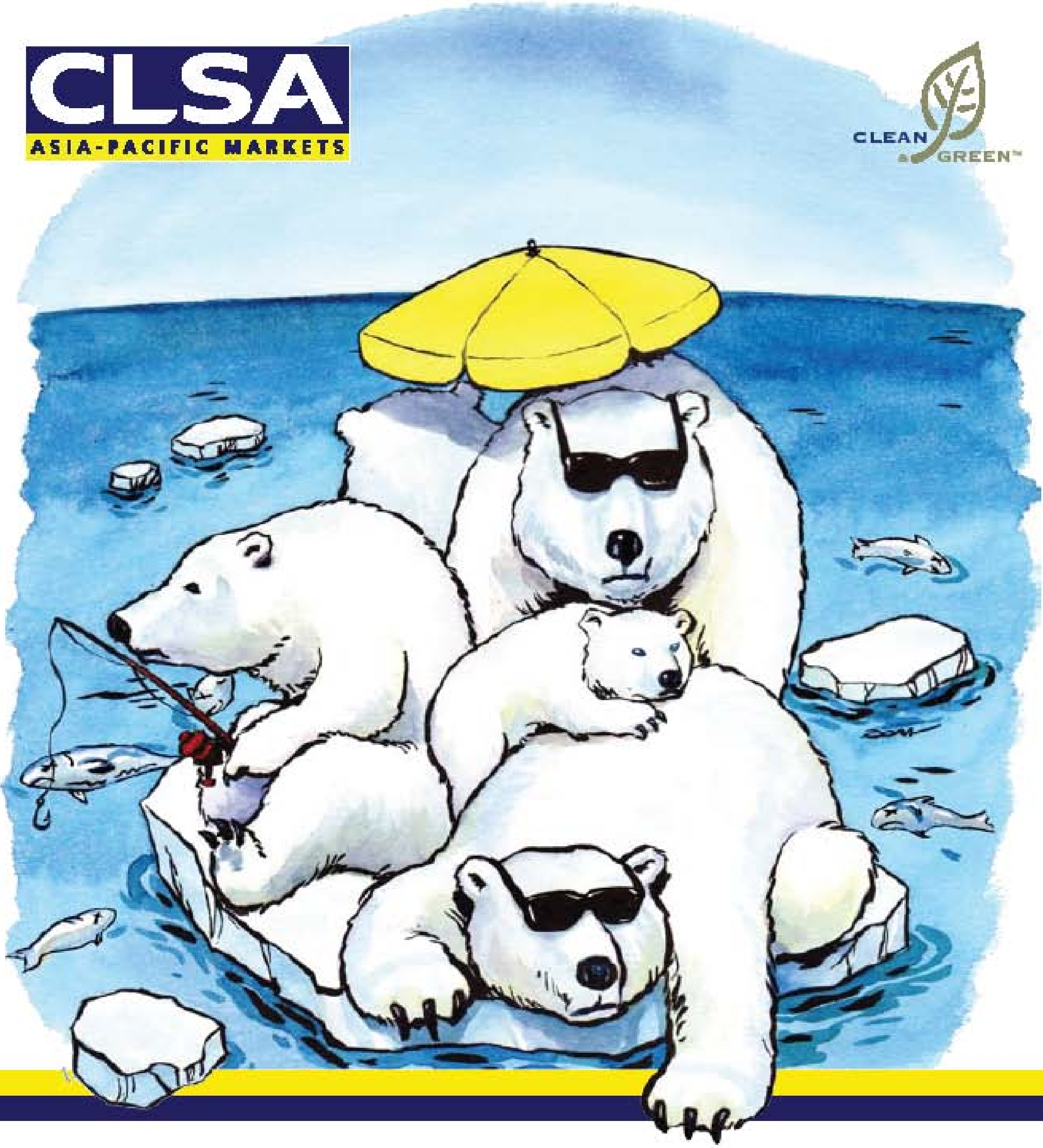

Panic button

When climate change gets real

Special report

September 2008

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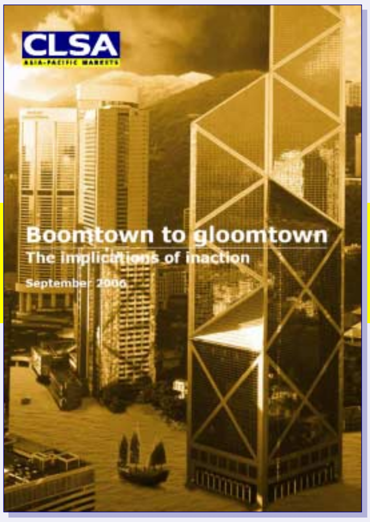
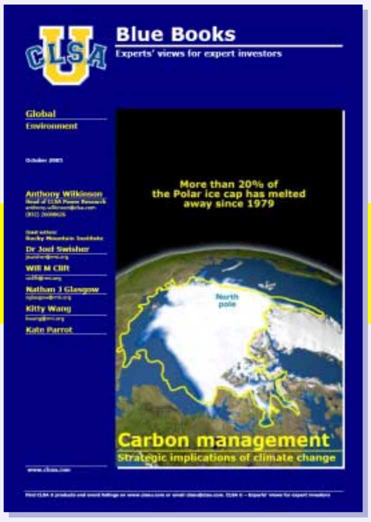
All prices quoted herein are as at close of business 16 September 2008, unless otherwise stated

Cold analysis from CLSA research





Panic button

Polar sea ice to disappear one summer soon

Rising seas are a well-documented implication of climate change, yet few recognise precisely when they will become a catastrophic threat. Data from scientists monitoring the Northern Polar region indicate a grim and impending reality, however, with 2013 potentially the first time the Arctic becomes ice-free in a single summer, raising sea levels and accelerating global warming

Governments panic and give out subsidies that make today's look derisory

This would trigger a "panic button" reaction from governments in the form of sweeping legislation and bigger subsidies for low-carbon industries. Under this scenario the already rapid penetration of renewables will increase. Low-carbon technologies - wind, solar, geothermal and nuclear - will receive more government help and support whereas polluting power will be buffeted by headwinds of higher carbon pricing and growth-restricting legislation.

Nuclear and geothermal – elephants in the corner

Our research suggests that nuclear power will see a resurgence. Despite the lengthy permit approval and construction process involved in building a plant, nuclear delivers one of the lowest estimated carbon dioxide footprints on a lifecycle basis. Meanwhile Geothermal-related technologies have been touted by Google as the potential "killer application" needed in the push to slow climate change, prompting the company's investment in the space.

Solar and wind the big short term winners

Solar and wind will immediately win big. However, investors should not discount energy-efficiency pushes either: while many countries are moving forward on using less energy, under a "panic button" scenario governments could drive through rapid reform that demands immediate, significant change in energy pricing, mandating higher levels of energy-saving.

Coal the big loser

Polluting power will come under even more scrutiny than it does today, with a scenario in which countries outlaw the building of any additional thermal coal-fired power plants - before turning their attention towards shutting down the existing ones – is a distinct possibility. In our foreword overleaf, Professor Tim Flannery of Macquarie University addresses the consequences of humanity's carbon-emitting habits to date.

Renewable energy penetration in panic button scenario

	Sector average 09F PE (x)	Opportunity for meaningful penetration increase by 2020	Carbon reduction impact	Tech maturity	Capex/CO_2 reduction	Potential for cost cutting	Constraints	Current level of subsidies	Comments
Wind	21	High	High	High	Mid	Mid	Intermittency	Medium	Ramping quickly in USA and China
LED general lighting	18	High	High	Mid	Low	High	Upfront cost	None	Still a niche play due to up front Capex and issue of fittings
Solar	16	Mid	High	High	High	High	Storage	High in some parts of Europe	Established markets in Europe - issue of cost per KWh will improve
Hydro	14	Low	Mid	High	Low	Low	Best sites taken	Limited	Up front Capex and environmental impact for the larger scheme - difficult to subsidise
Nuclear	13.5	Low	High	High	Low	Low	Long lead-time, waste	None	May start to get recognition for its lower carbon footprint but long approval and construction process, public concerns over safety
Geothermal	12	Low	High	High	Low	Mid	Limited geography	Limited	Only possible in certain locations. Work underway on hot rock technology may extend its reach
Carbon capture & sequestration (CCS)	-	Low	High	Low	High	Mid	Unproven at scale	High	Still very much a developing technology
Plug-in hybrid vehicles	11	Low	Mid	Low	Mid	High	Battery cost	Limited	Issue of refuelling stations , but growing demand side pull

Source: CLSA Asia-Pacific Markets

A new dark age

Tim Flannery
Professor, Macquarie University

In 2006 James Lovelock published a book which bluntly laid before us the consequences of the carbon imbalance. In it, Lovelock argues that Earth's climate system is far more sensitive to greenhouse-gas pollution than we imagine, and that it is already trapped in a vicious circle of positive feedback.

The events likely to destroy our civilisation include dramatic rises in sea levels, which will flood coastal cities and some of the best agricultural land; changes in rainfall and extreme weather; and the disappearance of the glaciers that act as dams and whose melt waters provide our most productive agricultural regions with water in the growing season. Yet it is the ensuing starvation, warfare and chaos that will be the greatest scourge: in Lovelock's projected Dark Age the warlords will be armed with nuclear weapons.

How probable is it that this bleak vision will come to pass? New scientific data and technological analysis mean that in 2008 we are better placed than ever to determine the scale of the threat and its imminence. Let's begin with a new analysis of work done by the Intergovernmental Panel on Climate Change (IPCC) in 2001. In its Third Assessment Report, the IPCC published a series of projections concerning key indicators of Earth's climate system.

These included estimates of how swiftly Earth's average temperatures might increase over the 21st century, how much the oceans would rise, and how quickly CO_2 would accumulate in the atmosphere. The projections had an upper and lower limit, and they encompassed a wide range of possibilities. That concerning temperature, for example, indicated that the increase might be as little as 1.4 degrees Celsius, or as much as 5.8 degrees Celsius. From the perspective of human survival, the difference between 1.4 degrees and 5.8 is profound. Humanity can probably cope with a warming of less than 2 degrees, but a 5.8 degree warming would be catastrophic, heralding an ice-free world, and human tragedy on the scale envisaged by Lovelock.

At the time these projections were published, climate sceptics lambasted them as unbelievable and grossly inflated, and widely proclaimed them in the popular press to be scientific scaremongering. By 2007, however, scientists had five to six years' worth of real-world data under their belts, allowing them to revisit the projections to determine their accuracy, at least over the near-term portion of the curve. What they discovered should have made the front page of every newspaper on the planet. Astonishingly, in every instance the real-world changes were right at the upper limit, or lay outside even the worst-case scenario presented by the IPCC. The full implications of these new studies have yet to sink in among those negotiating the global treaty that is supposed to protect humanity from dangerous climate change. They continue to argue on the basis of the old projections, which call for far less urgent action than what is actually required. Worse, the negotiations grind on as if we had an eternity to achieve outcomes. Lovelock, that seeming prophet of doom just two years ago, appears to have been right after all. Unless, that is, we can rouse ourselves to take immediate action.

Around 1975, scientists noticed that the Arctic ice had begun to melt away. At first the rate was hardly worrying, and indeed many thought that it might just be part of a long-term cycle. But the trend continued, so that by 2005 the Arctic ice cap had been melting at a rate of around 8% per decade for thirty years. At that rate, it would have taken until 2100 or thereabouts for the ice-cap to disappear altogether, and that was a comfortably distant date for many. But then, in the summer of 2005, a dramatic change occurred. The rate of melt accelerated, so that around four times as much ice melted as compared with previous summers. As at the onset of the melting trend, scientists were hoping that this was a freak or cyclic event, and that in a subsequent summer the melting would once again slow. But the summer of 2006 saw almost as much ice lost as in 2005. Then, during the summer of 2007, the very worst loss of Arctic ice ever witnessed occurred.

These changes in the Arctic have left many scientists worried that the region is already in the grip of an irreversible transition. During the winter months, the Arctic is now warming four times faster than the global average, while the existing temperature increase year-round already exceeds 2 degrees Celsius. As a result, profound shifts are occurring in species distribution: some fish stocks in the Bering Sea, for example, have already moved by 800km. None of the models used to predict how the Arctic will change as it warms has been able to replicate any of these changes. None, indeed, is remotely accurate, meaning that as we try to predict the region's future, we are truly flying blind.

The extent of confusion is illustrated by a straw poll conducted among Arctic experts in March 2008. It asked whether they thought that this summer would see a re-growth of the Arctic ice. The winter had been a cold one, and the great loss of ice the previous summer had been exceptional, leading the majority to say that a re-growth of the ice cap was likely. Yet by May 2008 the melting had begun once more, and the average daily loss of Arctic sea ice was, on average, 6,000km^2 per week greater than for the same period of 2007. As of early September, the 2008 summer melting season rivals that of 2007 as the worst on record. If the trend continues, the first ice-free summer in the Arctic is likely to be just a handful of years away - perhaps as early as 2013.

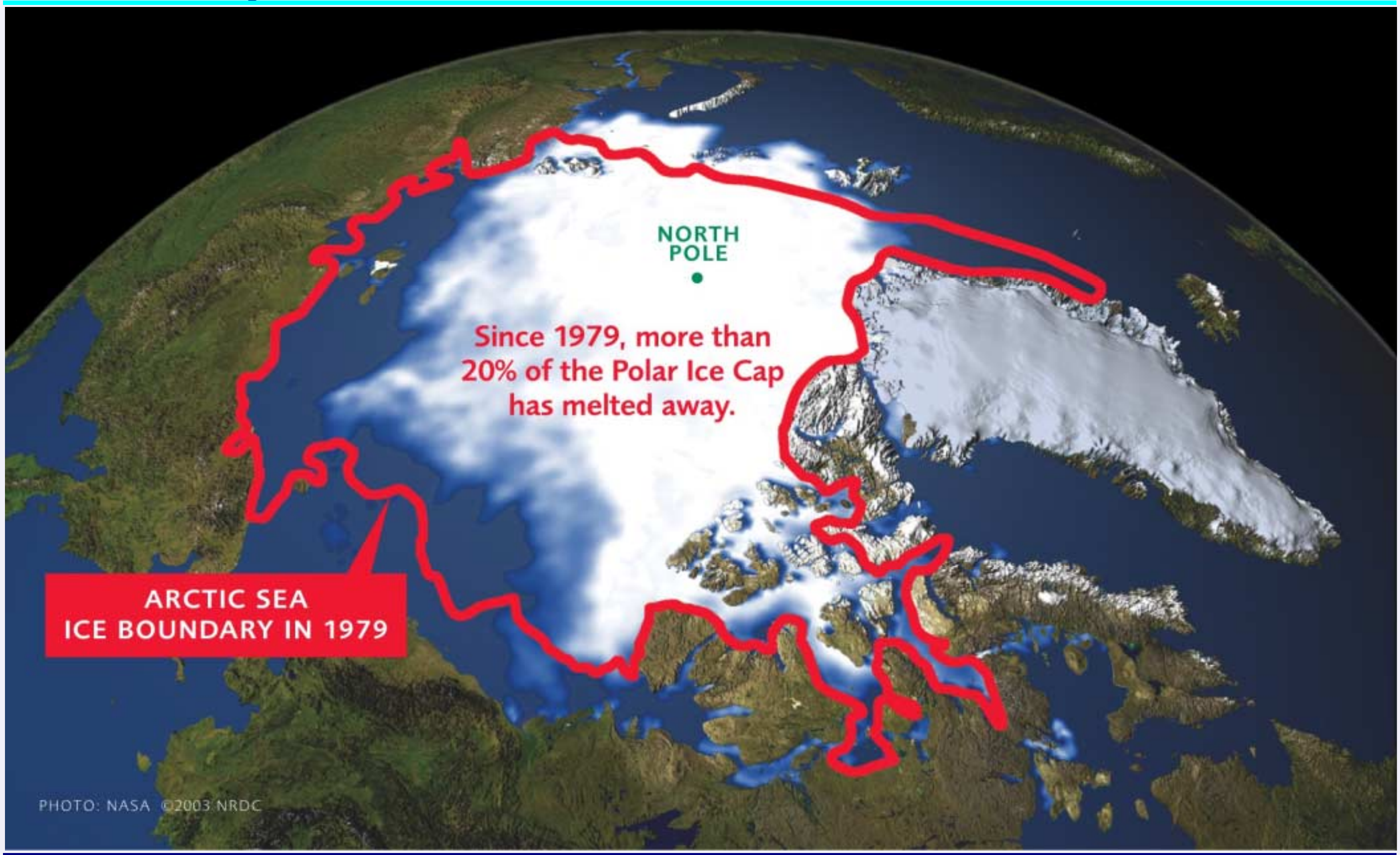
What will happen during that first iceless summer? Most likely, not much at all, for it will take several summers' worth of energy to warm the surface of the Arctic sea to a point where dangerous changes are generated further south. If recent history is anything to go by, during that first iceless summer the sceptics will say, "See, we told you that there was nothing to fear from an ice-free Arctic," and those who don't know any better will grasp at the reassurance. But each year thereafter, the ocean at the top of the world will inexorably warm, and the temperature gradient that controls climatic zones across the northern hemisphere will shift. It's difficult to know precisely how that will affect humanity, but if we go back 55 million years to the last time in Earth's history when such a great warming occurred, we see an ominously different world. Back then, lemurs sported in the rainforests of Greenland, while the tropics were covered in a spiny, thin and alien-looking cover of vegetation, which is today entirely extinct. No one knows how quickly the world's climate altered back then, but one cannot help but fear what a similar scale of change might mean for humanity today.

So swift are the changes already occurring in the Arctic that much of the human response to the crisis is rendered hopelessly inadequate. Warming has accelerated the rate of melt of the Greenland ice cap at between 250 and 300 cubic kilometres per year. Public policy responses and political discourse, meanwhile, are based on a previous rate of loss of just 50 cubic kilometres per year. And this melt has immediate relevance, for the Greenland ice cap sits on land, and as it melts, it contributes to a rise in sea level.

Even the most committed conservationists have been forced to rethink their strategies and also their priorities. Neil Hamilton, director of the WWF International Arctic Programme, said in a talk in Canberra in May this year that, 'We [WWF] are no longer trying to protect the Arctic,' because it is too late. He believes that the region's first ice-free summer may arrive before 2013, and admits to having no idea what the Arctic might look like in 2050.

Figure 1

Arctic ice sea melting



Source: NASA

Trigger and reaction

An ice-free Arctic soon translates to a 10-20 cm sea rise

We could conceivably experience an ice-free Arctic within five years. As Tim Flannery explains, this would severely stress the Greenland ice cap and potentially lead to a partial collapse, raising global sea levels by 10-20 cm. Suddenly, climate change would become real and tangible and governments would panic.

Flooding would threaten coastal communities even as some of the world's most populous regions faced drought. Fresh water and food supply would be crippled while diseases such as Malaria and Typhoid would flourish. A 10-20 cm rise in sea levels would leave many governments struggling to combat the symptoms. Yet even greater anti-climate change measures would be needed to prevent a catastrophic rise of up to five metres which would threaten to submerge New York, Shanghai and huge swaths of Bangladesh.

Governments will panic

It is far beyond the scope of this report to weigh in on the broader political and social implications of a world whose oceans suddenly become 20 cm higher. Clearly, they will be far-reaching and significant, with tensions stoked by short supply of resources and arable land. Amid all of this conflict and grab for scarce resources, all countries that are able to will roll out aggressive carbon reduction plans, both unilaterally and through international treaties such as Kyoto.

An ice-free arctic and Pearl Harbour

Most agree: Manmade greenhouse gases are driving climate change

There is strong evidence that the global climate is warming, and the few lingering deniers would disappear with the polar ice. There is also already consensus that this warming is being caused by an increase in greenhouse gas (GHG) concentrations caused largely by burning fossil fuels. Scientists continue to debate virtually every aspect of climate change, but the central tenets are almost universally accepted. Most importantly for the purposes of this report, they are fast gaining universal acceptance among governments. Thus, climate change policies worldwide are currently centered around minimizing greenhouse gas emissions, and will continue to be.

Some insist mobilisation like WW2 is necessary

Most developed countries around the world already have some smattering of climate change initiatives. Based on the accepted climate change models, even the most aggressive are pushing for too little too late to stave off significant temperature gains. The problem is too abstract and the expected impact (where will you be in 2100?) too distant for politicians to seriously consider the drastic measures needed. But, just as Pearl Harbour finally prodded America to plough belatedly into World War Two, an ice-free Arctic could prod the rich world to belatedly tackle global warming.

The starting point

Developed economies' emissions targets call for 40-80% cut by 2050

The table below demonstrates that climate change plans vary significantly from country to country and region to region. The closest thing we have to a global agreement, the Kyoto Accord, calls for industrialized countries to cut emissions by 5.2% below 1990 levels by 2012. In contrast to Kyoto's modest near-term goals, most stated emissions targets feature aggressive long-term policies. The EU, Japan, the UK and America's presidential candidates are all talking about 40-80% emissions cuts from 1990 levels by 2050. The interim is a bit hazier, but clear targets for 2020 are grouped around the 20% reduction (from 1990) range.

According to the IPCC study, stabilizing CO_2 equivalent (CO_2e) concentrations at 445-535 ppm would require cutting emissions by 30-85% by 2050. The WWF's shorter view estimates that emissions need to be cut 15-30% (vs 1990 levels) to keep carbon equivalent concentrations under 450 ppm.

Figure 2

Carbon-emission targets around the world

Country	Current emissions (tons per capita)	Policy name	Carbon emissions target
EU	11.0	Energy for a Changing World	20% cut in greenhouse gas emissions from all primary energy sources by 2020 (compared to 1990 levels), 50% cut in carbon emissions from primary energy sources by 2050 (compared to 1990 levels)
Japan	9.6	None	Reduce GHG emissions by 40-60% by 2050
Germany	10.2	Climate Protection Programme	40% reduction in emissions by 2020 as compared to 1990 levels
Spain	9.6		None
UK	9.5	Climate Change Bill (not yet enacted)	60% cut in the UK's carbon emissions by 2050 (compared to 1990 levels), with an intermediate target of between 26% and 32% by 2020 (not yet enacted)
USA	20.1	Energy Independence and Security Act of 2007	None
South Korea	10.3	None	
China	4.1	National Action Plan	None
India	1.1	National Action Plan on Climate Change	'Not to exceed that of developed nations'
Kyoto (global target)			The Kyoto Protocol requires 55 industrialised countries to reduce their greenhouse gas emissions to target levels 5.2% below that of 1990
Stern Review recommendations			25% below current levels by 2050

Source: EU, EIA, Reuters

Over two degrees warming could resemble a disaster film

Based on the IPCC models, carbon concentrations of over 450 ppm would make a temperature rise of over two degrees Celsius very likely. While this may not initially sound drastic, climatologist depictions of a world that is warmer by 2.1- 2.3 degrees Celsius are straight out of a disaster movie. Most strikingly, this is the point at which the Amazon rainforest could potentially burn down due to changing rain patterns and quicker evaporation wrought by higher temperatures. The world's largest rainforest would be transformed from a carbon sink (with trees sucking in carbon) to a carbon emitter, with the carbon stored in those trees released back into the atmosphere.

According to research from the Hadley Centre for Climate Prediction and Research (part of the UK's Meteorological Office), this flip would be enough to drive temperatures up a further 1.5 degrees Celsius. At this point, the West Antarctic ice sheet could break up and push global sea levels up as much as 70 metres.

World now five degrees warmer than during the last Ice Age

Put another way, this potential five degree change in temperature is equal to the difference in temperature between the last Ice Age and today.

Politics of scarcity - Lester Brown

Change can come very quickly and unexpectedly. The US was still a depression era economy when the Japanese attacked Pearl Harbour on 7 December 1941.

One month later President Roosevelt announced arms production goals of 45,000 tanks, 60,000 planes, 20,000 artillery guns, six million tons of shipping.

People were sceptical to say the least, because no one had ever seen numbers on this scale before for arms production. But what Roosevelt and his colleagues knew was that at that time the largest concentration of industrial power in the world was in the US automobile industry. Even during the depression, the industry produced between two to three million cars a year.

Roosevelt called in the leaders of the automobile industry and told them that because they represented such a large share of US industrial capacity, the government was going to rely heavily on them to reach its arms production goals. Roosevelt's banned the sale of private automobiles in the United States and from the beginning of April 1942 until the end of 1944, essentially no cars were produced in the United States and every one of those arms production goals was exceeded.

In the end the US produced not 60,000 planes, but 129,000 planes. It was extraordinary and it didn't take decades to restructure the US industrial economy. It didn't take years. It was done in a matter of months.

Figure 3

Degrees of pain

Degree change	Actual temperature in Celsius	Action needed (IPCC)	CO_2 target (IPCC)	What happens?
One degree	0.1-1.0 C	Avoidance probably not possible	350 ppm (today's level is 385 ppm)	Permafrost in Alaska and Siberia begins to melt for first time since the last Ice Age.
Two degrees	1.1-2.0 C	Peak global emissions by 2015	400 ppm	2.3 billion people across India, Pakistan, China, Peru, Ecuador and Bolivia face drought and famine as Andean and Himalayan glaciers disappear.
				Coral reefs around the world begin to die, threatening extinction for a wide range of sea-life, including several species of whales.
Threshold for carbon cycle feedback				
Three degrees	2.1-3.0 C	Peak global emissions by 2030	450 ppm	Changing rain patterns and faster evaporation put Amazon rainforest at threat of fire creating a feedback loop where carbon released from burning trees creates a 4-5 degree change.
IPCC target:			**445-535 ppm**	Polar bears driven to extinction as arctic ice melts completely.
Stern Review target			**500 ppm**	Tens of millions displaced as the Kalahari desert expands across southern Africa.
Threshold for Siberian methane feedback?				Complete thaw of Siberia releases huge methane stores, leading to a 5-6 degree change.
Four degrees	3.1-4.0 C	Peak global emissions by 2050	550 ppm	Greenland ice cap melts pushing sea levels up 5 meters or more; displacing 100 million people from low-lying Bangladesh, Egypt and Shanghai.
Five degrees	4.1-5.0 C			The West Antarctic ice sheet breaks up, whole planet becomes ice-free, and sea levels are 70 metres higher than today.
				Monsoon floods threaten millions in east India and Bangladesh.
				World food supplies run out.
Six degrees	5.1-6.0 C			Oceans lose oxygen, poisonous hydrogen sulphide gas released, ozone layer destroyed.
				Mass extinctions, possibly including humans.

Source: IPCC, Stern Review, *The Weathermakers*, *Six Degrees*

Science calls for a 20% carbon emissions cut from 1990 levels by 2020

Carbon cut by 2020: 54% from base case

The deadline for most of the binding carbon reduction targets is 2050 but policy makers are already moving toward stressing interim targets of 2020-2030. Below we assess the 2020 emissions targets and how realistic they are under our panic button scenario.

- IPCC and British Meteorological Office models indicate that warming by over two degrees creates feedback loops and runaway climate change.
- To keep the rise in temperature below two degrees, the atmosphere's carbon concentration should be kept below 450 parts per million (ppm).
- To keep this carbon concentration at or below 450 ppm, carbon emissions should be cut 50-80% from 1990 levels by 2050 and 20% by 2020.

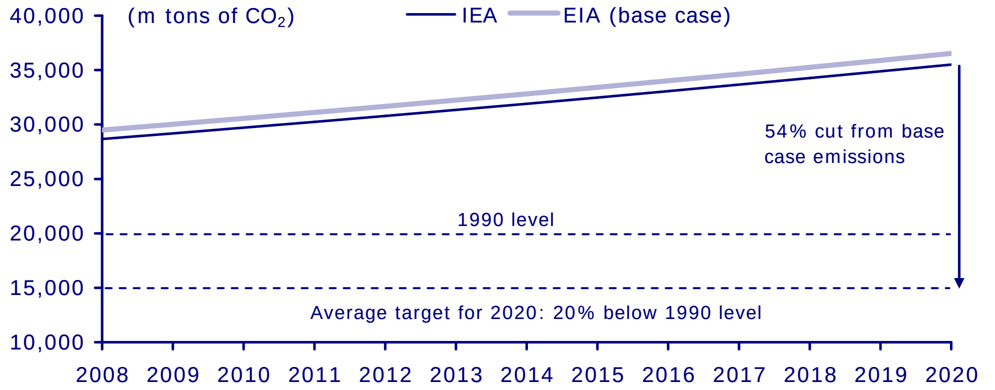
Base-case projections from the IEA and EIA suggest 50-55% rise in carbon emissions by 2020

In this context, the base-case forecasts for carbon dioxide emissions at both the International Energy Agency (IEA) and US Energy Information Administration (EIA) are troubling. Both bodies expect an approximate 20% rise in carbon emissions by 2020 from current levels, or a 50-55% rise from 1990 levels.

Despite some gross simplifications in these calcluations, none make the picture any prettier. Most notably, we are assuming no change in the other greenhouse gases or in the carbon sinks. This, in turn, assumes that deforestation will cease or be reversed, which seems like a long shot.

Figure 4

Forecast for carbon dioxide emissions from energy



Source: IEA, EIA, WWF

Stern Review estimates cost of restricting climate change in terms of global GDP

The framework: Ways and means

The most comprehensive and oft-cited study of how much climate change mitigation would cost comes from the 2006 Stern Review. Former World Bank Chief Lord Stern estimated that keeping carbon concentrations in the 450-550 ppm range would cost around 1% of global GDP, while not doing so would lead to costly environmental damage between 5-20% of GDP. In June 2008, he re-assessed his position and decided that we really should not pass the middle of that range (500 ppm), which would shave closer to 2% off global GDP.

Although offering a compelling economic trade-off, Stern's report is still a tough sell politically. Even governments panicked by a loss of Arctic sea ice might not be willing or able to make the prescribed carbon cuts. But the bar for political feasibility would be lifted dramatically. The most extreme climate change plans currently in place will look centrist by comparison.

Is it real? Doesn't matter

From an investment perspective it does not matter if you side with the climate change consensus or with the issue's contrarians. In terms of policy, the climate change debate is effectively dead. After twenty years the theory now has too much momentum in political, business and scientific communities to lose converts. Four or five years of record cold temperatures and expanding glaciers (both sea and mountain) could potentially change this but such a scenario is extremely unlikely. Even most climate change deniers admit that the climate is warming but point to other natural causes as an explanation for *why* it is changing.

Climate change legislation will not change course because it mostly promotes policies that are generally viewed as positive in the first place. Most climate change policies are centered around removing waste from the system (energy-efficiency) and improving energy independence. Policy goals for the developing world, such as preventing deforestation and promoting distributed energy, are also crowd pleasers.

Well known environmentalist Bjorn Lomborg volunteered one of the most interesting arguments against climate change policy: money spent mitigating greenhouse gases would be better spent on fighting AIDS, malnutrition or malaria. Lomborg brought together a group of renowned economists in a conclave dubbed the Copenhagen Consensus to prioritise aid spending.

We would argue that it takes a great deal of faith in human nature to believe that localized problems elsewhere, desperate though these problems may be, will take precedent over global problems. As a cause, global warming has traction because the rich world is not immune to it. Fortunately, the benefits of directly attacking global warming will accrue to the world's poor just as they do the rich. Assuming climate change does not turn out to be a hoax, most of the problems Lomborg suggests that international aid should focus on will be aggravated by climate change, and directly impacted by a 20 cm sea rise.

Finally, although some might dispute the reason, nobody can deny that the Arctic sea ice is melting. Man-made climate change is the most plausible culprit, and it is this that will drive the policy reaction to rising sea levels.

The mechanics of a plan

Targets in and of themselves are meaningless and the routes to achieving those targets would vary greatly from country to country and region to region. Yet there are some clear common elements that would emerge in panic button legislation:

- Carbon will have a price
- Support for renewables will get ratcheted up
- Energy-efficiency laws will be tightened considerably

Pricing carbon

A "price" needs to be put on carbon to control GHG emissions worldwide, explicitly through a carbon tax or emissions trading. This would illustrate the full cost to individuals and businesses of their actions, leading them switch away from high-carbon goods and services towards low-carbon alternatives. Economic efficiency points to the advantages of a common global carbon price because emissions reductions would then occur wherever they are the cheapest.

Carbon will be a new currency

The development of carbon markets presents an important opportunity to the financial sector. According to the World Bank, trading on global carbon markets doubled from 2006 to 2007, reaching US$50 billion. Expansions of the EU scheme to new sectors, and the likely establishment of trading mechanisms elsewhere, will lead to substantial carbon-market growth. *The Stern review* shows that if developed countries all had carbon markets covering all fossil fuels, the overall market size would grow 200%.

If markets were established in all the top-20 emitting countries, overall market size would grow 400%. Such a large and growing market needs intermediaries, presenting opportunities for many business and professional sectors - especially for financial centres, such as London and Hong Kong.

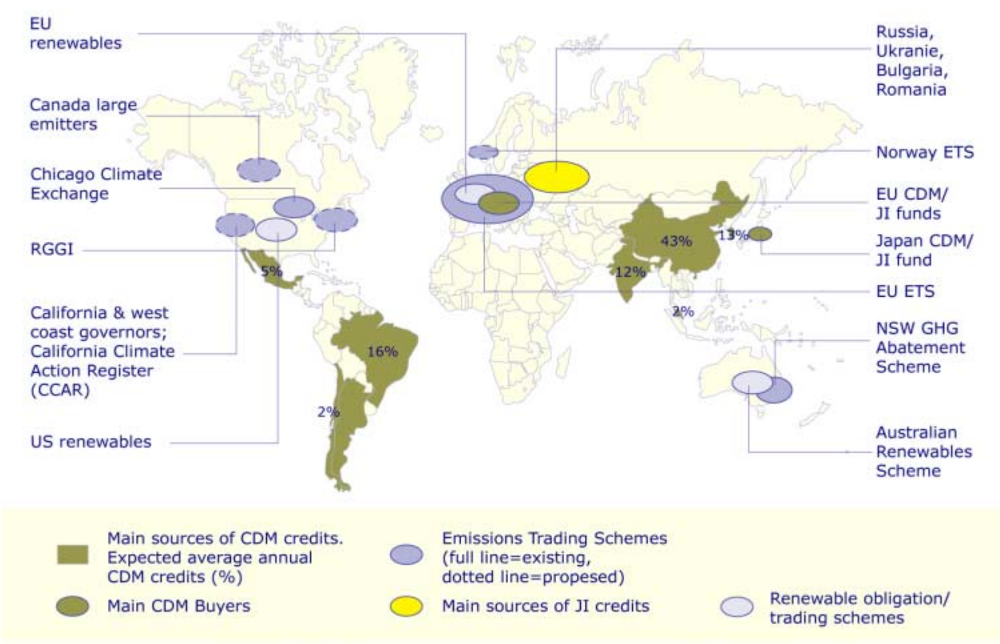
Carbon cap & trade systems by 2010

Developed economies worldwide will likely all have some sort of carbon cap and trade system by 2010, but the terms will tighten substantially under our panic button scenario. More industries will be included, and fewer carbon credits will be allocated freely. We do not expect developing economies to begin trading carbon, but they will benefit from the increased demand for carbon credits. If they want to continue selling credits as they are doing under Kyoto (CDM), developing countries will have to agree to other climate change measures.

The trend toward tighter carbon trading policies is clear in the EU's emission trading scheme, by far the largest in the world. The EU allocated far too many carbon credits in its first phase (2005-2007), leaving major polluters with excess carbon credits to sell (generating windfall profits), even though they had not cut emissions. Unlike Phases 1 and 2 when over 90% of credits were freely allocated, things have tightened considerably under Phase 2 (2008-2012) and there are already proposals to auction most (60%+) permits for Phase 3,Likewise, presidential candidate Barrack Obama proposes to auction off all of America's carbon credits in a cap and trade system, eliminating hand-outs and potential windfalls to polluters.

Figure 5

Global carbon market



Source: CLSA Asia-Pacific Markets

Othe issues: Who plays?

Developing economies to come to the table on climate change . . .

Under Kyoto, the world is divided into Annex 1 (developed) and Non Annex 1 (developing) economies, with Annex 1 countries bearing the brunt of the carbon reduction challenge. Indeed, this was America's excuse for not signing the treaty, and it will become more of a sticking point under the much more stringent regulations likely in a panic button scenario.

. . . but it is unrealistic and unfair to assume they should play by same rules

With the exception of some perennial basket cases, developing economies will ultimately have to come to the table. That said, it is ridiculous to expect China and India, for example, to play on even terms with the EU and North America. Per capita, they still emit a fraction the carbon of rich-world counterparts. Asking an Indian man to reduce his carbon emissions at the same rate we ask an American woman to cut back on hers is patently absurd.

Deforestation

Deforestation contributes to global warming since it results in the loss of trees that absorb CO_2, quantities of which are also released into the atmosphere when trees are burned. The burning of trees during deforestation contributes approximately 20 to 25% of the carbon emissions that cause climate change. Carbon emissions from deforestation far outstrip damage caused by planes and automobiles and factories. It is second only to the energy sector as a source of greenhouse gases according to report published last year by the Oxford-based Global Canopy Programme, an alliance of leading rainforest scientists. Indonesia and Brazil are among the largest emitters of greenhouse gasses after the US and China despite a relative lack of heavy industry as a result of deforestation. Currently 50,000 square miles of tropical forests disappear every year.

Controlling deforestation and increasing reforestation is easier said than done. Most of the forests being cleared right now are tropical forests in developing countries where it is often illegal to do so. Therefore any compensation schemes where countries are paid to maintain uncultivated forests are effectively paying to keep something illegal from happening, which comes with obvious problems. Further, despite quickly decreasing in size, forests in Brazil, Malaysia and Indonesia are still huge in terms of policing, making enforcement very expensive at best and impossible at worst. Those burning forests in developing countries are often living at a subsistence level, making enforcement or education problematic. Technology such as intercropping, where crops are grown within a forest, have been offered to slow deforestation, but as of yet there has been no international consensus on how to control it.

America leads emissions on both an absolute and (for large countries) per capita basis

Figure 6

Top-10 CO_2 emitters by country - 2004

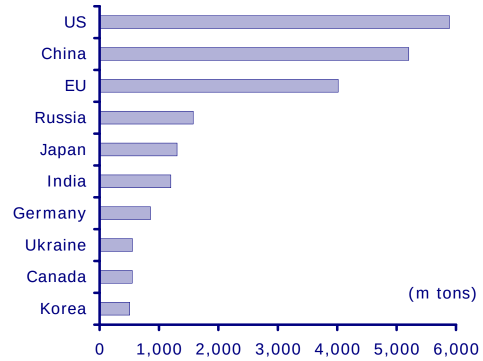
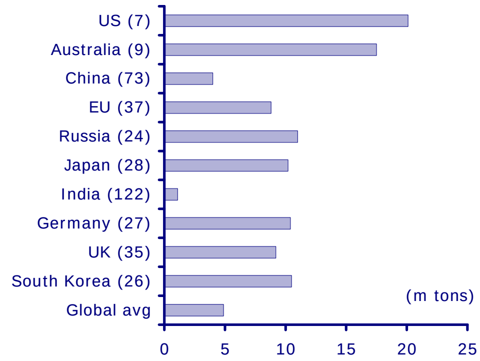


Figure 7

CO_2 emissions per person (rank) - 2004



Source: World Resources Institute (CAIT)

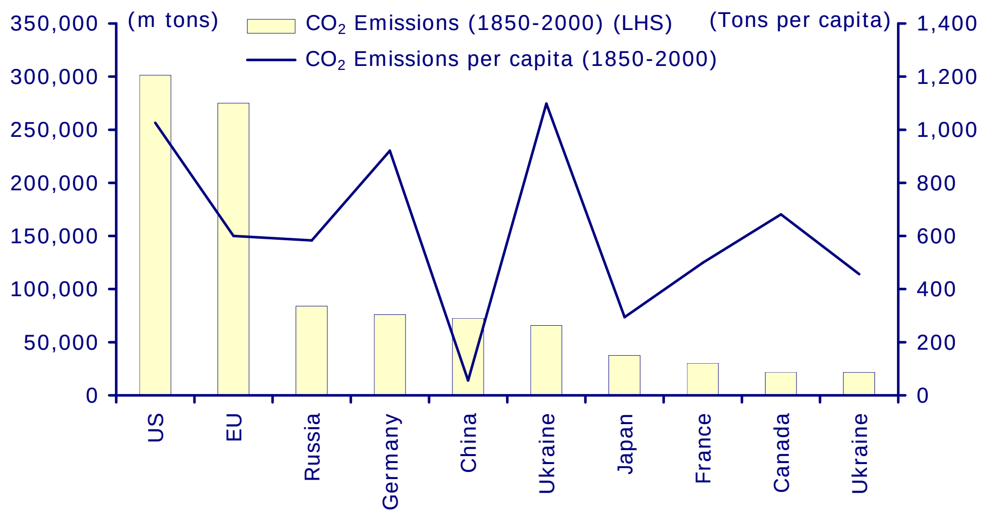
Developing economies are keen to catch up . . .

Demanding equal treatment would also be unreasonable because developed economies are responsible for the vast majority of greenhouse gases now in the atmosphere. Fossil fuels are crucial to their development with countries across Asia lifting hundreds of millions of people from abject poverty. They will not leave such a path without a compelling alternative.

. . . and they have a long way to go

Figure 8

CO_2 emissions from 1850-2000 (Absolute and per person)



Source: World Resources Institute (CAIT)

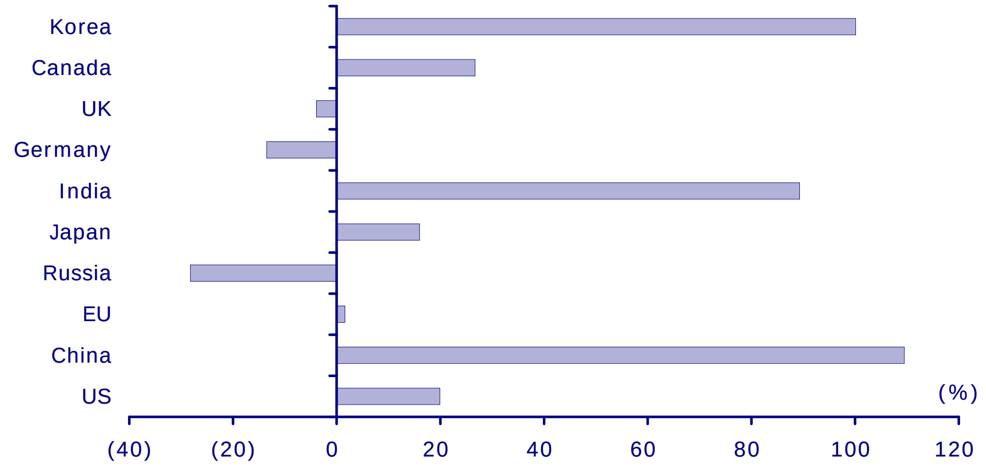
Developing economies crucial to reductions

Nevertheless, any climate change treaties that do not include developing economies are meaningless. Regardless of cuts in the West and Japan, current trends elsewhere will easily propel us past the carbon levels needed to trigger a two degrees Celsius change. If binding carbon caps prove impossible to work out, developing economies will therefore at least be at the table on energy intensity and efficiency measures.

Asia leads emissions growth

Figure 9

Change in CO_2 emissions from 1990-2004 (Top 10 emitters)



Source: World Resources Institute (CAIT)

A sectoral approach aligning companies in the same industry worldwide is one option

Sectoral approach. One of the more promising routes out of this impasse revolves around a *sectoral*, or *sector-based* approach. Under a sector-based approach, developing countries pledge to reach voluntary carbon intensity targets in energy intensive industries such as electricity, steel or cement. This could be a pre-condition for continuing the CDM program (discussed on p73) or alternatively, developing countries would receive technology incentives in exchange for agreeing to the targets.

Japan has been the biggest advocate of this approach. Important industry bodies have also offered strong support, with American and Chinese members of the Industry of Iron and Steel Institute (IISI) throwing their weight behind sector-based policies. The best-run steel mills globally would be natural beneficiaries, accelerating and spreading the trend of shutting down small, inefficient steel mills, power plants and cement plants.

Carbon sanctions

Is it fair that European companies have to pay for their carbon when other companies around the world get it for free? Many of the more heavily impacted industrials in Europe argue that it is not calling for a tariff on imports from countries with no carbon price. They are finding support among European politicians, who are seriously considering including a carbon tariff as in the next phase of the EU Emissions Trading Scheme (ETS), beginning in 2013.

Carbon tariffs would be extremely tricky from a free trade perspective. The idea has not been welcomed around the world, especially by the US. Clearly there would be some sort of retribution from affected countries, instigating yet another trade war. For the time being, this fear has taken hold in Europe, where the idea has been shelved until the ETS review in 2011.

By 2011 the rest of the developed world, including the US, will likely have some sort of carbon trading scheme in place. Such schemes may not demand a carbon tariff on goods from developing countries but carbon will clearly have to be addressed in trade negotiations. If major polluters among the developing nations aren't regarded to be approaching the table on climate change, there will be additional hurdles to international trade.

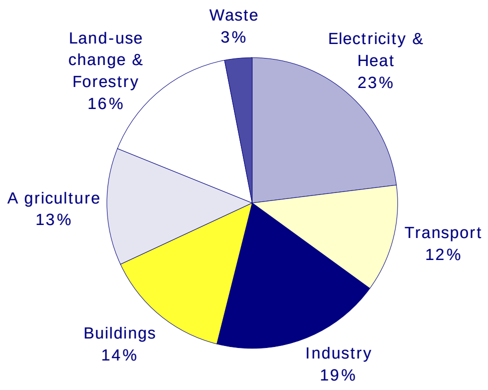
Energy accounts for 60% of the world's greenhouse gases

Renewing electricity

Nearly every facet of modern industrial society is responsible for some greenhouse gas emissions. The breakdown between sectors (Figure 10) can be somewhat misleading, however, as most of the GHG emissions from transport, buildings and industry are derived directly from energy production. In all, energy accounts for just over 60% of GHG emissions, primarily from fossil fuel combustion.

Figure 10

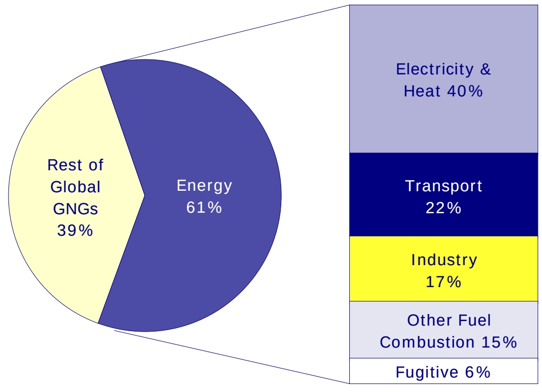
Greenhouse gas breakdown by segment



Source: World Resource Institute (2005)

Figure 11

All about energy



Source: CLSA Asia-Pacific Markets

There is a tight correlation between energy use and GDP

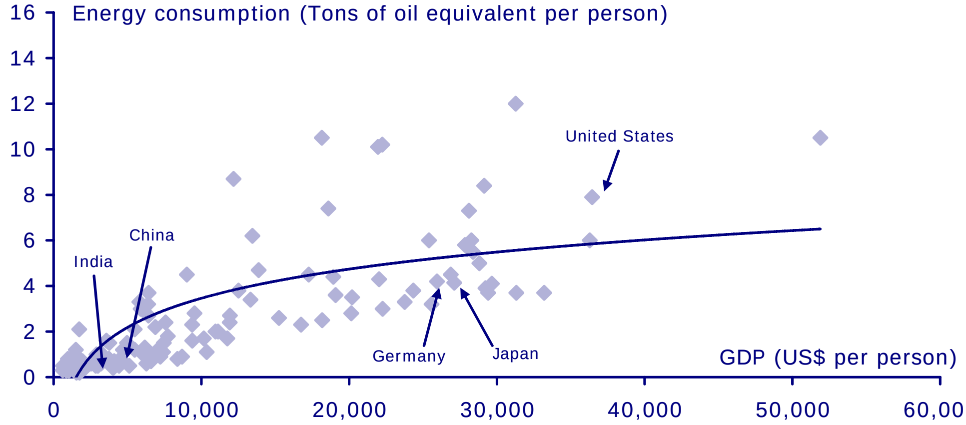
The economic imperative

The challenge in reducing energy is that it makes life so much more liveable. While many of us in the rich world might ocassionally wish for a car-free, TV-free world, there are three billion people aspiring toward the good life that suffer no such illusions. Mobility, light, music, communication, heat and steel are a few of the things made possible by energy. Naturally, those of us that have these things have no intention of giving them up, while those that don't cannot be expected to stop trying to change that.

Unsurprisingly a tight correlation exists between energy use and rising GDP. People naturally use more electricity and fuel as they move from agricultural societies to those that are industrial/consumer-driven. This curve flattens out as countries progress towards a services-based economy.

Figure 12

GDP vs. energy consumption: Quick rise before flattening



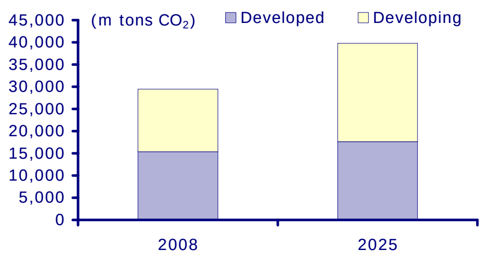
Source: World Resources Institute, UN, CLSA Asia-Pacific Markets

Developing economies driving emissions

As of now, emissions from energy are evenly split between the developing and developed world, although per capita emissions are of course much higher in developed economies. By 2025, the Energy Information Administration (EIA) expects developing countries to have taken a clear lead as they make and consume more goods with growing populations. Developed economies look good, but only by comparison.

Figure 13

Global energy emissions forecast (EIA)



Source: EIA

Figure 14

Base case electricity growth

(%)	07-20CL Cagr
China	7
India	6
Asia - Other	2
EU-25	1
North America	1
ROW	4
Global	3

Source: CLSA Asia-Pacific Markets

Hot showers and cold beer, not lumps of coal

The challenge. Eliminating these emissions without eliminating the goods that energy supplies is the challenge. As energy guru Amory Lovins says, “People don’t want raw kilowatt-hours or lumps of coal or barrels of sticky black goo. They want hot showers, cold beer, comfort, mobility, illumination.”

This is no small task. The energy infrastructure - for electricity and heat as well as transportation - has been built up since the dawn of the industrial revolution, and is among the most entrenched industries. Change therefore tends to come slowly with the last recognized “killer app” being nuclear power some 60 years ago.

Under a panic button scenario, we believe the energy industry would be coaxed and coerced into cutting CO_2 emissions 20% from 1990 levels by 2020. This is approximately a 50% cut from business as usual, and although the building blocks are in place, it will not without a difficult transformational shift in both the electricity and transport industries.

Electric light brigade

Electricity produces 1/3 of the world’s emissions

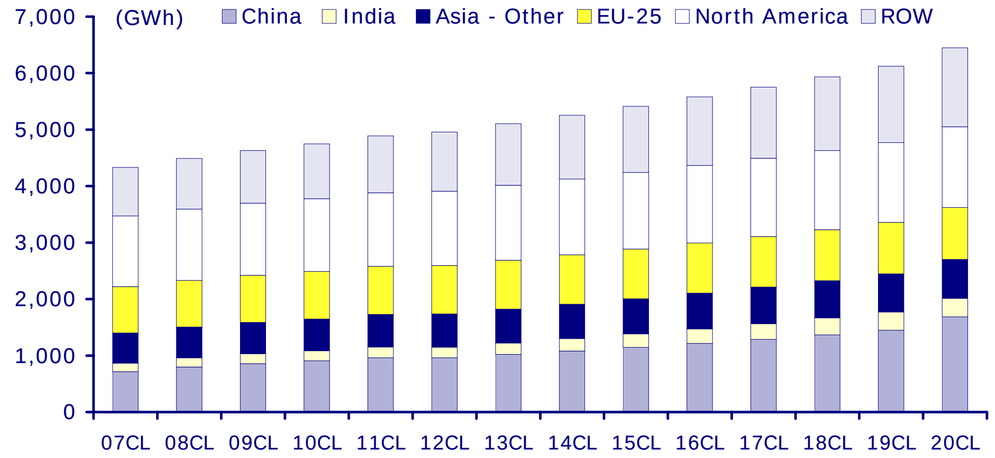
Electricity production accounts for around one third of the world’s carbon dioxide emissions, making it the single biggest contributor to global warming. In 2007, total carbon dioxide emissions from the sector were just under 14bn tons (IEA). Of this, roughly two thirds came from electricity. Rapidly growing demand, especially from emerging markets in Asia, is also pushing emissions from the sector higher.

Base case - No policy steer

Minus any explicit climate change or energy-efficiency policy, global demand for electricity would likely grow 48% from 2007 to 2020, or 3% Cagr. The biggest drivers are, unsurprisingly, China and India, followed by other emerging economies with low current per capita electricity use.

Figure 15

Base case: 48% electricity capacity growth from 07-20CL



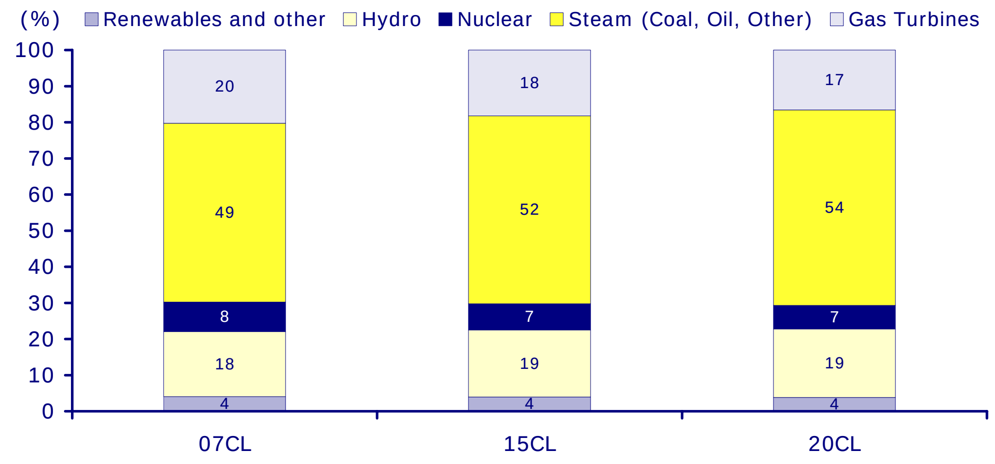
Source: CLSA Asia-Pacific Markets (For Asian markets); Cheuvreux (For others)

King coal is on the rise

Where is it coming from? The generation mix varies drastically from country to country, depending on past policy and available fuels. However, coal will clearly become a more important part of the electricity mix if there is no policy preventing it. Huge reserves and sky-high natural gas prices have boosted coal's popularity among utilities in developed markets such as the US, despite a popular backlash against new coal plants. It is also the fuel of choice for the key global growth markets, including China and India.

Figure 16

Electricity mix: Base case (No policy steer)



Source: CLSA Asia-Pacific Markets

Regional breakdown

Changing electricity mix reflects shift toward developing economies

While the US and Europe has reasonably similar generating mixes, there is still variation within Europe (most notably nuclear-happy France in comparison with its counterparts).

Figure 17
US electricity mix (07A)

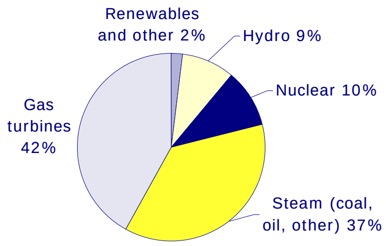
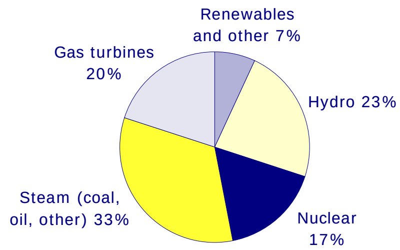


Figure 18
EU-25 electricity mix (07A)



Source: EIA, Cheuvreux

With electricity demand in developing economies growing at 3-6% per annum versus around 1% for developed economies, the developing world's predilection toward coal will show through into global mix.

China and India are heavily geared toward coal

Figure 19
China electricity mix (07A)

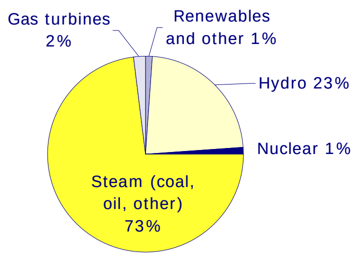
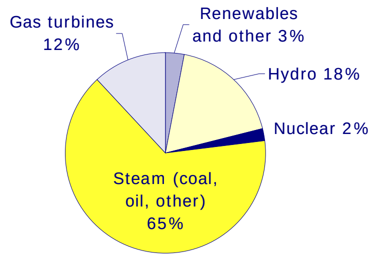


Figure 20
India electricity mix (07A)



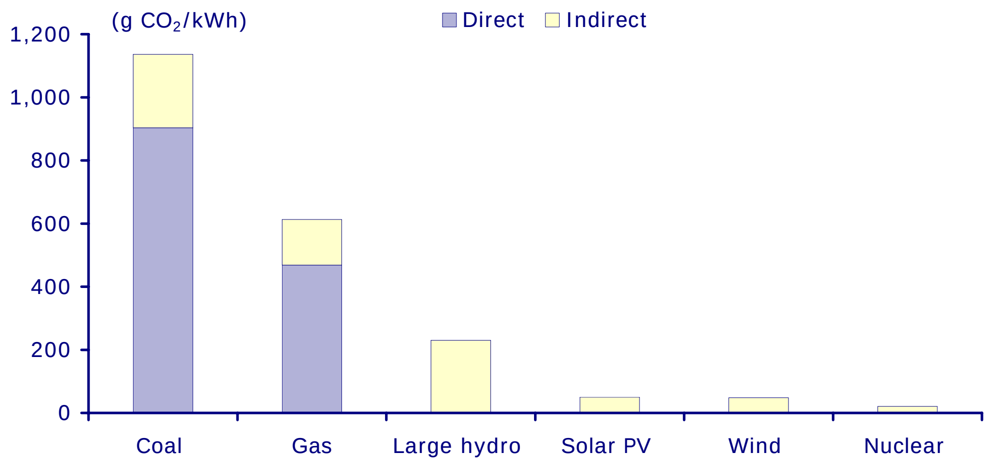
Source: IEA, CLSA Asia-Pacific Markets

Implications for CO_2 emissions

Our policy-free scenario is admittedly bleak. It assumes that no governments around the world really take their renewables or carbon reduction plans (highlighted in appendix four) in the least bit seriously. Most important, rising shipments of coal - easily the dirtiest fuel for electricity, even its cleanest form - amplifies the effect of climbing capacity on emissions.

De-carbonizing means shifting out of coal toward nuclear and renewables

Figure 21
Carbon footprint of various power sources



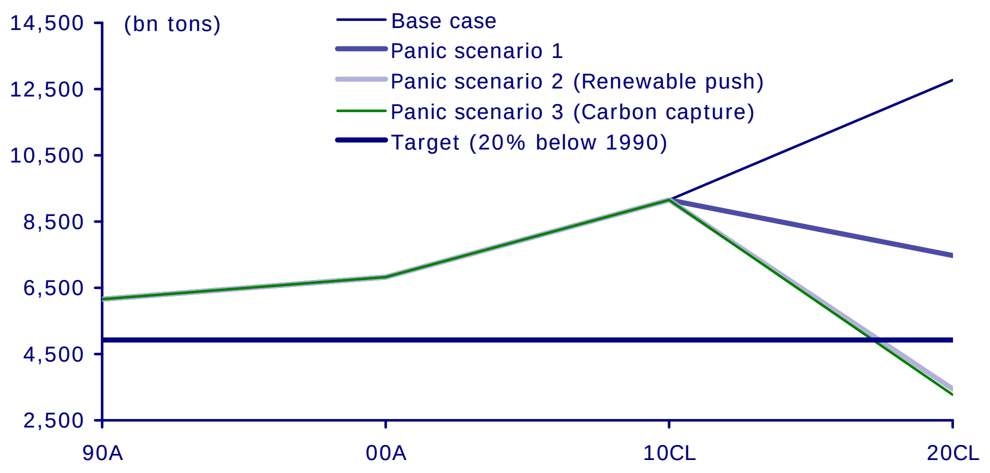
Source: CLSA Asia-Pacific Markets, IEA

With no policy steer, emissions would exceed targets by 160%

The implications of greater coal usage for CO_2 emissions (and thus climate change) are likewise bleak, resulting in a 48% rise in emissions from 2008 to 2020, 159% higher than the target level.

Figure 22

Base case: Emissions up 48% from 08CL to 20CL



Source: CLSA Asia-Pacific Markets

Surprisingly this increase in emissions is not far off the Energy Information Association's (EIA) base-case scenario, which does factor in a modicum of renewable energy and energy-efficiency. The EIA projects 35% growth in energy CO_2 emissions from 2008 to 2025, with slower (14%) growth in developed countries augmented by 57% growth in developing economies. Clearly, this sort of no policy scenario cannot exist in a panicked world.

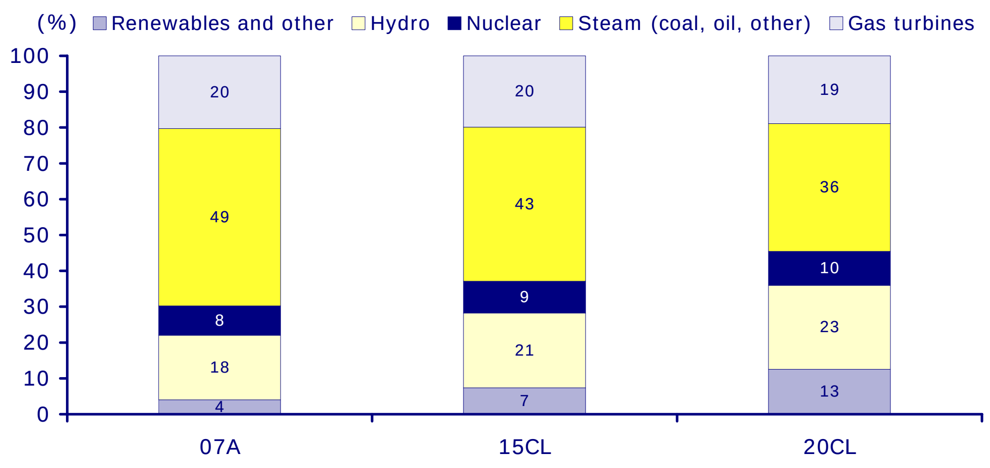
Panic scenario 1

Efficiency is the first step in an energy policy

Under our first policy-driven scenario, we include some energy-efficiency measures, renewable energy support and a moratorium on new coal-fire generation in the developed economies. We break down the mechanics of how this would work below.

Figure 23

Electricity mix: Panic scenario 1 (Efficiency, coal cutback, moderate renewables)



Source: CLSA Asia-Pacific Markets

Under Panic scenario 1, Europe nearly reaches its 20% renewables target

In this scenario, the EU falls just shy of its 20% renewable energy target by 2020 while China still relies heavily on coal. Continued emissions growth from the developing world makes the 30% reduction from 1990 levels unattainable under this plan.

Figure 24

EU electricity mix (2020) - Panic 1

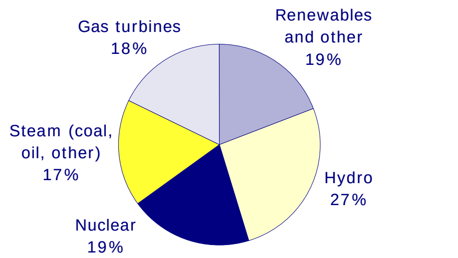
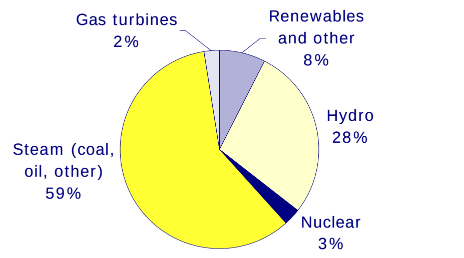


Figure 25

China electricity mix (2020) - Panic 1



Source: CLSA Asia-Pacific Markets

Panic scenario 2 (Renewable push)

A hard renewables push is the only way to reach a 20% CO_2 cut by 2020

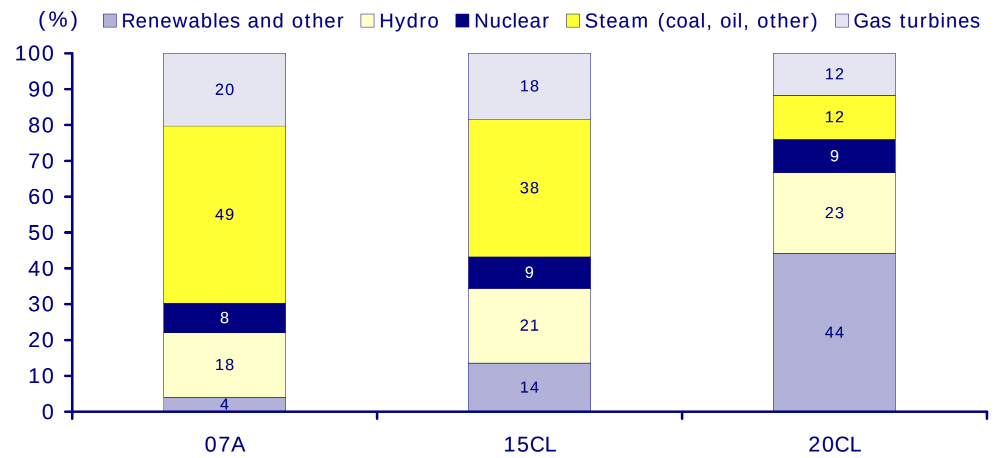
Under our second scenario, we assume that, in addition to the above policies on energy-efficiency and coal, renewable energy companies push through similar growth rates to what they have been achieving. The numbers are quite extreme, and would necessitate significant electricity grid and energy storage investments, while also incurring heavy costs by pre-maturely retiring fossil fuel plants. Carbon emissions under this scenario come under the target, leaving a little bit of excess slack to keep fossil fuel-fired plants on-line in the EU and US, but not that much.

Reaching renewable goal is a long shot, but could be a policy guideline

While we do not see such an extreme shift as likely, the key point is that something almost as extreme will be necessary for global carbon emissions to reach the prescribed targets and prevent a two degrees Celsius warming.

Figure 26

Electricity mix: Panic 2 (Renewable driven)



Source: CLSA Asia-Pacific Markets

National grids would struggle under this renewables ramp

In their current guise, the various national grids across Europe and in the US could not withstand such a massive flow of renewables into the system. The timing and consistency of generation is too sporadic. The current share of natural gas and coal-fire plants could not be entirely retired so quickly, even if the will was there.

Figure 27

EU electricity mix (2020) - Panic 2

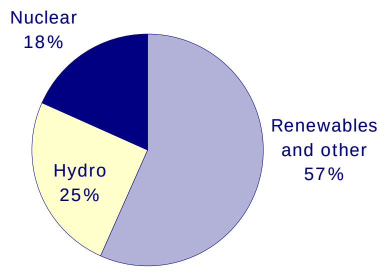
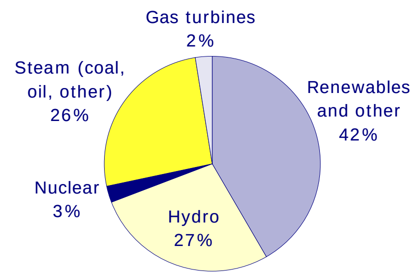


Figure 28

China electricity mix (2020) - Panic 2



Source: CLSA Asia-Pacific Markets

What will this cost?

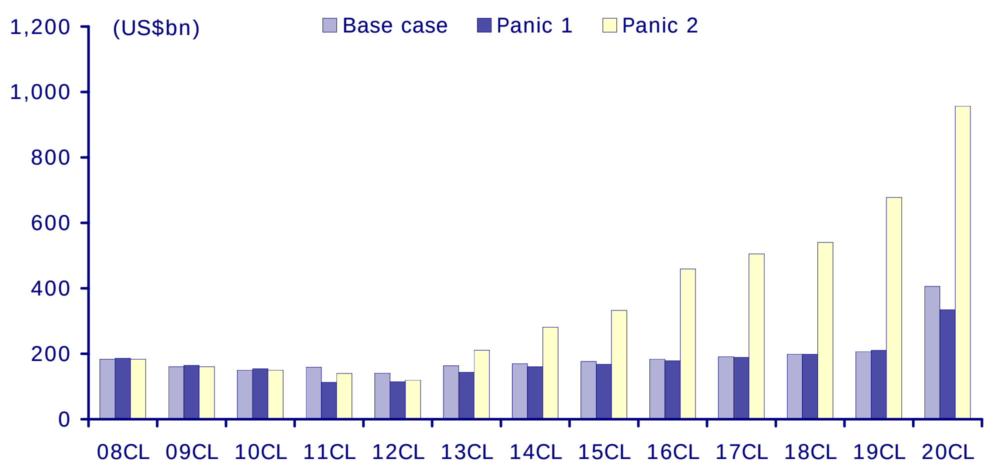
Upfront capex for power-gen could double by 2020

Pricing carbon into our electricity mix will not be cheap, regardless of how the electricity is produced. First, cleaner forms of electricity generation (from a carbon perspective) generally cost more upfront, even if they pay for themselves over time with lower fuel costs (in this respect wind is cheaper than coal). The figure below illustrates how annual capex on power generating equipment effectively doubles under the renewable-driven panic scenario.

Renewables feature much higher capex; but variable costs cheaper

Figure 29

Incremental capex on generating equipment (US$bn)



Source: CLSA Asia-Pacific Markets

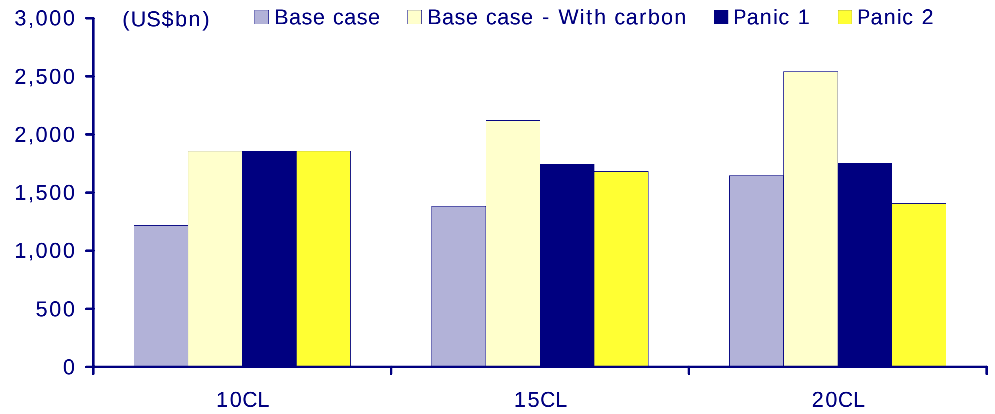
The chart above also underestimates the total cost of our renewable panic scenario. This is because over 600GW of coal-fire plants would have to be prematurely retired or be sitting idle by 2020, at a cost of over US$700bn.

Carbon adds 40-60% to electricity prices

Second, adding carbon as an additional variable cost adds 40-60% to the cost of producing electricity. While this will not all be added to utilities' costs immediately, it would all have to filter through to prices well before 2020.

Figure 30

Annual cost of electricity production on different scenarios



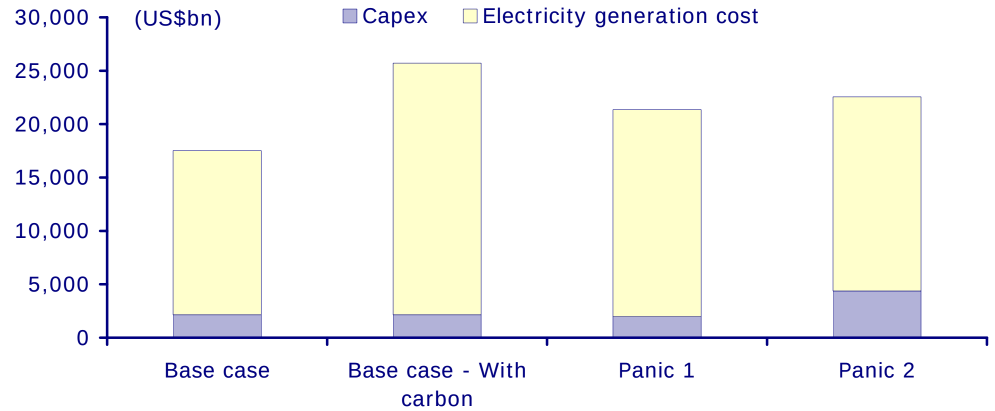
Source: CLSA Asia-Pacific Markets

Globally, the cost of working carbon out of the electricity infrastructure will add 30-50% to total costs from 2010 to 2020.

Total electricity costs worldwide will rise 30-50% as carbon is priced into the system

Figure 31

Total spending on electricity generation (2010-20)



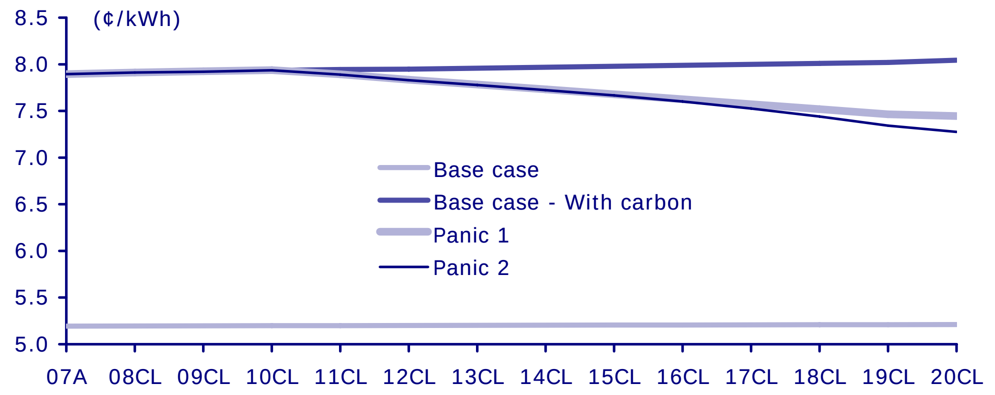
Source: CLSA Asia-Pacific Markets

Electricity prices for end-users will also inevitably continue their upward trend, regardless of where commodity prices go.

Leaving renewables out of the mix is the most expensive option in a carbon-constrained world

Figure 32

Electricity costs are set to rise (flat commodities)



Source: CLSA Asia-Pacific Markets, Cheuvreux

Carbon will be priced; renewables ramped; coal-fire banned; and efficiency forced

Flushing carbon out of the electricity mix

Four basic steps will be included in any new electricity generating policy focused on carbon: energy efficiency policies will be strengthened; new coal-fire power plants will be all-but-banned in the developed economies; carbon will be priced-in either through a tax or cap & trade system; government support for renewables will be ramped up.

Under our first panic scenario, we consider an approach that could reasonably gain support under the current climate. For the more aggressive scenario, we ignore what governments would be likely to do and consider what the science suggests is necessary and what renewable energy companies appear capable of producing.

Carbon capture and storage (CCS). Even the dirtiest coal could theoretically be cleaned up by pumping all of the emissions into the ground rather than the air. This clean coal, or carbon capture and storage (CCS) technology could ultimately hold a lot of promise, but it is unrealistic to expect that CCS will be implemented in more than 5% of existing coal-fire power plants by 2020, and even that is wildly optimistic. The basics are explained in more detail on page 48.

Step 1: Energy-efficiency

The panic button energy policy will firstly be determined by ramp up time followed by cost and finally political expediency. Cynically, we could say that this marks a reverse-order from current policy making criteria. Regardless, there is a very clear front-runner from both a cost and timeliness perspective:

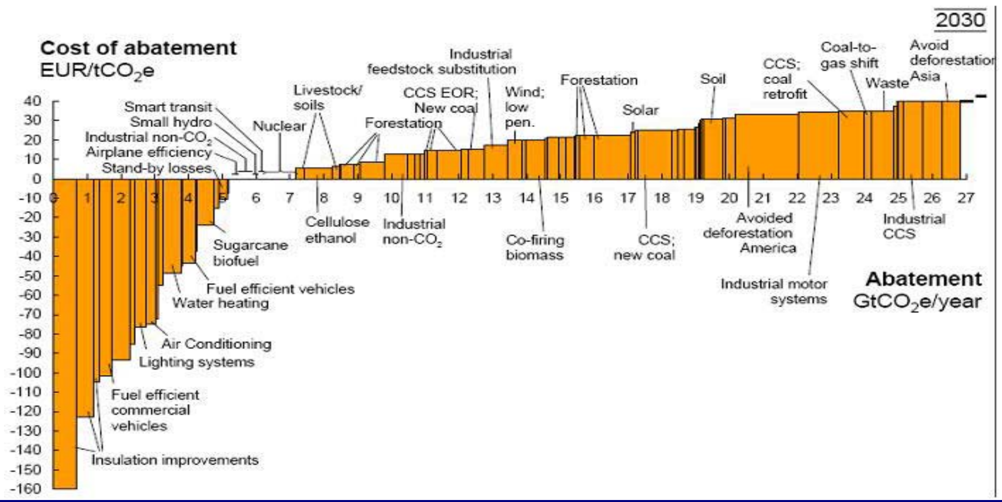
Energy-efficiency measures could save Europe up to €100bn each year by 2020

There is no clear-cut path showing what the ideal mix of renewables and nuclear power is. However, numerous studies and countless experiences show that the cheapest way to save energy is to not use it. As illustrated by the chart from Swedish power company Vattenfall below, energy-efficiency measures can often be made at a profit.

Our sister company, Cheuvreux, estimates that Europe could save 100bn Euros pa by 2020, and the US could save US$70bn pa by 2025 simply by implementing efficiency measures. The failure to capitalize on this comes down more to policy and institutional issues than technology.

Figure 33

Climate change mitigation on the cheap



Source: Vattenfall 2007

Buildings use 71% of all US electricity

Where to cut

Houses and commercial buildings are the primary target for energy-efficiency (aka demand reduction) measures. According to the US Green Building Council (USGBC), buildings use 71% of all electricity in the US and account for 39% of all CO_2 emissions.

Figure 34

Typical energy consumption split - Californian houses

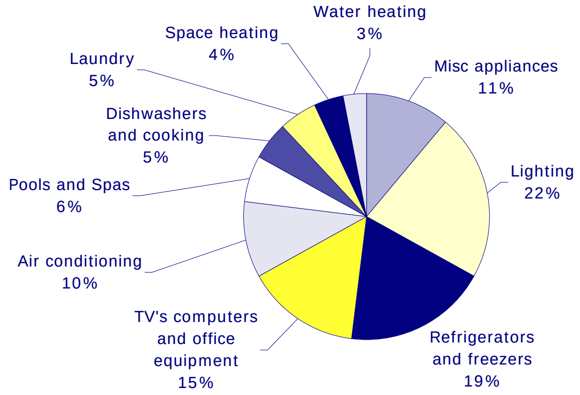
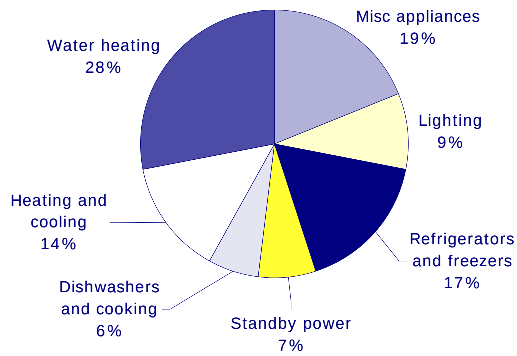


Figure 35

Typical energy consumption split - Australian houses



Source: California Energy Commission, Australian Department of Energy

Efficiency measures such as improving insulation or air conditioning systems offer positive returns and fast payback periods that are often measured in months, not years. Yet implementation of even old technologies is quite low, having been stifled by misconceptions about cost in many cases, and a mismatch of cost and reward in many others.

Additional efficiency costs of 2% can save 20% of a building's lifelong costs

Costs. While promoting greener building standards in Hong Kong, the Civic Exchange cites US studies claiming that an additional 2% in upfront costs to support more environmentally focused design would, on average, result in life cycle savings of 20% of total construction costs or more than 10 times the initial investment, over the life of the building. The net present values (NPVs) of sustainable buildings range from US$540 to US$4,300 per m^2 depending on the time period for the analysis (20 to 60 years) and the level of 'greenness': generally, the greener the building, the higher the NPV.

Yet the upfront costs for better heating and cooling systems, lighting, insulation and other measures are generally higher and long-term savings do not necessarily accrue to the purchaser. For example, energy efficient light bulbs cost one third as much as traditional incandescent bulbs over their lifetime because they last longer and use less electricity. But they cost 10 times as much upfront, so landlords would be unlikely to bear the upfront costs since they would not benefit from savings down the line. This is where policy comes in.

High oil prices drove auto efficiency in the 70s

Policy shift. To some extent, rising electricity prices stemming from the inclusion of carbon will drive efficiency measures (just as high oil prices drove demand for smaller cars in the 1970s and are starting to do so again today). Given the issues we lay out above, there will also be a raft of new efficiency laws pushed through. These will include the banning of incandescent light bulbs worldwide and the tightening of efficiency targets such as the Energy Star label for consumer electronics, appliances, heating and ventilation systems.

Andrew Lawson, from the Civic Exchange, has pulled together some of the key energy-efficiency policies around the world. We would expect to see more similar policies pop up across both developed and developing economies very rapidly in the event of an ice-free Arctic.

In the UK, carbon disclosure for all new homes

In the UK:

- From May 2008, all new homes must be assessed on a six-point rating system, which includes energy-efficiency. A six-star rating is given to buildings that are carbon neutral.
- Progressive tightening of the minimum energy performance standards in the building regulations means that by 2016, all new homes must be carbon neutral.
- Stamp duty exemptions will be given for zero carbon homes.[i]

A similar pattern of regulations and incentives is occurring across the European Union as a result of EU directives on the energy performance of buildings.

In the USA, tax breaks for HPBs

In the US, with the highest per capita GHG emissions in the world, the *Energy Policy Act* (EPA) 2005 offers favourable tax incentives to:

- Contractors that construct energy-efficient homes and to consumers who install energy-efficient windows, insulation, doors, roofs, and heating and cooling equipment.
- Businesses that improve the energy-efficiency of commercial buildings and those that install certain types of in-house energy generators (e.g. solar power).
- To manufacturers of energy efficient appliances.

In China, energy-efficiency is embedded in the Five Year Plan

In China, home to the highest total national emissions, the Government has used the 11th Five-Year Plan to set out various environmental targets for the period 2006-10, including reducing energy consumption per GDP by 20%. Other targets that could affect the way construction projects are implemented include targets to:

- Increase recycling of industrial wastes;
- Increase water use efficiency; and
- Reduce discharge of pollutants.

At an operational level, the Chinese Government has established a Green Building Council and green building rating system.

Ban the bulb

Big changes are on the way for the US$100bn global lighting industry. Lighting has a big impact on the environment: it is estimated to consume about 250bn kWh per year in the US alone. About 40% of this energy is used by inefficient light bulbs to generate only 15% of all light; the rest is produced by more efficient fluorescent tubes. In developed countries, some 5-20% of the total electricity bill is for lighting, but in developing countries lighting can consume almost 90% of all electricity.

Figure 36

Environmental load of today's global general-lighting-service (GLS)

Unit	All lighting	GLS lamps
Installed base of GLS lamps		15bn
Market volume (annual sales) of GLS lamps		12.5bn/year
Energy use	2,350TWh	720TWh (about 350 electric power plants)
CO_2 use		410m tonnes
Electricity cost	US$235bn/year (at US10 cents/kWh)	US$72bn/year (at US 10 cents/kWh)
Poisons	Fluorescent tubes: mercury Incandescent bulbs: lead	Fluorescent tubes: mercury Incandescent bulbs: lead

Source: European Lamp Companies Federation (IEA Workshop, Paris, 26 February 2007), and Eurotechnology Japan KK estimations and projections

Inefficiency of developing world's fuel-based lighting

World's poor pay most for least light

About two billion people, or about one-third of the world's population, are estimated to have no access to electricity and to rely on highly inefficient fuel-based lighting. This is estimated to cost them around US$48m annually - roughly 20% of the world's total spending on lighting for about 0.2% of the world's total illumination.

Developing countries could jump directly to LEDs

Given that efficient LEDs could potentially reduce the US$48bn lighting bill for the world's poorest by factors of 1,000 to 5,000, and reduce associated CO_2 emissions dramatically, there is a potentially large market for SSL in developing countries. Developing countries could therefore jump straight from fuel-based lighting to LEDs, bypassing incandescent-light bulbs, with great benefits for quality of life, as well as reductions of emissions and other pollution.

While semiconductor integrated circuits (IC) have long replaced vacuum tubes in televisions, radios and computers, no technology existed that could viably replace vacuum-tube technology (light bulbs and fluorescent tubes) for lighting until about 15 years ago, when Shuji Nakamura at Nichia in Tokushima prefecture, Japan, developed blue and white gallium-nitride-based (GaN) light-emitting diodes (LEDs) to the point of commercialisation.

CFLs provide a mid-term solution, but LEDs are here for the long haul

Figure 37

The future looks brighter, thanks to compact flourescent lamps (left) and LEDs

Source: Eurotechnology Japan KK

GaN-based light-emitting diodes (LED) promise to change all that

GaN-based LEDs are now making inroads in the lighting market and also finding many other applications, such as backlighting for flat panel displays, and lighting in mobile phones, medical applications and much more. The organic light-emitting diode (OLED) is another new technology that has reached commercial maturity around the same time as GaN-based LEDs, competing in some markets.

LEDs will take greater share of global lighting market

LED-based lighting will win a growing share of the global US$30bn electric-lamp market

The prospects are excellent for GaN-based LEDs to gain an increasing share of the global US$35bn electric-lamp market. Those companies that are well positioned will also be able to leverage success in the GaN-LED market into the much larger US$100bn market for lighting fixtures (luminaries).

Much of the incandescent-bulb business is based on replacements; LEDs do not burn out

Light bulbs have a life of about 1,000 hours, whereas LEDs have a life of about 50,000 hours or longer. This fact changes the business model of the global lighting industry. A large part of the incandescent-bulb business entails replacement of burnt-out bulbs. By contrast, LEDs do not burn out. Replacement purchases will not be motivated by burnt-out LEDs but by new effects and fashions. New applications will certainly also be invented.

Many investment opportunities in the LED industry

The GaN-based-LED and laser industry was created in Japan about 2005, and the Asia-Pacific region (particularly South Korea, Taiwan, China and Japan) will remain its centre of gravity, both for technology and production. Investors can find a range of pure plays in GaN LEDs and lasers. The crown jewel, Nichia, is a private company that has recently opened up capital by entering into a number of alliances and cross-shareholder agreements. Investors can link into Nichia's value chain via these partners.

Figure 38

Operating costs of comparable incandescent lamps, CFLs and LEDs

	Incandescent-light bulb	CFL	LED
Power consumption	100W	22W	10W
Life	1,000 hours	8,000 hours	50,000 hours
Energy cost for 8,000 hours (US$0.10/kWh)	US$80	US$17.60	US$8
Purchase price	8 x US$1.50 = US$12.00	US$15.00	
Total	US$96	US$32.60	US$8 + purchase price

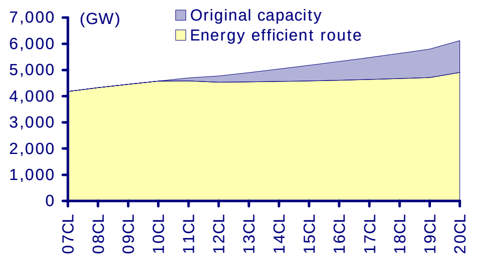
Source: Eurotechnology Japan KK and product sheets

Efficiency impact on electricity demand

We estimate that extensive efficiency measures could cut global electricity demand 30% from base case by 2020. Less efficient countries such as the US are cutting closer to 40%, while more efficient countries like Japan only need to cut around 10-15%. This is our starting point to see where the generating mix could go, and contrary to US Vice President Dick Cheney, this is absolutely a firm (and necessary) foundation for a comprehensive energy plan.

Figure 39

Effective energy-efficiency measures



Source: CLSA Asia-Pacific Markets

Figure 40

Changing American view

The old: US Vice President Dick Cheney

"Conservation may be a sign of personal virtue, but it is not a sufficient basis for a sound, comprehensive energy policy."

The new: US Presidential candidate Barack Obama

"I will call on businesses, government, and the American people to meet the goal of reducing our demand for electricity 15 percent by the end of the next decade. This is by far the fastest, easiest, and cheapest way to reduce our energy consumption - and it will save us $130 billion on our energy bills."

Source: Council on Foreign Relations

New coal-fire plants will be tough to build in a carbon constrained world

Step 2: Moratorium on coal-fire plants

Banning coal-fire power plants outright seems like an environmentalist's pipe dream at this point. Even the hyper-green Germans continue to build coal burners, and the US is ramping up construction despite public opposition. However, energy-efficiency measures could more than offset a potential moratorium on new coal-fire and natural gas plants in North America, Europe and Japan. We assume that developing countries will continue to build new coal-fire plants, but at a slower rate.

> When people in the US finally wake up to the reality of global warming, they may react in a very emotional way. They may decide 'Hell let's slap a fifty-dollar-a-ton tax on carbon.' Or, 'let's just shut the coal plants down.'
>
> *Tom Burke*, senior environment and political adviser to *Rio Tinto*

More likely, coal-fired plants will die off in developed economies not because they are banned, but because they become extremely uneconomic when carbon is priced in.

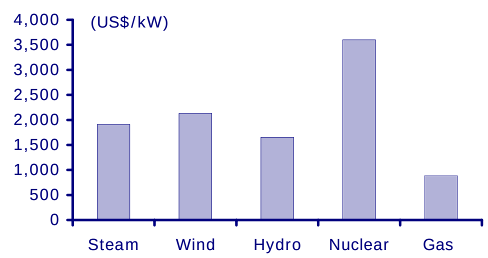
Step 3: Pricing carbon into the mix

Coal-generated power is so popular primarily because it is cheap, at least if environmental externalities are not priced in. The cost curve then flips when carbon prices are factored in.

Upfront capital costs. The charts below demonstrate how much cheaper it is to build coal-fire (aka steam, aka thermal) plants than to build wind turbines or nuclear plants. They also show how much cheaper it is to build power plants in China than Europe. A more detailed breakdown of global average costs can be found in the appendices.

Figure 41

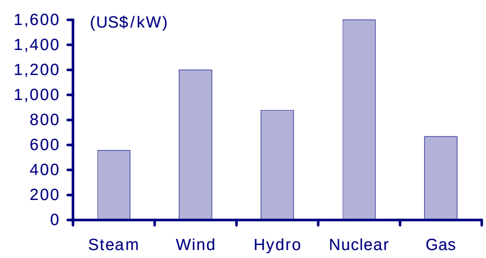
Power generation capital costs (EU)



Source: Cheuvreux

Figure 42

Power generation capital costs (China)



Source: CLSA Asia-Pacific Markets

Variable costs are much lower for renewables

Running costs. It is unfair to compare a fossil fuel powered plant to a renewable or nuclear plant on upfront basis. While the variable costs of fossil fuel powered plants exceed the depreciation costs for thermal and natural gas plants, the variable costs are negligible for renewables and quite low for nuclear.

In addition to the variable costs, we look at the impact of a 35 Euro / ton carbon price on the various types of generation. In Europe, adding carbon makes coal almost as expensive as wind and more expensive than everything else. In China's less efficient plants, coal-fire plants become the most expensive option if carbon is priced in.

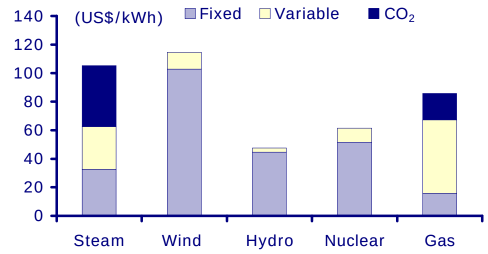
Carbon will be priced in gradually

Carbon costs will not be phased in overnight, even under a panic scenario. They will ultimately pass through to higher wholesale electricity prices as governments lower the base-case carbon caps for utilities in increments.

Coal –fire power is cheap under base case . . .

Figure 43

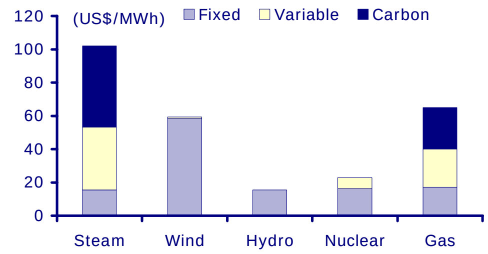
EU total electricity price



Source: Cheuvreux - Coal at US$85/ton

Figure 44

China total electricity price



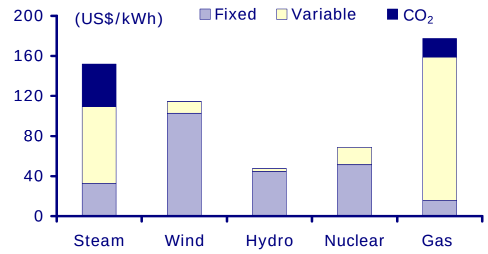
Source: CLSA Asia-Pacific Markets - Coal at US$90/ton

If we add a bullish commodity price scenario to the recipe, natural gas and especially coal lose all economic appeal even before carbon is priced in. Arguably, the cost of production for wind turbines and hydro plants would also rise along with higher steel and cement costs (both of which come under the EU carbon trading scheme).

. . . but much less attractive under a bullish commodities scenario

Figure 45

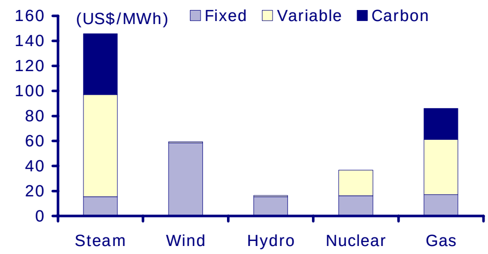
EU total electricity price



Source: Cheuvreux - Coal at US$240/ton

Figure 46

China total electricity price



Source: CLSA Asia-Pacific Markets - Coal at US$200/ton

There are a lot of uncertain variables to consider, but it is clear that fossil fuels will give up their cost advantage over other forms of electricity in the medium term.

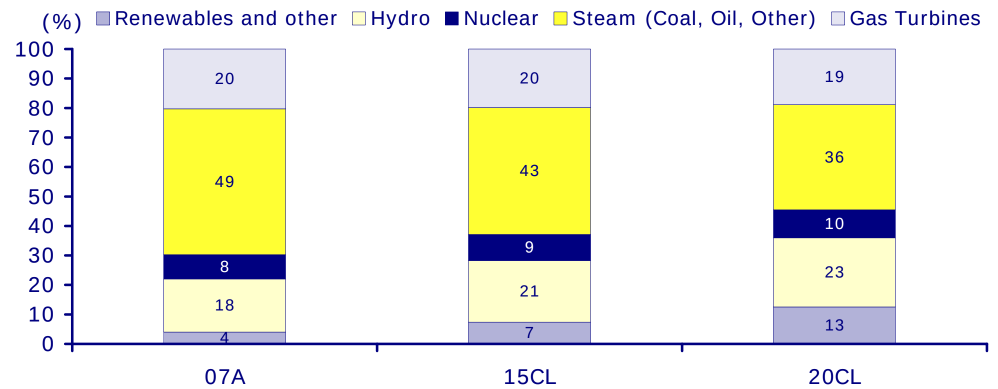
Support programs for renewables and nuclear are already in place

Step 4: Support for renewables and nuclear

Governments around the world already have some fairly aggressive targets for renewable energy as well as nuclear. They support renewable targets through up-front subsidies, tax incentives and feed-in tariffs. Overall, renewables take a substantial amount of market share from coal, as countries worldwide meet or beat existing renewable targets.

Figure 47

Electricity mix: Panic scenario (efficiency, coal cutback, moderate renewables)



Source: CLSA Asia-Pacific Markets

In this scenario, the EU falls just shy of its 20% renewable energy target by 2020. China still relies heavily on coal.

Figure 48

EU electricity mix (2020) - Panic 1

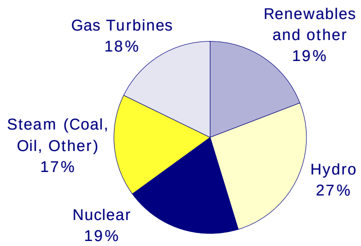
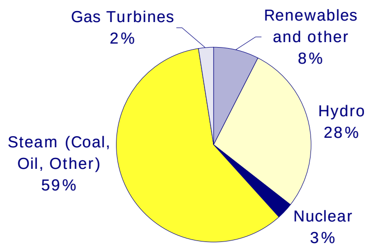


Figure 49

China electricity mix (2020) - Panic 1



Source: CLSA Asia-Pacific Markets

The breakdown

As governments move away from traditional fossil fuels they will pursue varying mixes of nuclear, hydro and renewables. Again, ramp-up speed and availability will be major determining factors.

1. A global nuclear revival?

The world's nuclear power industry has made slow progress

Until recently, the world's nuclear power industry had been progressing slowly. More than three quarters of the world's reactors went on line before 1990. No new nuclear station has been ordered in the US for 25 years, and only one is being built in Western Europe. Finland, Belgium, Holland and Sweden are beginning to phase out existing plants, and Austria, Denmark and Ireland have stated policies against nuclear. In many other places there is little or no public support, although a review has just begun in Britain.

But a nuclear renaissance is underway with the IAEA predicting 60 new plants in the next 15 years

However, growth prospects for nuclear energy are improving rapidly, not least because of environmental concerns. The International Atomic Energy Agency (IAEA) recently raised its nuclear capacity projection and conservatively anticipates at least 60 new plants in the next 15 - 20 years, with 430GW in place by 2020. That is 17% more than is installed currently and 60 new plants of 1,000MW each at US$2m/MW equates to over US$100bn of capex.

The 1980s saw 218 new power reactors starting up at an average of one every 17 days. These included 47 in USA, 42 in France and 18 in Japan. The average capacity was just over 900 MWe. It is easy to imagine a similar number being commissioned a decade on from 2015.With China and India getting up to speed with nuclear energy and world energy demand reaching double the 1980 level in 2015, a realistic estimate of what is possible might be the equivalent of one 1000 MWe unit being added worldwide every five days.

USA considering new nuclear plants for the first time in a generation

On top of the China and India growth plans, the USA is considering new nuclear plants for the first time in a generation. The 2005 Energy Bill includes tax breaks, government-backed insurance for project delays and loan guarantees to encourage nuclear power plant investment. Germany may also be forced to extend the 2021 date for its planned decommissioning of 19 nuclear power stations The UK government has explicitly not ruled out new nuclear plants as part of its energy review, mainly on environmental grounds but also with an eye on declining North Sea oil and gas production and its ageing nuclear plant portfolio. Nuclear power stations provide 22% of UK electricity needs. The government is committed to reducing the country's 1990 level of greenhouse gas emissions by 12.5% by 2010, and is on course to do so.

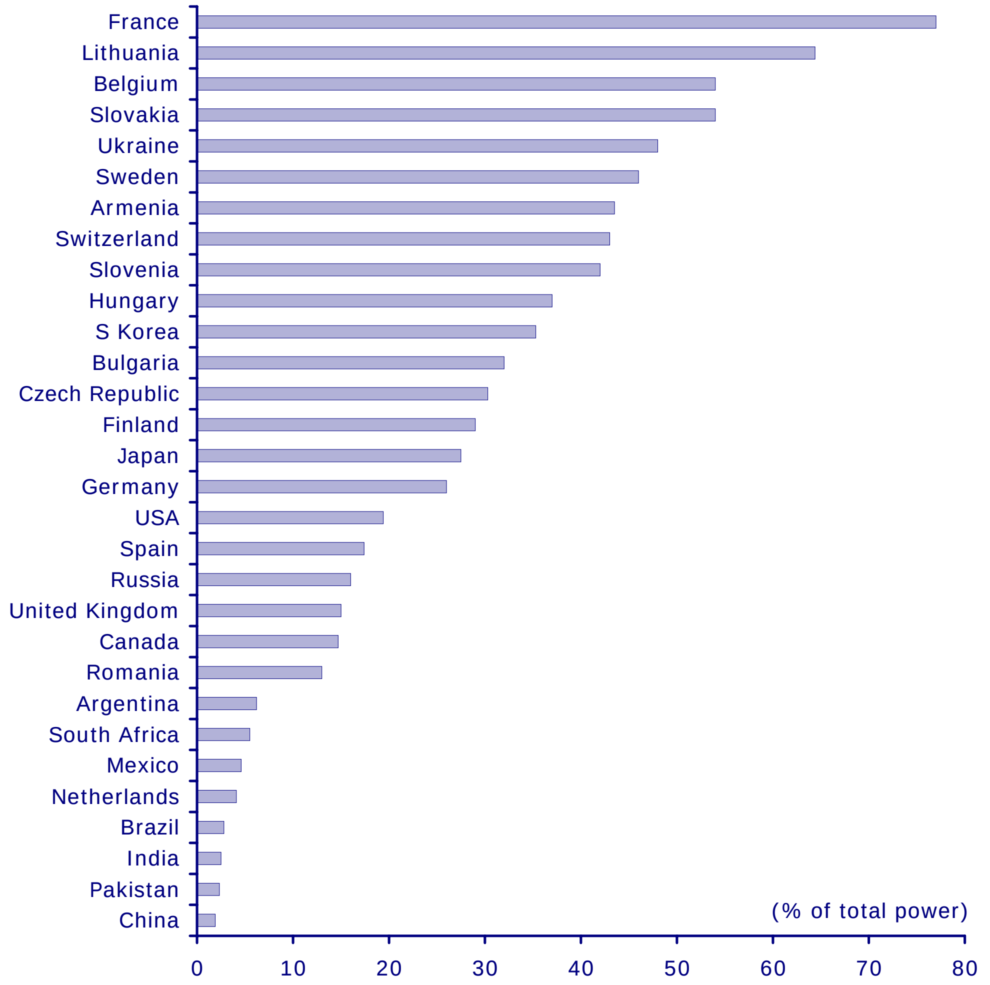
The carbon dioxide replacement of global nuclear power is significant

Globally, 29 countries operate 441 nuclear power plants with a total net installed capacity of 367,000MW. Nuclear power provides 17% of world electricity, compared to coal at 37%, oil at 8%, natural gas at 18% and hydro and other at 18%. It is especially suitable for large-scale, base-load electricity demand and offers a significant CO_2 emission saving of 2.3bn tonnes of CO_2 relative to coal. For every 22 tonnes of uranium used, a million tonnes of CO_2 emissions is averted.

The US, France and Japan generate the most nuclear electricity globally, but a surprising number of countries use nuclear power to contribute a very significant proportion of their electricity needs.

Figure 50

Nuclear contribution to national electricity generation (by %), 2008



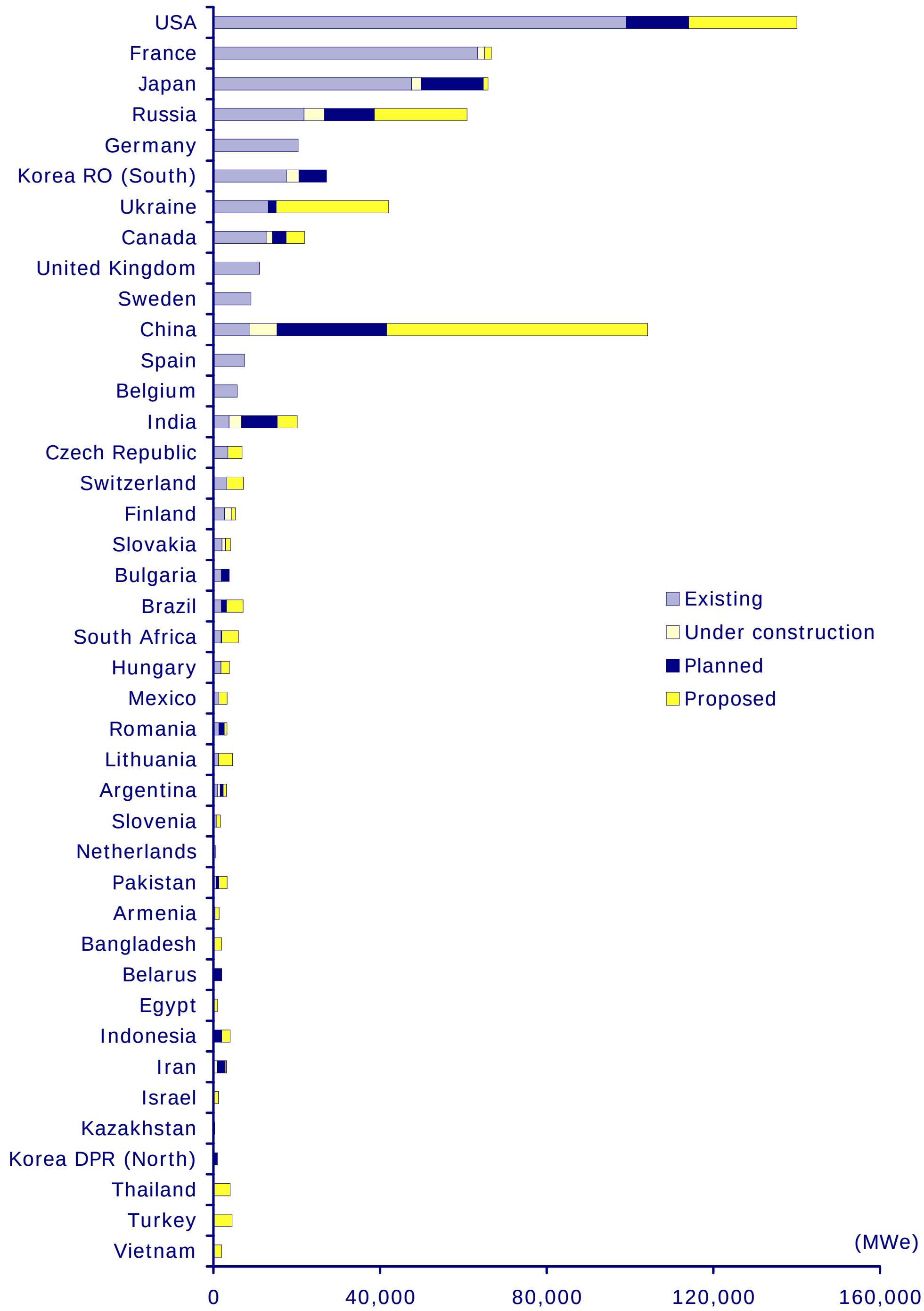
Source: IEA, WNA

GHG emissions targets are boosting the case for nuclear, as are high thermal fuel prices

The estimated growth is driven by specific plans in a number of countries, including China, India, Japan, Russia, Finland and France. In addition, national nuclear energy policies are being boosted by the GHG reduction requirements of the Kyoto Protocol, income potential from carbon credits, and the impact of high prices for thermal fuel, especially crude oil and natural gas. Even so, such growth merely implies a stable 17% market share for nuclear power by 2020 such is the expected growth in total electricity generated (rising at a much faster pace than global GDP).

Figure 51

Current and future nuclear capacity - as at 2008



Source: CLSA Asia-Pacific Markets IEA, WNA, IAEA

Nuclear - the environmental angle

2007 New York Post article indicates U-turn

Significant debate is raging as to whether nuclear can be regarded as renewable. The Greenpeace organisation has until recently been a significant opponent of adding to the global nuclear capacity. An article published in the New York Post last year illustrates an apparent U-turn however – just compare what Patrick said last year with what he said in 1976 to see how much of a change of heart he has had.

Figure 52

1976

"Nuclear power plants are, next to nuclear warheads themselves, the most dangerous devices that man has ever created. Their construction and proliferation is the most irresponsible, in fact the most criminal, act ever to have taken place on this planet."

Patrick Moore, Assault on Future Generations, 1976

Figure 53

2007

"There are few places where nuclear power makes as much sense or is as important as in New York. As such I strongly support the renewal of the license for Indian Point power plants in Westchester . . . . Nuclear power in fact makes economic sense"

Patrick Moore, Opinion New York Post Feb 2007

Source: Greenpeace, New York Post

Despite this change of heart Greenpeace as recently as last month successfully challenged the UK Government's plan to expand nuclear in the high court and obtained a ruling that forced the Government to rethink their plans.

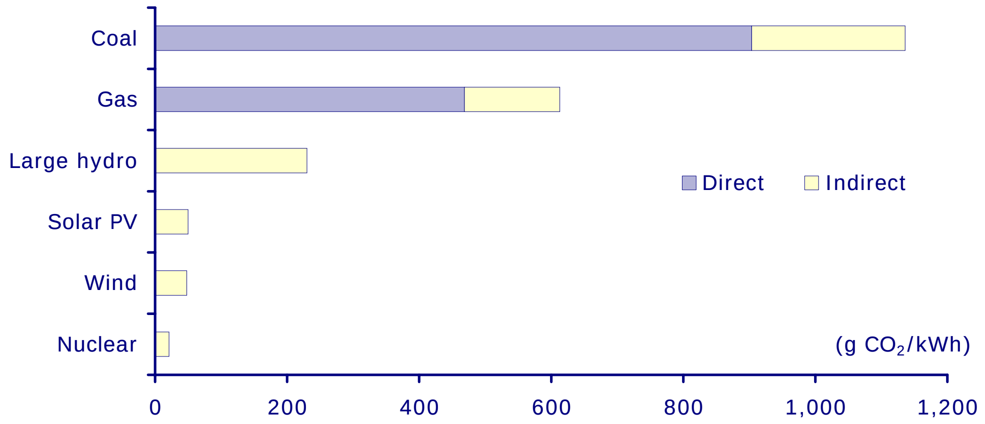
Nuclear offers small carbon footprint . . .

Recent developments by the UN suggest that discussions have been taking place that might provide the nuclear industry with access to carbon credits in the future. It is clear that taking a lifecycle view nuclear has a lower carbon footprint than hydro and other renewables and is capable of providing base load power.

. . . which cannot be said of coal

Figure 54

Carbon footprint of various power sources



Source: CLSA Asia-Pacific Markets, IEA

The above chart shows CO_2 emissions generated directly from burning fossil fuels and indirect emissions from the inputs required to build and run the plant. If all energy inputs are assumed to be from coal-fired plants at approximately one kilogram of CO_2 /kWh, it is possible to derive a greenhouse contribution from the energy input percentage of output. Supporting data from the 2005 Environmental Product Declaration for British Energy's Torness 1250 MWe power station shows 5.05 g/kWh

In France, despite relatively energy-inefficient enrichment plants which are run by nuclear power, the greenhouse contribution from a nuclear reactor using French-enriched uranium is similar to a reactor elsewhere using centrifuge-enriched uranium - less than 20 g/kWh overall.

Not as expensive as people think

One of the main concerns typically raised in relation to nuclear is expense of plant construction

One of the main concerns typically raised in relation to nuclear is that plants are expensive to build. Yet proponents of the third generation power plants under proposal claim that costs are substantially cheaper and build times are faster than the second generation power plants now in operation globally.

Lessons of single design demonstrated by the French Nuclear Program

The Nuclear Industry appears to have learned the lessons of single design demonstrated by the French Nuclear Program, and that this will be employed for the new power plants.

Westinghouse claims its Advanced PWR reactor, the AP1000, will cost US$1400/KW for the first reactor before falling to US$1,000/KW for subsequent reactors. They also claim these will be ready for electricity production three years after first pouring concrete.

Proponents of the CAMDU ACR and Gas Cooled pebble bed reactors make similar or stronger claims. This should be compared to second generation plants which, in the U.S.A., had construction costs up to US$5,000/KW and generally took more than five years to complete.

The first two ABWR's were commissioned in Japan in 1996 and 1997 and completed on time and on budget.

The General Electric ABWR was one of two third-generation nuclear plants to first be approved in 1996. Commissioned in Japan in 1996 and 1997, they took just over three years to construct and were completed on budget at a cost of around US$2,000/KW. Two additional ABWR's are being constructed in Taiwan, however these have faced unexpected delays and are now at least two years behind schedule.

Meanwhile the Chinese nuclear power industry has won contracts to build new plants of their own design at capital costs reported to be US$1,500/KW and US$1,300/KW.

US subsidy designed to encourage new reactor construction

Given previous issues with nuclear plant construction in the US (most notably delay) financiers quite rightly view the industry as a higher risk investment and demand a premium on capital. An Energy Bill recently passed by the US Congress assumes this risk and provides production credits of $0.018 cents/KWh for the first three years of operation. This subsidy is equivalent to what is paid to wind power companies and is designed to encourage new nuclear reactor construction in the US.

If the AP1000 lives up to its promises of US$1,000/KW construction cost and three year construction time, it will certainly provide cheaper electricity than many other fossil fuel-based generating facilities

Waste is the big issue

Currently, no country has a complete system for storing high level nuclear waste permanently but many have plans to do so in the next 10 years. There are a number of well-developed proposals from the USA, Sweden, Finland and France for the disposal of long-life radioactive waste.

Isolate the waste from the atmosphere for at least 100,000 years

All the proposed disposal techniques employ multiple barriers to isolate the waste from the atmosphere for at least 100,000 years. All of the proposed disposal methods face strong opposition from environmental groups, particularly because a number of programs in the past have seriously mishandled the issue of nuclear waste. The British decision to reprocess spent-fuel appears to have been both an environmental and financial mistake while the US nuclear weapons program at Hanford, Washington created enormous environmental issues that have so far cost US$5.7 bn in clean-up costs.

Consensus to pursue geologic disposal as final phase

Globally the industry appears to have reached the consensus that geologic disposal of nuclear waste is the most effective solution. Waste is currently being held in temporary storage facilities until the method of long-term disposal is agreed upon, but this delay will no longer be feasible as capacity ramps up.

2. Hydro

We are hesitant to add too much hydro capacity to our assumptions. This is partly because changing rain patterns and melting mountain glaciers will make suitable locations increasingly difficult to find.

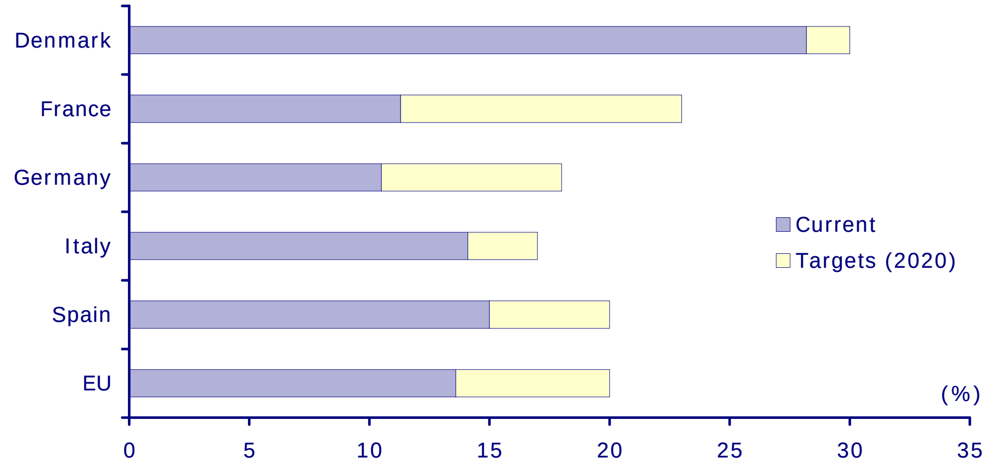
3. Renewables

We are assuming that renewables are generally able to ramp up in-line with existing targets.

Europe on pace to meet its 2020 renewable energy goals

Figure 55

Renewable energy targets in Europe (as share of total electricity mix)



Source: Ren21, EU, CLSA Asia-Pacific Markets

Pricing in a carbon component would add major impetus to renewable projects and help to ensure that countries met their targets. These subsidies come in a variety of forms:

Feed-in tariffs make lending to renewable energy projects much more attractive

Feed-in tariff - Popularized in Europe, this is the most popular subsidy type for both wind and solar. With a feed-in tariff, the utility (at a government's behest) guarantees that it will buy all of the electricity produced by a renewable source at either a fixed rate or a fixed premium to average wholesale prices. This system assures steady returns for investors. See appendix 9 for a list of major wind and solar feed-in tariffs.

Tax credit - This is the main renewable support at the Federal level in the US. The US ensures US$0.02 per kWh tax credits to wind operators for 10 years (in addition to whatever the state program is).

Upfront subsidy - The practice of paying back a share of the initial capital costs has been falling out of favour.

Emerging markets can sell carbon credits under Kyoto

Carbon credit - Selling carbon credits (certified emission reductions (CER)) through the clean development mechanism (CDM) program has become a significant driver for wind power in China, and could do so in other developing countries.

Green Certificate (GC) - To enforce renewable energy targets, governments sometimes hand out GCs to renewable operators, who then sell them to utilities bundled with electricity. The utilities have to demonstrate that a pre-determined share of the electricity that they sell is green either by proving their own renewables capacity or showing the regulator their GCs.

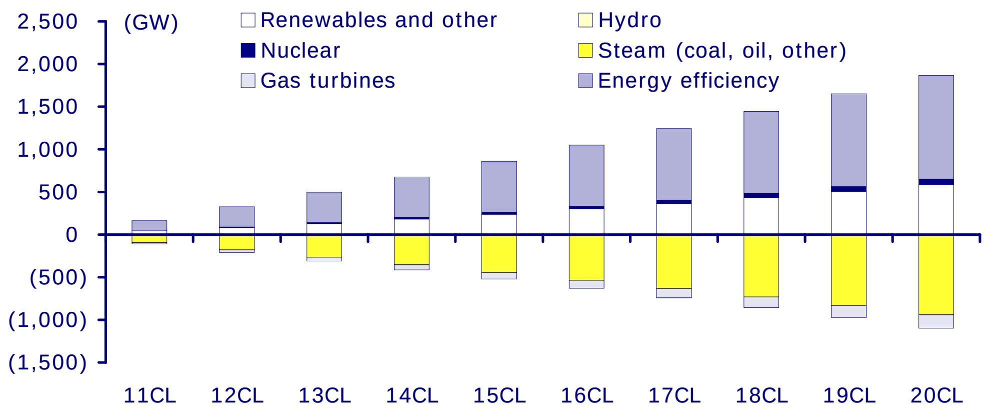
Reduced fossil fuel expansion is offset by energy efficiency meaasures

The new mix: Still not there

Even after any implementation of energy-efficiency measures and shift from fossil fuels to renewables (summarized in the table below), CO_2 emissions would still be well above the target of 20% below 1990 levels by 2020.

Figure 56

Changes from base case to panic scenario



Source: CLSA Asia-Pacific Markets

Achieving a 20% reduction by 2020 requires a much faster renewables ramp

More panicked: Renewable ramp

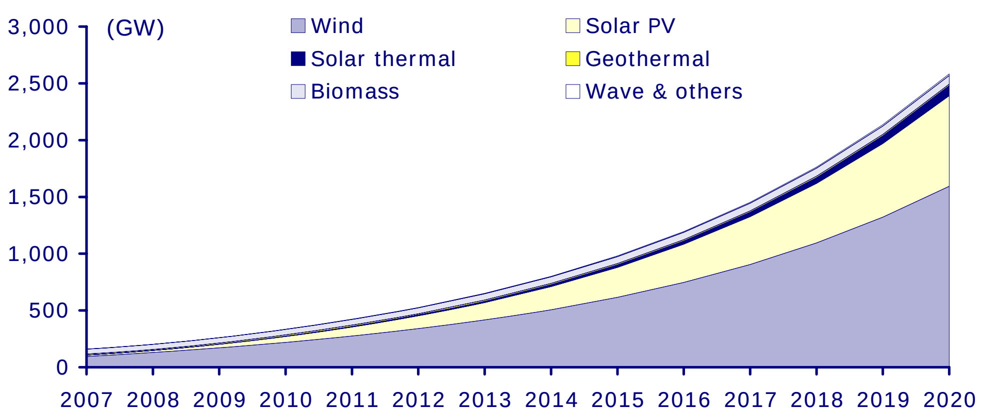
The most ambitious climate action plans, such as those devised by Lester Brown or Al Gore call for all electricity to come from renewables by 2020. Although we have difficulty envisioning this, renewables could easily make up a much larger share of the electricity mix by 2020 than current government targets suggest.

In our blue sky scenario for renewables (ex-hydro), total installations reach 2490GW by 2020, up 16x from 2008. Wind takes more than half of this, followed by solar photovoltaic (PV), as the two most mature and universally applicable technologies. Concentrating solar thermal plants could potentially grow much faster in hot, dry climates, but they have to build up a track record and reduce their water consumption. Wave and tidal power could also grow much more quickly, at least on paper, but both are in very early stages of development. We could also be too conservative on biomass, but this partly reflects hopeful expectations for its use in next-gen biofuels.

2490GW of renewables by 2020

Figure 57

Bluesky renewables ramp: 44% of the mix by 2020



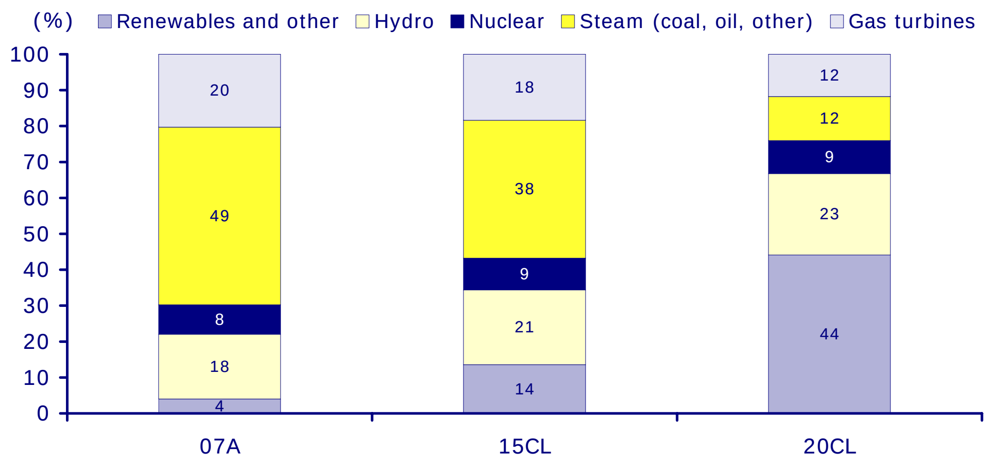
Source: CLSA Asia-Pacific Markets, REN21, IEA

Figures suggest decommissioning US$700bn in coal-fire plants

Under this scenario, we assume that excess supply is offset by cutting or idling coal-fire and then gas capacity. Generally, just under one unit of fossil fuel power can be cut for every two units of renewables, which operate only 20% (solar) to 35-40% (wind) of the time. Even so, over 600 GW of coal-fired plants would have to be prematurely retired or idled by 2020, at a cost of over US$700bn to achieve 44% renewables in the global electricity mix.

Figure 58

Electricity mix: Panic 2 (Renewable driven)



Source: CLSA Asia-Pacific Markets

Tough to succeed, but aspirational targets likely in-line

This would be extreme, and maybe not even possible in a "panicked" scenario. We believe that the main components – wind turbines and solar panels – could hit the targets, but we're less certain about the feasibility of bulking up electricity grids and realising energy storage solutions so quickly. Nevertheless, this is in-line with the type of mix that consensus science seems to demand. As such, this is a mix that policy support would push for, whether or not it was ultimately successful.

Wind and solar are the bread and butter

Wind and solar PV are the biggest winners under widespread panic

Wind and solar photovoltaic power are the two biggest beneficiaries under a true panic scenario. Although they produce less than 2% of current electricity demand, both technologies (led by wind) have been proven in the field and both will be able to ramp quickly, and both are well suited to emerging markets where demand is growing fastest. From 1980 to 2007, wind turbine shipments grew at 32% Cagr, while solar shipments expanded at 27% Cagr. Both are growing faster right now, but will inevitably flatten out a bit going forward, maintaining 20% growth rates beyond 2010.

A challenging ramp: Pushing up against feasibility

Such aggressive growth would repeatedly push the industries up against major barriers and bottlenecks. Even if the wind turbines and solar panels could be made, could they slot into existing grids? Although difficult, we believe that this would be possible but not without a concerted effort to upgrade electricity grids and energy storage worldwide. These two technologies will face a lot of similar difficulties in ramping at such a pace, but the market roll-outs and conditions are unique.

Figure 59

Wind shipments: 270 GW in 20CL

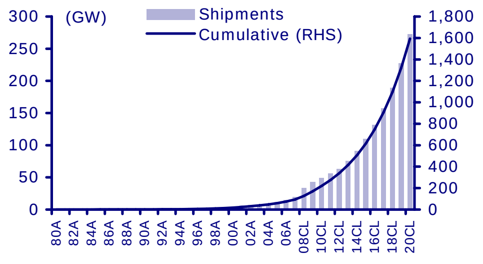
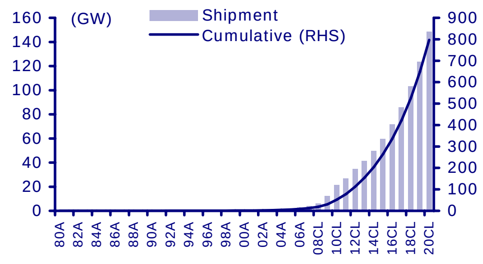


Figure 60

Solar (PV) shipments: 150 GW in 20CL



Source: CLSA Asia-Pacific Markets, IEA

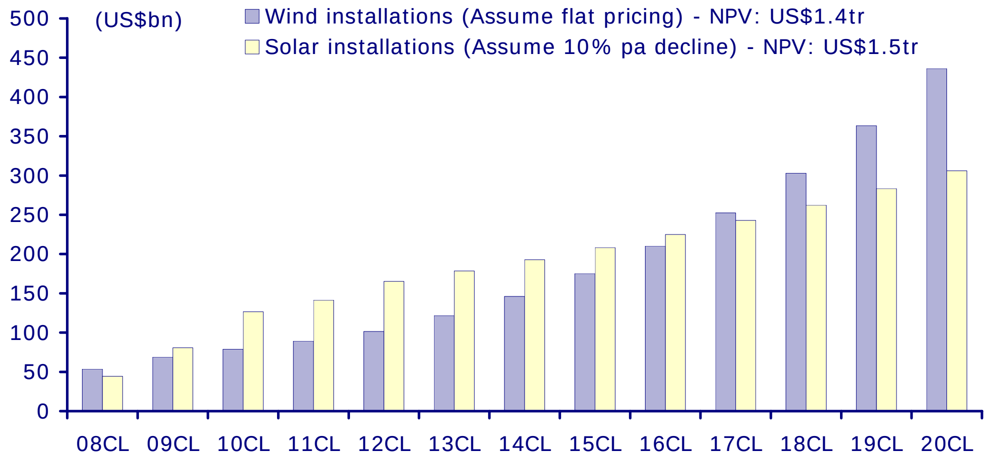
Wind turbines would consume approximately 3% of 2007's total annual steel supply

For each doubling of cumulative capacity the cost of wind power has fallen by 13%, and the cost of solar has fallen 23% according to research from UC Berkeley and Navigant Consulting. Supply shortages have actually driven both technologies' prices up over the past two of years. For solar, de-bottlenecking will drive significant price declines from next year. We are assuming no price declines in wind turbines going forward. By the time bottlenecks are worked out of the system in 2012, carbon pricing will make the technology cheaper than fossil fuels, ex-subsidies. We are therefore assuming no price declines (though this could prove pessimistic).

In all, wind installations under a panic scenario present total value of US$1.4tr from 2008 to 2020 while solar installations reach US$1.5tr.

Figure 61

Global wind and solar shipment outlook (panic scenario)



Source: CLSA Asia-Pacific Markets

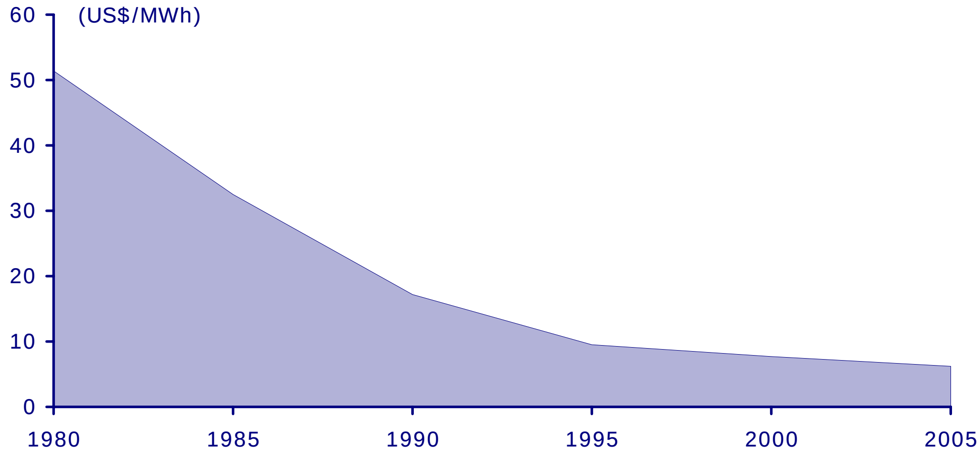
Wind: A half-step away

Since Ronald Reagan was first inaugurated in 1980, wind turbine shipments have grown more than one thousand times and the cost of wind energy is now around one tenth what it was then. The industry started this trip entirely dependent on subsidies, but almost stands on its own now. Wind farmers world-wide still rely on subsidies (generally feed-in tariffs) to push IRRs up to acceptable rates, and although it varies the global average is around 12%.

Falling generation costs are a combination of falling turbine costs and O&M cost

Figure 62

Cost trends of wind power generation



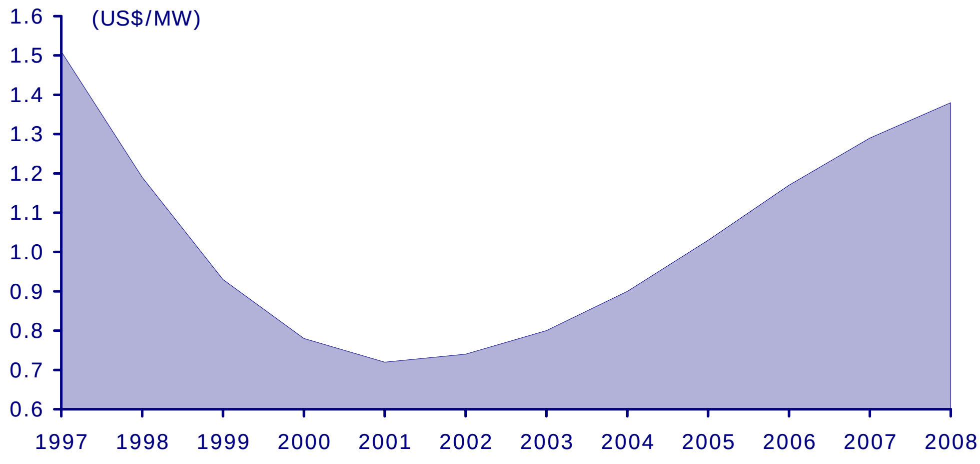
Source: NREL Energy Analysis Office, reflections of historical cost trends, not precise annual data

Lately, wind has become a victim of its own success. Wind power has been stalled at "*almost* cost competitive" since around 2001 because strong demand has pushed turbines (and components) into short supply, driving prices up. As Dave Dai, our China wind analyst points out, falling operating and maintenance (O&M) costs have kept the cost of wind energy dropping, albeit very slowly.

Project cost trend has been driven by increased turbine costs . . .

Figure 63

Cost trends of wind turbines



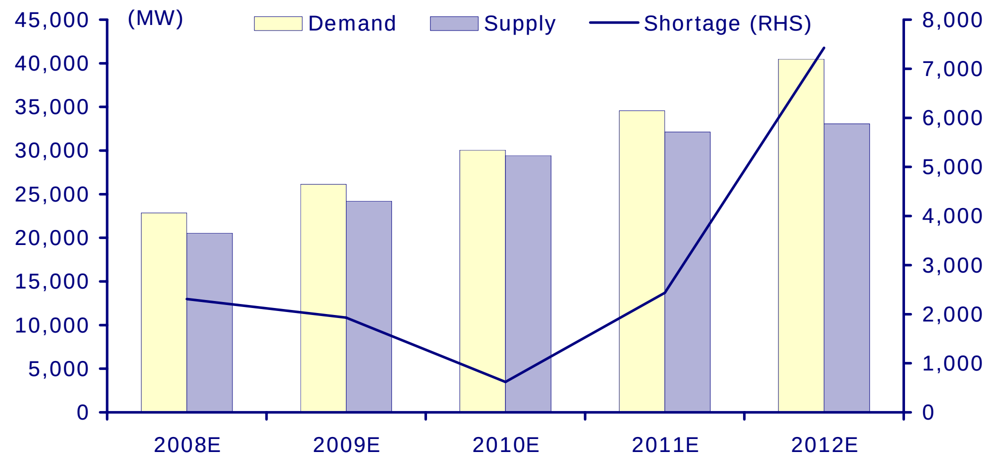
Source: Berkeley Lab database

Under our base case scenario, CLSA wind analyst expects demand-supply balance by 2010

When will prices start dropping again? The shortage of key turbine components - including gearboxes, bearings and cast iron and forged items – is likely to begin easing in 2009. Under our base case, Dai expects demand to catch up with supply in 2010, suggesting that capital costs will start coming down again.

Figure 64

CLSA global wind power demand and supply forecast



Source: CLSA Asia-Pacific Markets, Chevreux

Component shortage could be extended under a panic scenario

Under our panic scenario, a balance between demand and supply could prove elusive, however. On a basic level, we believe that continued improvements in technology and wind farm management will be sufficient to offset tight supply and rising steel costs (as one of the major energy consuming industries, steel faces significant cost hikes when carbon is priced in). Again, as illustrated in figure 63 prices vary substantially from market to market. The rising share of US and, especially, Chinese and Indian turbine demand will have a deflationary effect on the blended average price.

The cost of subsidies: Wind

Wind is already economic in some spots

Some of the major wind subsidies worldwide are listed in Appendix 4 In certain areas wind is already cost competitive. Such locales will only become more numerous as carbon and deregulation force up global wholesale electricity prices.

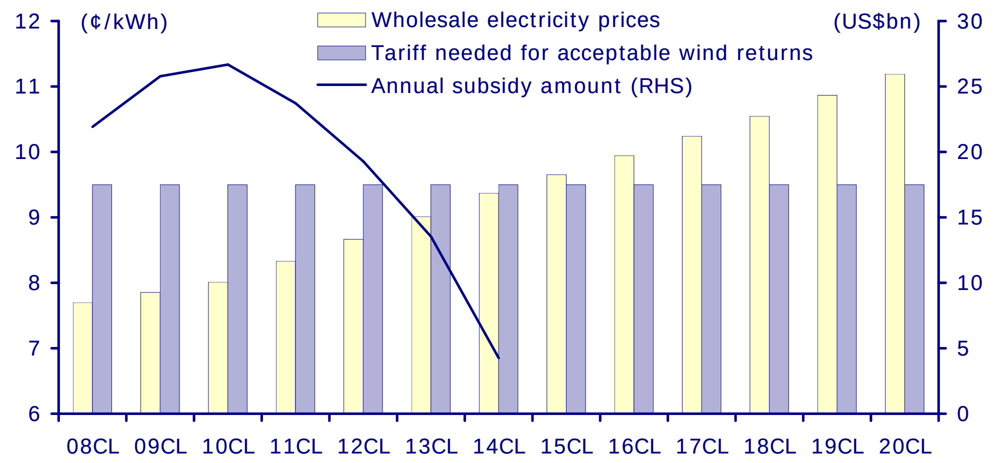
To get a rough estimate of how much money in subsidies wind installations will need, we assume that wind farm operators will continue to demand around US$0.095 per Watt (based on flat turbine costs) to set up wind farms and achieve the average 12% IRR they currently enjoy. This requires subsidies of around US$0.02 per kWh produced. Assuming annual wholesale electricity price inflation of 3%, this will have faded to zero by 2014.

A minimum of US$135bn in subsidies from 2008 to 2020

In all, this suggests a present value for total wind subsidies of US$135bn from 2008 through 2020, based on an average of 15yr feed-in tariffs. The real number could come in much higher than that for a few reasons. Primarily we are not factoring in higher tariffs for off-shore wind; investors need to demand higher returns than 12% if demand growth is to keep pace with supply; and in keeping with the panic scenario, governments could quite simply hand out more money than is really needed to drive investment, though that would lead to a tax-payer backlash in the mid-to-long-term.

Figure 65

Global wind subsidies under panic button scenario: US$135bn (2008 dollars)



Source: CLSA Asia-Pacific Markets

Solar PV: Two steps away and moving fast

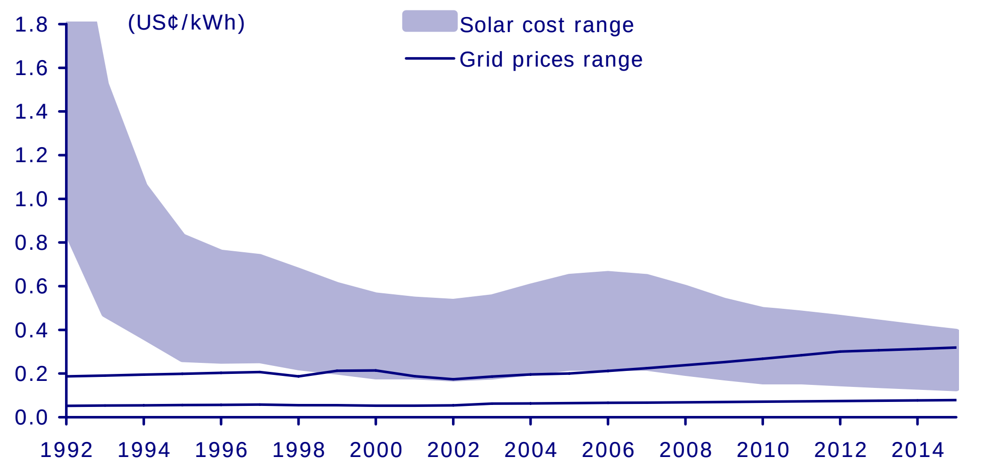
Solar costs have dropped 90% in the past 15 yrs

The cost of generating solar power has dropped around 90% since the early 90s, turning up again over the past three years on supply bottlenecks and unexpectedly strong demand.

Solar costs are about to resume long-term decline

Figure 66

The long-term cost curve for solar: About to start heading south again



Source: CLSA Asia-Pacific Markets

Prices will start to fall again in 2009

Costs are set to begin falling again in 2009, as the long-seated shortage in polysilicon comes to an end. Spot polysilicon prices have jumped from US$40/kg in 2004 to over US$400/kg currently, with Asian companies paying an average of US$250/kg. At this price point, polysilicon makes up approximately two thirds the cost of a standard solar panel. Note that polysilicon is effectively sand purified through a complex chemical process. The number of producers is growing from 5 in 2004 to as many as 175 by 2010.

Even with the price drop, solar is still more than twice as expensive as wind power, but that is not an entirely accurate comparison.

Solar is a distributed form of electricity

Most solar power is generated on site, whereas other forms of electricity are usually generated by utilities and then transmitted to the end user. Solar is ideally suited to distributed generation and should be compared to electricity tariffs rather than generation costs. Comparing the cost of solar power to electricity tariffs presents a much more accurate, and compelling picture. Solar power is less than twice as expensive as the going rate in many markets, and only 58% more expensive than grid rates in Japan.

Grid parity: Holy Grail closer than most expect

Nearly economic with retail prices

Ultimately, the case for solar power comes down to economics. If grid parity (ie, the cost to consumers is as low as electricity tariffs) is not reached, the recent industry growth trend cannot last. We believe that solar power costs are actually below utility grid prices in a number of major markets. By 2010, the solar industry could reduce end-user prices to below grid prices across Western Europe, Japan and the US coasts. Whether or not they do will depend on how subsidies evolve.

Peak capacity and kilowatt-hours

So how far is solar from grid parity? Module prices vary from region to region depending mostly on government support, while installation and other system costs are lowest in the largest markets. Germany and Japan have large, competitive networks of competent distributors and installers, and therefore enjoy lower installation costs.

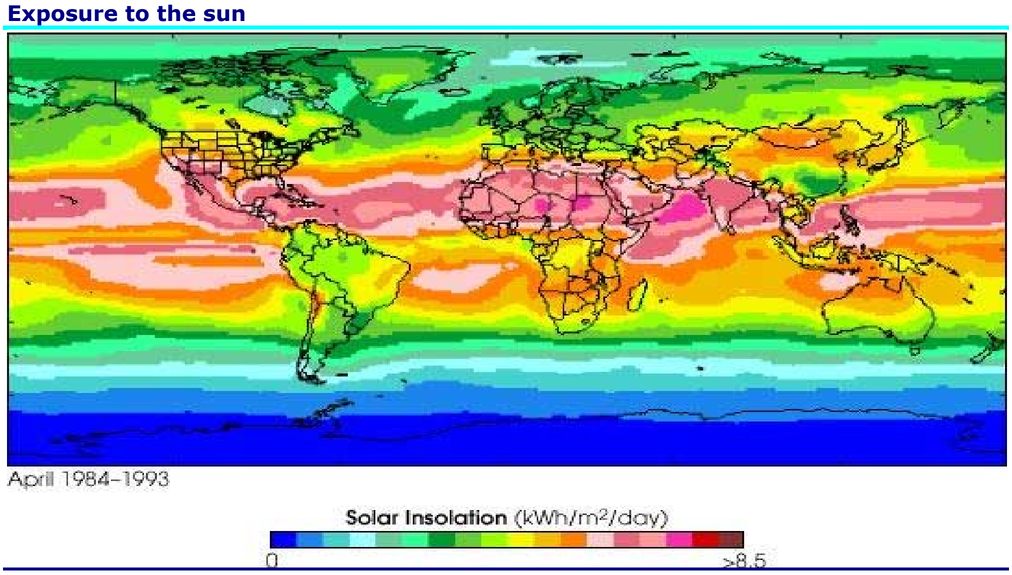
Before comparing solar power to grid electricity, it is important to distinguish peak capacity from electricity generated. Solar panel sales and prices are given in watts of peak capacity, which measures the maximum electricity generated at a given moment. We do not pay utilities for peak capacity, but rather for electricity generated, measured in cents per kilowatt-hour (US¢/kWh).

Naturally, the electricity generated by any given solar panel varies from place to place, depending on sunshine levels (see insolation map below). The importance of this is often glossed over. A US$4/watt solar panel will generate approximately twice as much electricity in Los Angeles as in Berlin. So, in terms of electricity generated (US¢/kWh), a panel sold in Los Angeles is actually half the price of an equivalent panel in Berlin.

Not all locales are made equal for solar

Figure 67

Exposure to the sun



Source: NASA

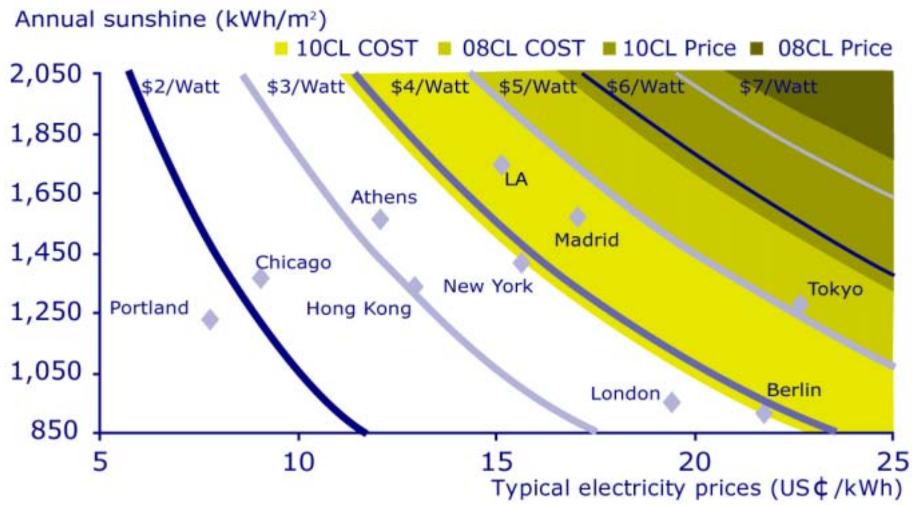
Figure 69 illustrates what different solar installation prices (US$/Watt) mean in terms of cost for electricity generated (US¢/kWh). Cities are plotted on the graph according to how much sunshine they receive and their average residential electricity tariffs. Solar power is best suited to cities that receive more sunshine and have expensive electricity tariffs.

Solar is attractive in sunny places with expensive grid electricity prices

The lines coming down the chart show how solar cost per watt (installation) compares to the cents per kilowatt hour (kWh) that each of us pays on our electricity bill. These lines show where solar becomes cost effective without subsidies. For example, when the installation cost of solar comes down to US$4/Watt, it would be cheaper to install solar panels than to pay your electricity bill anywhere to the right of the US$4/Watt line, including Madrid, Los Angeles and Tokyo. It is important to note that there is a wide range of electricity prices in each city depending on the customer. Some residential customers in LA, for example, pay up to US$0.30 per kWh for electricity.

Figure 68

How solar installation prices stack up around the globe



Source: International Energy Agency, US Dept of Energy, CLSA Asia-Pacific Markets

Japan aims to have 70% of newly built houses equipped with solar panels by 2020

At current price levels, solar is only economical for niche applications, such as telecom towers off the electricity grid, and for some customers in sunny areas. While we believe that solar power will start reaching grid parity soon, government subsidies will continue to drive demand in the meantime. They will also help to prop up ASPs, even after grid parity is reached. There are three primary types of government incentives that directly affect solar: Feed-in tariffs, tax benefits and monetary grants.

Feed-in tariffs are by far the most important. With this type of tariff, the government or utility company guarantees that it will buy solar power for a set number of years at a set price, generally much higher than the going rate for utilities. System buyers can easily view a solar power system as an investment with a set rate of return and payback period.

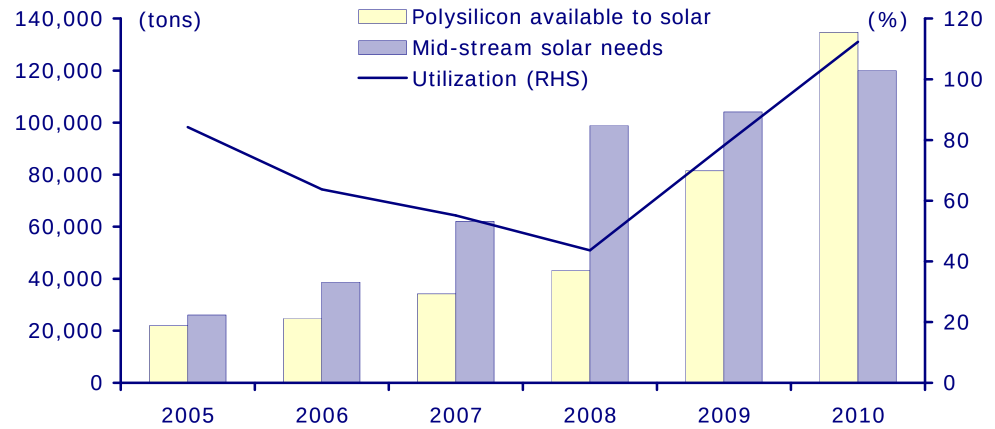
Sun-starved Germany is a solar pioneer

The best-known example of a feed-in tariff is in Germany, where around three times the grid price is offered for energy produced using solar. This generous policy drove Germany - not exactly known for its sun - to the forefront of solar nations. More than 40 countries worldwide have implemented, or are planning to implement feed-in tariffs.

Ample polysilicon supply will drive down solar costs from 2009

Figure 69

Polysilicon shortage will bottom in 2008



Source: CLSA Asia-Pacific Markets

Global solar subsidies could top US$555bn under a panic scenario

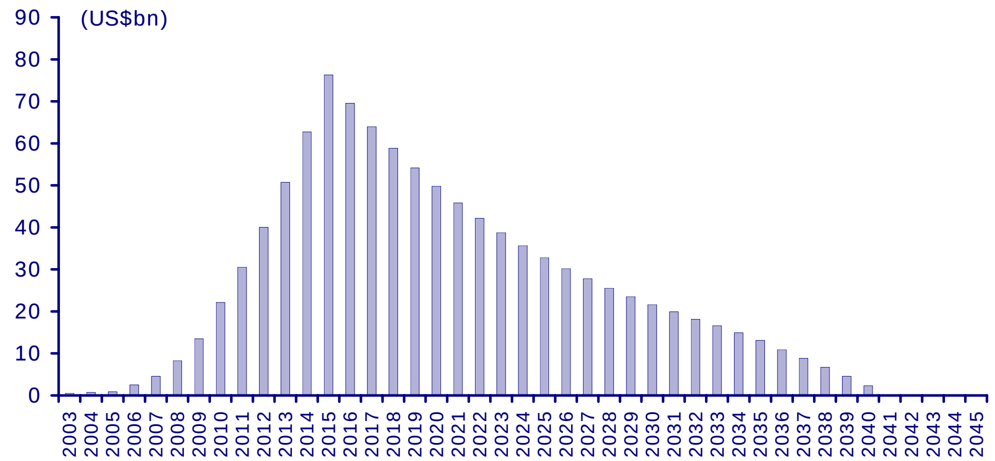
The cost of subsidies: Solar PV

We expect that solar will reach full economic viability by 2015 at a cost of around 12 cents per kWh (based on average global sunshine). The higher crossover point for solar is due to its status as a distributed form of electricity. At 12 cents, solar will be competitive with retail electricity prices across the globe, especially if the cost of carbon is factored in.

Total subsidies for solar could reach US$555bn

Figure 70

Global solar subsidies under a panic scenario: US$555bn (2008 dollars)



Source: CLSA Asia-Pacific Markets

We estimate that with perfect policy timing, total subsidies for solar installations could be halved. Countries are paying more than they really have to in order to drive solar demand, as exemplified by Spain in 2007 and 2008.

Potential for other renewables to ramp more quickly as they are proven

The other renewables

We have chosen to focus on wind and solar PV because they are relatively proven and the infrastructure is in place for them to ramp quickly. We would see the biggest upside risk in concentrating solar thermal power (CSP), which can compete as a form of base load power in sunny climes. On paper, tidal power looks very attractive as well, and there are a number of projects currently underway but the technology is still in its very early stages of deployment. The success of geothermal currently depends on technology breakthroughs but the potential is strong if these occur.

Concentrating solar thermal power (CSP)

Solar thermal power technology is the dark horse of the renewable energy field

The dark horse of the renewable energy field, solar thermal power technology works by focusing the sun's energy on a receiver pipe that runs inside a single-axis reflector. The water or organic working fluid in the pipe is therefore heated to drive a steam turbine, producing reliable power in any sun-rich region. After more than 15 years of operation, the Solar Electricity Generating Systems (SEGS) plant in California generates 354 MW of power, which can be firmed with thermal storage or gas-fired backup.

Storing energy as heat is also much cheaper than storing electricity in batteries, providing CSP with an economical means to overcome intermittency issues. New solar thermal power systems are now under development in the U.S., Europe and India.

Our estimates could prove too bearish if a host of new projects prove successful over the next two years

The cost of electricity from CSP plants is roughly US$0.13-17/kWh, meaning that CSP with thermal storage is competitive today relative to gas-fired power plants. The US Department of Energy (DOE) aims to reduce costs to US$0.7-10/kWh by 2015 and to US$0.5-7/kWh by 2020; leading CSP producer Ausra (unlisted) has similar price targets but 5 years earlier.

Figure 71

The *other* solar - Concentrating solar thermal (CSP)

Source: Rocky Mountain Institute (From CLSA's *Carbon Management)*

Geothermal power

The resource potential is huge if "hot dry rock" becomes feasible to exploit

Geothermal power from underground steam and hot water is a significant and cost-effective power resource in many parts of the world, including Iceland, New Zealand, the Philippines, Central America, Italy and California. While this resource is limited and highly site-specific, the resource potential is huge if "hot dry rock" becomes feasible to exploit. This experimental technology extracts heat directly from deep under the Earth's surface, using a closed fluid loop without extracting water or steam. Google has established a research and development group which is currently exploring ways to make this work.

Tidal and wave power

A wide variety of tidal and wave power technologies have been under development for some time. Some tidal power designs are essentially reversible hydropower systems using large barrages to control tidal flows in both directions. While such tidal barrages are available in only a few sites, wave power technologies are emerging and have the potential to be much less site-specific.

Current technology is maturing

Recently, tidal current technology, which requires little or no impoundment, is becoming increasingly promising and mature. Free-flow tidal current (and hydro) technology is beginning to be demonstrated by UK and US-based firms including an installation on the East River in New York City. There are additional potential distributed applications in, for example, manmade watercourses (aqueducts, etc.) with no boats, no fish, and few regulatory obstacles to restrict siting and development.

Supporting technologies a must-have

Even as wind and solar PV achieve economic attractiveness, their intermittency would make them nearly impossible to incorporate into national power grids as they sit today. Essentially solar panels only produce power when the sun is shining and wind turbines only work when the wind is blowing.

When the sun and wind are not cooperating, the grid draws on base-load power, the minimum amount of electricity that has to be constantly fed into to the grid to ensure uninterrupted electricity operation. Base-load plants typically have to run all year, except for scheduled maintenance shutdowns, making it best suited to steady, dependable power supplied by coal or nuclear plants. Generally, base-load capacity should make up 20-40% of an electricity grid's capacity, depending on the location.

Transmission & distribution

Grids will have to be strengthened to take the renewables load

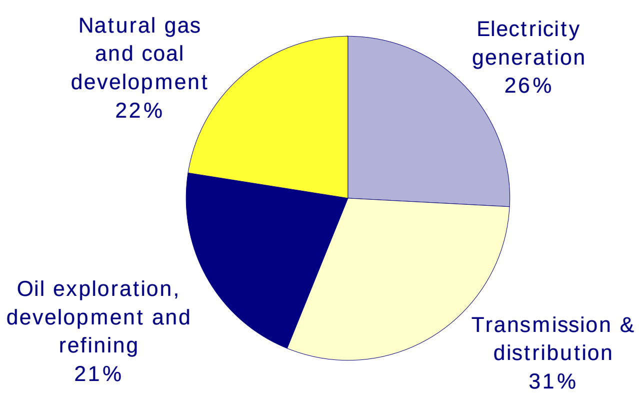
In our panic button scenario, renewables reach 44% of total electricity generation, versus just 32% for coal and nuclear base-load power. To avoid frequent black-outs and brown-outs, grids will need major facelifts including the installation of ultra high voltage (UHV) DC transmission lines and advances in energy storage.

Moving from AC to DC

The importance of a robust electricity grid, particularly to wind, is simply this: Although wind does not blow all the time in any given spot, it is always blowing somewhere. In theory, a smart electricity grid would be able to balance the varying inputs from around a region to keep steady electricity flowing. The backbone of such a system has to be a beefed up UHV DC grid. Leakage from DC transmission lines barely increases from a ten-mile trip to a hundred-miles to a thousand miles, and the higher the voltage the less loss there is. An extensive DC grid system would be able to transmit wind power from North Dakota to New York with minimal waste.

Figure 72

Cumulative energy investment out to 2030



Source: IEA

Energy storage

Energy storage is a key hurdle

Solar is more predictable, also meaning that it is predictably off at night, Barring extensive undersea transmission infrastructure linking continents, our panicked solar ramp will need to be accompanied by a large-scale ramp of energy storage solutions. Improved storage capability would also greatly benefit wind.

There are no clear game changers in the short-to-mid-term. The field of contestants is headed up by deep-cycle batteries, pumped-air storage, pumped hydro and fuel cells. At the same time, a lot of research time and money is going into other options such as advanced flywheels and ultra-capacitors, though the end-markets do not match up exactly.

Deep cycle batteries

Deep cycle batteries are fairly reliable, but too expensive

Deep cycle batteries are designed to provide steady current over a long period of time. They can also be deeply discharged repeatedly, which would quickly kill car batteries, although both are mostly lead-acid batteries. Although reliable, deep cycle lead-acid batteries only last around five to eight years (vs 25 yrs for panels) and add approximately 20-30% to the cost of a solar energy system.

In certain conditions, such as telecommunications towers or oil pipelines, the cost will not be an issue (there is no viable alternative to solar). But, whereas the cost curve for solar panels and other aspects of installation is clearly declining rapidly, there is no obvious roadmap for a rapid drop in battery costs. To move down the cost curve, batteries are moving to different chemistries, such as nickel metal hydride and lithium ion. Super-sized 'flow batteries' that use tanks of electrolytes are receiving more attention. But at this point, there does not seem to be any magic bullet.

China's transmission boom

China is already building out a UHV transmission infrastructure of the kind that renewable energy backers in the US could barely hope for. The focus is coal and hydro, but it would certainly play into better positioning for wind and solar under a more aggressive renewable ramp. Steven Zhang and Manop Sangiambut have a detailed breakdown of China's T&D build in their Nov 2007 report *Transmission Boom*.

The State Grid has started studies on UHV transmission since 2004 and has made the programme the cornerstone of power-grid development in the 11th Five Year plan. The needs for UHV transmission in China are to satisfy robust power demand as well as geographical imbalance. More than 80% of hydro-power resources are in Central and West China, while two-thirds of coal resources are in the North. The load centres are in the East, however, where two-thirds of power demand is concentrated. The UHV projects will ease pressure of coal transportation and help improve the environment in the East. Transmission capability also increases exponentially with level of voltage.

The State Grid set a target for UHV line length of 4,200km by 2010, with transformer capacity of 39mkVA, which accounts for 2% of estimated total transformer capacity by that time. Some industry contacts we met believe the Rmb1.2tn investment budget may not fully include the UHV programmes. This is an area that will likely be monopolised by the top-three local players in each segment and other foreign firms.

Figure 73

Global T&D market share

	1	2	3
High voltage	ABB	Siemens	Areva
Medium voltage	ABB	Schneider	Siemens
Transformers	ABB	Siemens	Areva

Source: ABB

Pumped-air storage

Under pumped air storage, or compressed air storage, excess electricity is used to pump air into an underground, pressurized cavern. The air is later released to drive a turbine and produce electricity. These systems are still in early stages of development, with only two plants in operation.

Fuel cells

Simply a battery

Fuel cells are generally touted as a key component of the hydrogen economy. A fuel cell is a device that converts chemical energy directly into electricity and heat. There are several types of fuel cells, but all share the use of hydrogen as fuel. Some, like solid oxide fuel cells, can also utilise carbon monoxide, which make them more versatile when using fuels such as natural gas or propane.

Fuel cells can be regarded as batteries that, when provided with fuel and air, will not run down. They are electrochemical devices that convert the chemical energy of the fuel directly into electricity and heat, and do so more efficiently than combustion engines. Fuel cell technology has proven it is reliable, but it has yet to show it is cost-effective.

Carbon capture and sequestration (CCS)

Carbon capture and sequestration (CCS) pumps carbon into the ground, not the air

Carbon capture and sequestration (CCS) is a process whereby CO_2 from power plants is captured, transported and stored. The process of sequestration involves the injection of CO_2 into deep underground geological formations, such as saline aquifers or depleted oil or gas reservoirs.

CCS is expensive and scalability unproven

The process itself is nothing new. Oil companies have been injecting CO_2 into oil fields to improve recovery for over 20 years. The key challenge is the complexity and expense involved in retrofitting existing coal burners for CCS. Newer integrated gasification combined cycle (IGCC) plants are much better suited, but also much more expensive. Other challenges include the fact that only some areas are geologically suited to CCS, and China does not have many. Thirdly there will be extensive cost, and lead-time to build the necessary infrastructure. Finally, the scale is massive: over the course of its 25-year life, the world's current largest CSS project (Weyburn) will only store as much carbon as an average new coal-fire plant produces in one year.

CCS costs are determined by: (i) the type of technology chosen; (ii) the pureness of the CO_2; (iii) where the emissions are produced and stored/captured. The table below shows the different cost per kWh for the different types of plants.

Figure 74

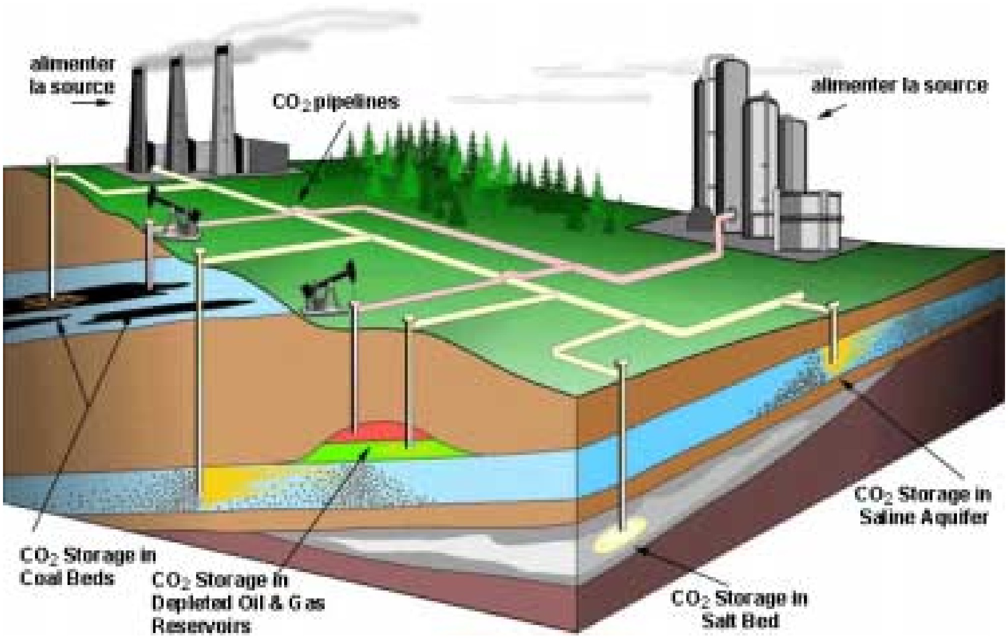
Impact of CCS Technologies on costs per kWh

Type of plant	Natural gas combined cycle (US$/kWh)	Pulverized coal (US$/kWh)	Combined cycle with integrated gasification (US$/kWh)
Without capture (benchmark scenario)	0.03-0.05	0.04-0.05	0.04-0.06
With capture and geological storage	0.04-0.08	0.06-0.10	0.05-0.09

Source: IPCC Special report on Carbon dioxide Capture and Storage 2005

Figure 75

Carbon storage solutions



Source: CO_2-handle.com.de

CCS could have a future, but the past is not promising

Carbon sequestration is also an integral part of 'Clean Coal', the industry's holy grail and best chance for long-term success in a carbon-constrained world. Clean coal advocates aim to develop technologies that can generate hydrogen and electricity from coal while capturing all carbon emissions. It still seems to be a long-shot, though: the most prominent project, FutureGen in the US, was cancelled in 2008.

Transport: Moving emissions

Transport almost matches emissions from electricity

The transport sector is a core focus for climate change policy. In all, the sector accounts for around 22% of energy-related GHG emissions and 12% of total emissions. Road travel contributes the lion's share of this, at around 70%, almost all from oil-burning (diesel or petrol) internal combustion engines.

Figure 76

Transport sector emissions

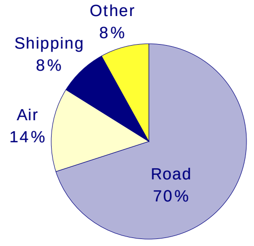


Figure 77

The root of the problem: Petrol, not cars

Source: Climate Analysis Indicator Tools (CAIT), showing total emissions of 5743 Mt CO_2 for the Transport sector (2004); Rocky Mountain Institute

North America is far and away the biggest emitter, both in per capita and absolute terms. While unsurprising given the region's reputation for sprawling suburbs and SUVs, the real issue for climate change is in the developing world. The IEA expects transport-related emissions from countries like China and Indonesia to more than doubly by 2020.

A 20% cut from 1990 transport emissions by 2020 will require tighter fuel economy standards, hybrids and next-gen Biofuels (which have yet to prove viability)

As with electricity, it is clear that any sort of policy reaction that appears acceptable in today's environment would not be sufficient to push emissions down 20% from 1990 levels by 2020. Success would require a massive ramp in public transit, much tighter fuel efficiency standards, successful introduction of next-generation Biofuels and increasing penetration of hybrids and plug-in vehicles. From an Asian standpoint, the biggest immediate, direct and measurable impact would be rising demand for hybrids and plug in vehicles. Asian auto and battery makers own most relevant technology and experience.

Figure 78

Global share of CO_2 from transportation

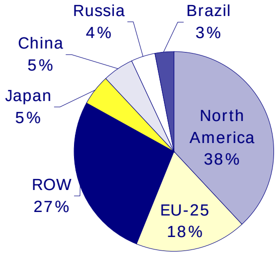
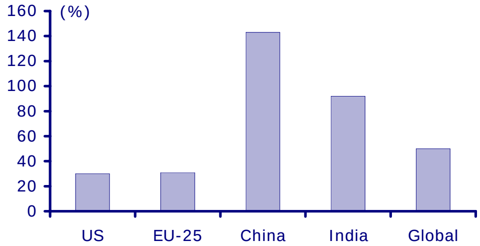


Figure 79

Projected change through 2020

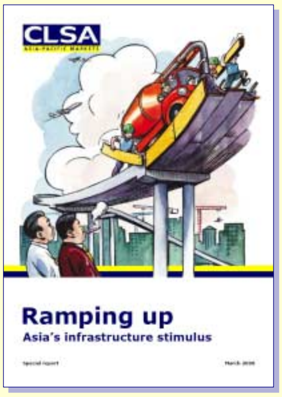


Source: IEA (2002), World Resources Institute

Source of the problem

As highlighted in Amar Gill's Mar-08 report on Asian infrastructure *Ramping up*, transport almost unanimously tops investment agendas, accounting for more than half the infrastructure budget among countries in Asia. The lion's share of transport spending generally goes to the construction of toll roads and expansion of highways.

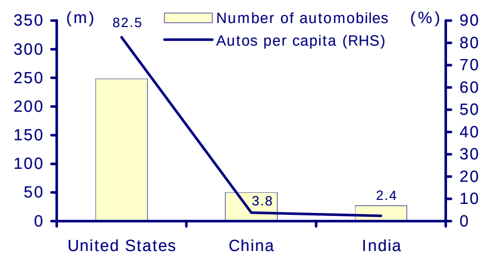
Car ownership is dovetailing with massive roads build in Asia



Driving the development of roads is the huge potential for car ownership in Asia. China has just over 50m automobiles for a population of 1.3bn while India's 1.1bn people run on only 26m automobiles. (Compare this with the 248m automobiles that300m people own in the US.) China's GDP per capita, which currently hovers around the US$2,500 level, will soon cross the critical US$3,000 level associated with explosive car ownership growth.

Figure 80

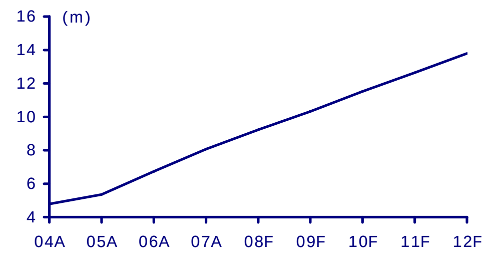
People and cars



Source: CEIC, CLSA Asia-Pacific Markets

Figure 81

China's light auto shipment, outlook

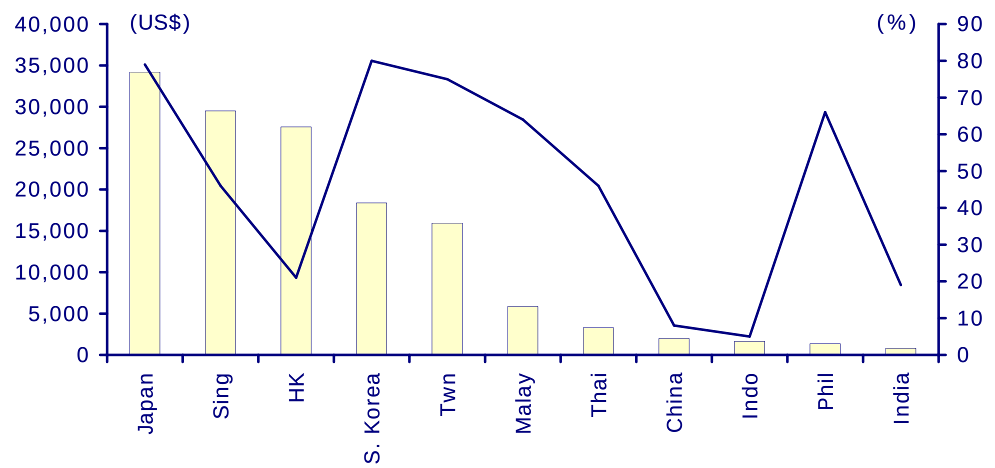


Source: JD Powers, CLSA Asia-Pacific Markets

It is almost certain that the 5% car ownership of urban households will push fast to levels typical of countries like Thailand with a GDP per capita of US$4,000 and car ownership of 45% and Malaysia where per capita income is US$5,000 with car ownership at 60% of households.

Figure 82

Per-capita income and car ownership



Source: CLSA Asia-Pacific Markets

The policy fix for autos

The first step in mitigating the impact of automobiles on the climate is to minimize the expansion of the fleet. Given the car's association with economic prosperity and freedom, that is not an easy task. But there has been some shifted emphasis toward improving public transport, especially rail and light rail. For example, China is now moving beyond expressways and making rail links a higher priority in the 11th Plan where spending on highways fell marginally by 2% compared to spending in the previous five years.

Carbon impact of transport

	CO_2 emissions per passenger (kg/km)
Car	36.6
Train	5.2
Bus	4.3

Source: Testimony to UK parliament

Even with heavy promotion of public transport there will be more cars in 2020 than there are today, barring a global economic meltdown. To minimize emissions from this growing fleet of autos, governments are pushing for improved fuel efficiency and more carbon-friendly fuels.

Improving efficiency. Governments promote fuel efficiency by directly mandating it, raising petrol/diesel taxes and backing specific technologies.

Fuel economy standards. The bluntest policy instrument to improve fuel economy standards is for governments to dictate that automakers improve their fleet fuel economy standards.

Direct support for hybrids and biofuels. Hybrids are growing rapidly from a niche position. Biofuels have rightly come under fire for driving up food prices and accelerating environmental degradation. There are ways around that, however, that new policies are taking into account.

Fuel economy standards around the world are tightening

Standards around the world are already tightening. The EU has agreed on a plan targeting a 20% decrease in greenhouse-gas emissions by 2020, and even the gas-guzzling US is raising its Corporate Average Fuel Economy (CAFE) target to 35mpg for all passenger vehicles by 2020. Under a panic button scenario, these regulations will tighten faster. Benefits will accrue to fuel-efficient Asian auto makers, who are actually expanding their lead with improvements in hybrid and electric vehicles.

Figure 83

Global fuel economy standards

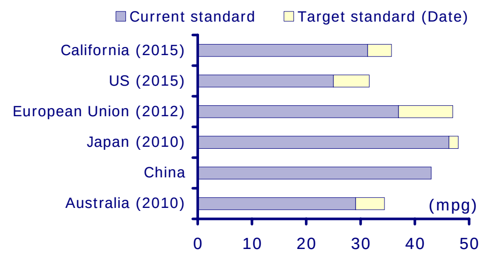
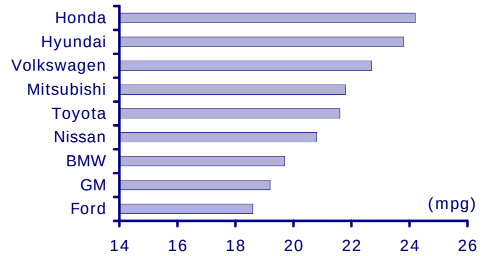
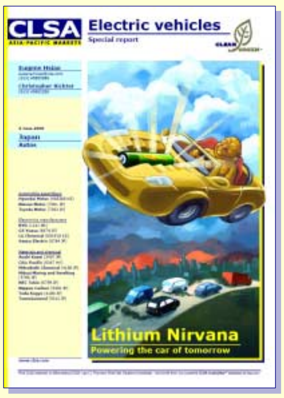


Figure 84

Automakers' US fuel economy (mpg)



Source: OECD, ICCT, LA Times, CLSA Asia-Pacific Markets, CERES



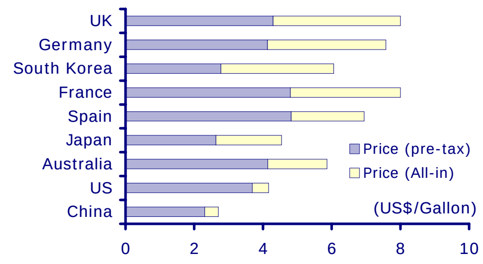
Hybrids

Hybrids that combine traditional internal combustion engines with electric motors offer one route to better fuel efficiency. While they currently make up only 2% of total car sales, they have been enjoying nearly a 70% Cagr since 2000. Much of this growth can be attributed to selling hybrids as a brand rather than simply a fuel-efficient alternative. However, macro factors from fuel prices to government environmental initiatives will also make hybrids economically viable. We estimate that hybrid cost premiums are already justified at gasoline prices of US$3 per gallon, which would include most of the developed world at this point.

Hybrids also have an inherent emissions advantage from well-to-wheel. When comparing the relative total emissions from various drivetrains (the system connecting the engine to the wheels), hybrids have shown to produce less than half the emissions of a standard gasoline internal combustion engine.

Figure 85

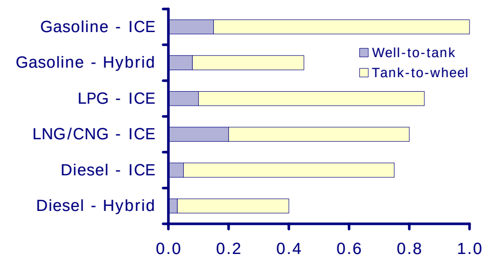
Global petrol prices (US$/Gallon)



Source: OECD, AAA, Shell, CLSA Asia-Pacific Markets

Figure 86

Relative well-to-wheel emissions



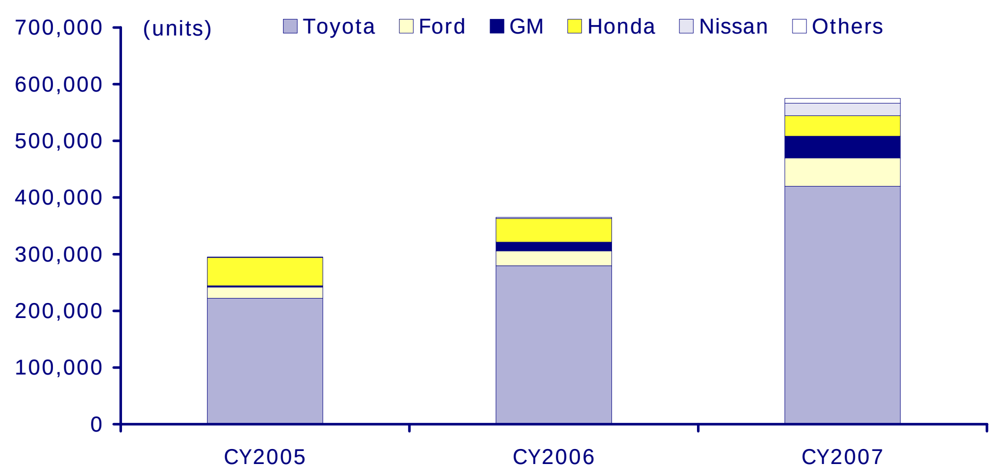
Source: Toyota Motors (ICE: Internal Combustion Engine)

Hybrid growth booming in the past five years

Since 2000, new-hybrid-vehicle sales in the US have enjoyed a Cagr of 68% while gradually gaining a greater share of total auto sales. Though at present, hybrids only account for 2% of total US light-vehicle sales, the number of new models from all makers is steadily increasing, with several more to be released in late 2008. Recent industry forecasts predict hybrid vehicle sales to reach 2.2m-4.5m units worldwide by 2013, accounting for 10-20% of both the US and Japanese markets. Hybrid growth is predicated on several factors, primarily rising fuel costs, environmental initiatives and public awareness.

Figure 87

Global hybrid shipments



Source: CLSA Asia-Pacific Markets, Wardauto

Plug-in electric vehicles - Coming soon

Plug-in could mean never fuelling for short distances

The plug-in electric vehicle is widely predicted as the next step in the EV market. Conceptually, the biggest benefit of plug-in vehicles is the ability to perform short- to medium-range driving without burning any fuel. This potentially provides a readily realisable solution to energy/ecological concerns without any significant economic infrastructure costs. In practice there are two types of plug-in vehicles in development: hybrid plug-ins and pure-electric vehicles.

Hybrids with a punch

Big 2010 plans from GM and Toyota

The plug-in hybrid electric vehicle (PHEV) has garnered much attention as the most readily available solution applying plug-in technology. Both General Motors (GM) and Toyota have made official announcements that they hope to release a plug-in hybrid by 2010. There have also been some notable efforts to sell plug-in conversion kits for current hybrid vehicles but these systems are not yet cost-efficient enough to be widely practical. To date, there has not been a commercially released PHEV due to technical obstacles and impractical costs of the battery.

Figure 88

Plug-in hybrid Prius

Source: Toyota Motor

Figure 89

GM Volt: Plug your cars in for Detroit

Source: General Motors

EVs mostly use existing technology, with notable exception of batteries

With the exception of the battery, there are no significantly new components to be used in PHEVs. The only other major differences between hybrid systems and internal combustion engines (ICEs) are the additions of an electric motor and regenerative braking systems. These systems are already well-understood in current hybrid designs and have been practically implemented for over a decade. The most significant technological success of current hybrid vehicles is more likely the adoption of sophisticated drivetrain management systems that maximises vehicle efficiency and maintains battery performance and safety.

Waiting in the wings

Battery costs still too expensive for PEVs

Automakers still have hopes to develop pure-electric vehicles (PEVs), which face even greater battery technology and cost limitations than plug-in hybrids. This has not stopped niche makers from providing options using more immediately available technologies such as the US$100,000 Tesla Roadster released this year. The cost of the Li-ion battery pack in the Roadster is estimated to be US$20,000 with a total weight of 450kg. This is significantly higher than the current hybrids at US$2,500 and 55kg, making the packs used in the Tesla PEV impractical for standard passenger cars.

No shortage of PEV concept vehicles

Automakers such as Nissan, Mitsubishi and GM have stated their intention to release plug-in PEVs and have developed various vehicle concepts such as the Nissan Denki Cube, Pivo2, Mixim and the Mitsubishi i-MiEV. Nissan, in particular, has been aggressive in pursuing a PEV as part of its goal for zero-emissions vehicles. However these concepts will all need better batteries before becoming a practical reality.

The battery challenge

Current batteries neither light nor powerful enough

Electric vehicles require a small and light, but powerful and cheap energy source. Standard lead-acid batteries are cheaper than nickel metal-hydride (NiMH) batteries by capacity, but have only half the energy density. Yet, nickel metal-hydride batteries are expensive - a NiMH battery capable of 40 miles of electric driving would cost US$17,000.

Lithium-ion is superior

Lithium-ion is chemically superior to other batteries. Lithium is abundant, with enough known reserves for 40 billion Toyota Prius hybrids and thus has the potential for further cost reduction. But benefits are limited by expensive cobalt-oxide cathodes, roughly 50% of total cell costs. Several companies globally are developing promising new cathode chemistries for vehicle use, with some on the cusp of mass production.

Asian companies leading the Li-ion revolution

Producing more than 80% of Li-ion cells globally, Asia provides several investment opportunities to tap into the growth of EVs. Automobile assemblers will hedge their bets across several green and fuel-efficient technologies. Electronics makers have been involved primarily through private joint ventures with auto companies. Materials and chemical firms will also see growth but typically only within subsidiaries and secondary businesses.

Figure 90

Hybrid storage market share (%)

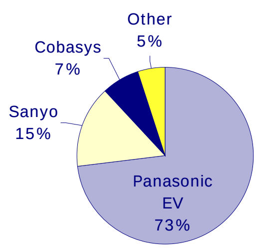
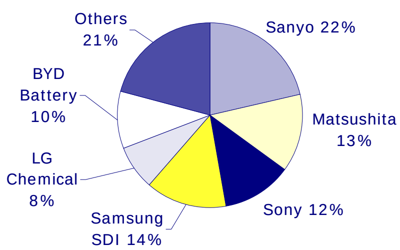


Figure 91

Lithium ion battery market share (%)



Source: CLSA Asia-Pacific Markets

Playing the theme

Many companies involved but few will fully benefit from Li-ion future growth

Asia will have a leading role to play in the introduction of lithium-ion automotive batteries. For years Japanese companies such as Sony, Sanyo and Panasonic have been the leading developers of portable Li-ion cells and set the international standards for production. However, leading Korean and Chinese companies such as LG Chemical, Samsung SDI, and BYD have seen tremendous growth in the last five years. For vehicle batteries, few publicly traded companies will generate significant revenues from Li-ion related sales alone. The best bets along the value chain range from speciality chemical companies to automobile assemblers.

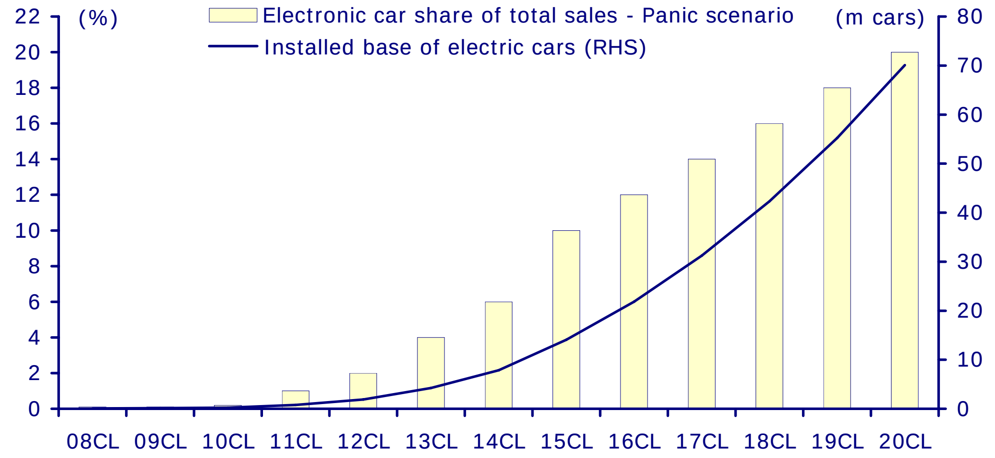
The electric impact (panic button scenario)

Battery costs still too expensive for PEVs

Our Japanese auto analyst, Chris Richter, estimates that plug-ins could account for roughly 5% of Japan's auto shipment by 2020, while regular hybrids are likely to make up 10% of Toyota and Honda's shipments by 2010. The most aggressive policy positions suggest potential upside. For example, US presidential candidate Barack Obama is calling for 1 million plug-in hybrids, or over 5% of the annual shipment, by 2015. Under a panic scenario, we could see targets of up to 20% plug-in hybrids by 2020.

Figure 92

Electric car shipments under a panic scenario

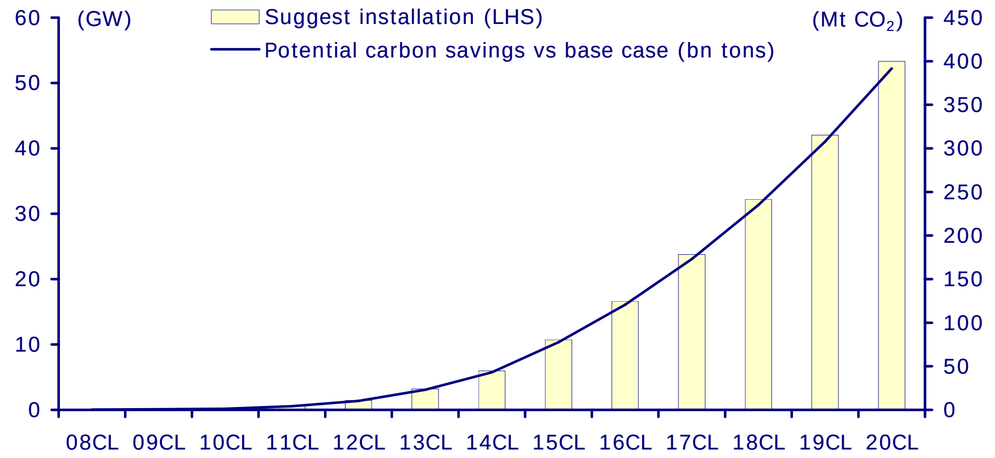


Source: JD Powers, CLSA; Assumption for total car shipments based on continued 3.5% shipment growth pa overall through 2020, in-line with our 2004-2013 shipments and forecasts

Even under this ambitious target penetration, plug-in hybrids would only make up around 6% of the total car fleet and require an additional 50 GW of installed generating capacity (1% of the global total). Based on the current electricity mix, around 200m tons of CO_2 per annum would be saved (versus the base case scenario) by electric vehicles by 2020. This corresponds to approximately 5% of total emissions from cars currently, which would not be enough to offset incremental emissions from new drivers in the developing world. The move to electric vehicles will only be one prong in government transport policy to fight climate change.

Figure 93

Impact of electric vehicles on electricity demand and carbon emissions



Source: CLSA Asia-Pacific Markets; CLSA assumptions: 5 miles/Watt, based on Chevy Volt forecast and 120 grams/mile of CO_2 emissions.

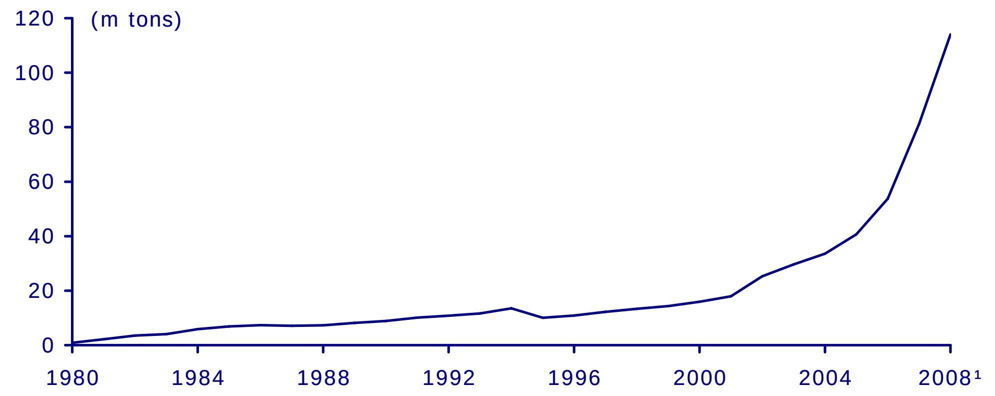
What about biofuels?

Biofuels face serious hurdles

Biofuels could play an important part in the effort to reduce auto emissions. Studies such as those by the US Environmental Protection Agency (EPA), show that from a well-to-wheel perspective biofuels can provide significant carbon reductions However, not all biofuels are created equal, and major support policies in the US and Europe are coming under fire for their ecological and economic effects. In the US, neither US presidential candidate supports the current target for 36bn gallons of ethanol by 2020 (up from 7bn today). The EU is trying to incorporate life-cycle sustainability targets into its goal for 10% mix of bio-diesel by 2020.

Figure 94

US grain used for fuel ethanol (m tons)



¹ 2008 values are projections by Earth Policy Institute. Assumes 80% of distilleries currently under construction are completed to take feedstock from 2008 harvest. Source: US Department of agriculture, Earth Policy Institute

Biofuels offer a promising alternative to oil. Depending on how loosely you define it, the Biofuels sector can include anything from ethanol or biodiesel refiners, to companies growing the feedstock (palm, corn, jatropha, etc) to companies that improve yields either through fertilizer or bio-engineering. A broad array of soft commodities can be tied to biofuels indirectly as demand for bio-ethanol or bio-diesel drives up demand - and prices – for food crops as well. Biofuels' share of the responsibility for the global food crisis is well documented.

But carbon-emission reduction benefits vary widely

Figure 95

Greenhouse-gas (GHG) reduction potential from biofuels

Biofuel/feedstock	GHG emissions reduction versus conventional diesel/gasoline (%)
Ethanol corn (US)	15-35
Ethanol wheat (EU)	20-35
Ethanol sugarcane (Brazil)	45-60
Ethanol cellulose	70-100
Biodiesel rapeseed (EU)	40-60
Biodiesel palm oil (Malaysia, Indonesia)	50-60

Source: Bio-era, International Energy Agency

The above table actually overstates the positive potential of most biofuels by ignoring indirect environmental impact. For example, Indonesian and Malaysian biodiesel is made at palm plantations located on what was previously rainforest. The clearing of that rainforest more than offsets any beneficial environmental impact of burning biodiesel rather than petrol-based diesel.

Typical Asian biofuels plays consist mostly of palm oil plantations and, in a looser sense, the fertilizer companies in China. Given the dubious environmental merits of cutting down tropical rainforests for palm oil, and the tenuous link between most Chinese fertilizer companies and biofuels, we are not presently including biofuels in our clean and green universe. However, that may change as Asian companies move into more environmentally friendly biofuels production methods using the likes of cellulosic ethanol, algae or non-food crops on marginal land.

Global biofuels consumption could reach 325 billion litres by 2020

Private research and advisory firm Bio-era estimates the market potential for biofuels consumption in 2020 to be about 325 billion litres (286 million tonnes), assuming that oil prices average in the range of US$60–65 per barrel (bbl). Significant increases in international trade in biofuels and feedstocks will be required to reach these levels. The wholesale value of biofuels sales could reach US$150 billion by 2020.

Running the numbers

Figure 96

Beneficiaries under panic button scenario

Name	Code	Mkt cap	PE (x)		PB (x)		ROE (%)		Sales (%)		EPS Cagr	Rec
		(US$m)	2008E	2009E	2007A	2008E	2007A	2008E	2007A	2008E	2008-10	
Renewables												
Wind												
CHST	658 HK	2,073.9	32.2	21.4	4.3	2.9	16.9	15.2	60.8	61.2	31.2	O-PF
Japan Wind Development	2766 JP	369.3	57.4	32.1	na	na	6.6	5.6	na	22.1	na	NR
Pyeong San	089480 KS	548.5	na	na	na	na	na	na	na	na	na	NR
Taewoong	044490 KS	1,224.9	20.1	15.7	na	na	na	na	na	na	na	NR
Xinjiang Goldwind	002202 CH	2,890.4	21.1	14.5	14.5	4.8	44.6	22.6	na	127.0	na	NR
Suzlon Energy Ltd.	SUEL IN	6,497.4	28.2	19.9	9.3	4.2	27.7	20.3	107.9	71.3	42.8	U-PF
Average		**2,267.4**	**31.8**	**20.7**	**9.4**	**4.0**	**24.0**	**15.9**	**84.4**	**70.4**	**37.0**	
Solar												
Gintech	3514 TT	832.2	12.7	5.9	3.7	3.4	11.6	31.5	1,111.8	178.0	77.1	BUY
Eton	3452 TT	648.2	17.0	7.3	1.8	1.7	14.2	10.5	77.5	108.0	na	SELL
Motech	6244 TT	1,057.5	12.9	9.0	2.6	2.4	25.8	19.1	92.3	49.2	na	U-PF
Moser Baer	MBI IN	382.8	5.7	na	0.8	0.8	9.4	n.a.	28.5	27.8	na	NR
Trina Solar	TSL US	639.6	13.3	8.1	1.9	1.3	12.8	11.4	165.7	174.6	na	SELL
LDK	LDK US	4,336.2	26.2	10.5	7.4	4.9	34.4	22.7	396.9	112.4	na	SELL
Suntech	STP US	6,051.2	25.1	15.7	8.0	6.6	22.2	29.7	125.1	61.7	na	BUY
DC Chemical	010060 KS	4,954.1	18.6	na	14.4	na	na	na	na	na	na	NR
Average		**1,992.5**	**16.1**	**9.4**	**3.7**	**3.0**	**18.6**	**20.8**	**285.4**	**101.7**	**77.1**	
Clean energy operators												
PNOC EDC	EDC PM	1,105.7	10.6	9.9	1.9	1.8	27.8	17.4	(27.0)	(3.2)	5.4	BUY
China Everbright Int'l	257 HK	564.7	12.2	9.1	1.7	1.6	15.2	13.5	52.5	39.7	34.2	BUY
China Power New Energy	735 HK	452.7	170.6	12.1	13.6	11.8	(17.1)	7.4	226.1	581.6	389.6	BUY
Zhongde Waste incineration	ZEF GR	429.3	10.3	8.2	3.3	2.5	35.5	27.8	63.9	97.2	25.0	BUY
Average		**1,496.6**	**50.7**	**11.5**	**4.7**	**4.2**	**11.8**	**13.6**	**69.1**	**155.5**	**103.0**	
Transmission and distribution												
Tianwei Baobian	600550 CH	2,853.4	18.9	10.9	8.2	6.1	20.1	36.9	2.5	44.9	41.0	BUY
Tebian	600089 CH	2,694.3	23.0	15.5	6.7	5.3	25.3	25.8	45.8	41.5	42.2	BUY
Wasion Meters	3393 HK	199.8	5.0	4.2	1.1	1.1	23.6	22.1	35.5	43.9	14.6	BUY
Energy Efficiency												
LED												
Everlight	2393 TT	705.5	na	na	na	na	na	na	na	na	na	O-PF
Neo Neon	1868 HK	195.7	-	-	-	-	-	-	-	-	na	NR
Seoul Semiconductor	046890 KG	481.1	31.6	14.9	2.0	2.0	12.3	6.3	36.1	14.4	83.0	SELL
Epistar	2448 TT	783.4	na	na	na	na	na	na	na	na	na	U-PF
Toyoda Gosei	7282 JP	2,390.0	12.2	9.1	1.7	1.6	15.2	13.5	52.5	39.7	34.2	SELL
Average		**541.4**	**15.8**	**7.4**	**1.0**	**1.0**	**6.2**	**3.1**	**18.0**	**7.2**	**na**	
Light materials												
Formosa Plastics	1301 TT	9,485.8	7.9	8.8	1.3	1.3	21.6	16.7	23.2	14.8	(4.9)	O-PF
Toray	3402 JP	6,243.4	10.7	15.1	1.1	1.1	13.2	10.3	8.3	6.7	(9.7)	U-PF
Teijin	3401 JP	2,989.4	6.5	18.8	0.8	0.8	10.2	12.3	7.6	2.7	(30.8)	U-PF
Mitsubish Rayon	3404 JP	1,545.1	9.8	16.8	0.8	0.8	12.7	8.9	21.1	0.2	(19.7)	U-PF
Average		5,066.0	8.7	14.9	1.0	1.0	14.4	12.1	15.0	6.1	(16.3)	
Fuel efficient auto makers												
Toyota	7203 JP	149,013.5	8.8	11.2	1.3	1.3	14.7	14.5	13.8	9.8	(1.2)	SELL
Nissan	7201 JP	31,446.2	6.8	8.1	0.9	0.9	15.8	13.6	11.0	3.4	(10.7)	BUY
Hyundai	005380 KS	12,625.2	9.4	8.5	1.1	1.0	9.8	10.7	11.5	9.7	9.4	SELL
Average		**64,361.6**	**8.3**	**9.3**	**1.1**	**1.1**	**13.4**	**12.9**	**12.1**	**7.6**	**(0.9)**	
Energy storage												
NGK Insulators	5333 JP	3,597.7	11.8	12.5	1.4	1.3	10.5	11.5	12.8	14.0	4.2	BUY
BYD Auto	1211 HK	2,155.2	10.2	8.2	1.5	1.3	20.1	13.6	63.9	34.6	13.0	U-PF
GS Yuasa	6674 JP	1,775.9	na	24.5	na	na	na	na	na	na	na	NR
Sanyo Electric	6764 JP	3,449.5	45.3	30.5	3.1	3.6	(4.0)	8.2	(10.1)	(0.9)	(1.0)	NR
LG Chemical	051910 KS	5,563.0	9.2	10.2	1.7	3.6	18.8	17.6	12.7	25.1	(0.9)	U-PF
Average		**3,308.3**	**19.1**	**17.2**	**1.9**	**2.4**	**11.4**	**12.7**	**19.9**	**18.2**	**3.8**	
Water												
China Water Affairs	855 HK	211.9	20.4	17.3	1.4	0.8	10.0	5.9	154.7	468.2	9.7	U-PF
Tianye Water	840 HK	47.4	-	-	-	-	-	-	-	-	na	NR
Manila Water	MWC PM	679.1	13.8	11.1	2.8	2.4	18.2	19.0	18.2	18.8	21.7	BUY
Torishima Pump	6363 JP	533.7	41.8	29.1	2.1	2.3	2.3	5.2	16.0	29.9	31.1	O-PF
Kurita Water	6370 JP	3,132.8	19.0	17.0	2.1	1.9	8.7	10.5	11.2	7.1	na	U-PF
Jain Irrigation	JI IN	631.1	20.3	16.4	5.6	4.0	25.4	27.9	38.5	67.6	na	BUY
Hyflux	HYF SG	883.9	19.1	13.9	5.5	4.1	12.3	24.3	11.4	219.6	na	NR
Average		**312.8**	**11.4**	**9.5**	**1.4**	**1.1**	**9.4**	**8.3**	**57.6**	**162.3**	**15.7**	

Source: CLSA Asia-Pacific Markets; Bloomberg

Clean energy needs to grow at a faster pace

Clean and green: Bigger, better faster

Under a panic button scenario, clean energy will have to ramp-up to a much larger size than current predictions call for, and at a much quicker pace. This transition will be supported by a redistribution of profits from polluting companies to those perceived as clean. Traditional companies will accelerate their activities in the space, either directly or through M&A cycles for renewables.

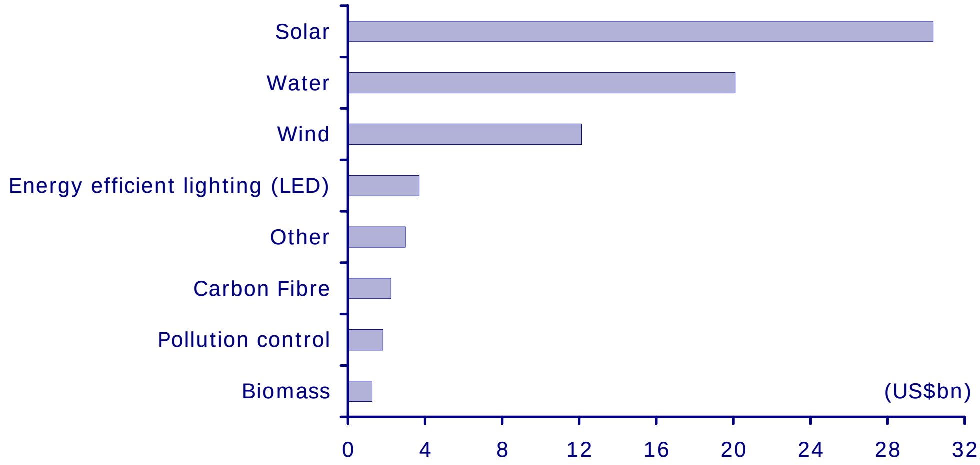
Boost to wind and solar shipments

Under our renewable-driven panic button scenario, wind and solar shipments from 2008-2020 approach US$3tr (2008 dollars). By comparison, our current universe of Asian clean and green stocks has a total market cap, attributable to Clean & Green businesses (ie, Sharp gets credit for the 5% of its business that comes from solar panels), of US$75bn.

Solar leads the way . . .

Figure 97

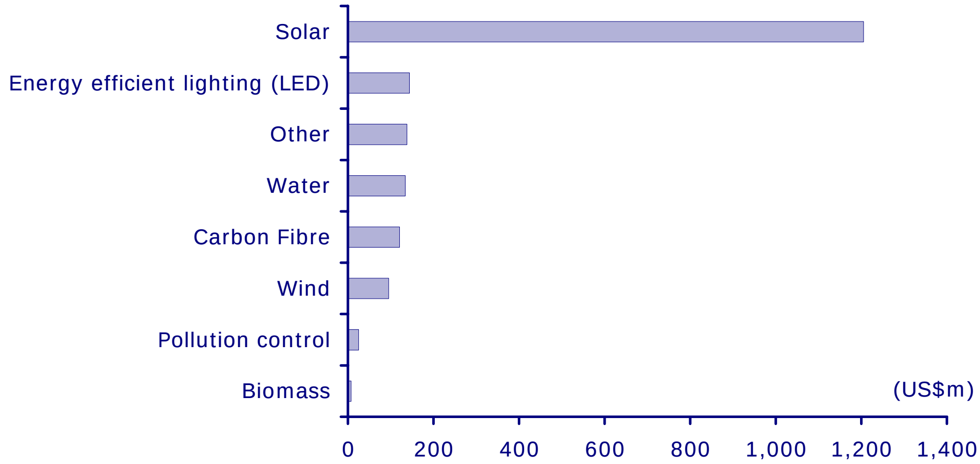
Attributable market cap of CLSA's Clean & Green universe (US$bn)



. . . and is attracting liquidity

Figure 98

Attributable daily trading volume of CLSA's Clean & Green universe



Source: Bloomberg, CLSA Asia-Pacific Markets

The world's solar workshop

Solar

For solar, Asia is still mostly focused on equipment production. China, in particular, is the solar workshop for the world, but the end market for the foreseeable future will continue to be relatively small. To get an idea of the scale, China has 4GW of annual panel production capacity, but is only targeting cumulative solar installations of 1.8GW by 2020.

On the equipment side, Chinese and Taiwanese companies have a head start in equipment production, but India and Korea are keen to catch-up. Leading panel makers such as Suntech (STP US – Buy) have a significant lead in building channels with installers and integrators.

Wind

Equipment focus

Production and use of wind turbines is more balanced in Asia. However, the liquid, tradable wind-related equities are mostly on the equipment side. India's Suzlon (SUEL IN – U-PF) is an established top-five wind turbine maker, and there are a number of Chinese companies, led by Goldwind (002202 CH – NR) and Sinovel (unlisted) chasing. Traditional equipment makers, most notably Dongfang Electric (1072 HK – O-PF), are also following in General Electric's tracks by getting into the wind turbine business. With carbon policy tightening, others would be forced to follow suit to make up for lost sales in their traditional business.

Clean energy operators

Dearth of clean energy in Asia

There is a dearth of pure clean energy operators in Asia. Most renewable projects are run either by traditional utilities as a small part of their business or by small, unlisted project operators. The notable exceptions include: China Power New Energy (735 HK - Buy), which runs wind, waste-to-energy and hydro projects; China Everbright International (257 HK - Buy), a leading waste-to-energy operator in China; and PNOC (EDC PH - Buy), a pure play geothermal energy operator in the Philippines.

Transmission & Distribution

Grids need more muscle

National electricity grids around the world will have to be substantially beefed up to improve efficiency and absorb the rapidly growing mix of intermittent renewables. Globally, this business is dominated by ABB, Areva and Siemens. In China, the main beneficiaries of the government's aggressive grid expansion project, with an emphasis on high voltage DC lines that do not lose efficiency over greater distances, are Tianwei Baobian (600550 CH) and Tedian (600089 CH).

Smart meters are advanced electricity meters that help reduce total energy consumption and improve grid efficiency by improving information flow. There are metering companies in Asia, most notably Wasion Meters (3393 HK – Buy),that are working at this, but more at the R&D stage.

Energy-efficiency

Seeing in a different light

Around 19% of the world's electricity goes to lighting, due mostly to our continued dependence on the incredibly inefficient incandescent lightbulb popularized by Edison. The current focus is mostly a shift toward more efficient compact fluorescent (CFL) bulbs, but the endgame is a shift to semiconductor-based light emitting diodes (LED). LEDs were originally developed in Japan and, as with other semiconductors, production is increasingly dominated by Taiwan and Korea.

The biggest listed LED names include downstream packager Everlight (2393 TT – O-PF), and upstream chipmakers Epistar (2448 - U-PF) and Seoul Semiconductor (046890 KS). Patent licensing agreements are a constant issue in the sector, with the threat of litigation from the major patent holders – Nichia (unlisted – Japan) and Osram, always looming, particularly for brighter general lighting solutions.

Light materials

More mileage with carbon fibre

Fuel consumption in jets and autos is directly related to the vehicle's weight. Shifting from traditional stainless steel construction to lighter materials such as carbon fibre improves mileage and cuts emissions.

Teijin, Toray, Mitsubishi Rayon and Formosa Plastics are some of the world's leading carbon fibre makers. While they will benefit from the increasing usage of carbon fibre in wind turbine blades and autos, they are facing short-term disappointments from airlines. This could be a long-term concern as well. Under a panic button scenario, carbon pricing will add substantial costs to flying and thus hinder the airlines' fleet growth. Airlines operating in Europe could face carbon constraints as soon as 2010 under the EU ETS.

Energy storage

Key hurdles

While wind and solar have been racing down the cost curve, battery technology has been pretty much stuck in neutral. Cheap, reliable energy storage, either through fuel cells or advanced battery technology, is a key hurdle that needs to be cleared before renewables can become a major feature of the electricity grid.

Asian firms dominate the battery supply for consumer electronics as well as advanced auto batteries. Leaders include Sanyo (6764 JP – NR), LG Chem (051910 KS), GS Yuasa (6674 JP) and BYD Auto (1211 HK).

A number of large Japanese companies, particularly auto makers, are working on fuel cells, but contributions to revenue and profits are negligible. Battery makers across East Asia are also working on a variety of new technologies, but still rely on traditional batteries for consumer electronics or autos for the bulk of their sales. This is a space we are watching closely, but there is nothing public yet.

Water

More water but less of it that we can use

Many of the most visibly pressing environmental issues in Asia revolve around the scarcity of clean water, and this would be exacerbated by climate change. According to an Intergovernmental Panel on Climate Change (IPCC) report, the Andean and Himalayan glaciers will start to melt with every one to two degree change, manifesting dry rivers and the disappearance of lakes. Perennial rivers such as the Ganges in India and the Yellow river in China will turn into seasonal rivers with the net effect being a decrease in water, and in turn food security.

The biggest impact on the business of water will revolve around agriculture which represents 70% of global water demand, of which over 55% is wasted through traditional flood irrigation. A shift toward sprinkler, and ultimately drip irrigation systems (which is twice as efficient) will benefit the likes of Jain Irrigation Systems (JI IN – Buy).

Generally drier climates in locales that can ill afford less water, such as Australia, will also drive demand for de-salinization pumps. The global leader, Torishima Pump (6363 JP – U-PF), is a key beneficiary.

Fuel efficient auto makers

Mix-and-match engines a strong possibility

Broadly speaking, the trend toward more fuel efficient autos is well entrenched. Tighter fuel economy standards worldwide, possibly alongside higher fuel taxes, will continue the push for more fuel efficient cars, favouring Asian automakers nearly across the board.

Beyond the broader trend electric vehicles (EV), clean diesel engines and next-generation bio-fuels will all play a part to achieve the 20% carbon emissions cuts from 1990 levels by 2020.

> Emissions - ultimately, it's got to be zero.
>
> Nissan CEO, Carlos Ghosn (40th Tokyo Motor Show)

Only the largest makers have the resources to bet on several technologies

Our Japan autos team has broken down the clean & green credentials of regional automakers. We prefer those with a broader exposure to several technologies, effectively hedging their bets on future growth. Given the high level of capital investment and research required, only the largest car companies will have the means to fully develop several engine technologies, leading us to top Japanese makers such as Toyota Motors and Nissan Motors.

Figure 99

Asian automaker exposure to energy efficient energy technology

	Clean diesel	Li-ion hybrid	Plug-in hybrid	Pure EV	Fuel cell	Note
Toyota	Plan for Tundra Sequoia clean diesel (no date)	Plans for use in future line-up (no release date)	Plug-in Prius fleet testing in 2009, targeting release by 2010	Test vehicles but no target for production	Limited testing of fuel cell hybrid vehicles, no target set	Views hybrids as a key strategic advantage. Wants to maintain the innovative, green mantle by moving aggressively into plug-in.
Honda	Plans to release Acura clean diesel by 2009 for NA markets	New HEV in 2009, four scheduled in lineup, NiMH or Li-ion unconfirmed			Public testing of FCX Clarity concept in mid 2008	Lags in hybrid sales despite early adoption. Promising growth in clean diesel. No plans for PHEV. Focused on developing fuel cell.
Nissan	Plans to release Maxima clean diesel by 2010	Original and Infiniti hybrids scheduled for 2010 release		Plans for retail EV by 2010 in specific global markets	Test vehicles, no target for production	No current plans for PHEV, but has shown the most initiative in developing an aggressive PEV strategy of the Japan Big 3.
Mitsubishi	European 2009 production planned of Concept cX		Targeting domestic sales by end 2009 of i-MiEV PHEV	Fleet testing of i-MiEV PEV in late 2008	Test vehicles, no target for production	Plans for clean diesel in Europe. Focusing on early release of small car PHEV and PEV.
Hyundai	Slated for 2009 or 2010 release	Domestic Elantra LPG hybrid scheduled for 2009 release	Original PHEV40 targeting release by 2011		Limited testing in 2012, full release target 2015 or beyond	Management has stated that hybrid technology to be a priority in future vehicle line-up.
BYD Auto			F6DM PHEV60 targeting late 2008 release	e6 crossover PEV to be sold by 2010, also planned for export		May be first to market with PHEV and PEV. No proven track record in global automobile market.

Source: Wards Auto, Edmunds, Automotive News, Company websites

Mounting risk for energy hogs

Under a scenario where the cost of carbon is fully priced into our economic system, no sectors and no companies are entirely unaffected.

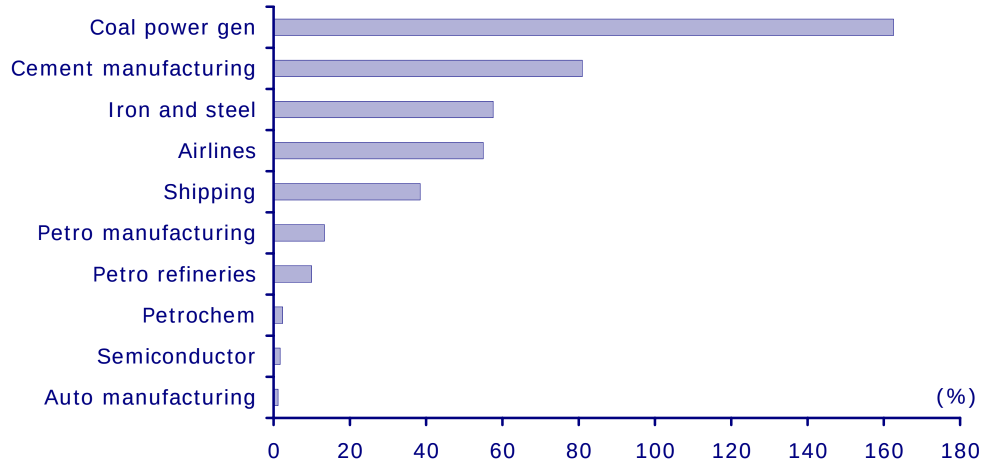
Taking the EU ETS as a model, energy intensive sectors will likely be given some allotment of carbon credits reflecting sector average emissions. That allotment will decline each year, forcing companies to either figure out how to cut their emissions or buy carbon credits from renewable energy or other carbon abatement projects.

European countries over-allocated carbon credits in the first phase of their trading scheme, allowing utilities to reap windfall profits by selling the excess carbon credits (even though they had not cut emissions). The system has been tightened for Phase 2 in Europe, and potential carbon trading programs elsewhere have also learned from those early mistakes. The mood has definitely shifted in favour of auctioning off all credits rather than allocating.

CLSA has worked with the London-based environmental research organization Trucost to assess the potential impact of carbon (and other pollutants) on companies' earnings. Of course, some of these costs will be passed on downstream, and ultimately to the end customer. However not all, and not immediately. The figure below looks at how much Ebitda would decline by for different sectors if carbon were completely priced into costs.

Figure 100

Carbon cost as a share of Ebitda (07A Ebitda; carbon price: US$34 per ton)



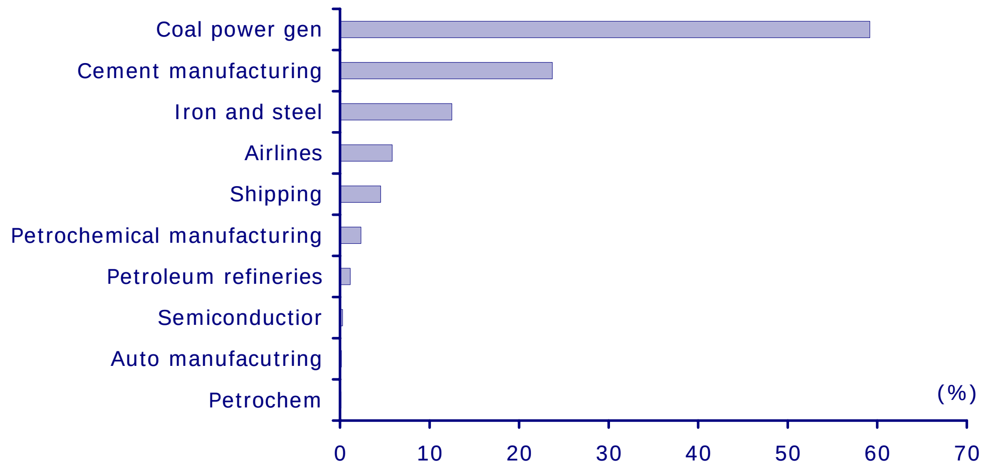
Source: Trucost, CLSA Asia-Pacific Markets

There should not be too many surprises about which sectors are most energy intensive. To get an idea of how much these companies would need to raise prices in order to offset carbon costs, we can also look at carbon costs as a share of sales. With the exception of the power-gen sector in Asia, which would have to raise prices by 60% to offset carbon costs, most sectors would have to raise prices by 20% or less.

Prices rising to offset CO_2 costs

Figure 101

Carbon cost as a share of sales



Source: Trucost, CLSA Asia-Pacific Markets

Not all carbon footprints are created equal

Energy intensity varies significantly among different companies in the same sector, and the companies in each sector that would come out worst are the smaller, less efficient ones. In China, for example, carbon pricing would accelerate a trend toward rotary cement kilns and away from smaller, less efficient vertical kilns. Appendix 9 shows a list of the biggest polluters in MSCI Asia-ex Japan, as per the Trucost data. Given that these are already the biggest regional names in their respective sectors, they would fare much better than many of the smaller listed and unlisted competitors.

Chinese energy intensive sectors less efficient

Generally speaking, China is also much less efficient than the global norm for energy intensive sectors. As highlighted in James Kan's May 2008 report *Harmonious Links*, China's steel sector is 15% more energy intensive than the global average and cement production is 53% more energy intensive. Carbon pricing will accelerate consolidation in these sectors.

Spotlight on Asian utilities under the panic button

In view of the outsized impact that carbon pricing has on utilities, we have broken down the emissions levels for Asian IPPs on a project-by-project basis. The complete results can be found in our report *Pollution Pains*. Most Asian utilities come out poorly in a situation where carbon could be priced into their costs. This is due both to their reliance on fossil fuels, especially coal, and their inability to pass on cost increases by raising tariffs, as highlighted by the recent challenges posed by high commodity prices.

We do not anticipate that carbon will be priced into the fuel mix in Asia ex-Japan anytime soon. However, carbon will be priced into electricity costs by 2020 either directly or indirectly, and the charts below are illustrative of how much relative risk each of the utilities face.

Figure 102

Winners and losers

Losers	Loser's emissions cost/ Ebitda (%)	Winners	Winner's emissions cost/ Ebitda (%)
CPI	114	PNOC-EDC	0
Huadian Power	93	YTL Power	51
Huaneng Power	64	First Gen	52
CRP	62	Tanjong	51
NTPC	59	Tenaga	60

Source: CLSA Asia-Pacific Markets

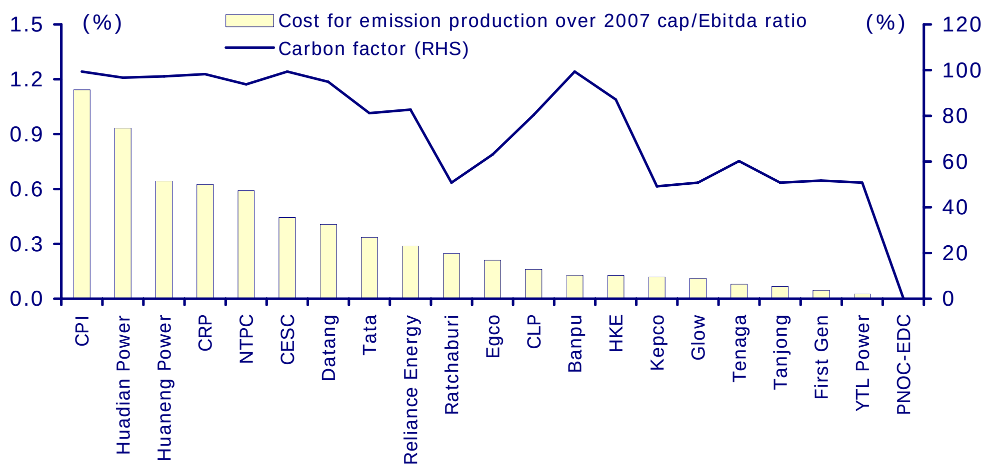
The higher the exposure to fossil fuel, the higher the emissions cost

The chart below shows the emission cost/Ebitda ratio for various companies. CPI's 2007 emissions costs makes up 114% of its Ebitda. The higher an IPP's exposure to fossil-fuel generation, the higher the emissions cost and the ratio.

IPPs using more coal will have higher emissions costs/Ebitda ratio

Figure 103

Emissions cost/Ebitda ratio (2007)



Source: CLSA Asia-Pacific Markets

The carbon factor

The carbon factor is a measurement of the total carbon produced over the total energy produced. Companies with high exposure to coal will have carbon factors of almost 100%, since approximately one tonne of carbon is produced for every MWh of coal energy generated. Companies with high exposure to natural gas will have carbon factors of around 50%. Gas-fired generation produces approximately half the carbon that a natural-gas plant does. Any IPP with a carbon factor other than 100% or 50% will have a more diverse portfolio.

Losers: CPI, Huadian, Huaneng, CRP and NTPC

The IPPs with the highest carbon factor will be the most adversely affected if emission policies were implemented today. These include CPI (a carbon factor of 99%), Huadian (97%), Huaneng (97%), CRP (98%), and NTPC (94%). These high carbon factors indicate heavy coal exposure.

Winners: PNOC, YTL, First Gen, Tanjong, and Tenaga

PNOC (a carbon factor of 0%), YTL (51%), First Gen (52%), Tanjong (51%) and Tenaga (60%) will be the least impacted, if emissions policies were implemented today. Carbon factors around the 50% mark represent heavy exposure to natural-gas generation. Kepco and Tenaga, with carbon factors of 49% and 60% respectively, have more diversified portfolios (see Figure 8 Asian IPPs' fuel mix).

PNOC-EDC the best play on future emissions policies

PNOC-EDC is the best play on the implementation of emissions policies because its installed capacity is 100% geothermal, which produces almost zero emissions. There are three outliers in this analysis, including CLP, Banpu and HKE. Though they have higher carbon factors than Ractchaburi and Egco, their emissions costs/Ebidta are lower. This is due to the higher tariffs for their power, or cheaper fuel costs.

Appendix 1: Greenhouse gases

What is a CO_2 equivalent?

GHG's global-warming potential is converted into a CO_2 equivalent

Emissions of the six GHGs (CO_2, CH_4, N_2O, PFCs, HFCs and SF_6) originate principally from the generation and use of energy, industrial processes, municipal waste and land-use activities, such as deforestation. For reporting and tracking purposes, the global-warming potential (GWP) of each gas is converted into a CO_2e. Methane, for example, has a GWP that is 23 times that of CO_2. In our study, we only model CO_2 emissions production.

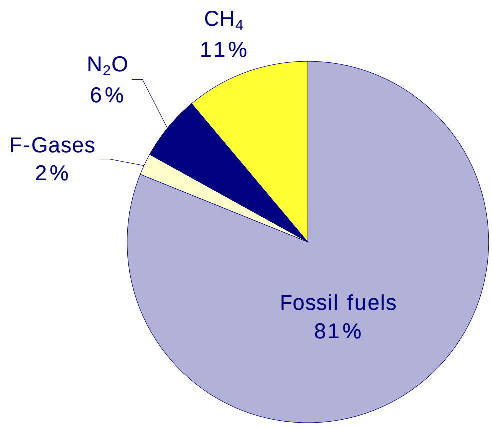
Carbon is the most significant GHG

CO_2 equivalent comparison

Greenhouse gas	Tonnes of CO_2 equivalent /tonne of gas	Source
Carbon dioxide	1	Fuel combustion
Methane	23	Rice cultivation, domesticated animals, waste treatment
Nitrous oxide	296	Fertiliser
Hydroflurocarbons	12-12,000	Industrial gas
Perflourocarbons	5,700-11,900	Industrial gas
Sulphur hexafluoride	22,200	Industrial gas

Source: IPCC, CLSA Asia-Pacific Markets

Greenhouse gases (by gas)



Source: CLSA Asia-Pacific Markets

Climate change poses much more complicated externalities

Externalities of climate change

It is a global externality, as the damage is the same regardless of where the GHGs are emitted, but the impacts are likely to fall very unevenly around the world.
Their impact is not immediately tangible, but is likely to be felt in the future.
There is uncertainty about the scale and timing of the impacts and when irreversible damage from emission concentrations will occur.
The effects could occur on a massive scale.

Source: *The Stern review on the economics of climate change* (2006)

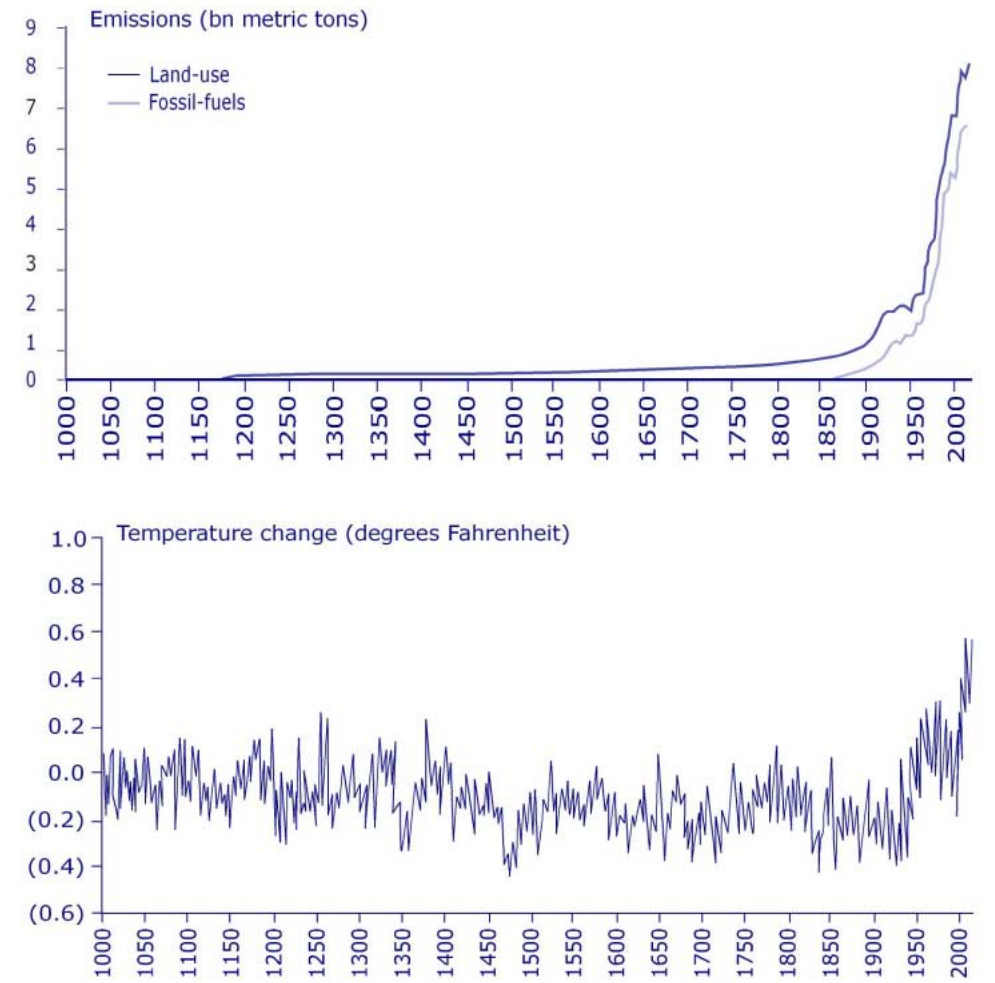
Appendix 2: Science of climate change

The greenhouse effect

The greenhouse effect makes life possible on Earth

Earth's climate is determined by complex interactions between the sun, ocean, atmosphere, land, and living things. Certain gases (including water vapour, carbon dioxide, methane, halocarbons, ozone, and nitrous oxide), called "greenhouse gases," absorb heat radiated from the Earth's surface, creating what is commonly called the greenhouse effect. Without it, the average temperature of the Earth's surface would be about 33°C (60°F) colder than it is making life support impossible.

Land and fossil fuel use vs temperatures for the past 1,000 years



Source: National Assessment Synthesis Team

Has the earth warmed?

Concentrations of CO_2 and other GHGs have increased since the industrial revolution

Scientists observed that the atmospheric concentrations of CO_2 and GHGs have increased since the industrial revolution. Higher atmospheric GHG concentrations intensify the greenhouse effect, making the earth warmer. During the 20th century, the global average surface temperature increased by over 1ºF (0.6ºC), compared to data from the previous 1000 years. Half this rise occurred since the late 1970s alone. Seventeen of the eighteen warmest years in the 20th century occurred after 1980.[1]

The global warming of the past century has brought about a number of significant and observable changes, such as reduction in global snow and ice cover, a rise in global sea levels, an increase in total global precipitation, and an increase in the frequency of heavy precipitation.

The carbon cycle simplified

The science of climate change rests on an understanding of the Earth's carbon cycle

The science of climate change rests on an understanding of the Earth's carbon cycle. There are two pools of carbon on earth, the biosphere pool and the geologic pool. The biosphere pool consists of carbon that cycles through living systems-oceans, plants, animals and soil on the earth's surface. The geologic pool is composed of sedimentary rock carbonates and fossil fuel deposits such as gas, coal, and oil.

For most of human history, the geologic carbon pool remained separate from the biosphere pool. But since the industrial revolution, humans have been transferring the geologic carbon pool into the biosphere by burning fossil fuels. At current rates, we are annually returning to the biosphere an amount of carbon that took about 100,000 years to remove.[2]

Ninety-five percent of global carbon dioxide emissions come from natural sources

Primary GHGs comprise 95% of global carbon dioxide emissions and derive from natural sources. These carbon emissions are reabsorbed by natural "carbon sinks" such as vegetation growth and the ocean, in a finely balanced cycling of carbon in the biosphere. The influx of carbon to the atmosphere from human activities represents about only 3% of annual natural emissions, but it is enough to exceed the absorption capacity of the earth's carbon sinks.[3]

The upshot of this carbon cycle imbalance is striking; atmospheric concentrations of CO_2 have increased by 31% since 1750, to concentrations not likely seen for the past 20 million years.[4] Human activities are also causing an increase in concentrations of other GHGs such as methane (up 150% since 1750), nitrous oxide (up 17% since 1750), and halocarbon gases, which are entirely manmade.

An even greater threat

Pound for pound, each of these other GHGs has an even greater potential to cause global warming than CO_2.per unit, with CO_2 currently the primary GHG simply because of its sheer volume in the atmosphere. It contributes to more than 80% of all human-caused global warming.

Once present in the atmosphere, GHGs can persist for thousands of years. Several centuries after CO_2 emissions occur, about a quarter of the increase in CO_2 concentration caused by these emissions is still present in the atmosphere.

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[1] National Assessment Synthesis Team. 2001. Climate Change Impacts on the United States. Report for the United States Global Change Research Program. Cambridge Univ. Press, www.usgcrp.gov/usgcrp/Library/nationalassessment/overviewclimate.htm

[2] Personal communication with David Hawkins of the Natural Resources Defense Council, 2 April 2002

[3] From the World Meteorological Program Commonly Asked Questions about Climate Change, www.gcrio.org/ipcc/qa/05.html

[4] Intergovernmental Panel on Climate Change Working Group 1, 2001. Third Assessment Report Summary for Policymakers. www.ipcc.ch

Therefore, it is the long-term, cumulative emissions that determine the increase in atmospheric CO_2 concentration and the potential for climate change.

Reaching carbon limits in fifty years

If we want to preserve the option of stabilizing atmospheric concentrations of carbon at 450 parts per million, a level 60% above pre-industrial levels, we can add only about 340 billion tons of carbon to the atmosphere. If we consider the rate of carbon dioxide emissions, this amount will be reached in about 50 years.

What the scientists have to say:
The United Nations' Intergovernmental Panel on Climate Change (IPCC) is a highly visible international body examining the science of climate change and its impacts. In its 2001 report, the IPCC found that most of the warming observed over the past 50 years is likely to have been due to the increase in GHG concentrations. In response to a request from the Bush Administration in 2001 for further guidance on the findings of the IPCC, the US National Research Council's (NRC) Committee on the Science of Climate Change prepared a review of the IPCC report. The NRC report, Climate Change Science: An Analysis of Some Key Questions found that the IPCC report's conclusion that most of the observed warming of the last 50 years was due to the increase in GHG concentrations "accurately reflects the current thinking of the scientific community on this issue. Despite . . . uncertainties, there is general agreement that the observed warming is real and particularly strong within the past 20 years."

Sources: Intergovernmental Panel on Climate Change Working Group 1, 2001. *Third Assessment Report Summary for Policymakers;* National Research Council, *Committee on the Science of Climate Change, Division on Earth and Life Studies. Climate Change Science: An Analysis of Some Key Questions,* National Academy Press, 2001.http://www.ipcc.ch/

The link between human activities and global warming

How do we know the atmospheric build up of greenhouse gases is due to human activities?

Four lines of evidence link the recent build-up of carbon dioxide to human activities. Primarily, scientists are able to distinguish between carbon emitted from fossil fuel combustion and carbon released from natural sources by measuring the amount of natural radioactivity (C14) in the nuclei of carbon atoms. Carbon nuclei released by fossil fuel combustion are older and have much less C14 than carbon from natural sources. Studies done on tree rings show that trees' uptake of newer, more radioactive carbon has been decreasing over time, as the concentrations of older, less radioactive carbon increase in the atmosphere.

Second, in the 1950s, scientists began making precise measurements of the total amount of carbon dioxide in the atmosphere. Their data show that both global atmospheric CO_2 concentrations are rising and that these increases are consistent with the rise in human-caused CO_2 emissions.

Third, evidence from ice cores corroborates this finding. Air bubbles in samples of ancient glacial ice provide a historical record of carbon dioxide concentrations, dating back over 200,000 years. Concentrations of CO_2 in shallow ice, only a few decades old, are nearly identical to those measured in the atmosphere, thus supporting the scientific credibility of this method of measurement. The older ice core samples show that carbon dioxide amounts were about 25% lower than today's concentrations for the ten thousand years prior to the onset of industrialization and changed very little over that period.

Most of the human activities that produce carbon dioxide are in the northern hemisphere

Finally, most of the human activities that produce carbon dioxide are in the northern hemisphere. These CO_2 emissions take about a year to circulate through the atmosphere and reach the southern hemisphere. As might be expected, measurements show a slightly higher atmospheric CO_2 concentration in the northern hemisphere than in the southern.

Projected climate changes and impacts

In 1992, the IPCC established several scenarios for global climate change for the next 100 years. These scenarios took into account a range of factors such as population growth, economic and technological developments, energy use, and environmental sensitivity to GHG emissions. In 2001, the IPCC revised and updated these scenarios. Global temperatures are predicted to rise in all six scenarios, ranging from an increase of 1.4 to 5.8 °C (2.5 to 10.4 °F) relative to 1990 levels.

Further reductions of snow and ice cover

These temperature increases are predicted to lead to further reductions of snow and ice cover; increased frequency and severity of precipitation events; increased risk of drought in some areas; a further rise in sea levels; and a weakening and possible shut-down of the ocean currents that warm the European continent. Indeed, global warming could cause a dramatic cooling of much of Northern Europe.[5] Moreover, even in the more conservative IPCC scenarios, the models project temperatures and sea levels that continue to increase well beyond the end of this century, suggesting that assessments that examine only the next 100 years may well underestimate the magnitude of the eventual impacts.[6]

Introduction to emissions trading

Defining emissions trading

A market mechanism to reduce air emissions in most cost-effective way

The basic idea behind emissions trading is to allow participants in a market to determine the most cost-effective and economically efficient manner to achieve a required level of emissions reduction. Since individual polluters have different marginal costs of pollution control, trading provides an opportunity to collectively find the least expensive way to accomplish government environmental goals.

When used effectively, emissions trading offers the following advantages:

- It allows emitters flexibility in choosing how to address their pollution-reduction obligations.
- It encourages the use of the most economically efficient pollution-reduction measures, allowing emitters to save money and placing the minimal burden possible on the economy as a whole.
- It promotes innovation in finding less expensive ways to reduce pollution.

Since emissions trading emerged in the late 1970s as a market-based mechanism for environmental protection, it has been endorsed as a cost-effective tool by the Organisation for Economic Cooperation and Development (OECD), United Nations (UN), World Bank, US Environmental Protection Agency (USEPA) and many others.

How emissions trading schemes work

The 101 of emissions trading

All emissions trading schemes share a number of characteristics. A regulating body, usually a government, decides on a target for the maximum amount of pollution allowed for a group of emitters over a given period of time. This

[5] See, for example, Broecker, W.S., "Thermohaline Circulation, the Achilles Heel of Our Climate System: Will Man-made CO2 Upset the Current Balance?" Science, 278, 1582–88, 28 November 1997.

[6] Intergovernmental Panel on Climate Change Working Group 1, 2001. Third Assessment Report Summary for Policymakers. www.ipcc.ch

amount should be based upon the environmental goal and is typically below what is found in a "business-as-usual" (BAU) situation. Some form of tradable pollution right is created equivalent to a set amount of emissions, and a regulatory enforcement scheme must ensure that polluters hold the necessary pollution rights for the amount of emissions they emit. Polluters will then face a choice: they can reduce their own emissions to exactly meet the new target, control beyond the amount required and sell that additional reduction, or go to the market to buy permits to cover all of their emissions. Some emitters will face higher reduction costs than others creating a market opportunity. Emitters with low reduction costs will be incentivised to reduce their emissions more, so that they can sell their credits at a profit to emitters with higher reduction costs. Emitters with higher reduction costs will want to buy these credits, as long as the cost is less than the cost of reducing their own emissions.

Is it a replacement for emissions reduction by regulation?

It works side-by-side with direct regulation . . .

In an ideal world, economic theories could be routinely applied to any problem. In the real world, emissions trading works side-by-side with direct regulation. It helps make the regulatory scheme more cost-effective and efficient and hence optimises benefits to the environment.

Emissions trading may be thought of as a reform measure within environmental regulations that brought together the best strengths of science, engineering and economics to create new ways of dealing more effectively with pollution.

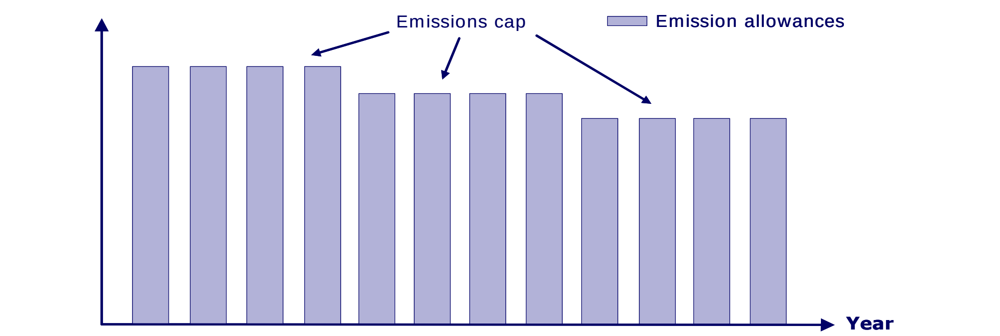
Cap and trade

. . . and "cap-and-trade", eg, US Acid Rain Program and EU's carbon trading

In this approach, the regulator sets an overall emission limit (a "cap"), which is the total (quantity) amount of a pollutant that the participants in the scheme are allowed to emit in a given period of time (e.g., one year). In the US Acid Rain Program, for example, emission allowances let a polluter emit one tonne of sulphur dioxide (SO_2) in a specific year. The allowances were distributed free-of-charge to market participants - although participants typically received fewer free allowances than the amount they previously emitted (since the programme ultimately resulted in a 50% reduction in emissions). It should also be noted that the legislation specifically stated that allowances did not constitute a formal pollution right for market participants. If the government subsequently decided to reduce the level of allowances, it could do so without having to compensate the participants, or be subject to "takings" lawsuits for usurping private property. The regulator sets specified procedures to monitor the actual emissions of the participants. Participants polluting beyond the allowances they hold need to buy them from others who have spare allowances. Those who emit more pollution will therefore require more allowances, while those who have reduced emissions will be rewarded by having allowances available to sell.

Allowable budget trade

Trade in allowable budget



Source: Adapted from OECD, 1997

Appendix 3: The Kyoto Protocol

A growing carbon market

The Kyoto Protocol, opened for signature in 1997, and its subsequent ratification in 2005 has led to a rapidly growing carbon market. Carbon-financing mechanisms are proving to be important to both industrialised and developing countries, and climate change is now emerging as one of the most important issues facing the global community.

Section 1 has already discussed emissions trading as a market mechanism that lowers the cost of environmental protection. This section introduces the Clean Development Mechanism (CDM), which is the means under the Kyoto Protocol, by which developing countries can access clean-energy technologies (and specific forestry projects) that in turn offer significant benefits in terms of foreign capital flows, technology transfer and sustainable development. This section also describes climate exchanges.

The background

The Kyoto Protocol is a multilateral treaty made under the United Nations Framework Convention on Climate Change (UNFCCC), which became open for governments to sign on 9 May 1992 at the UN Conference on Environment and Development, more commonly known as the Earth Summit, held in Rio de Janeiro, Brazil. Upon ratification, the UNFCCC committed the signatory governments to a voluntary non-binding effort to reduce GHGs in the atmosphere with the goal of ‘preventing dangerous anthropogenic interference with earth's climate system’. According to terms of the treaty, the UNFCCC would come into force once ratified by over 50 countries as it was on 24 March 1994. There is no end date to the UNFCCC and so there is no set expiry time to the international regime under the treaty.

A multilateral treaty signed on 9 May 1992 at the Earth Summit

Kyoto Protocol signatory countries

Annex I (industrialised countries)	Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, European Community, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, and USA
Non-Annex I (developing countries)	China, India, Indonesia, Laos, Malaysia, North Korea, Pakistan, Philippines, Singapore, South Korea, Thailand, Vietnam Note: no GHG reduction obligations but must submit an annual national GHG inventory and are expected to institute policies and practices that will help mitigate their GHG emissions

Source: CLSA Asia-Pacific Markets

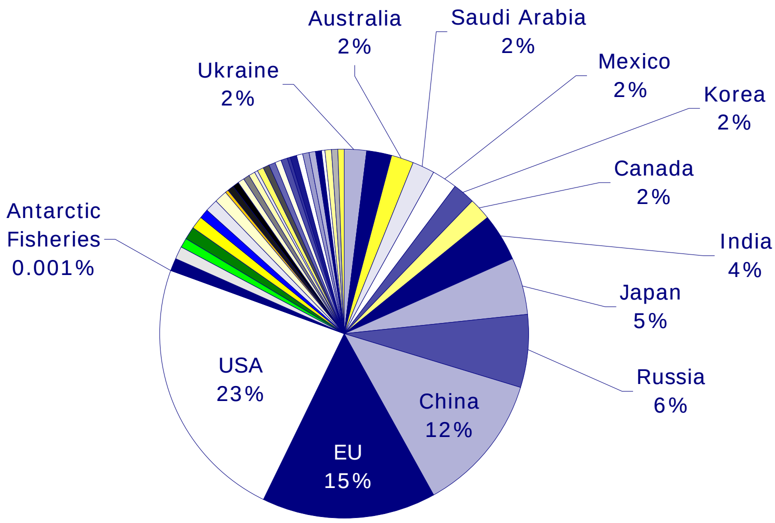
Common but differentiated responsibilities

This division between Annex I and non-Annex I countries was made because the signatories to the UNFCCC agreed to set ‘common but differentiated responsibilities’ on the basis that the largest share of historical and current global GHG emissions were originated in the industrialised countries and that per-capita emissions in developing countries are still relatively low. Also, the share of global emissions originating in developing countries will need to grow to meet their social and development needs.

Since the UNFCCC entered into force, the parties have been meeting at the annual Conference of the Parties (COP) to assess implementation and progress in dealing with climate change. The COP is the only entity with the authority to adopt new member states or global commitments through amendments of the UNFCCC and entering into protocols to the convention.

A few countries really matter

Allocation of world emissions



Source: www.pesd.stanford.edu

Beginning in the mid-1990s, the signatory countries began to negotiate the establishment of legally binding obligations for the industrialised countries to reduce their GHG emissions. The Kyoto Protocol was adopted by the third COP on 11 December 1997 in Kyoto but was not opened for signature until 14 March 1998 before eventually coming into effect on 16 February 2005. It took so long because the Kyoto Protocol was not ratified by many states until the "flexible mechanisms" were negotiated and put into place at one of the COP sessions. By December 2006, a total of 169 countries had ratified the Kyoto Protocol. The annual COP to the UNFCCC also serves as the Meeting of the Parties (MOP) to the Kyoto Protocol. In other words, these are the gatherings responsible for officially approving the procedures and modalities that govern the UNFCCC and the Kyoto Protocol.

The objectives

Kyoto Protocol regulates six greenhouse gases . . .

The Kyoto Protocol is a binding agreement to regulate CO_2 and five other GHGs - methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hexafluorocarbons (HFCs), and sulphur hexafluoride (SF_6). These emissions originate principally from the generation and use of energy, industrial processes, municipal wastes and land-use activities, such as deforestation. For reporting and tracking purposes, the global-warming potential (GWP) in the atmosphere of each gas is converted into a CO_2 equivalent. Methane, for example, has a GWP that is 23 times that of CO_2.

. . . and set emission-reduction targets for Annex I countries

The Kyoto Protocol sets individual GHG emission-reduction targets for Annex I countries under the UNFCCC. These individual targets are specified in Annex B of the Kyoto Protocol. For the Annex I countries that had ratified the Kyoto Protocol (all except Australia and the US), their assigned GHG amounts act as a legally binding cap on emissions between 2008 and 2012. All countries with specific emission-reduction commitments are listed in Annex B. Their average emissions reduction is 5.2% below the 1990 levels, and this must be achieved by 2012.

Carbon is the most significant GHG

Greenhouse gas	Tonnes CO_2 equivalent/ tonne of gas	Source
Carbon dioxide	1	Fuel combustion
Methane	23	Rice cultivation, domesticated animals, waste treatment
Nitrous oxide	296	Fertiliser
Hydroflurocarbons (HFCs)	12-12,000	Industrial gas
Perflourocarbons (PFCs)	5,700-11,900	Industrial gas
Sulphur hexafluoride	22,200	Industrial gas

Source: IPCC, CLSA Asia-Pacific Markets

Three flexible mechanisms

How to reduce emissions

Annex B countries of the Kyoto Protocol can reduce emissions in a number of ways - through domestic regulation, or through the use of three flexible mechanisms incorporated into the Protocol to facilitate economic efficiency in achieving emission-reduction goals. These mechanisms, agreed to in 1997, were crucial in getting a sufficient number of countries to sign and ratify the treaty so that the Kyoto Protocol could come into force.

The flexible mechanisms allow Annex I countries to pursue opportunities to cut emissions or sequester carbon more cheaply in another country than within their own domestic market. These mechanisms include the following:

International emissions trading

The Protocol provides for a quantity-based cap-and-trade scheme

The Kyoto Protocol provides for a quantity-based cap-and-trade scheme that imposes national caps on the emissions of Annex I countries. International emissions trading is limited only to Annex B countries. The national allocations used in trading are called assigned amount units (AAUs). Although these are national allocations and commitments, in practice, individual countries devolve their emission targets and requirements down to major industrial entities, such as power plants and other large emitters. Thus, the ultimate market participants may be individual companies that expect their emissions to exceed their quotas.

Clean development mechanism (CDM)

CDM lets public or private entities invest in GHG-mitigating activities

The CDM has two goals, to reduce GHG emissions and to foster sustainable development. It is a project-based mechanism that allows public or private entities to invest in GHG-mitigating activities in developing countries, and to earn abatement credits for these projects, which can then be applied against their own GHG emissions or be sold in the open market. The resulting emissions reduction, known as certified emissions reductions (CERs), can be transferred to Annex I countries to assist them in meeting their GHG-reduction commitments. The CDM market had a size of US$2.65 billion in 2005, and US$2.27 in the first quarter of 2006.

Joint implementation

Joint implementation is a project-based mechanism that assists UNFCCC Annex I countries in meeting their Kyoto targets by participating in projects with other Annex I countries. Entities may take part in joint implementation projects to generate emissions credits, known as emission-reduction units (ERUs), in order to use them for compliance with their targets or to sell on the international emissions trading market. These projects may start as early as 2000, but can only begin generating ERUs in 2008 (as this has yet to come into play, we are not discussing this mechanism in this report).

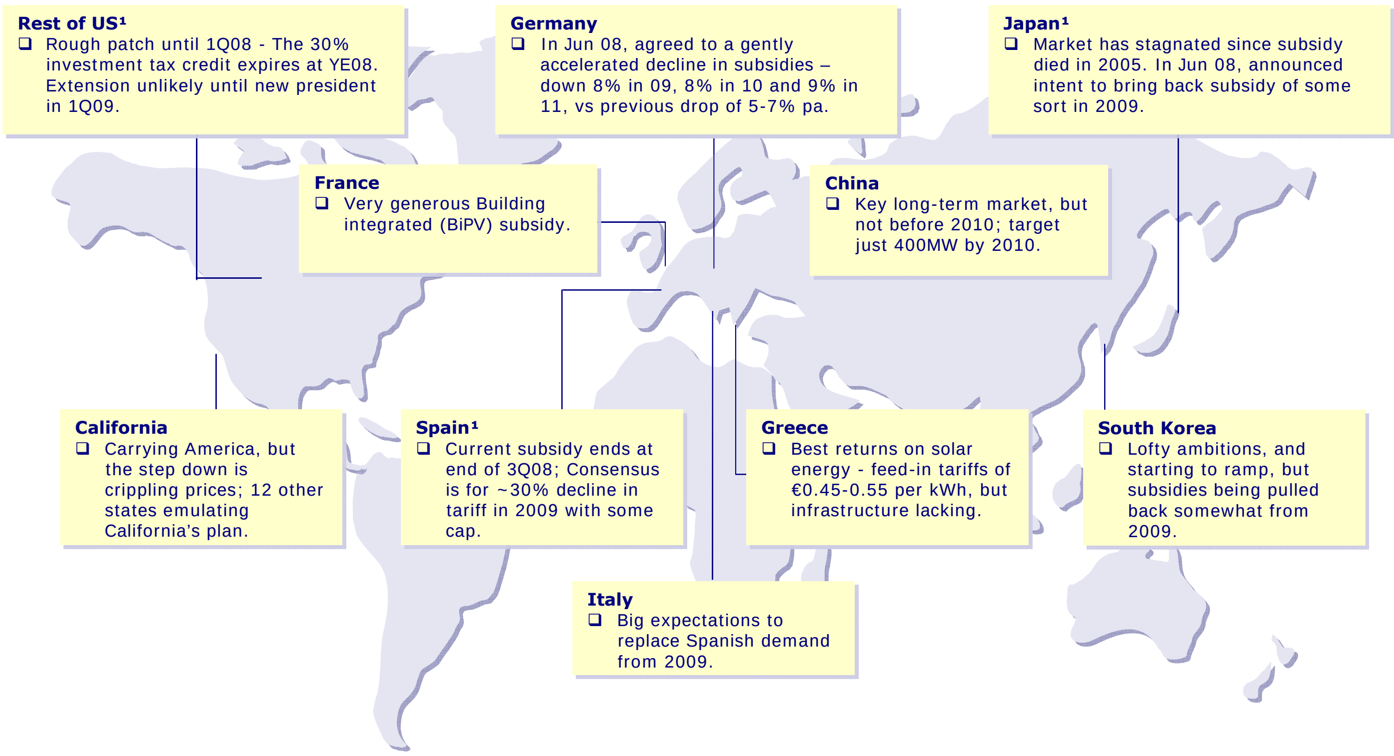
A brief history of global climate change policy

Date	Event	Summary
1979	First World Climate Conference	Agreement to treat climate change as major issue and governments are called on to prevent man-made climate changes.
1985	First major international conference on the greenhouse effect at Villach, Austria	Warns that greenhouse gases will create greatest rise of global temperature in man's history and that gases other than CO_2 contribute to warming.
1988	IPCC established, Congressional hearings in Washington DC, and meeting of climate scientists in Toronto	UN sets up the Intergovernmental Panel on Climate Change (IPCC) to report on scientific findings. At congressional hearings US drought is blamed on global warming. Climate scientist call for 20% cuts in global CO_2 emissions by the year 2005.
1990	The first report of the IPCC	Finds that the planet has warmed by 0.5°C over the past century. IPCC warns that only strong measures will prevent serious global warming. This provides scientific basis for UN negotiations for a climate convention. Negotiations begin after the UN General Assembly in December.
1992	Climate change Convention in Rio	154 nations sign agreement to prevent excessive warming from greenhouse gases and sets target of reducing emissions from industrialised countries to 1990 levels by the year 2000.
1994	The Alliance of Small Island States meeting	The Alliance of Small Island States demand 20% cuts in emissions by the year 2005 to cap sea-level rise at 20cm.
1995	First full meeting of the Climate Change Convention	Industrialised nations agree to negotiate real cuts in their emissions by the end of 1997.In November, the IPCC states that global temperatures will rise by 1°C and 3.5°C by the year 2100.
1996	Second meeting of the Climate Change Convention	The US agrees for the first time to legally binding emissions targets. Scientists warn that most industrialised countries will not meet the Rio agreement to stabilise emissions at 1990 levels by the year 2000.
1997	Kyoto Protocol	Participating countries agree to legally binding emissions cuts for industrialised nations, averaging 5.4%, to be met by 2010. The US government says it will not ratify the agreement unless there is stronger participation in reducing emissions from developing countries.
2001	Kyoto Protocol talks	George W. Bush renounces the Kyoto Protocol because he believes it will hurt the US economy. Other nations agree to continue without the US. Talks in Bonn in July and Marrakech in November conclude the protocol. Nations are urged to ratify the protocol in their national legislatures so that it may come into force before the end of 2002.
2002	Kyoto Protocol talks	The European Union, Japan and others ratify Kyoto. Ratification of the Kyoto agreement hinges on Russia after Australia and the US decline to sign.
2004	Kyoto Protocol talks	On November 18, the Russian parliament ratifies the protocol so that it may come into force in 2005.
2005	Kyoto Protocol goes into effect	The Kyoto Protocol comes into effect. Countries signing the Kyoto Protocol agree to discuss emissions targets for beyond 2012, while countries without targets such as the US and China agree to continue to talking about their future roles in curbing emissions.
2007	Australia ratifies Kyoto Protocol	Australian Prime Minister Kevin Rudd ratifies the Kyoto protocol on December 3, 2007. This came into effect after 90 days.
2007	Bali - UN Climate Change Conference	Negotiations on a successor to the Kyoto Protocol dominated the conference. A meeting of environment ministers and experts held in June called on the conference to agree on a road-map, timetable and 'concrete steps for the negotiations' with a view to reaching an agreement by 2009.
2009	Copenhagen - UN Climate Change Conference	Potential topics include carbon capture and storage, biofuels, adaptation financing, technology transfer, sustainable agriculture, emissions targets and tropical forests.

Source: IPCC, Stern Report, New Scientist

Appendix 4: Support and economics

Demand: Significant uncertainty about government support beyond 2008



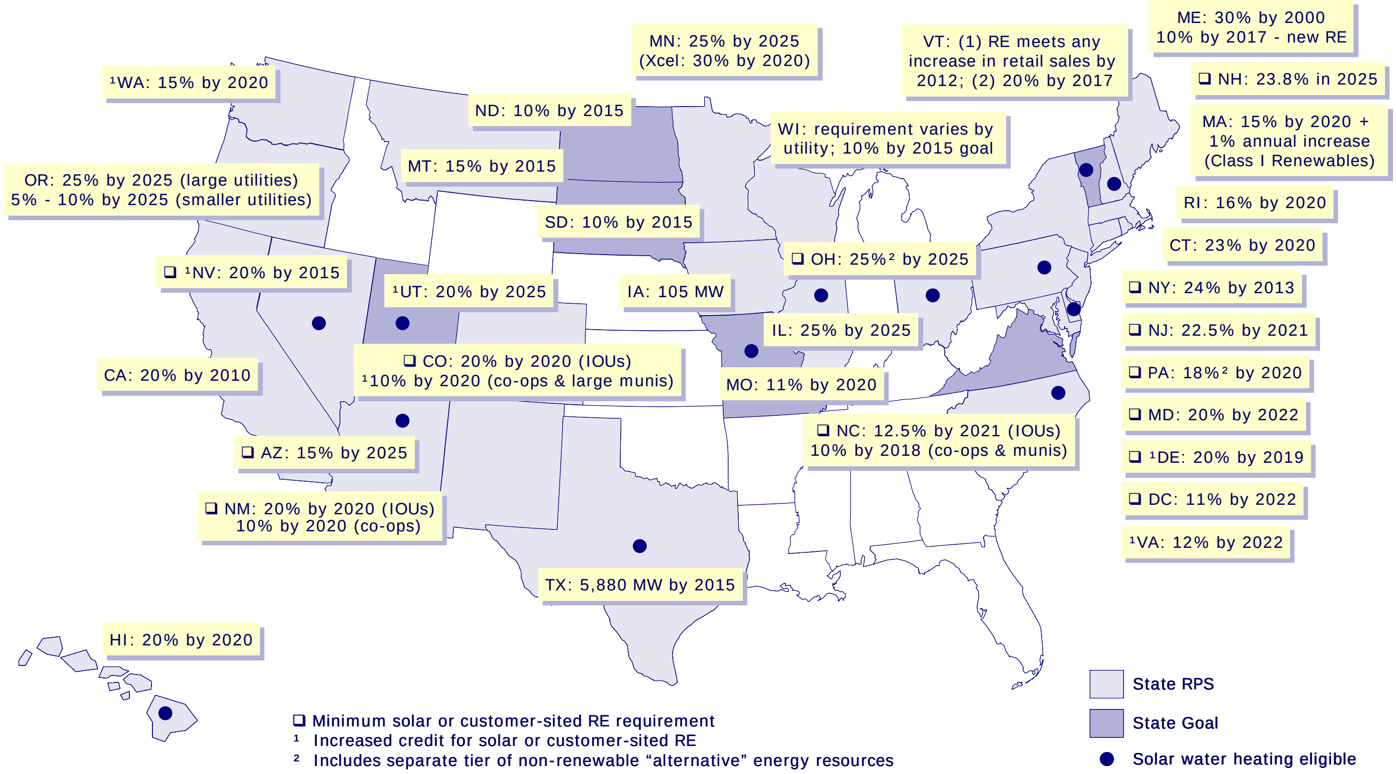
¹ Markets with uncertain policies for 2009. Source: European Commission Joint Research Centre, CLSA Asia-Pacific Markets

Global wind support policies

Country	Feed-in tariff	Details
Germany	$0.11/kWh	Duration: 20 years
Spain	Onshore: €0.073/kWh	Duration: 20 years
	Offshore: €0.061/kWh	+20 years
Greece		
France	Onshore: €0.082/kWh	Duration: 15 years
	Offshore: €0.13/kWh	
Italy	€0.124/kWh	Duration: 1-8 years
	€0.062/kWh	8-20 years
Austria	$0.11/kWh	Duration: 13 years
Portugal	$0.11/kWh	Duration: 12 years
USA (Michigan)	Year 1-5 Rotor diameter >17m: $0.11/kWh Rotor diameter <17m: $0.25/kWh Year 6-20 Rotor diameter >17m *Yield (kWhs/m²)* <700: $0.11/kWh	❑ The utility must interconnect and purchase from an renewable electricity provider ❑ The interconnection costs are covered by a ratepayer surcharge ❑ Duration of the power purchase agreement is 20 years
USA (Ontario)	$0.42/kWh	❑ Duration: 20 years ❑ In years 6-20, the tariff is based on a sliding scale, paying less to projects with higher yields
South Korea	107.66won/kWh	

Source: CLSA Asia-Pacific Markets

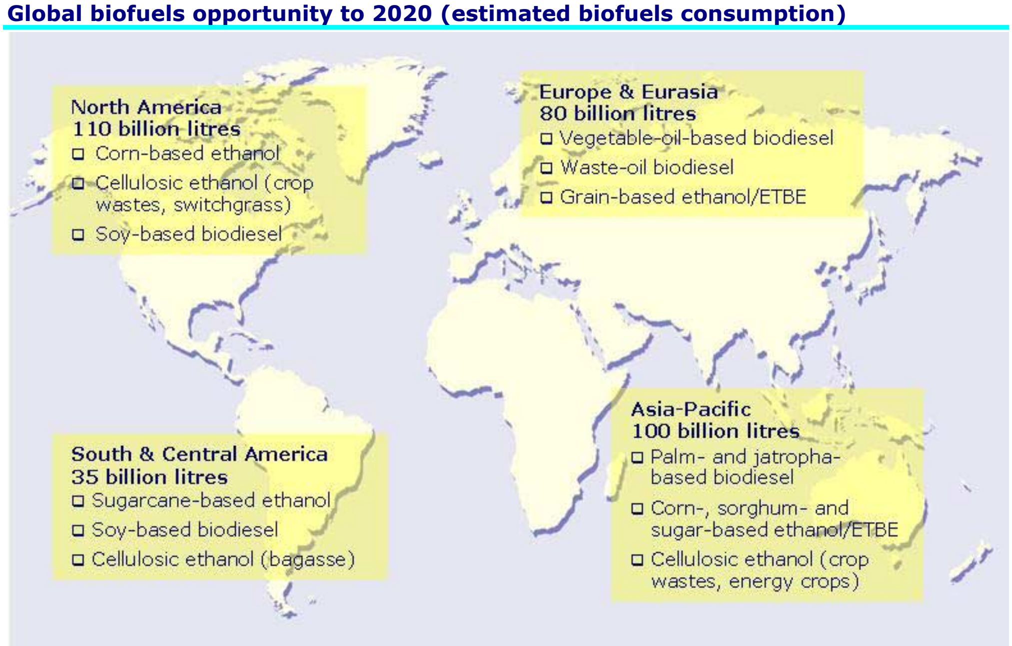
Renewable Portfolio Standards in the US



Source: DSIRE Renewable energy data base

The wholesale value of biofuels could reach US$150 billion

Global biofuels opportunity to 2020 (estimated biofuels consumption)



Source: CLSA Asia-Pacific Markets, Bio-era estimates

China's energy-saving policy and realities

To build an energy-efficient society

China's policy goals provide for the building of an energy-efficient society. The 11th Five Year Plan sets the goal of quadrupling GDP by 2020, while only doubling energy consumption. Energy consumption per unit of GDP is to be cut by 20% of 2005 levels by the end of 2010 (ie, 4% a year). China's Medium and Long Term Energy Conservation Plan, if implemented in full, will limit energy consumption by 2020 to three billion TCE, instead of the four billion TCE predicted, if current trends continue.

Major climate change-related laws in China

Year	Law
1979	Environmental Protection Law for Trial Implementation
1984	Water Pollution Prevention and Control Law
1984	Forest Law
1987	Air Pollution Prevention and Control Law
1991	Water and Soil Conservation Law
1995	Solid Waste Law
1997	Energy Conservation Law
2002	Cleaner Production Promotion Law
2002	Environmental Evaluation Law
2005	The Renewable Energy Law

Source: State Environmental Protection Administration of China (SEPA)

Focus on energy saving

Following the passing of the 11th Five Year Plan, numerous initiatives have been taken at national and provincial levels to focus on energy saving. These include requiring provincial authorities to restrict the expansion of high energy consuming industries and to include energy-efficiency standards in approval of projects. The government warned enterprises consuming high levels of energy that they would be closed if they did not fall into line with national industrial policies. China has also started to adopt variable pricing for peak and off-peak periods of electricity demand. A number of specific administrative measures have been implemented to improve energy-efficiency of buildings, vehicles, and electrical appliances, and to reduce the energy intensity of various industry sectors.

Efforts hampered by longstanding systemic weaknesses

These measures have yielded mixed results. In 1H08, China's energy intensity fell 2.9% YoY, and the NDRC has admitted that it will be very difficult to achieve its goal. Despite the many efforts by the central authorities, China's challenges in achieving higher efficiency are hampered by longstanding systemic weaknesses (although there will be continuous efforts for reform):

- Policies contain clear objectives, but few implementation details
- Incompleteness of laws and regulations
- Weak enforcement of laws
- Lack of support from financial and taxation policies
- High proportion of energy-intensive secondary industries
- Artificially low energy prices
- Lack of investment in efficient use of energy
- Lack of compliance by local officials

Germany is the world's most important market for solar, but by 2010 it could be the US

Appendix 5: Wind, solar demand

Solar demand forecast by market (MW)

	2007A	2008CL	2009CL	2010CL	2011CL
Germany	1,310	1,506	1,732	1,992	2,390
Japan	230	219	240	264	291
Spain	640	1,000	500	500	500
Italy	110	243	450	450	450
Europe - Other	169	415	1,202	1,700	1,950
California	110	243	238	683	786
US - Other	97	194	410	1,379	1,690
Global - Other	136	287	569	704	833
Off-grid market[1]	507	659	857	1,114	1,448
Showcase projects[2]	200	260	338	439	571
Niche products	115	138	166	200	201
Total measurable demand	**3,625**	**5,164**	**6,702**	**9,426**	**11,110**
Unallocated demand	**590**	**859**	**5,415**	**11,477**	**14,285**
Sum	**4,215**	**6,023**	**12,117**	**20,904**	**25,395**

[1] Including developing markets such as China and India [2] Focused on government buildings.
Source: CLSA Asia-Pacific Markets

Wind power demand forecast by end market (MW)

New Capacity (MW)	2006A	2007A	2008CL	2009CL	2010CL	2011CL	2012CL
Germany	2,194	1,625	1,425	1,500	2,100	2,300	2,500
Spain	1,588	3,530	3,700	3,800	2,500	2,400	2,350
USA	2,454	5,215	5,500	5,700	5,000	6,000	6,900
India	1,840	1,730	1,850	1,900	2,500	2,600	2,700
Denmark	14	(11)	0	0	0	0	0
China	1,344	3,446	2,420	3,388	4,743	6,640	9,297
Italy	406	603	800	1,000	1,000	1,150	1,250
Portugal	502	187	917	500	800	800	800
UK	363	673	1,000	1,019	1,600	1,650	1,750
France	389	887	1,000	1,019	1,600	1,650	1,750
Netherlands	351	210	450	500	100	300	360
Japan	298	350	350	500	500	500	550
Rest of world	6,253	2,656	3,438	5,311	7,605	8,576	10,289
Total	**17,996**	**20,541**	**22,850**	**26,137**	**30,048**	**34,566**	**40,496**

Source: CLSA Asia-Pacific Markets

Appendix 6: Ethanol from biomass

Enzymatic conversion will transform the industry

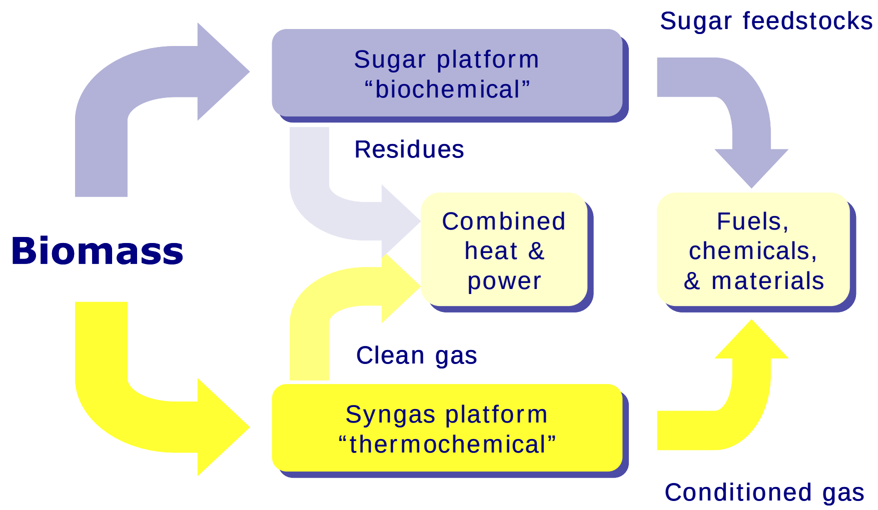
Conversion of cellulosic biomass into ethanol looms on the horizon as the technology advance that could transform the biofuels industry. At US$25–35/tonne, biomass could offer an extremely low-cost feedstock for producing liquid transport fuels through either thermochemical or biochemical conversion processes. Biochemical conversion "platforms" are rapidly being developed using enzymes to break down the cellulose and hemicellulose material in plants into simple sugars that can be fermented into alcohols or converted into plastics and other bio-based products. The synthetic gas (or "syngas") platforms use thermochemical processes that are typically capital- and energy-intensive, using heat to create liquid fuels and other products.

Perfecting cellulosic conversion pathways

Intensive research and development activity is now focused on perfecting cellulosic conversion pathways as well as on the development of specialised energy crops that can deliver high yields with minimal inputs of artificial fertilisers and water. The prospect of this technology is to significantly increase the maximum available yields of biofuels to significantly higher levels than are available using current biofuels production technologies. While these new technologies could bring advances in dedicated energy crops, they also hold the promise to convert significant volumes of agricultural wastes such as rice straw, sugarcane bagasse and other materials to ethanol or butanol. While these technologies are advancing rapidly, their large-scale penetration into commercial biofuels production still stands 5-10 years in the future.

Nonetheless, the rapid advance of fundamental enabling technologies that support biotechnology - specifically the exponential improvements in DNA sequencing and synthesis technology - are making it cheaper and faster to develop new biological pathways for production of a wide variety of products.

The biorefinery concept



Source: National Renewable Energy Laboratory

Eliminating waste

Appendix 7: Efficiency measures

Energy-efficiency measures for buildings

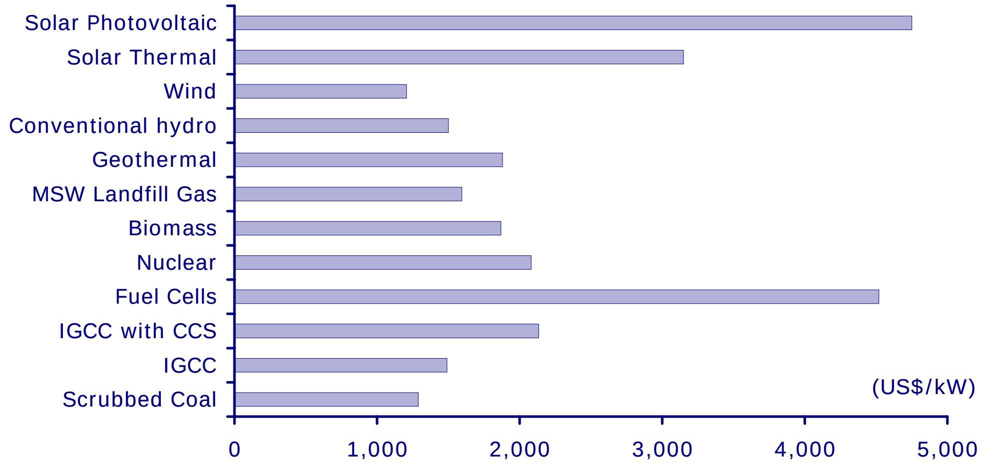
Measure	Description and estimated energy savings
Efficient lighting	❑ Four- to fivefold reduction in residential lighting energy use compared with incandescent/halogen lighting. ❑ In commercial buildings, energy use can be cut by 50% compared with old systems by efficient lamps (e.g., T8), ballasts, reflectors, occupancy sensors, and light colour finishes. 40-80% of remaining energy use can be saved in perimeter zones through daylighting. ❑ Using low background lighting, with levels of greater illumination at workstations can cut lighting energy use in half.
Reduce cooling loads	❑ High-reflectivity building surfaces, external shading, optimal building form and orientation, glazing with low solar-heat gain, natural and night-time ventilation, internal thermal mass, external insulation. ❑ High-efficiency lighting systems and efficient equipment. ❑ Load reductions by a factor of 2 are possible.
Passive design for ventilation and cooling	❑ Estimated savings in cooling energy use in a variety of Californian climate zones: 92-95% for a house and 89-91% for a classroom.
Efficient HVAC systems	❑ Displacement ventilation systems can reduce energy use for cooling and ventilation by 30-60%.
Efficient equipment, properly sized, and fully commissioned	❑ Realistic sizing can reduce annual energy use by 6–22%. ❑ Computer-based systems for monitoring, data storage, communication and control estimated to save 5-40%. ❑ Results of building commissioning in the USA show energy savings of up to 38% in cooling.
System approach to energy-efficiency and the role of the design process	❑ Savings in the order of 35-50% for a new commercial building are achievable by: (1) selecting a high-performance envelope and efficient equipment, properly sized; (2) incorporating an energy management system that optimises the equipment operation and human behaviour; and (3) fully commissioning and maintaining the equipment.
Retrofits of existing buildings	❑ Energy savings of 50-75% in commercial buildings through integrated measures. ❑ Standard measures such as thermal envelope upgrades can be combined with re-configuration of the building to make use of solar energy for heating, cooling and ventilation. ❑ Solar air collectors and domestic hot water heaters; advanced balcony glazing; external transparent insulation; and construction of a second skin over the original façade have achieved energy savings of 40–70%.

Source: Urge-Vorsatz et al. 2007

Calculating generation costs

Appendix 8: Electricity generation costs

Capital costs of different power plants (US$/kW)



Source: EIA

Appendix 9: Wind and solar returns

Comparisons of wind farm investments

Typical wind turbine price for selected markets (gearbox-driven models)					
(US$/Watt)	**2004**	**2005**	**2006**	**2007**	**2008CL**
USA	0.90	1.05	1.15	1.30	1.30
Germany	1.34	1.37	1.40	1.42	1.42
China	0.51	0.53	0.54	0.55	0.56
India	0.82	0.85	0.83	0.92	1.12
Global blended average	0.89	0.95	0.98	1.05	1.10
Wind capital cost (US$/Watt)					
USA	1.30	1.40	1.44	1.50	1.50
Germany	1.68	1.71	1.75	1.78	1.78
China	0.85	0.88	0.90	0.92	0.93
India	1.03	1.06	1.04	1.15	1.40
Global blended average	1.21	1.26	1.28	1.34	1.40
Wind tariff price for selected markets (US¢/kwh)					
USA	0.06	0.06	0.05	0.06	0.06
Germany	0.12	0.12	0.12	0.12	0.12
China	0.07	0.07	0.08	0.08	0.08
India	0.08	0.08	0.08	0.08	0.10
Global blended average	0.08	0.08	0.08	0.08	0.09
IRR (for 1MW investment, 22 year life, 80% debt, no CDM) (%)					
USA	9.6	8.2	7.7	7.3	7.3
Germany	14.0	13.7	13.3	13.1	13.1
China	13.3	13.5	14.7	14.7	14.7
India	14.4	14.3	14.3	13.7	13.3
Global blended average	12.8	12.4	12.5	12.2	12.1

Source: US Annual Wind Report, India and Germany government, CLSA Asia-Pacific Markets

Simple IRR and NPV for rooftop solar installations (2007)

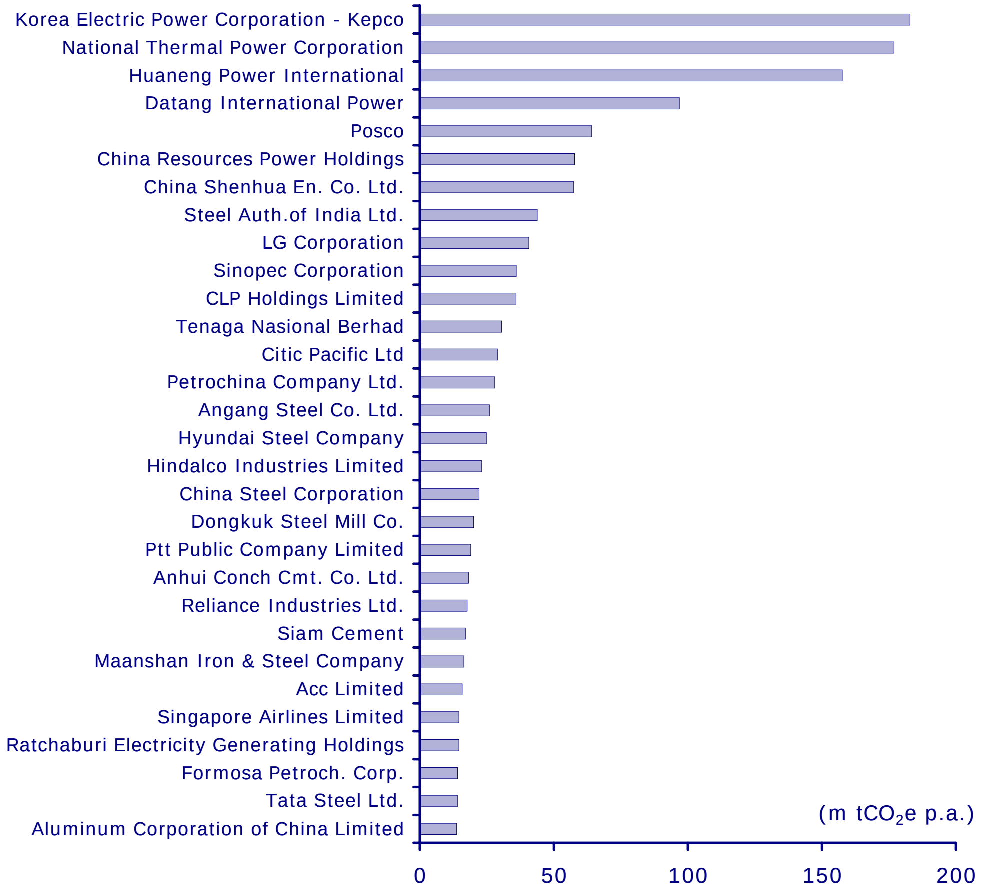
	Berlin, Germany	**Madrid, Spain**	**Los Angeles, USA**	**Tokyo, Japan**	**Naples, Italy**	**Athens, Greece**
System cost (US$/Watt)	7.2	7.9	8.2	6.1	8.1	8
Minus subsidies (US$/Watt)	0	0	4.5	0	0	0
Upfront cost (US$/kW)	7,200	7,900	3,700	6,050	8,100	8,000
Annual energy produced (kWh)	918	1,567	1,747	1,278	1,368	1,564
Where feed-in tariffs are available						
Feed-in tariff (US¢/kWh)	63.9	57.2	-	-	63.7	61.1
Annual income (US$)	587	896	-	-	872	955
Where no net metering						
Typical electricity tariffs (US¢/kWh)	20.2	15.8	14.0	21.0	19.0	11.2
Annual savings (US$)			245	268	260	
Discount rate (%)	6	6	6	6	6	6
Internal rate of return (IRR %)	6	12	8	4	10	11
Net present value (NPV) (US$)	113.9	5,343.4	644.6	(1,151.1)	2,691.9	3,797.5

Source: International Energy Agency, US Department of Energy, CLSA Asia-Pacific Markets

Appendix 10: Emissions by company

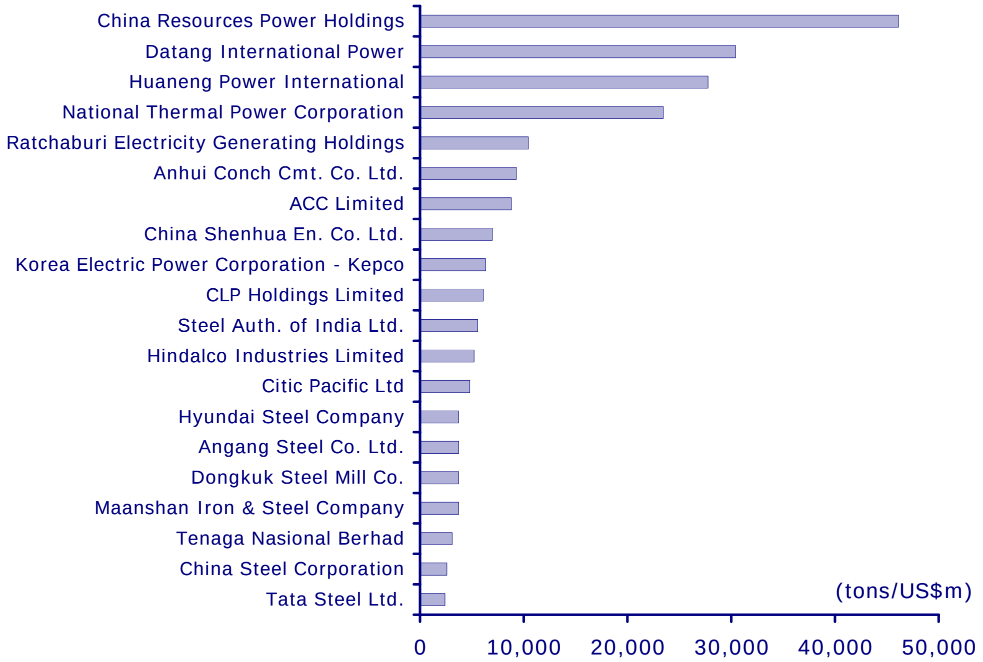
Asia's biggest emitters

Top-20 CO_2 emitters in Asia (Absolute)



Emissions per sales

Tons of CO_2e emissions per unit of sales (tons)



Source: Trucost, CLSA Asia-Pacific Markets

Notes