

Scoring Climate Change Risk

Which countries are most vulnerable?

9 August 2011

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Issuer of report: HSBC Bank plc

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- ▶ **Climate change is already exacerbating underlying resource stress in global energy, food and water systems**
- ▶ **The physical effects of climate change have economic consequences. We rank the climate vulnerability of the G-20 as a means of incorporating ‘the climate factor’ into investment frameworks**
- ▶ **We estimate that India, Indonesia, China, Saudi Arabia and Brazil are the most vulnerable to climate change. The least vulnerable are Canada, the USA, Japan, the UK and South Korea**

Climate change as a threat multiplier

Over the last century, the planet has warmed by 0.7°C, and even if greenhouse gas (GHG) emissions ceased, it would warm by at least another 0.6°C. But emissions continue to rise, and insufficient policy ambition means that restraining warming to 2°C this century now looks increasingly hard.

The global economy is already constrained by rising resource stress, reflected in high commodity prices. We believe that the climate factor is best seen as a threat multiplier for these underlying stresses. This is not a distant threat but a present reality. Food yields are down because of slow, chronic effects of rising temperatures. The costs of extreme weather events have also almost doubled in the last 10 years (2001-2010) compared with 1991-2000, and global warming is increasing the probability of these events.

Uncertainty surrounding the scale and speed of future impacts mean that climate, food, energy and water risks need to be factored into investment strategies. In this note, we assess the climate vulnerability of the G-20 countries in terms of their exposure, sensitivity and adaptive capacity. We find that India, Indonesia, China, Saudi Arabia and Brazil are the most vulnerable. Currently, these five economies account for 15% of global output. By 2050, HSBC’s economists estimate that these countries will contribute almost 37%. We believe the time for integrating the climate factor has arrived.

Summary

- ▶ Climate change exacerbates existing supply and demand imbalances in energy, food and water
- ▶ We evaluate the climate vulnerability of the G-20 across 14 indicators of exposure, sensitivity and adaptive capacity
- ▶ Evaluating climate and resource risk enables superior understanding of potential investment risk in key markets

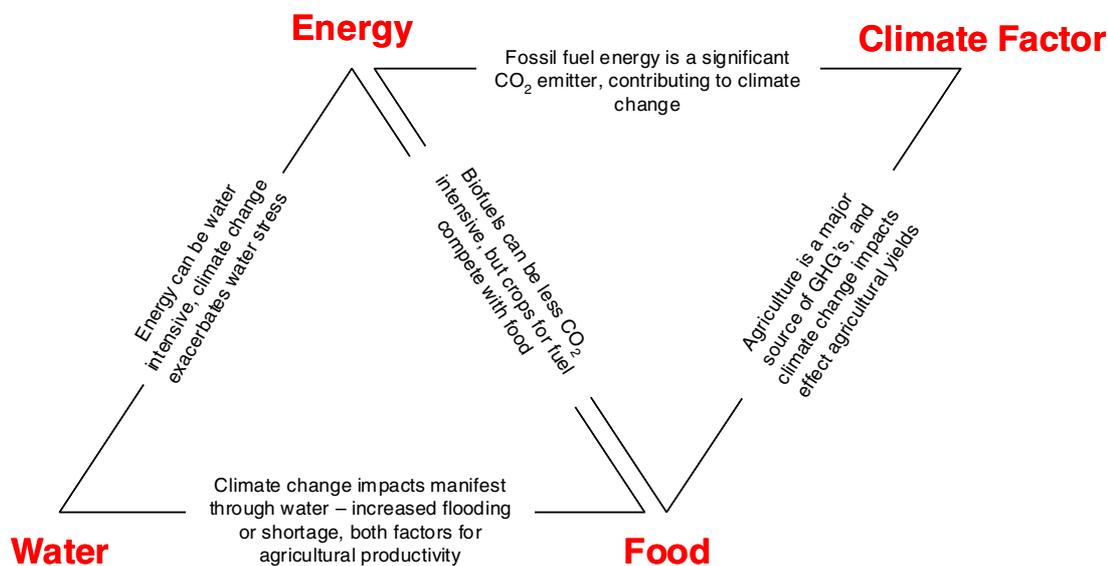
Existing resource stresses...

Even without climate change, soaring demand for natural resources on the back of demographic growth, economic expansion and the shift in the economic axis towards the emerging world is driving up commodity prices and intensifying resource risks.

...are being exacerbated

Global average temperatures are rising: 2010 tied with 2005 as the hottest years on record since 1880. In spite of the global financial crisis, atmospheric concentrations of GHGs continue to deepen. And insufficient policy ambition makes temperature rises higher than 2°C increasingly likely, and earlier than expected.

Chart 1: The climate factor exacerbates existing resource stress



Source: HSBC

The physical effects of climate change are manifest by water availability – too much (storms, floods) in some areas and too little (heatwaves droughts) in others. We expect these effects to intensify over the coming years and to add to regional cost burdens. Between 2001 and 2010, damage from extreme weather events cost G-20 countries USD636bn, up from USD391bn in the previous decade¹.

Climate change is shifting the odds in favour of increased resource disruption at a time when the supply of natural capital is declining and demand is rising. In our view, evaluating country vulnerabilities to the climate factor is a critical tool for risk management, informing both asset allocation and value chain pressures.

More vulnerable than others

We score the G-20 according to their climate vulnerability from page 4. We look at four factors: exposure, impact sensitivity, adaptive potential and adaptive capacity. **Exposure** captures the likelihood of vulnerability to climate change effects, based on current metrics. Impact **sensitivity** demonstrates the magnitude of disruption from these impacts.

Adaptive potential measures the economic resources available to a country to reduce vulnerability. And **Adaptive capacity** assesses the key socio-economic factors that could modulate this economic potential.

Our analysis measures vulnerability to climate change by country on a relative basis. Charts 2 and 3 summarise the results, where the highest scoring (top right) countries are the most vulnerable to climate change. A complete table of country rankings and indicators is on page 9. The five most vulnerable countries are **India, Indonesia, China, Saudi Arabia and Brazil**. The least vulnerable are **Canada, the USA, Japan, the UK and South Korea**.

Chart 2: Exposure and sensitivity (top right most vulnerable, bottom left least vulnerable)

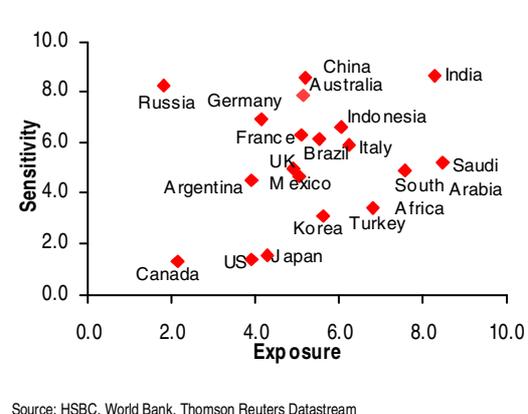
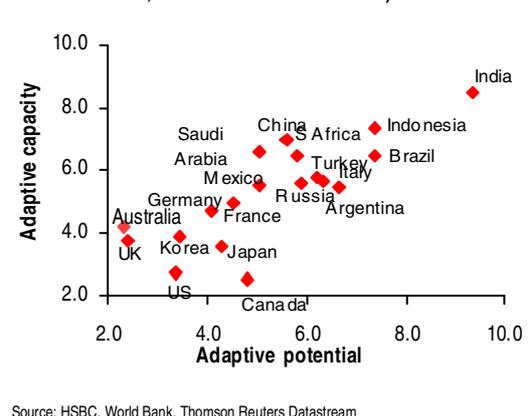


Chart 3: Adaptive potential and capacity (top right countries most vulnerable, bottom left least vulnerable)



Currently the five most vulnerable countries account for 15% of global output. According to the projections of HSBC's economists in [The World in 2050](#), dated January 2011, by the mid-century this will rise to almost 37%, making an understanding of how climate factors could fuse with wider resource stress critically important for long-term investment strategies.

We gratefully acknowledge the assistance of Rajiv K Chaturvedi and Beate Sonerud in the preparation of this report

¹ We do not assess the EU as a whole as four of largest nations are already included: Germany, France, Italy and the UK

Ranking the G-20

- ▶ Emissions are global, but impacts are local and vulnerability to climate change factors have economic consequences
- ▶ Evaluating climate and resource risk enables superior understanding of potential investment risk in key markets
- ▶ Among the G-20, we find that India, Indonesia, China, Saudi Arabia and Brazil are the most vulnerable to climate change

Location, location, location

Identifying individual country vulnerability to climate change factors is important from an economic perspective for several reasons, including:

- ▶ **Inflation:** Climate effects could have an impact on food or energy output, driving up prices.
- ▶ **Attractiveness of FDI:** Smarter globalised companies are incorporating climate factors into operational growth strategies. Regions with low vulnerability to extreme events driven by climate change carry less risk.
- ▶ **Balance of payments:** Countries with high exposure to climate factors could face higher trade deficits as companies choose to source goods from other countries where climate risks are lower to mitigate supply chain disruption.

The uncertainty of climate factors in terms of frequency and magnitude of disruption all add up to regional growth volatility. HSBC completed a first country climate vulnerability assessment in [Too close for Comfort](#) in December 2009. Then, we found that the countries most at risk were India, Indonesia and Brazil, South Africa and

China. However, this model could not be updated on a regular basis as it was based on one-off assessments such as the Stern Review.

Here, we provide a new way of measuring climate vulnerability, using more detailed metrics. The summary ranking of countries by category is in Table 1 below. Overleaf we show summary rationale for indicators in Table 2.

Table 1: Overall ranking by country and indicator (1 indicates most vulnerable, 19 least vulnerable)

Overall rank	Country	Exposure	Sensitivity	Adaptive Potential	Adaptive Capacity
1	India	2	1	1	3
2	Indonesia	6	6	2	1
3	China	9	2	9	2
4	Saudi Arabia	1	9	11	4
5	Brazil	8	7	3	7
6	South Africa	3	11	8	5
7	Turkey	4	16	6	8
8	Italy	5	10	5	11
9	Russia	19	3	7	10
10	Mexico	12	12	10	6
11	Argentina	16	14	4	9
12	France	11	8	13	12
13	Germany	15	5	15	14
14	Australia	10	4	19	19
15	South Korea	7	17	16	15
16	UK	13	13	18	16
17	Japan	14	18	14	13
18	US	17	15	17	17
19	Canada	18	19	12	18

Source: HSBC

Table 2: Summary of vulnerability indicators

Indicator	Weight	Value	Summary rationale
Exposure 25%			
1) Avg. temperature		Average °C 2001-10	A higher starting average temperature indicates a greater vulnerability
2) Temp. changes		% change 1991-2000 to 2000-10	A higher rate of increase in average temperature suggests a higher vulnerability to changing weather factors
3) Water availability		m ³ renewable / per capita / yr	A lower water availability per capita value indicates a greater vulnerability to climate change factors
4) Water availability		% from 1997-2008	A higher negative percentage change of renewable water per capita indicates a greater vulnerability
5) Extreme events		Land adjusted number of events	A high level of extreme events indicates a higher exposure
6) Chg in extreme events		% change 1991-00 to 2000-10	A higher rate of change of event indicates an increasing magnitude of climate risk
Impact sensitivity 25%			
1) People affected		Number affected by weather events	More people affected reflects a higher vulnerability
2) Deaths		Number killed by weather events	More people affected reflects a higher vulnerability
3) Damage costs		USD as a proportion of GDP	Higher damage costs as a proportion of the economy reflect a higher vulnerability to climate change driven weather events
Adaptive potential 25%			
1) Wealth		Income per capita (USDm)	A lower GDP per capita indicates a higher vulnerability because of the lower ability to invest to adapt
2) Budget		Debt to GDP ratio	Higher debt indicates a lower capacity to pay for infrastructure build
Adaptive capacity 25%			
1) Rule of law		Index to denote perception of confidence in rule of law	Higher rule of law indicates better governance which demonstrates an ability to implement change
2) Corruption		Index to denote perception of control of governance	Better control of corruption indicates a greater likelihood of proper allocation of funds for adaptation
3) Education		Ratio of total enrolment to the population officially corresponding to tertiary education age	Higher education indicates a higher skills base to change

Source: HSBC, Thomson Reuters Datastream, World Bank

Ranking climate vulnerability

There are four factors for consideration on how climate change affects countries: exposure, impact sensitivity, adaptive potential and adaptive capacity.

Exposure captures the likelihood of vulnerability to climate change impacts, based on current metrics. **Impact sensitivity** demonstrates the magnitude of disruption from these impacts.

Adaptive potential measures the economic resources available to a country to reduce vulnerability. And **adaptive capacity** assesses the key socio-economic factors that could modulate this economic potential.

Our analysis measures vulnerability to climate change by country **on a relative basis**. This provides insight for long-term strategic decision making for corporates and policy makers in the context of potential climate change risk.

Exposure to climate change

By climate exposure, we mean measuring the character, magnitude, rate of climate change and variation to which a system is exposed². These factors could be both positive and negative. For example, northern latitude territories may benefit from a longer growing season as a result of higher temperatures. However, our analysis aims to address country vulnerabilities to climate change, therefore our indicators focus on the negative aspects of exposure.

Exposure measurement indicators are centred on temperature, water availability and extreme events.

For temperatures we studied two metrics: decade-average temperatures by country and the change in degrees Celsius between the last two decades (ie 1991-2000 and 2001-2010). We used average

² This is in line with the definition from the Intergovernmental Panel on Climate Change (IPCC).

temperatures in the last decade as a proxy for latitude because countries with a higher average temperature tend to be nearer the equator, whereas the change between the last two decades shows the magnitude and direction of variation.

For water, we examined availability per capita and the change over the last decade – so that countries with the lowest availability and largest decrease over the decade are most exposed to disruption from climate change.

For events, we observed the number of extreme events, normalised by adjusting for land mass. Extreme events are defined as droughts, floods, extreme temperatures and wildfires³. Table 3 shows the results.

Table 3: Exposure (ranked by highest exposure)

Weight	Temp change	Avg temp	Water resource	Water resource	Extreme events	Overall Score
	°C change	°C	m ³ /yr/cap	% change	Events/10,000km ²	
	15%	20%	25%	25%	15%	100%
Saudi Arabia	0.8	27.3	95	-23.8	0.05	8.5
India	0.3	24.6	1,224	-16.3	0.40	8.3
S Africa	0.3	17.7	902	-13.7	0.15	7.6
Turkey	0.9	12.7	3,071	-14.3	0.29	6.8
Italy	0.9	17.3	3,062	-4.2	0.71	6.2
Indonesia	-0.1	27.3	8,881	-13.3	0.37	6.0
S Korea	0.1	12.8	1,347	-5.7	1.24	5.6
Brazil	0.5	20.5	28,223	-13.2	0.05	5.5
China	0.2	13.3	2,092	-7.7	0.12	5.2
Australia	0.5	18.5	23,346	-12.1	0.05	5.1
France	0.5	11.7	3,224	-5.9	0.44	5.1
Mexico	-0.3	18.4	3,768	-12.5	0.14	5.0
UK	0.3	10.8	2,359	-4.7	0.70	4.9
Japan	0.2	16.6	3,378	-1.0	0.38	4.3
Germany	0.1	10.1	1,301	-0.4	0.40	4.2
Argentina	-0.2	15.3	6,920	-10.6	0.08	3.9
USA	0.2	12.2	9,042	-10.9	0.10	3.9
Canada	-0.1	11.2	85,691	-10.2	0.03	2.1
Russia	0.7	6.3	30,503	4.7	0.03	1.8

Source: HSBC, World Bank, Thomson Reuters Datastream

Integrating these factors, we found Saudi Arabia, India and South Africa to be the most vulnerable countries in terms of their current exposure to climate change. The main driver behind Saudi Arabia's pole position is the lack of water

availability. We ascribe a higher weight to water than for temperature or events on the basis that it is fundamental for economic stability and growth and also because climate change is expressed most keenly through water.

Impact sensitivity to extreme events

For this dimension, we measure the degree to which a country is affected by an extreme weather event. To do this we used three indicators: the number of deaths from weather events; the cost of the event in terms of GDP; and finally the number of people affected (other than death) to certain levels (i.e. homelessness vs. physical injury). We normalised the data by adjusting for population levels. The results are in Table 4.

Table 4: Sensitivity (Highest overall score most vulnerable)

Weight	Deaths	Damage costs	People affected	Overall Score
	Average number, pa, per million of population	% of GDP	Average number, pa, per million of population	
	30%	40%	30%	100%
India	2	0.22	46,958	8.6
China	1	0.29	74,002	8.6
Russia	40	0.19	1,302	8.3
Australia	3	0.24	1,224	7.9
Germany	11	0.10	402	6.9
Indonesia	1	0.06	1,364	6.6
Brazil	1	0.05	3,458	6.3
France	35	0.08	91	6.2
Saudi Arabia	1	0.06	101	5.9
Italy	35	0.06	30	5.2
South Africa	0	0.04	32,428	4.9
Mexico	0	0.05	2,749	4.9
UK	1	0.06	622	4.6
Argentina	0	0.05	1,810	4.5
USA	0	0.03	0	3.4
Turkey	0	0.03	223	3.1
South Korea	0	0.01	724	1.5
Japan	0	0.00	93	1.3
Canada	0	0.01	55	1.3

Source: HSBC, EM-DAT, World Bank, Thomson Reuters Datastream

Integrating these factors shows that India and China are the most vulnerable countries. This is mainly driven by the number of people affected but the level of damage costs is also significant.

³ Sourced from the International Disaster Database from the Centre for Research on the Epidemiology of Disasters.

Having identified which countries are the most exposed and sensitive to climate change, the natural progression is to look at whether a country has the propensity to adapt ('climate-proof' itself). This can be determined from the economic conditions (adaptive potential) and the socio-economic factors of a country (adaptive capacity).

Adaptive potential

From a financial perspective, countries with higher income per capita and lower debt-to-GDP will be better positioned to take pre-emptive action and to react to disasters.

For adaptive potential, we examined GDP per capita with the rationale that the less wealthy a country is, the less likely it will be able to channel available capital specifically towards adaptation. We also studied debt levels, on the basis that a lower debt-to-GDP ratio indicates greater potential to increase spending on 'climate-proofing'. We ascribed a higher weight to GDP per capita than to the debt ratio.

Table 5 shows that India and Indonesia have the lowest potential to adapt based on the given economic indicators.

Table 5: Adaptive potential (highest overall score most vulnerable)

Weight	GDP per capita	Debt-GDP ratio	Overall score
	USD 2000	Gross % GDP	
	60%	40%	100%
India	536	72.5	9.4
Indonesia	914	49.7	7.4
Brazil	3,898	69.4	7.4
Argentina	8,093	72.1	6.6
Italy	19,130	111.0	6.3
Turkey	4,302	52.7	6.2
Russia	2,152	28.3	5.9
South Africa	3,266	34.7	5.8
China	1,287	15.7	5.6
Saudi Arabia	9,399	50.8	5.1
Mexico	5,926	43.2	5.1
Canada	23,922	81.9	4.8
France	22,081	65.4	4.5
Japan	37,755	168.2	4.3
Germany	23,378	65.5	4.1
South Korea	12,628	22.0	3.5
USA	35,582	67.7	3.4
UK	26,033	49.4	2.4
Australia	22,596	17.6	2.3

Source: HSBC, World Bank, Thomson Reuters Datastream

Adaptive capacity

Adaptive capacity measures the socio-economic dimensions that can influence underlying potential. In this report, we considered three indicators: the rule of law, corruption and education using data from the World Bank.

We assume that where governance on the rule of law is strong, and corruption tends to be lower, and a higher rate of further education is in place the potential for making positive behavioural changes among the general population is higher. Indonesia has the lowest propensity to adapt based on these metrics as shown in Table 6.

Table 6: Adaptive capacity (highest overall score least able to adapt on socio economic metrics)

Weight	Rule of law	Corruption	Population in tertiary education	Overall Score
	Index	Index	% enrolled of those that have requisite qualification	
	2.5 = best -2.5 = worst	2.5 = best -2.5 = worst	35%	100%
Indonesia	-0.72	-0.80	23.5	9.3
China	-0.38	-0.46	24.5	8.4
India	0.16	-0.36	13.5	7.7
Saudi Arabia	0.13	-0.91	32.8	7.6
South Africa	0.07	-0.07	15.4	7.4
Mexico	-0.43	0.45	27.2	7.1
Brazil	-0.32	-0.04	37.6	6.7
Turkey	0.02	-0.13	38.4	6.7
Argentina	-0.48	-0.38	67.7	6.6
Russia	-0.88	-0.23	77.2	6.3
Italy	0.63	0.48	67.2	4.0
France	1.40	1.39	54.6	3.9
Japan	1.31	1.18	58.0	3.9
Germany	1.62	1.86	47.2	3.4
South Korea	0.88	0.37	98.1	3.2
UK	1.65	1.90	57.4	2.7
USA	1.54	1.53	82.9	2.1
Canada	1.70	1.99	62.3	1.8
Australia	1.72	1.91	77.0	1.2

Source: HSBC, World Bank, Thomson Reuters Datastream

Overall climate vulnerability

Combining all four factors (exposure, impact sensitivity, adaptive potential and capacity) creates an aggregate score, and therefore ranking, which can be used to determine the climate vulnerability of a particular country. We have equally weighted the four categories in our analysis.

The end result is that India, Indonesia, China, Saudi Arabia, and Brazil are the five countries most vulnerable to climate change. In [The World in 2050](#) Karen Ward assessed the growth potential of the world's top 30 economies which make up the vast majority of economic output. Currently the five most vulnerable countries to climate risks

according to our analysis account for almost 14% of aggregate output; by 2050, this will more than double to almost 37%. This makes an assessment of how climate factor is fusing with underlying resource stress critical for long-term investment strategy. In our view, evaluating country vulnerabilities to the climate factor is a critical tool for risk management, informing both asset allocation and the understanding of pressures along global value chains.

Table 7: Country indicators ranked by most vulnerable countries

Weight	Overall Score	Temp change °C	Exposure				Sensitivity			Adaptive potential		Adaptive Capacity		
			Av. Temp °C	Water resource m3 /yr/cap	Water resource % change	Extreme events Events/10,000km ²	Number of deaths Av p.a. per mn pop'n	Damage costs % of GDP	People affected Av p.a. per mn pop'n	GDP per capita Constant 2000 USD	Debt-GDP ratio Gross % GDP	Rule of law Index: 2.5 = 2.5 = best, -2.5 = worst	Corruption Index: 2.5 = 2.5 = best, -2.5 = worst	Education % pop'n in tertiary ed'n
		15%	20%	25%	25%	15%	30%	40%	30%	60%	40%	35%	30%	35%
India	8.5	0.3	24.6	1,224	-16.3	0.4	2	0.22	46,958	536	72.5	0.16	-0.36	13.5
Indonesia	7.3	-0.1	27.3	8,881	-13.3	0.37	1	0.06	1,364	914	49.7	-0.72	-0.80	23.5
China	6.9	0.2	13.3	2,092	-7.7	0.12	1	0.29	74,002	1,287	15.7	-0.38	-0.46	24.5
Saudi Arabia	6.6	0.8	27.3	95	-23.8	0.05	1	0.06	101	9,399	50.8	0.13	-0.91	32.8
Brazil	6.4	0.5	20.5	28,223	-13.2	0.05	1	0.05	3,458	3,898	69.4	-0.32	-0.04	37.6
South Africa	6.4	0.3	17.7	902	-13.7	0.15	0	0.04	32,428	3,266	34.7	0.07	-0.07	15.4
Turkey	5.8	0.9	12.7	3,071	-14.3	0.29	0	0.03	223	4,302	52.7	0.02	-0.13	38.4
Italy	5.6	0.9	17.3	3,062	-4.2	0.71	35	0.06	30	19,130	111	0.63	0.48	67.2
Russia	5.6	0.7	6.3	30,503	4.7	0.03	40	0.19	1,302	2,152	28.3	-0.88	-0.23	77.2
Mexico	5.5	-0.3	18.4	3,768	-12.5	0.14	0	0.05	2,749	5,926	43.2	-0.43	0.45	27.2
Argentina	5.4	-0.2	15.3	6,920	-10.6	0.08	0	0.05	1,810	8,093	72.1	-0.48	-0.38	67.7
France	4.9	0.5	11.7	3,224	-5.9	0.44	35	0.08	91	22,081	65.4	1.40	1.39	54.6
Germany	4.7	0.1	10.1	1,301	-0.4	0.4	11	0.1	402	23,378	65.5	1.62	1.86	47.2
Australia	4.1	0.5	18.5	23,346	-12.1	0.05	3	0.24	1,224	22,596	17.6	1.72	1.91	77.0
South Korea	3.8	0.1	12.8	1,347	-5.7	1.24	0	0.01	724	12,628	22	0.88	0.37	98.1
UK	3.7	0.3	10.8	2,359	-4.7	0.7	1	0.06	622	26,033	49.4	1.65	1.90	57.4
Japan	3.5	0.2	16.6	3,378	-1	0.38	0	0	93	37,755	168.2	1.31	1.18	58.0
USA	2.7	0.2	12.2	9,042	-10.9	0.1	0	0.03	0	35,582	67.7	1.54	1.53	82.9
Canada	2.5	-0.1	11.2	85,691	-10.2	0.03	0	0.01	55	23,922	81.9	1.70	1.99	62.3

Source: HSBC, World Bank, Thomson Reuters Datastream

Existing resource stress

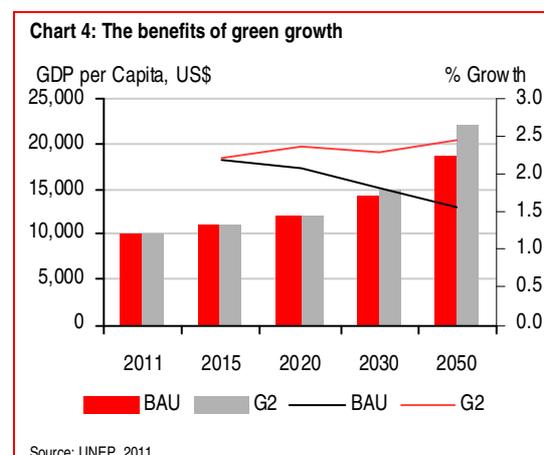
- ▶ Rising resource stress is limiting global economic growth
- ▶ Supply and demand imbalances in energy, food and water are projected to tighten further
- ▶ ‘Normal’ weather already costs around 3.4% of GDP in the US; abnormal weather set to cost more

The value of natural capital

The vital contribution of natural resources – land, water, energy feedstocks – to global growth still goes largely unrecognised. It remains a missing element in most macroeconomic models. This invisibility has resulted in growing depletion of energy, water and agricultural resources, a deterioration often taking place in a synergistic way. We think the value of natural capital will become ever more apparent as resource squeezes impact growth. Over the medium term, we expect this to be integrated into macro-economic modelling.

Earlier this year, to address the contribution of natural assets to growth, the United Nations Environment Programme (UNEP) released a new report, *Towards a Green Economy*. In the words of the economist Partha Dasgupta, “ecosystems are capital assets. Like reproducible capital assets...ecosystems depreciate if they are misused.” But natural capital is profoundly different from capital stocks as traditionally understood by economists and investors. Firstly, its depreciation can be irreversible; secondly, it is difficult, if not impossible, to replace a depleted natural asset with another; and finally, ecosystems can collapse abruptly.

The *Green Economy* report looks forward to 2050 and examines the impact different levels of investment in natural capital can have on global GDP, as well as key environmental and social indicators. In UNEP’s ‘business as usual’ (BAU) scenario, insufficient maintenance of soils, water, biodiversity and the climate means that the rate of economic growth slows, when compared with the preservation of natural capital, which is shown in Chart 4 below. ‘G2’ indicates the progression of wealth and growth if 2% of GDP was invested in natural capital per annum.

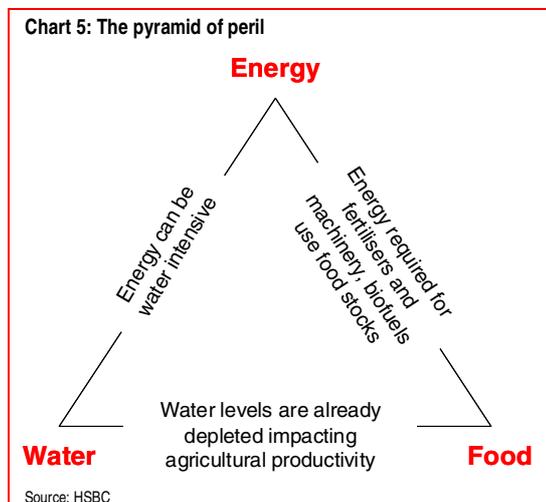


UNEP’s analysis shows that, by 2050, without natural capital investment global GDP still rises from an estimated USD69 trillion to USD151

trillion – however the global ecological footprint also grows from 1.5 to 2.2 times the Earth’s bio-capacity and natural capital continues to depreciate under this BAU scenario. By contrast, an investment of 2% of global GDP into natural capital helps to de-couple growth from resource use. In the G2 scenario, global GDP in 2050 rises to USD199 trillion, and the footprint is cut by a fifth to 1.2 times available bio-capacity.

The pyramid of peril

Even without climate change, soaring demand for natural resources on the back of demographic growth, economic expansion and the shift in the economic axis towards the emerging world is driving up commodity prices and intensifying resource risks, particularly at the intersection of energy, food and water as illustrated by Chart 5.



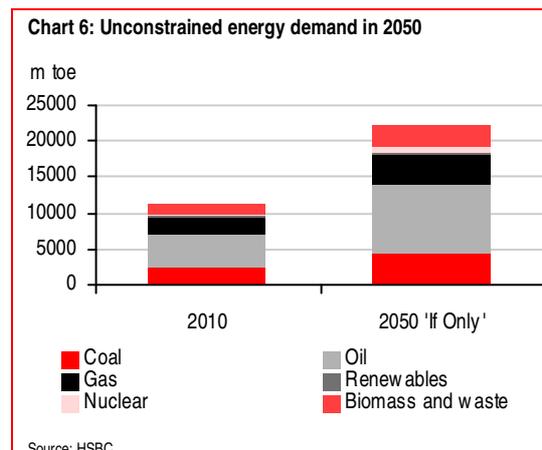
Energy: oil road to electric avenue?

Over the past year, conflict in the Middle East and major safety failings in the oil (Gulf of Mexico) and nuclear (Fukushima) industries have exposed the acute vulnerabilities of the current energy system, which is still unable to provide modern energy to more than 1.4bn people.

In HSBC’s Q2 2011 Global Economics report, [An Economic Oil Slick](#), dated 31 March 2011 we raised 2011 oil forecasts from USD85 pb to

USD105 pb and trimmed growth estimates accordingly: “Never before have we seen such large increases in the cost of raw materials so soon after the end of a deep and protracted recession in the Western world.” Bringing more oil on-stream is constrained by long lead-times and the rising costs of having to tap harder to access sources of supply (e.g. deep water and unconventional reserves).

In our [Energy in 2050](#) report, we projected a 110% increase in oil demand to an unrealistic 190 mbpd as motorisation takes off in the emerging world – a scenario we describe as our ‘if only’ world with no resource or environmental constraints.



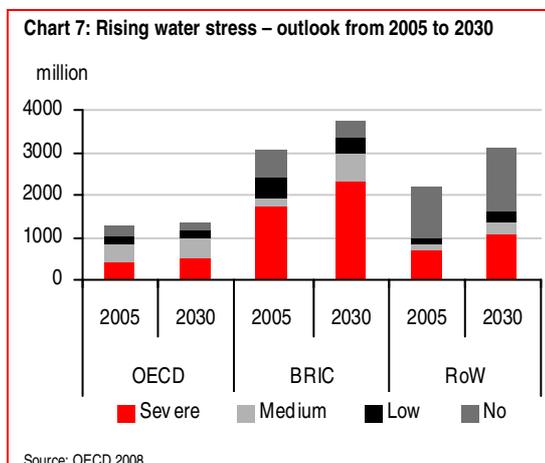
With oil supplying 94% of the energy required for transportation, substitution with other sources is emerging as a policy imperative. Gas is one option – and LPG/CNG vehicles are likely to gain share particularly in regions with abundant shale gas reserves (such as the USA). Gas is also an attractive low-emission alternative to coal-fired power generation – although long-term it will need to be fitted with carbon capture and storage (CCS) to meet global climate targets. Another option has been the increased use of biofuels derived from agricultural crops such as corn, sugar and palm. However, ‘burning food’ creates its own problems, severely limiting the scope for ‘first generation’ biofuels.

As a result, transport electrification offers the most attractive long-term option to the oil crunch, not least because of the inherent efficiencies of electric motors compared with the internal combustion engine. This is where we see the climate factor working to turbo-charge the transition.

Water: no longer everywhere

This year's 'Arid Spring' in Europe and China – followed by heavy rainfall and, in some cases, floods – has highlighted economic vulnerability to water stress. The current water supply into the global economy is estimated at around 4,500 bn m³ per annum, with agriculture accounting for over 70% (Water Resource Group, 2009). This still leaves 1bn people without access to clean drinking water, and 2.6bn without access to improved sanitation services. In particular, underground aquifers are depleted in key regions such as China, India and the USA.

The OECD estimates that 44% of the global population – 2.8bn people – currently live in areas with severe water stress, measured as places where the ratio of water use to renewable supply exceeds 40%. This is expected to rise to 47% by 2030, leading 3.9bn people to experience severe water stress.



Although water stress impinges most clearly on the agricultural sector, the risks to the power sector are already becoming manifest. In India, for example, over 79% of planned thermal power capacity-addition is in areas already suffering from water shortages (WRI, 2010). HSBC's India power utilities analyst estimates that by 2013 water scarcity could erode power sector earnings by as much as 5% (Arun Kumar, [Same problem, new execution risks](#), October 2010).

Similarly in the USA, generating energy consumes 20% of the water not used by agriculture. With high energy demand and diminishing water supplies, the water efficiency of different energy options is becoming a critical factor. For example, irrigated first-generation soy- and corn-based biofuels can consume thousands of times more water than traditional oil drilling (World Policy Institute, 2011). In the power sector, run of river hydro, wind and solar PV emerge as the most water efficient technologies. As for other low-carbon options, nuclear consumes around three times as much water as conventional natural gas, while carbon capture and storage technologies can consume 30-100% more water.

Food: eating oil, burning food

Just like energy, the global economy currently displays a tendency towards structural over- and under-consumption of food – with negative health effects in both cases.

The levelling-off of agricultural yields in recent years has contributed to record food price levels, with environmental factors explaining some of the production slowdown. According to the UN's Food and Agricultural Organisation, for example, nearly one-quarter of the world's farmland – about 2 billion hectares – is currently degraded. In addition, modern agriculture has become highly energy intensive. One estimate suggests that each hectare of corn production requires over 6mn kilocalories of fossil energy inputs – an energy input to output ratio of about 1:4 (Pimental,

2008). Rising costs of energy and other fossil fuel inputs (eg natural gas for nitrogen fertiliser production) clearly have a knock-on impact (Chart 8). Not only does the world ‘eat oil’, but an increasing share of food crops produced have been devoted to biofuels. In the USA, for example, the proportion of corn crop diverted to ethanol production rose from 7% in 2001 to 39% in 2010. Earlier enthusiasm for setting ambitious targets for biofuel use is now waning in light of mounting evidence of the poor carbon performance of some key feedstocks (notably corn ethanol and palm) and the competition with food production; bioethanol from sugar cane emerges as one of the few resilient feedstocks. In addition, the development and deployment of second and third generation biofuels is taking place much slower than expected.

Water is already a constraining factor on food production and this looks set to intensify. According to the World Economic Forum, food production needs to grow by 70-100% over the next 20 years; this is considerably more than the more conservative estimate from the FAO for a 70% increase in demand by 2050. Over the same period, however, water scarcity could cause annual grain losses equivalent to 30% of current world consumption – and this is even before considering the effects of the ‘climate factor’ on water availability.

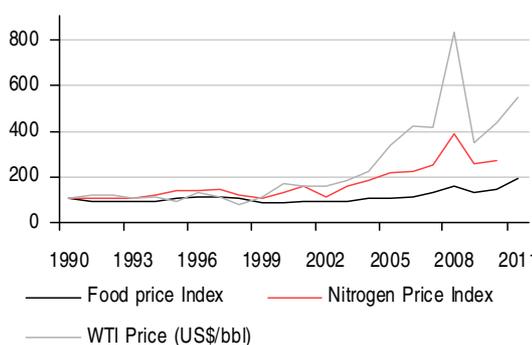
Even normal weather costs

Even in a post-industrial economy such as the USA, routine weather has a sizeable impact on growth and output. The National Center for Atmospheric Research has estimated that “the influence of routine weather variations on the economy is as much as 3.4 percent of U.S. gross domestic product” (USD485 billion) (Lazo, 2011).

Globally, the cost of extreme weather has been on a rising trend. Using data from EMDAT, we calculate that extreme weather events cost the G-20 nations USD636bn in the last ten years (2001-2010), compared with USD391bn in the previous decade (1991-2000) (See Chart 9). The full cost of the extreme weather events of 2011 is not yet available. However, a preliminary analysis of just nine events suggests a loss of about USD40 billion over the first six months of 2011. This includes an estimated USD14.5bn from US tornadoes, USD\$5bn from the Mississippi floods and USD7.3bn from Australian floods; the total rebuilding cost of Australia is likely to reach USD32.1bn. The final bill for weather related natural disasters in 2010 reached USD80bn.

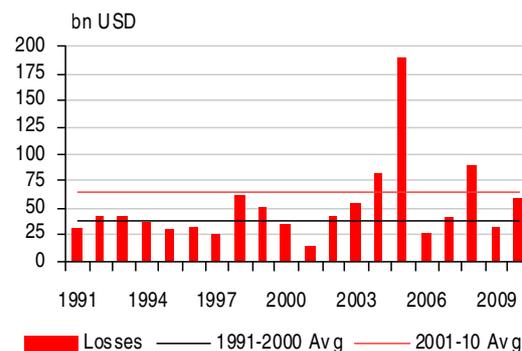
The question is how far the ‘climate factor’ is now driving further resource stress.

Chart 8: Rising Food, Oil and Fertilizer Prices; 1990-2011



Source: FAO, USDA, Thomson Reuters Datastream. Note for nitrogen prices 2010 is a preliminary value

Chart 9: Rising cost of weather extremes in the G-20



Source: EMDAT database

The climate factor amplifies resource stress

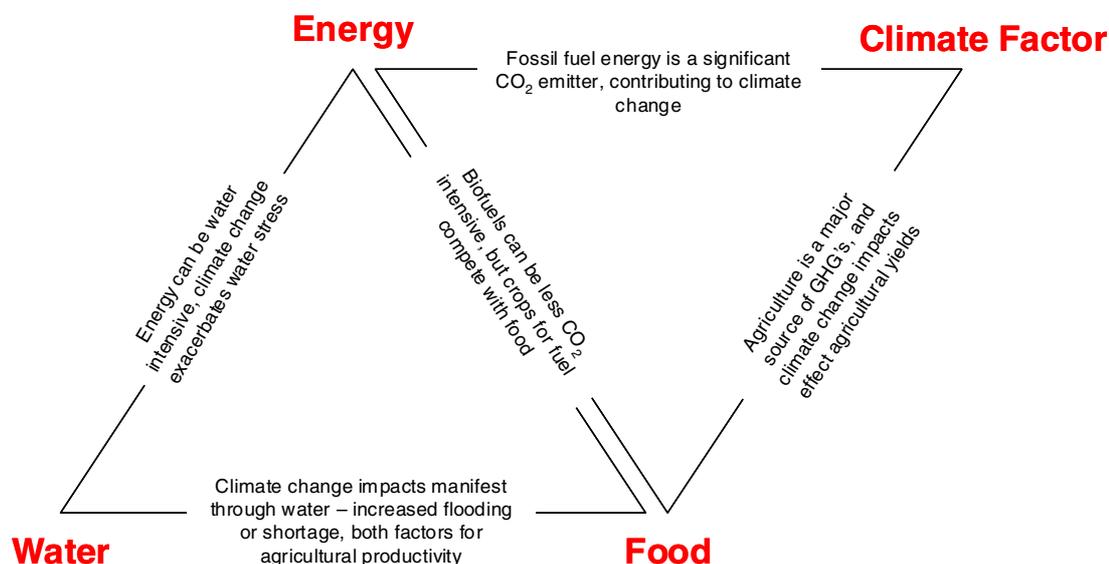
- ▶ Climate change is a disruptive force, changing the pattern of mean and extreme weather events
- ▶ Crucially, the climate factor makes previous assumption about weather variability obsolete, increasing risk and volatility
- ▶ Keeping global warming below 2°C looks increasingly hard, making understanding the risks of a 4°C world critical

And then there were four

Climate change is affecting all three of these interlocking resource stresses. The climate is best understood as ‘average weather’ expressed in terms of temperatures, seasonal variations, rainfall, as well as extreme events such as floods,

storms and droughts. What climate change does is disrupt these historical patterns. Many uncertainties remain about the full range of climate impacts, but the key impacts on water, food and energy are depicted in Chart 10.

Chart 10: Climate change exacerbates existing resource stress



Source: HSBC

Climate change and food

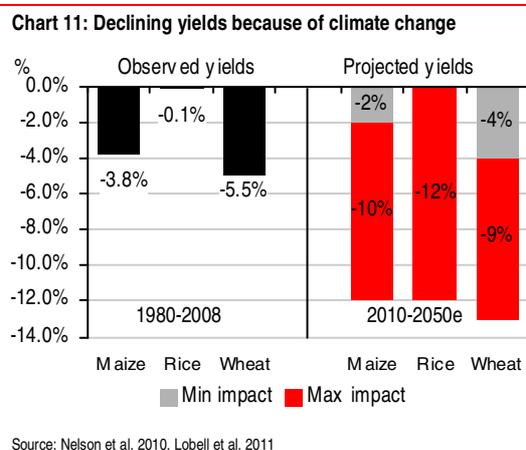
Rising temperatures and increasing levels of carbon dioxide in the atmosphere have direct impacts on agricultural output. These are not always negative: increased carbon can enhance fertilisation (up to a certain point) and in temperate, colder regions, increasing temperatures can boost yields. However, beyond key thresholds, rising temperatures curb output. More severe and frequent extreme weather events will also increase the volatility of output and prices.

Even at moderate levels, the effects of heat can be significant for agricultural based economies, where, for every 1°C temperature gain above the optimum during the growing season, yields decline by 10%. In addition, higher temperatures require more water for irrigation, power supplies can be affected if water availability is depleted, and electricity transmission is also affected.

The food value chain is also a significant source of GHGs, accounting for 10% of direct emissions (including fertiliser production) and 30% when land conversion and ‘farm-to-fork’ emissions are included (Foresight, 2011).

Back in 2007, the IPCC concluded that the global potential for food production would increase with local average temperature rises of 1-3°C above the 1990 baseline. Above these levels, production would decrease (IPCC, 2007).

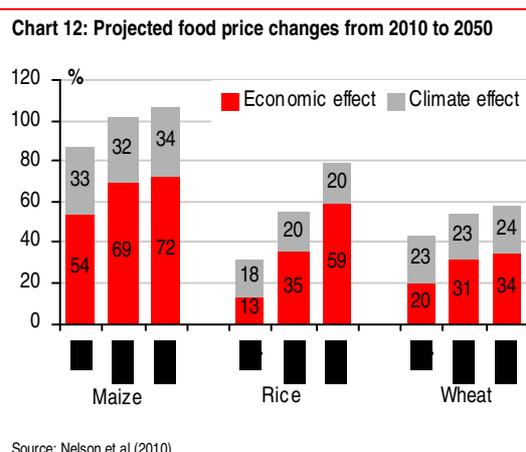
Scientists are now isolating the impact of temperatures on grain productivity, and have found that corn production was 3.8 % lower between 1980 and 2008 due to rising temperatures; wheat was 5.5 % lower, as shown in Chart 11. Rice, however, had exhibited only a -0.1% fall. Looking to 2050, this is set to change with corn, rice and wheat potentially experiencing a 12-13% fall in production, on these estimates.



This loss of output could worsen existing food price trends, and for maize could be an additional 30% of ‘climate inflation’ on top of almost 70% of underlying price growth (Chart 12).

The ‘climate factor’ also places a constraint on the potential expansion of farmland in the future, as tropical deforestation is a major source of GHGs.

While the main lines of the climate and food intersection are understood, it is important to highlight the uncertainties that remain, notably around the implications for rainfall and water demand.



Climate change and water

Water is the primary vector of global warming – the means by which climate change manifests itself. Rising temperatures increase the rate of evaporation, accelerating the hydrological cycle. Indeed, the water holding capacity of air increases exponentially with temperature. Rainfall is also predicted to rise in the tropics and higher latitudes, but fall in already dry areas which are expected to get drier and hotter. Mountain glaciers will also be destabilised, another critical source of freshwater recharge.

In essence, rising temperatures look set to increase water stress. Examining water stress in terms of the ratio of annual surface run-off to population in key river basins, one recent assessment suggests that in a 2°C world, 71% of river basins would show an increase in water stress, rising to 74% in a 4°C world. However, in a 2°C world, the increase in water stress is dominated by rising population; in a 4°C world, the climate signal becomes stronger (Fung, 2011). Chart 13 below sets out the potential impacts on food and water as temperatures rise.

Considerable uncertainties remain, however, According to the FAO, “while temperature can be projected by global circulation models with a high degree of ‘convergence’, the same cannot be said of water vapour” (Turrall, 2011).

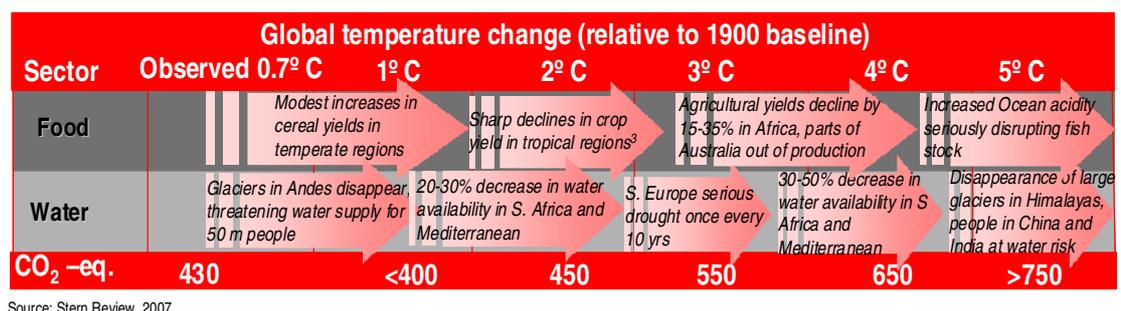
Climate change and energy

Overall supplies of energy are, for practical purposes, unlimited. But conventional energy is dominated by fossil fuels which are the source of around two-thirds of global GHGs; renewable resources, notably solar are even more abundant.

For energy, adding the climate factor means driving a profound decarbonisation of energy supply and demand – in order to restrain the acceleration of global warming. Our long-term analysis of how this could evolve is set out in the solution scenario of the [Energy in 2050 report](#). In summary, energy efficiency in buildings, transportation and industry is the largest source of emission reduction, followed by halving the fossil fuel share in global primary energy, and combining this with the mass deployment of CCS and a seven-fold expansion of the renewable energy share (including doubling nuclear’s share).

Beyond the decarbonisation driver, the climate factor will also impinge on the choice of energy supply options, with key low-carbon options (such as biofuels, CCS and nuclear) considerably more water-intensive than baseload gas, or wind and solar. As water stress deepens with rising population and rising temperatures, resource efficiency, solar and wind are set to become more attractive as energy options.

Chart 13: Rising temperatures and possible impacts on food and water systems



Aim for 2°C, prepare for 4°C

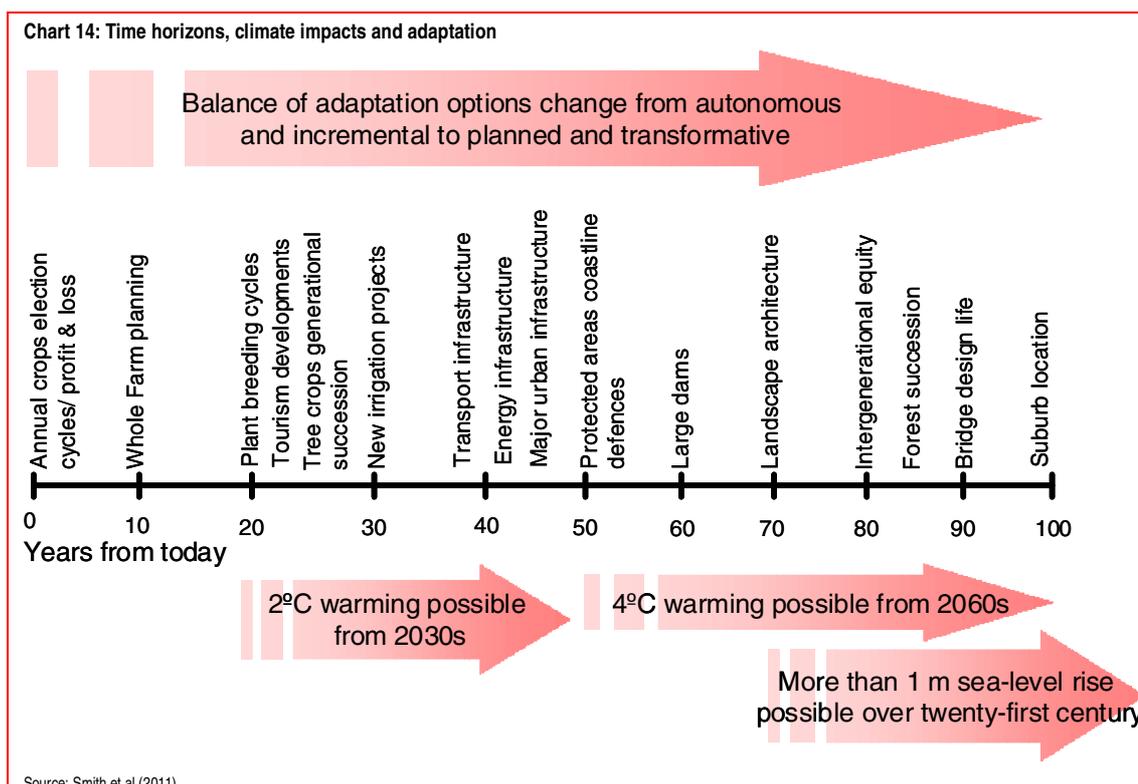
Last December at Cancun, governments agreed that global average temperatures should be kept below 2°C above preindustrial levels – adding that a target of 1.5°C would be considered at a review in 2013. Governments might call for “urgent action” and “deep cuts” in greenhouse gas emissions to hit this target, but current policies imply a temperature increase of between 2.5 to 5°C before the end of the century (UNEP, 2010). Indeed, the IEA’s chief economist, Fatih Birol, argues that “we are only inches away from saying goodbye to 2°C” (Birol, 2011).

From a risk perspective, this means that higher rises in temperature, earlier than expected, have to be factored into investment horizons. For example, 2°C warming is now possible from the 2030s and 4°C from the 2060s. Although beyond the time horizons of most investors in global equity markets, for example, these are well within the planning horizons of listed corporations,

particularly in core infrastructure sectors such as building, energy, transport and water. Chart 14 lays out the predicament, generating four types of decisions to be considered for adaptation by investors, corporations and countries:

- 1) Short lead-time, short consequence-decisions (such as annual crop selection).
- 2) Short lead-time, long consequence-decisions (such as house building).
- 3) Long lead-time, short consequence-decisions (such as development of new plant cultivars).
- 4) Long lead-time, long consequence decisions such as city planning (Smith, 2011).

Our climate vulnerability scores highlight where investors could prioritise their efforts for risk assessment, investment appraisal and company engagement. In the final section, we review the latest findings on the science of climate change, underscoring the severity of the threat.



Updating the science

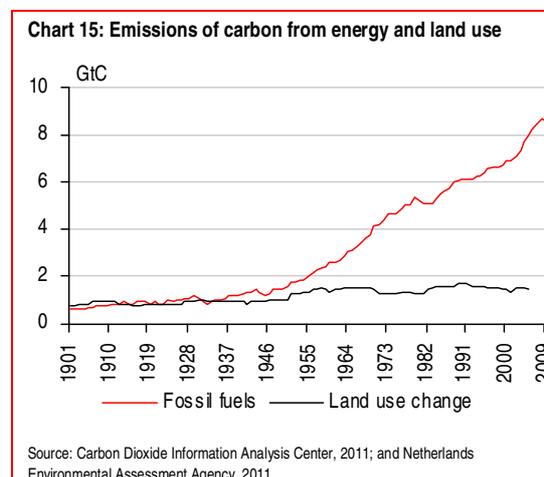
- ▶ The global financial crisis has slowed emission growth, but stocks of GHGs have not stopped rising
- ▶ Temperatures have continued to climb: 2010 tied with 2005 as the warmest year on record for 100 years
- ▶ Key indicators of warming – sea-level rise, glacier melt, extreme events – are also deteriorating

The 2007 Fourth Assessment Report from the IPCC is the latest global compendium of the scientific consensus. However, this included material only up to the end of 2006, and so is now potentially six years out of date in terms of the latest thinking. In addition, a number of errors were identified in its findings in 2010, throwing doubt over the credibility of climate science as a whole. We believe that its core conclusions remain secure, however (see Science, Opinion & Markets, April 2010). Furthermore, since 2007 new material has served to underscore the narrative of rising emissions, building deeper atmospheric stocks of greenhouse gases, driving higher temperatures and generating climate impacts in the seas and on land.

Emissions: temporary slowdown

2009 is the last year for which full data are available. The global financial crisis meant that for the first time since 1992, GHG emissions did not rise. The global average masks a surge in GHGs from China and India of 9% and 6%, with corresponding emission contraction of 7% in both the EU and the USA (Oliver, 2010). With the

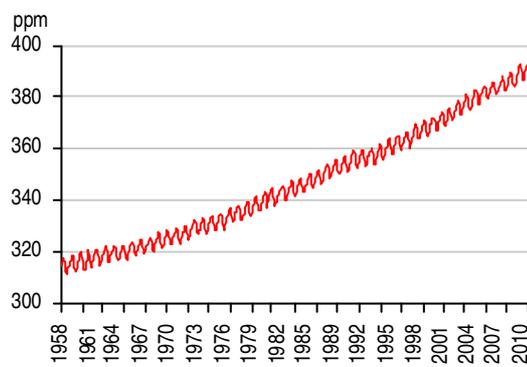
global economy returning to growth in 2010 – delivering 3.8% GDP expansion – we expect GHGs will similarly have resumed their upward course with a 3% increase.



GHG stocks: deepening

Emissions lead to a stock of GHGs in the atmosphere, deepening the natural greenhouse effect. Since the start of the Industrial Revolution in c1750, the atmospheric concentration of CO₂ has climbed by 40%, rising by 22% in the last 50 years alone to 391 ppm (see Chart 16). It has been 30 to 32 million years since this level of concentration has existed in the atmosphere (Kiehl, 2011). The global financial

Chart 16: Climbing concentrations of atmospheric CO₂



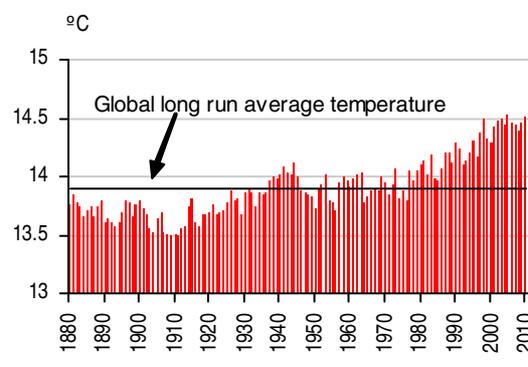
Source: NOAA (Mauna Loa)

crisis has certainly had an impact, but inertia in the system has meant that growth has continued. GHG concentrations therefore rose by 2.2% in 2007, falling to 1.6% in 2008 and 1.9% in 2009. As the economy recovered in 2010, concentrations rebounded once more with a 2.4% annual increase.

Temperatures: hotting up

2010 tied with 2005 as the warmest year on record in the last 100 years (Chart 17). As a whole, the last decade from 2001-2010 was the warmest since records began, according to the World Meteorological Organisation (WMO). In 2007, the IPCC concluded that it was “very likely” that the rise in global temperatures since the mid-20th century was due to rising GHGs. In other words, rising GHGs were the cause with a confidence level of over 90%. A team at the UK Met Office has since tightened the attribution between human-induced emissions and warming, arguing that there is a less than 5% chance that the 50-year warming trend could have been due to natural variability alone (Stott, 2010).

Chart 17: Rising global average temperatures 1880-2010



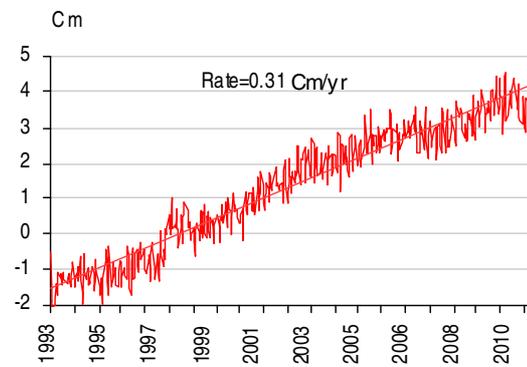
Source: NCDC/NOAA

Back in 2007, the IPCC suggested that global temperatures could rise in the range of 1.1 to 6.4°C towards the end of this century compared with pre-industrial times. More recent research from the MIT (2009) projects warming of about 5°C. Temperature rises are unlikely to be smooth. Beyond a certain point, small changes in warming could trigger a nonlinear response. For example, the loss of the summer Arctic Ice – potentially within the next decade – could accelerate warming by removing the reflective capacity of the ice (Lenton, 2008).

Sea levels: rising

Warmer temperatures are projected to lead to rising sea levels, largely as a result of the thermal expansion of the oceans. The current rate is about 0.31cm per year, and since 1993 it has risen by 5.1cm (Chart 18) The 2007 IPCC report is generally regarded to have underestimated the potential for further increases during this century at 18cm to 56cm, and the most recent research suggests a sea level rise of up to 1-1.4 metres by 2100 (Vermeer et al. 2009). With a temperature increase of more than 4°C, it could grow as much as 0.5m to 2m, although the probability of rises at the high end is very low (Nicholls, 2011). This could lead to a real risk of forced displacement of around 2.4% of the global population, which could be avoided by an upgrade in coastal protection costing just 0.02% of global GDP.

Chart 18: The rise of sea levels

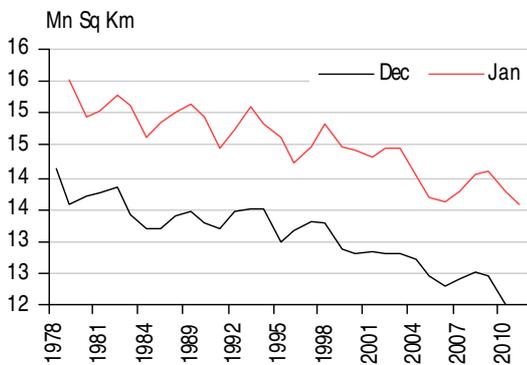


Source: Sea Level Research Group, University of Colorado, 2011

Ice: melting

Levels of Arctic sea ice have been declining for the past 30 years (Chart 19). The 2010/11 winter is the lowest Arctic sea ice extent since satellite records began.

Chart 19: Melting Arctic sea ice



Source: National Snow and Ice data Center, 2011

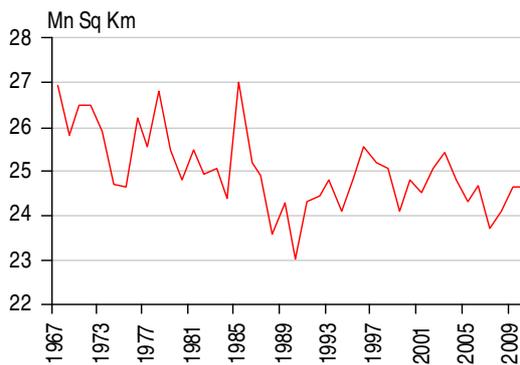
There is no consensus on when the Arctic will be completely free of ice in the summer. The IPCC suggested the end of the century, but Muyin Wang and colleagues of Washington University projected around the year 2037, while Weslaw Maslowski, an Oceanography professor at Monterey's Naval Postgraduate school, expects it could be as early as 2016 – potentially triggering the first serious climate 'tipping point'.

Glaciers: shrinking

In 2010, the world's mountain glaciers lost mass for the 20th consecutive year (NCDC/NOAA, 2010). Satellite data from Rutgers University in Chart 20 suggests that overall the annual snow extent in the Northern Hemisphere has been on a declining trend since satellite monitoring began.

The error in the IPCC's 2007 report that the Himalayan glaciers would disappear by 2035 was at the centre of the backlash against climate science last year. The fact remains that three benchmark glaciers in the Himalayas continue to melt as fast as their global counterparts and in some cases even faster (Fujita, 2011).

Chart 20: Falling snow extent in the northern hemisphere



Source: Rutgers University

Heatwaves: intensifying

Record global average temperatures have been matched by localised extremes in heat. For example, this year the UK and Germany experienced the warmest April in a century and France the warmest for the last fifty years. In the last decade, a series of unprecedented heatwaves have been experienced, as shown in Table 10, most recently the 2010 heatwave in Russia.

Table 10: Extreme heatwaves in last decade

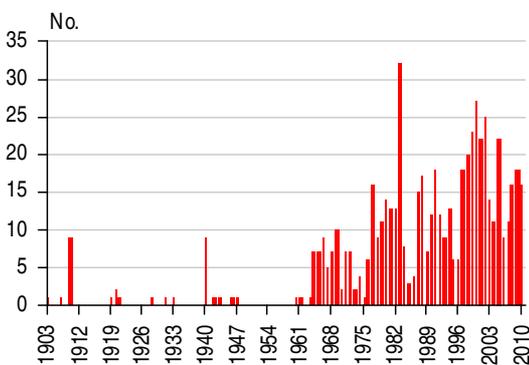
Date	Region	Event
2003	Europe	Unprecedented heat waves during the summer. Record breaking temperatures surpassing 40°C
2005	Canada	Warmest summer on record in central Canada
2008	Scandinavia	Mild winter. With monthly anomalies exceeding 7°C, large parts of Norway Sweden and Finland had the warmest winter ever recorded.
2009	Australia	Record heat waves during January/ February, August and November. The highest temperature ever recorded so far south in the world observed in Victoria at 48.8°C.
2009	Argentina	An exceptional heat wave in late October/early November in northern and central Argentina had record breaking temperatures of more than 40°C.
2010	Russian Federation	Extreme heat and drought in July and August led to bushfires

Source: World Meteorological Organisation, 2011

Droughts: increasing

The 2007 consensus captured by the IPCC suggested that it was “likely” the area affected by drought would increase in the 21st century – a confidence level of 66%. Chart 21 shows the frequency of droughts since 1900, with the number of droughts increasing by 8% in the past decade. As for the severity of these droughts, there have also been a number of extreme events, listed in Table 11, with the East African drought perhaps the most stark.

Chart 21: Annual drought frequencies from 1900 to 2010



Source: EMDAT database, 2011

Table 11: Severe droughts in the last decade

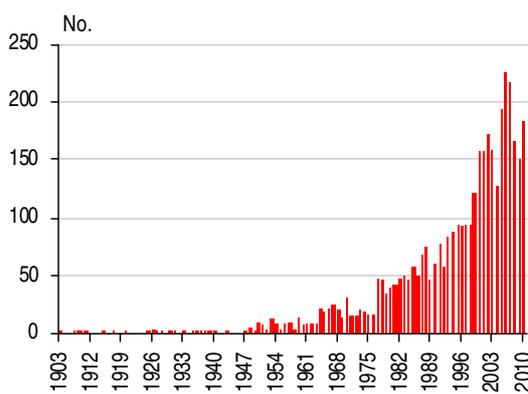
Date	Region	Event
2005	Brazil	Worst drought in 60 years in Brazil caused the lowest Amazon flow in 30 years.
2006	Africa	Long-term drought continued in the early part of the year over greater horn of Africa
2006-07	USA	Severe to extreme drought was present across large parts of western United States as well as in the southern plains. Fires caused massive destruction
2008	Latin America	Prolonged drought hit Argentina, Uruguay, Paraguay and southern Brazil damaging agriculture, livestock and water resources. Driest year on record for large areas
2009	Australia	Dry conditions reinforced long-term drought in Southern Australia. These conditions exacerbated water shortages in Murray - Darling Basin, resulting in crop failure.
2011	Cuba	Worst drought in nearly half a century
2011	Texas, USA	Worst drought in 50 years
2011	East Africa	Worst drought in 60 years

Source: World Meteorological Organisation, UN

Floods: growing

The IPCC reports noted that "along with the risk of drying, there is an increased chance of intense precipitation and flooding due to the greater water-holding capacity of a warmer atmosphere." Chart 24 shows a significant growth in the number of floods since the 1900s.

Chart 22: Increasing frequency of floods 1900 to 2010



Source: EMDAT database, 2011

The extreme flooding events of the last decade are noted in the table below.

Table 12: Severe flood events in the last decade

Year	Country	Event and losses
2000	UK	Flooding in UK caused losses of about \$1.5bn
2002	Europe	Flooding in Europe cause losses of about \$16bn
2005	Germany	Flooding in Germany caused losses of about \$3bn
2007	UK	Worst flooding in UK in 60 years, caused losses worth \$4bn
2009	US & Canada	Floods in US and Canada caused losses of about \$1bn
2010	Pakistan	Pakistan witnessed its worst flood in history. More than 20 million people affected
2010	China	Heavy floods killed more than 1500 people in north-west China
2011	Australia	Worst flooding in about 50 years, rebuilding costs include losses of more than \$32.1bn
2011	China	Floods in China cost about \$1.19bn
2011	US	Record floods in US cost more than \$5bn
2011	Canada	Floods in Canada cost about \$1bn
2011	Columbia	Columbian floods this year Jan to June, have estimated to have cost more than \$5.8bn

Source: World Meteorological Organisation, 2011; Earth Policy Institute, 2011; AOL Benedict, 2011

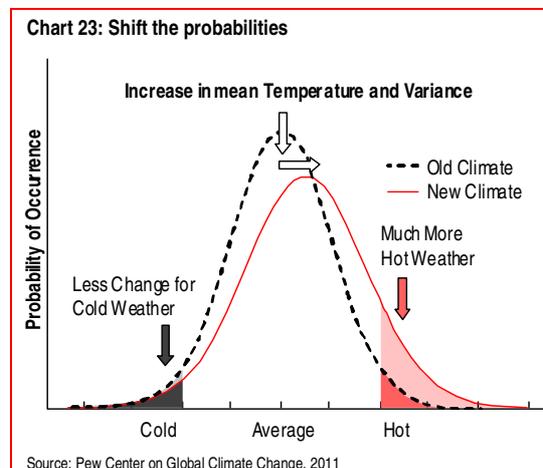
Cyclones: hunting the signal

The direct relationship between climate change and tropical cyclones is one of the most uncertain of the impacts of temperature rise. The 2007 assessment report concluded that “there is evidence from modelling studies that future tropical cyclones could become more severe, with greater wind speeds and more intense precipitation.” More recently, the Pew Center found that the global intensity and frequency of tropical cyclones has not changed much. In the North Atlantic, there has been a clear increase in the frequency of tropical storms and major hurricanes (Pew Center, 2011). Overall, “the detection or attribution of an anthropogenic signal in tropical cyclone loss data is extremely unlikely to occur over periods of several decades (and even longer)” (Crompton et al. 2011)

Attributing extremes

Since climate is ‘average weather’, it is very difficult to attribute specific events to global warming. Nevertheless, there is increasing confidence about the linkage. For Munich Re, “it would seem that the only plausible explanation for the rise in weather-related catastrophes is climate change” (Munich Re, 2010).

The key is how climate change shifts the balance of probabilities. For the Pew Center “climate change is widening the probability distribution for temperature extremes and shifting the mean and the low-probability tails toward more frequent and intense heat events” (Huber et al. 2011) To take one example, the European summer heat-wave of 2003 has changed from a 1-in-1000 year event in pre-industrial times to a likely every-other-year event by the 2040s (Huddleston, 2010). At the global level, the WMO acknowledges that “it is impossible to say that an individual weather or climate event was ‘caused’ by climate change”, but adds that one should “anticipate that the magnitudes, frequency and duration of extreme events are likely to be altered as the Earth’s atmosphere warms due to the increased concentrations of greenhouse gases” (WMO, 2011). More light should be shone on this relationship in the IPCC’s forthcoming special report on extreme events, expected at the end of 2011.



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Notes

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