



Association of Civil Engineering Departments

# climate change, sustainable development & resilience

Mark Fletcher

13<sup>th</sup> NOVEMBER 2009



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# change – what drives it?



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# drivers of change

- S** Social
- T** Technological
- Ec** Economic
- En** Environmental
- P** Political



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# drivers of change



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# drivers of change climate change

## can we survive without rain?



The Murray-Darling river basin is Australia's primary agricultural area. In April 2007 the government announced there would be "insufficient water available to allow any allocation for irrigation" from the river system if the record breaking drought continued.

Source: Water contingency planning in the southern Murray-Darling basin. Joint statement by the Prime Minister and the Premiers of New South Wales, Victoria and South Australia, April 2007  
<http://www.murrayirrigation.com.au/files/3290950.pdf>

## mega droughts

climate change

social

## could you recognise the rash preceding Lyme disease?



© Gustavo Fernando Durán

The World Health Organisation estimates that the warming and precipitation trends due to anthropogenic climate change of the past 30 years already claim over 150 000 lives annually.

Source: Patz et al. Impact of regional climate change on human health, Nature, 17 November 2005  
[www.nature.com/nature/journal/v438/n7066/abs/nature04188.html](http://www.nature.com/nature/journal/v438/n7066/abs/nature04188.html)

disease



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climate change

social

## will you cope without air conditioning?



In January 2006 the Spanish government introduced a working hours directive, which prevents public sector employees from taking a traditional afternoon siesta.

Source: J Ward Anderson and Jennifer Green, Shaking Spain out of the siesta, 23 April 2006  
(c) 2006, The Washington Post. Reprinted with permission.  
<http://www.washingtonpost.com/wp-dyn/content/article/2006/04/22/AR2006042201123.html>

passive design



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social climate change

## are you a high flyer?



© Michael Cohn

One person flying a return trip between Europe and New York generates around 2 tonnes of CO<sub>2</sub>. This is approximately the amount an average European generates at home for heating and electricity in one year.

Source: Greenskies, 2005  
<http://www.aef.org.uk/downloads/Factsheetclimate.pdf>

aviation



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social climate change

## are you a carbon consumer?



© Sean Nelson

"The granny next door doesn't drive and doesn't do much air travel. So she has spare carbon points that she can sell. At the end of the year she finds herself better off."

Source: Speech by the Rt Hon David Milliband MP - "The great stink: towards an environmental contract" at the Audit Commission annual lecture, Wednesday, 19 July 2006  
<http://www.defra.gov.uk/corporate/ministers/speeches/david-miliband/dm060719.htm>

personal carbon



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technological climate change

## have you heard today's forecast?



© The Earth Simulator Center, Japan

"After so much hard reasoning, may one play with a fantasy? Imagine a large hall like a theatre, the walls of which are painted to form a map of the globe. A myriad of computers are at work upon the weather of the part of the map where each sits."

Source: Lewis Fry Richardson, 1922

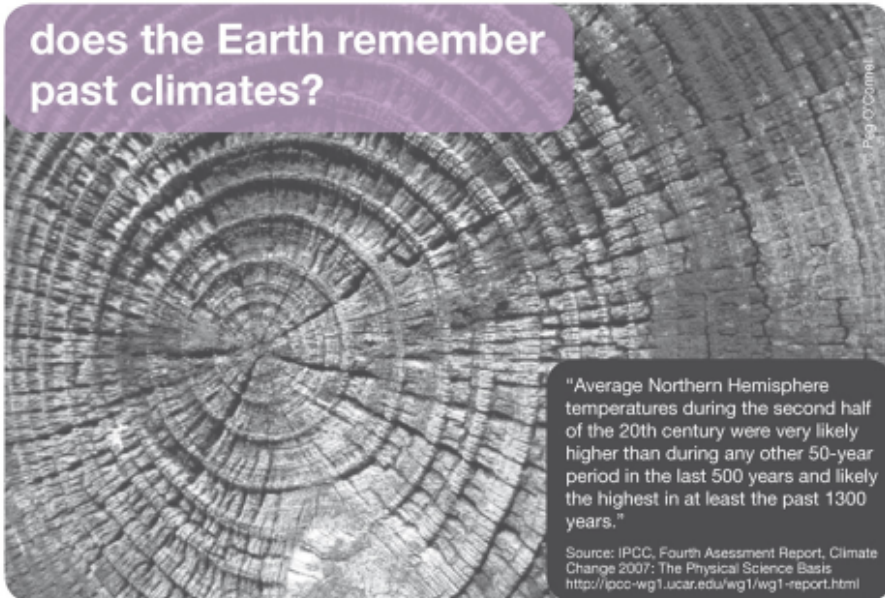
## climate modelling



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technological climate change

## does the Earth remember past climates?



© Peg O'Connell

"Average Northern Hemisphere temperatures during the second half of the 20th century were very likely higher than during any other 50-year period in the last 500 years and likely the highest in at least the past 1300 years."

Source: IPCC, Fourth Assessment Report, Climate Change 2007: The Physical Science Basis  
<http://ipcc-wg1.ucar.edu/wg1/wg1-report.html>

## paleoclimatology



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technological climate change

technological climate change

## can we ever be carbon free?



© Martin Cartwright

It is estimated that stabilising greenhouse gas emissions at between 450 – 550 parts per million CO<sub>2</sub> will be required to avoid dangerous climate change. Ultimately stabilisation – at whatever level – requires annual emissions be brought down to more than 80% below current levels.

Source: Sir Nicholas Stern, The Stern Review, 2006  
[http://www.hm-treasury.gov.uk/independent\\_reviews/stern\\_review\\_economics\\_climate\\_change/sternreview\\_index.cfm](http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm)

## decarbonisation

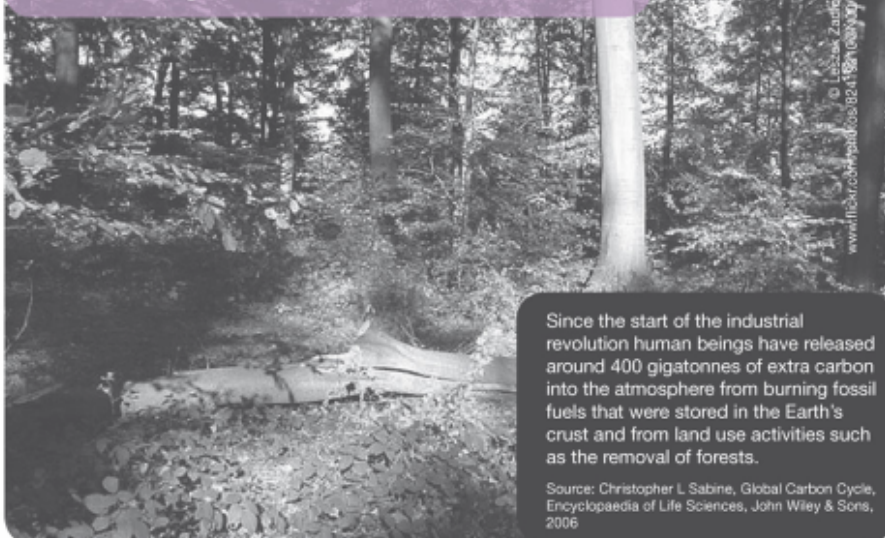


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technological climate change

technological climate change

## can we put the carbon back?



© Leszek Zurek  
[www.flickr.com/photos/1824158@N03/507197](http://www.flickr.com/photos/1824158@N03/507197)

Since the start of the industrial revolution human beings have released around 400 gigatonnes of extra carbon into the atmosphere from burning fossil fuels that were stored in the Earth's crust and from land use activities such as the removal of forests.

Source: Christopher L Sabine, Global Carbon Cycle, Encyclopaedia of Life Sciences, John Wiley & Sons, 2006

## sequestration



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climate change

technological

## could we control the climate?



© Gaila McGimsey  
Courtesy AVO/USGS

The dust and ash thrown into the atmosphere from the Mount Pinatubo eruption in 1991 reflected enough sunlight back into space to cool the Earth by around 0.5°C for a year or two afterwards.

Source: Richard A Kerr, Pollute the planet for climate's sake?, Science, 314, 20 Oct 2006  
<http://www.sciencemag.org/cgi/content/summary/314/5798/401a>

## geoengineering



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climate change

economic

## pay now or later?



© NASA

"Our actions now and over the coming decades could create risks of major disruption to economic and social activity, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century. And it will be difficult or impossible to reverse these changes."

Source: Sir Nicholas Stern, The Stern Review, 2006  
[http://www.hm-treasury.gov.uk/independent\\_reviews/stern\\_review\\_economics\\_climate\\_change/sternreview\\_index.cfm](http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm)

## mitigation vs adaptation



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## can we afford a low-carbon future?

climate change

economic



The International Energy Agency predicts that US\$300bn per annum is required to meet the energy needs of developing countries to 2030. The World Bank estimates the premium to achieve this development in a low-carbon manner may be as little as 10%.

Source: Make Markets Work for Climate, Background Document, 2006 [www.makemarketswork.com/](http://www.makemarketswork.com/)

## the developing world



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## does your policy have a climate change premium?

climate change

economic



Estimated economic losses of over US\$170bn were caused by the three large hurricanes of 2005 (Katrina, Wilma and Rita). Only around one third of these losses were insured.

Source: Swiss Re, Sigma No 2/2008: Natural catastrophes and man-made disasters, 2005 [www.swissre.com](http://www.swissre.com)

## insurance



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will carbon be the currency of the future?

climate change

economic



The international carbon market grew in value to an estimated US\$30bn in 2006, three times greater than the previous year. The volume of carbon traded was 1.6GtCO<sub>2</sub>.

Source: The World Bank, State and Trends of the Carbon Market, 2007  
[http://carbonfinance.org/docs/Carbon\\_Trends\\_2007\\_-\\_FINAL\\_-\\_May\\_2.pdf](http://carbonfinance.org/docs/Carbon_Trends_2007_-_FINAL_-_May_2.pdf)

carbon finance



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is your business climate ready?

climate change

economic



2005 was a record year for investment in the renewable energy sector at US\$38bn, 27% up on the previous year.

Source: Renewables Global Status Report 2006, REN21, 18 July 2006  
[www.ren21.net/globalstatusreport/g2006.asp](http://www.ren21.net/globalstatusreport/g2006.asp)

business opportunity

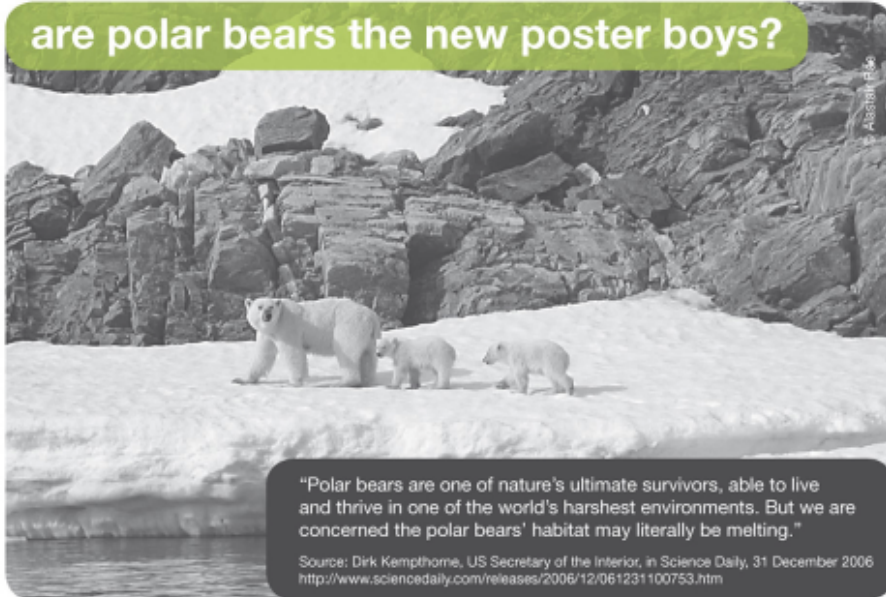


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## are polar bears the new poster boys?

climate change

environmental



"Polar bears are one of nature's ultimate survivors, able to live and thrive in one of the world's harshest environments. But we are concerned the polar bears' habitat may literally be melting."

Source: Dirk Kempthorne, US Secretary of the Interior, in Science Daily, 31 December 2006  
<http://www.sciencedaily.com/releases/2006/12/061231100753.htm>

## the big thaw

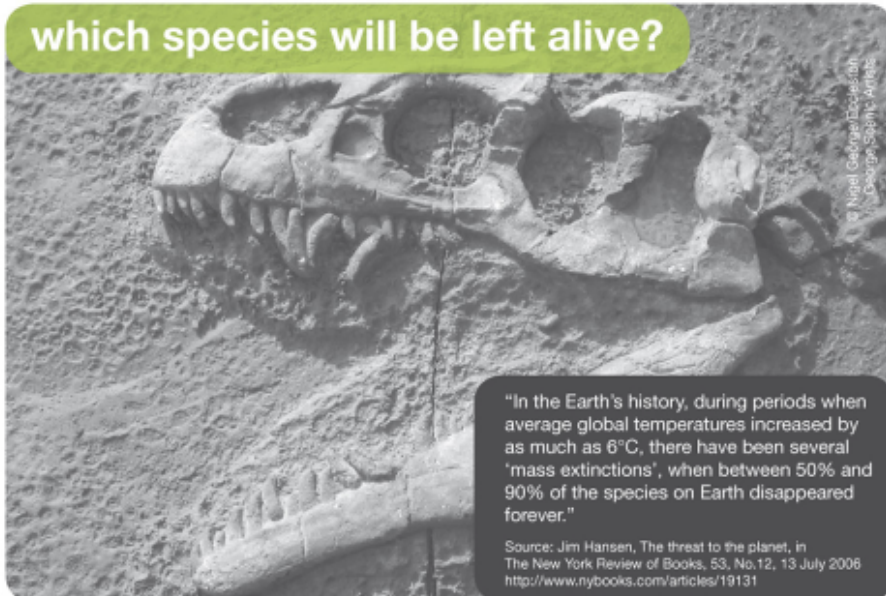


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## which species will be left alive?

climate change

environmental



"In the Earth's history, during periods when average global temperatures increased by as much as 6°C, there have been several 'mass extinctions', when between 50% and 90% of the species on Earth disappeared forever."

Source: Jim Hansen, The threat to the planet, in The New York Review of Books, 53, No.12, 13 July 2006  
<http://www.nybooks.com/articles/19131>

## mass extinctions



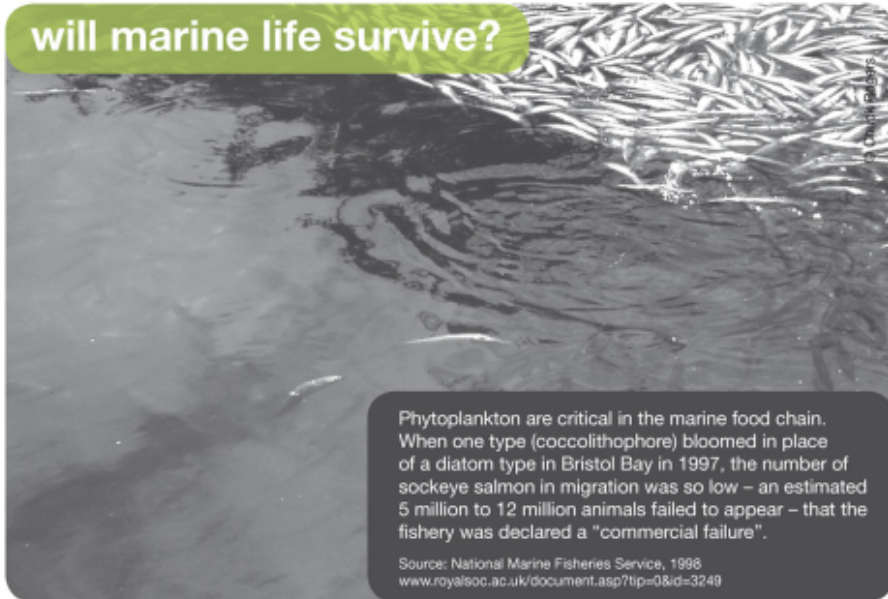
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## will marine life survive?

climate change

environmental



Phytoplankton are critical in the marine food chain. When one type (coccolithophore) bloomed in place of a diatom type in Bristol Bay in 1997, the number of sockeye salmon in migration was so low – an estimated 5 million to 12 million animals failed to appear – that the fishery was declared a "commercial failure".

Source: National Marine Fisheries Service, 1998  
[www.royalsoc.ac.uk/document.asp?tip=0&id=3249](http://www.royalsoc.ac.uk/document.asp?tip=0&id=3249)

## ocean acidification



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## how important are trees?

climate change

environmental



"In the next 24 hours, deforestation will release as much CO<sub>2</sub> into the atmosphere as 8 million people flying from London to New York."

Source: Daniel Howden, Deforestation: the hidden cause of global warming, The Independent, 14 May 2007  
<http://www.commondreams.org/archive/2007/05/14/1175/>

## deforestation



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where will you be the day after tomorrow?

climate change

environmental



"We have a window of only 10-15 years to take the steps we need to avoid crossing catastrophic tipping points."

Source: Tony Blair and Jan Peter Balkenende, extract from open letter to EU leaders, October 2006  
<http://www.number10.gov.uk/files/pdf/Vanhanen.pdf>

tipping points



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is Kyoto working?

climate change

political



"In the 1990-2004 period total global emissions of greenhouse gases by human activities increased by about 25%."

Source: The Netherlands Environmental Assessment Agency (MNP)  
<http://www.mnp.nl/en/dossiers/Climatechange/TrendGHGEmissions1990-2004.html>

international cooperation



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## who will feed the hungry?

political climate change

political



One in six countries in the world face food shortages this year because of severe droughts that could become semi-permanent under climate change.

Source: John Vidal and Tim Radford, One in six countries facing food shortage, The Guardian, 30 June 2005  
[www.guardian.co.uk/climatechange/](http://www.guardian.co.uk/climatechange/)

grain belts

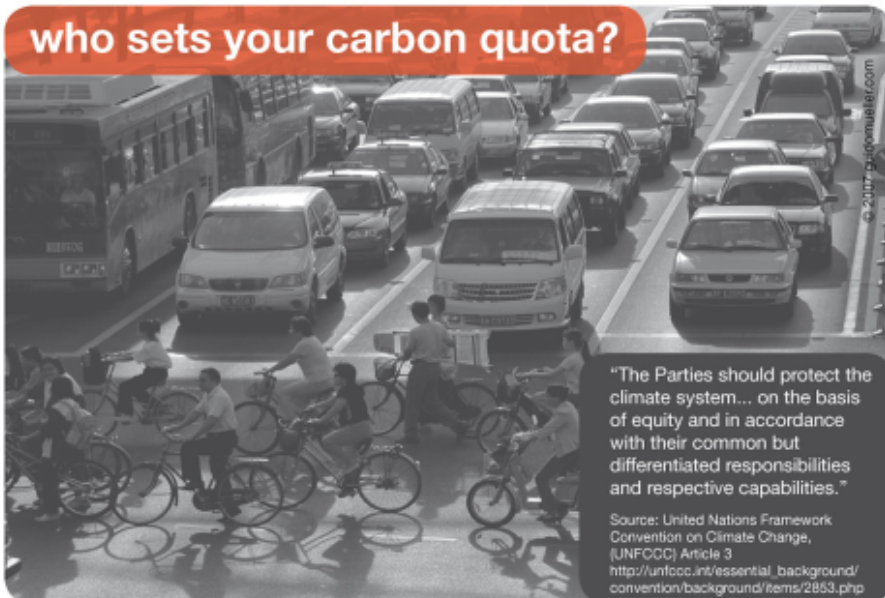


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## who sets your carbon quota?

political climate change

political



"The Parties should protect the climate system... on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities."

Source: United Nations Framework Convention on Climate Change, (UNFCCC) Article 3  
[http://unfccc.int/essential\\_background/convention/background/items/2853.php](http://unfccc.int/essential_background/convention/background/items/2853.php)

equity



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## where else could you live?

political climate change

political



© Art in All of Us,  
Stephanie Rabemialara

Tuvalu in the South Pacific is an island nation made up of coral atolls standing less than 4.5 metres above sea level. Its government has made requests to Australia and New Zealand to unconditionally accept its population of 12 000 people if rising sea levels make evacuation necessary, so far without success.

Source: A citizen's guide to climate refugees,  
Friends of the Earth Australia  
<http://www.safe.com.org.au/foe-climate-guide.htm>

sea level rise

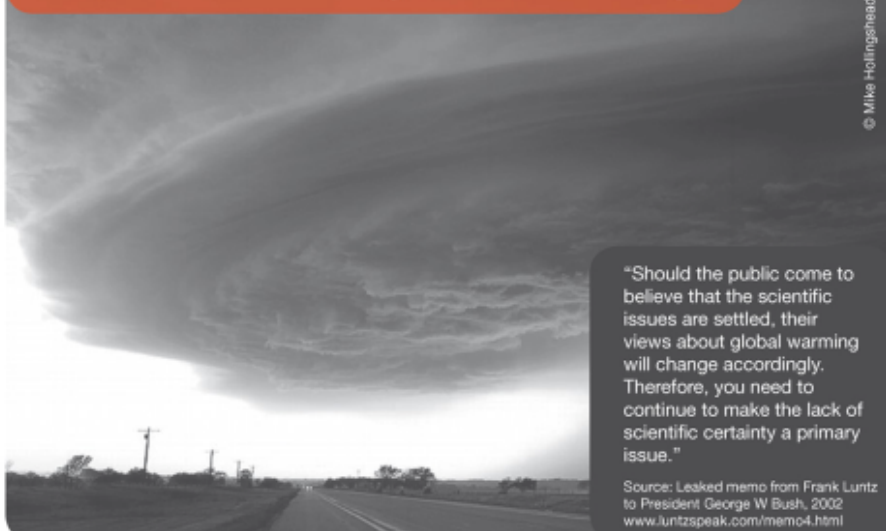


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## do you believe in global warming?

political climate change

political



© Mike Hollingshead

"Should the public come to believe that the scientific issues are settled, their views about global warming will change accordingly. Therefore, you need to continue to make the lack of scientific certainty a primary issue."

Source: Leaked memo from Frank Luntz to President George W Bush, 2002  
[www.luntzpeak.com/memo4.html](http://www.luntzpeak.com/memo4.html)

public opinion



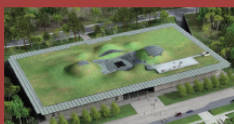
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# how can climate change inform a research agenda?



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## climate change



### Adapting cities for climate change: external microclimate design

This project researches the way in which building form, massing, materials and greenspace can be used to reduce the urban heat island of cities. The outcome of the work will be a software tool enabling designers to quantify the benefit of different options. The objectives are to reduce temperatures in cities and thereby to reduce cooling loads on buildings and increase the amenity of outdoor spaces.

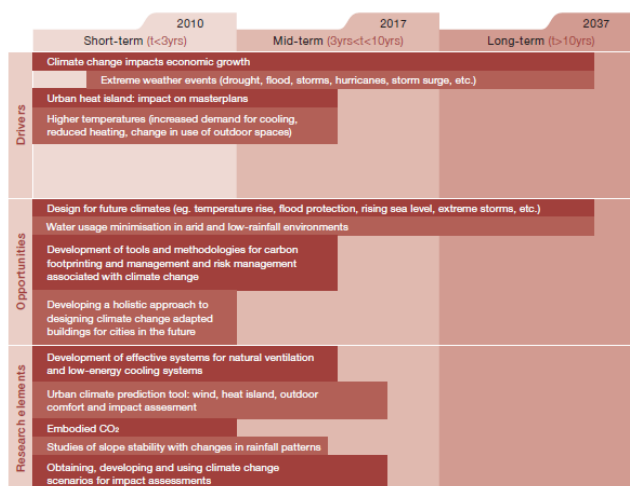
The tool will inform LUCID, a \$500,000 EPSRC research project on the urban heat islands of London in which our contribution is matched by EPSRC.

We are forging beneficial links with academic institutions in researching urban heat islands and the effect of climate change on cities. The insights gained will apply to other cities around the world.



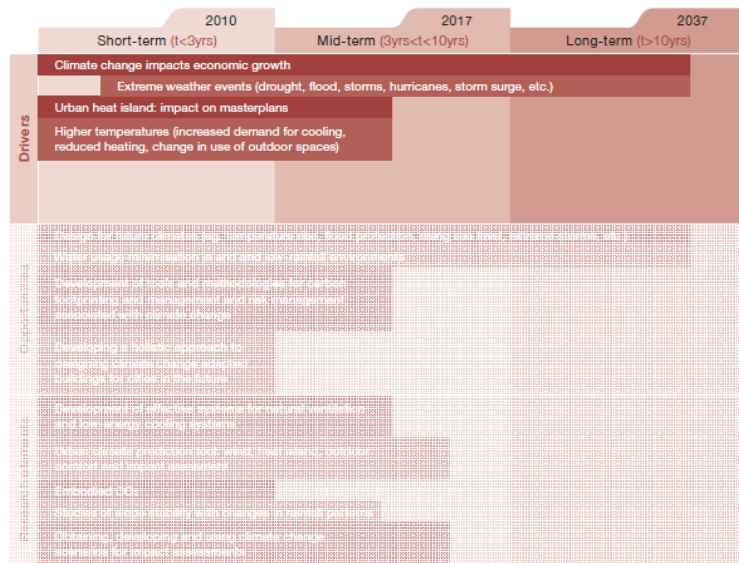
"It is essential for Arup to think about the long term. Roadmaps help us to do this."

Mike Glover  
Arup Fellow

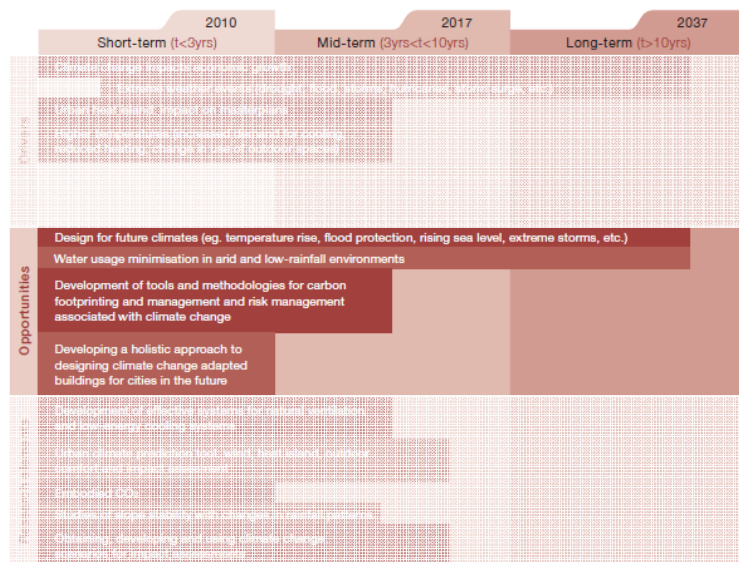


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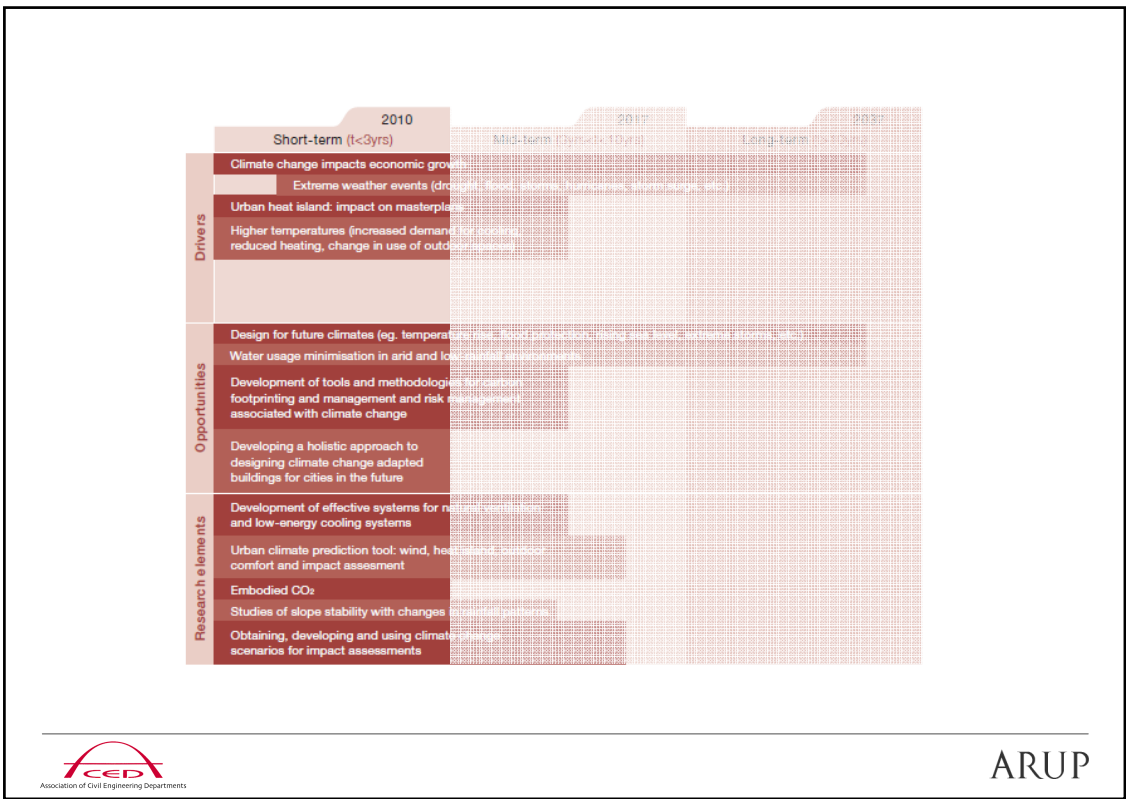
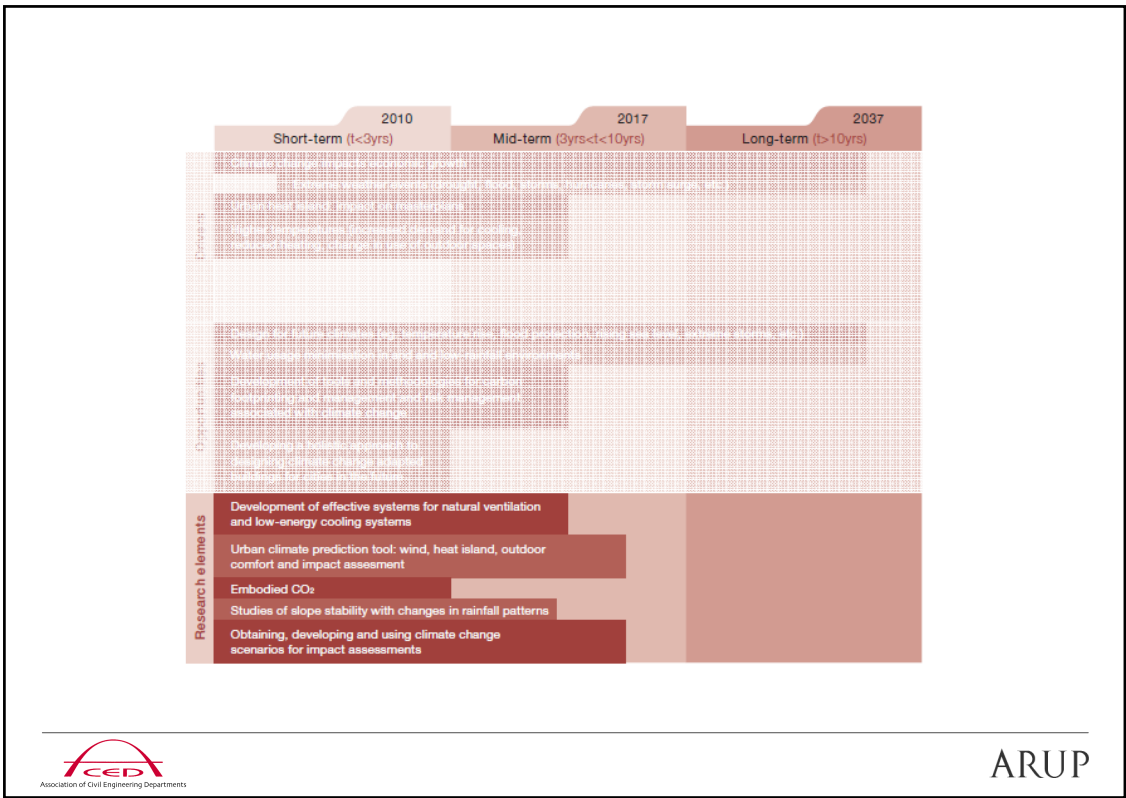


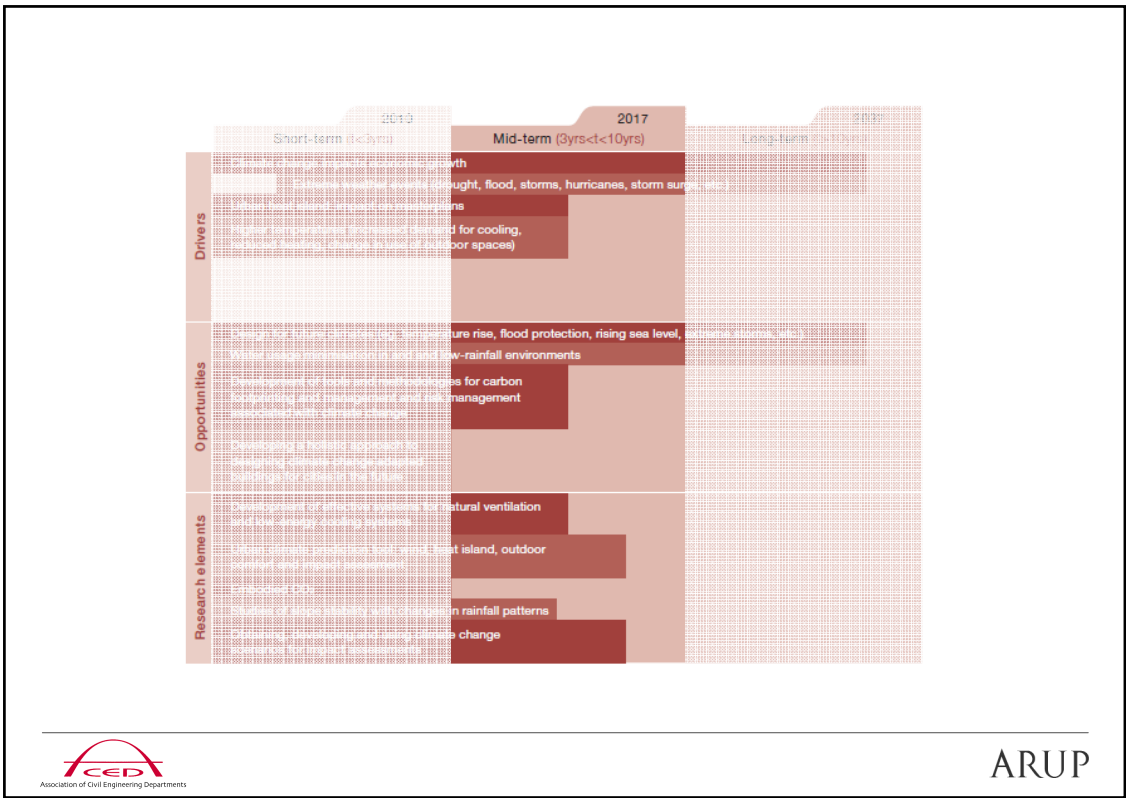


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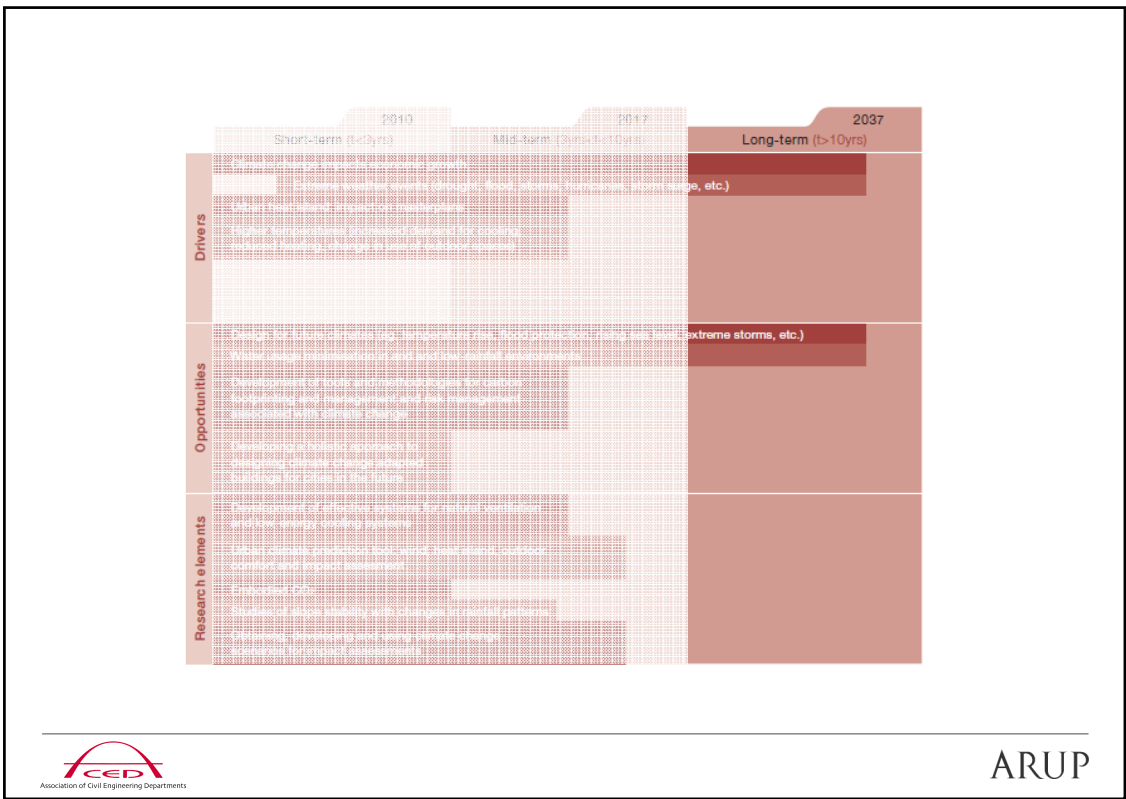


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# water



Architectural Services

**A guide to anaerobic digestion technology**

Anaerobic digestion is a means of managing and generating energy from a range of waste streams. This research project will enable us to advise clients on the appropriateness of anaerobic digestion in utility planning at an early stage in a project.

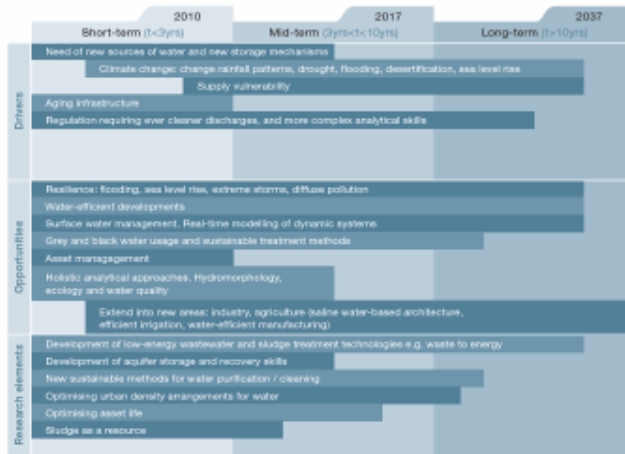
The research consolidates the Buildings London Sustainability group's experience of assessing the feasibility of anaerobic digesters with waste management expertise in the Planning and Transportation group and the Leeds Water group's experience in the anaerobic digestion of sewage sludge for Yorkshire Water.

The project builds on the Energy group's biomass software tool, Biorex, which includes an anaerobic digestion calculator. We may also use collaborate with the Organic Resource Agency.

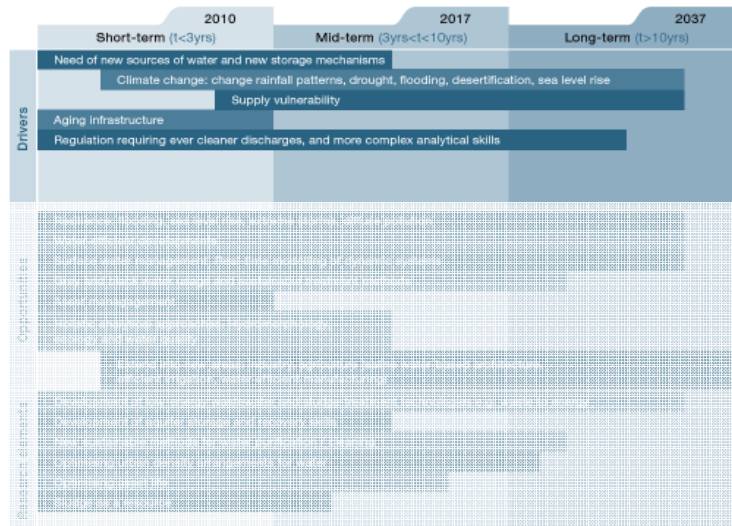


"Roadmaps demonstrate our strategic thinking and planning for the future."

Tishran Corliss  
Chair, Building Sector Board

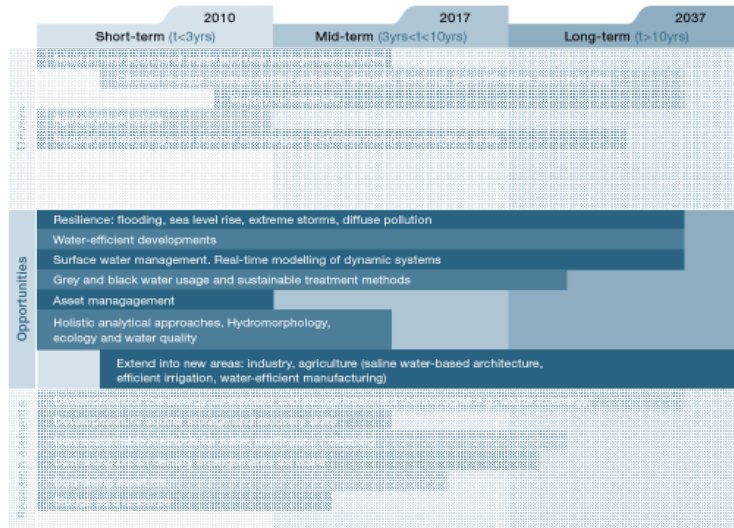


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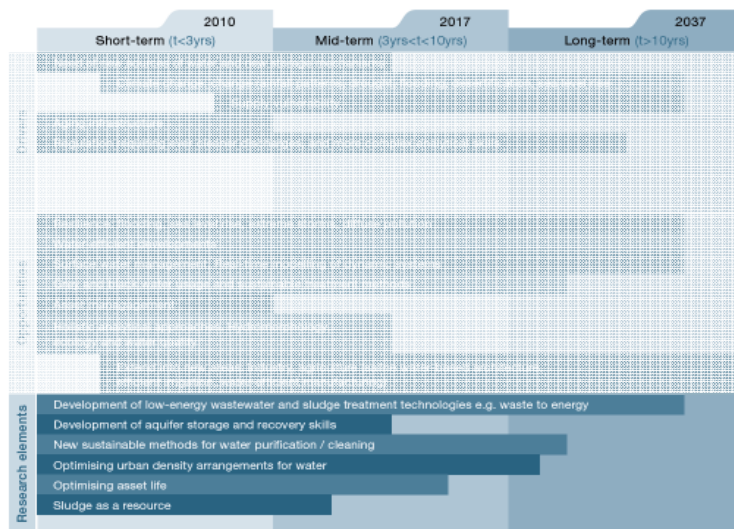


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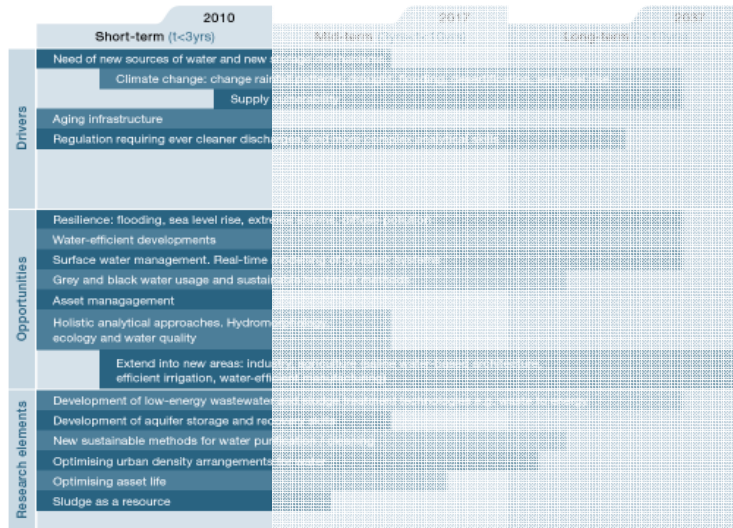




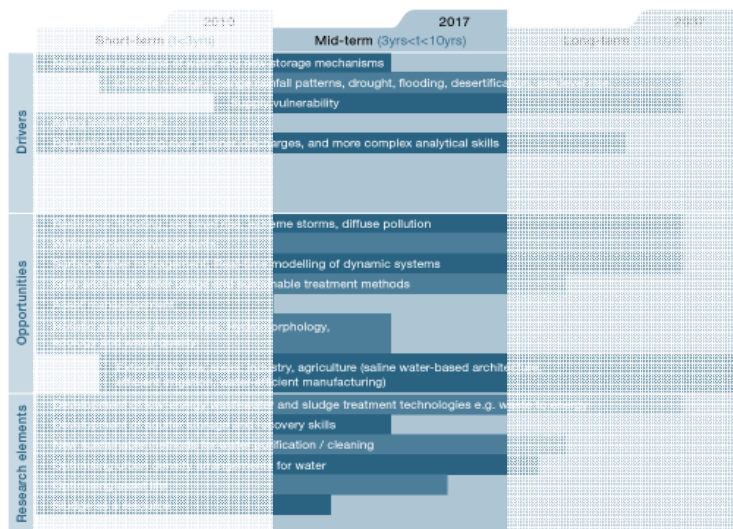
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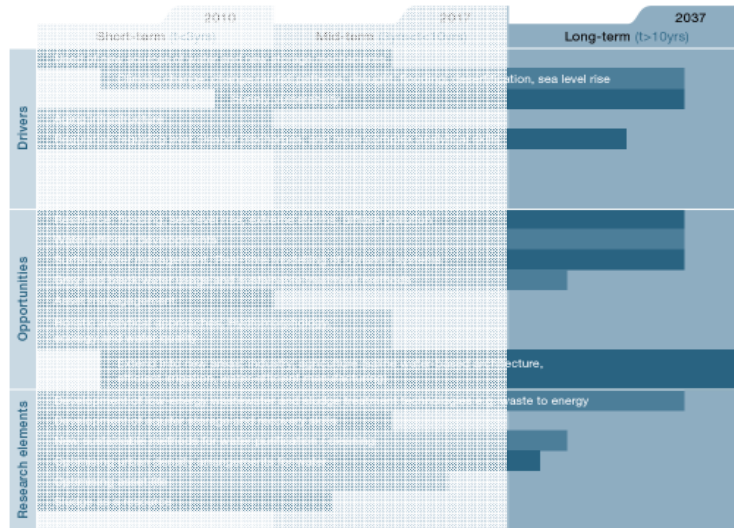
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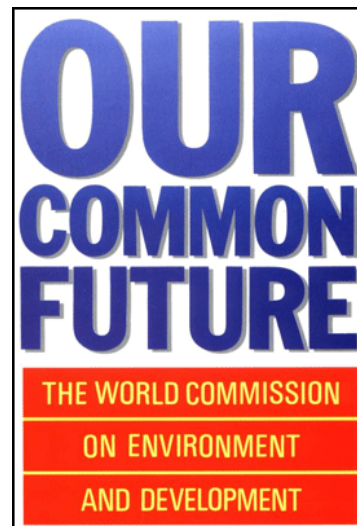


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# sustainable development

'...development that meets the needs of the present without compromising the ability of future generations to meet their own needs'  
BRUNDTLAND REPORT – OUR COMMON FUTURE 1987

.....'Where possible it also mitigates the negative impacts of previous human activity'



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# triple bottom line

'...in corporate reporting including the concept of ecological and social performance in addition to financial performance'

JOHN ELKINGTON – CALIFORNIA  
MANAGEMENT REVIEW 1994

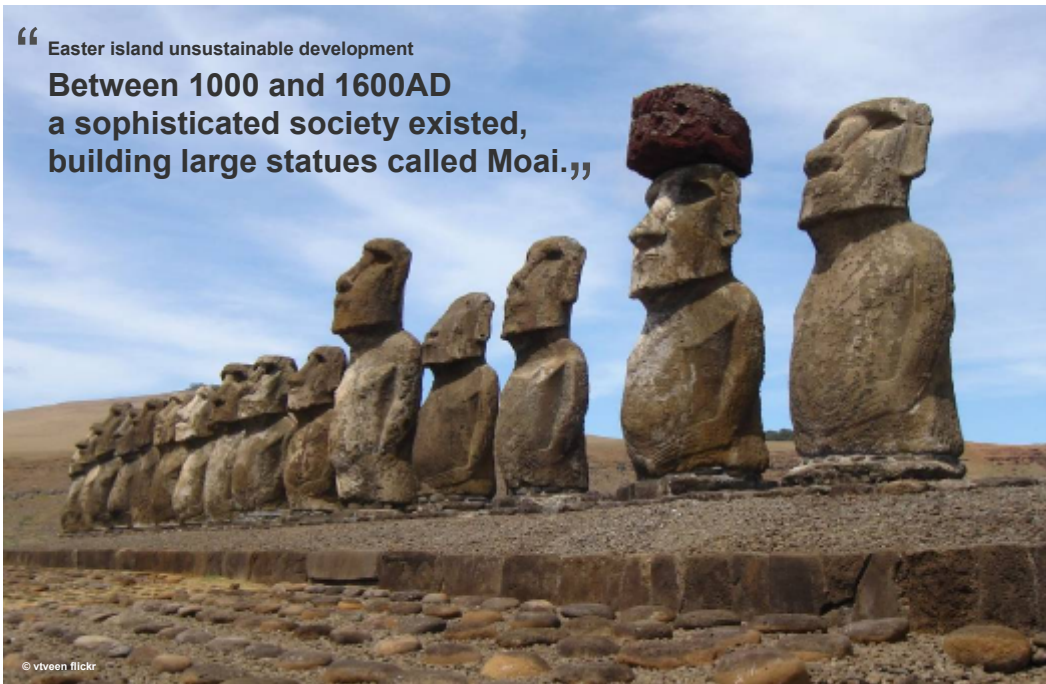


© John Elkington



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“ Easter island unsustainable development  
Between 1000 and 1600AD  
a sophisticated society existed,  
building large statues called Moai.”



© vtveen flickr



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## Easter Island

(Karen mulder 2005)



© [Source Massachusetts Institute of Technology March 2005]



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## Unsustainable development



© vtveen flickr

- Easter Island is located 3747km from Chile in the Pacific Ocean.
- Between 1000 and 1600AD a sophisticated society existed, building large statues called Moai.
- The island's trees were felled to transport Moai, for housing, canoes, to clear land for agriculture and for cremation ceremonies.
- Competition between clans and chiefs drove the erection of bigger statues requiring more wood, rope and food .
- Deforestation lead to land degradation, nutrient leaching, decreased crop yields, a loss of materials for compost and widespread erosion, habitat destruction – the island ran out of food.
- There was no potential for emigration as the nearest island is 3000km away.
- Incremental change in critical resources was not identified until it had passed a tipping point
- 'Group Think' didn't notice!



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## conclusions

Sustainable development has twin aims:  
“living within environmental limits” and  
“safe healthy and just society”

At Easter Island these were **NOT achieved**

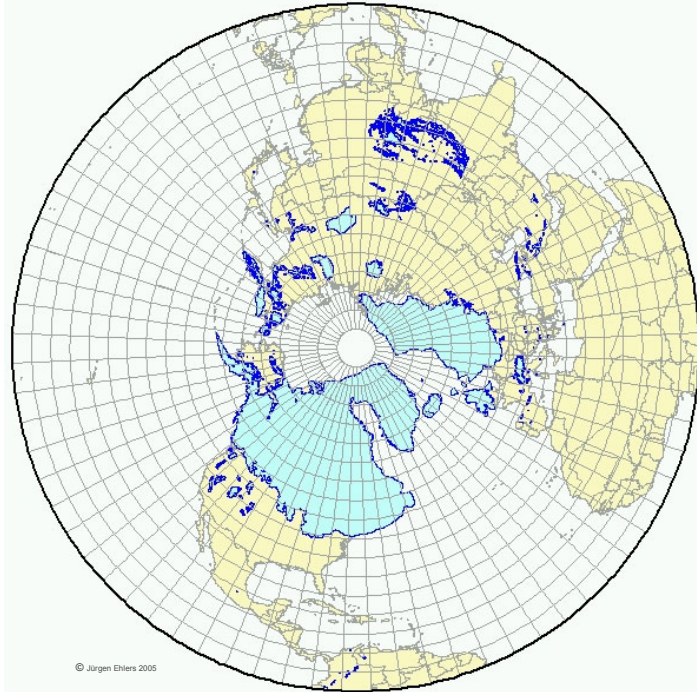
- Limited resources were **exhausted**
- Clan **warfare** followed

Development of Easter Island was  
**Unsustainable**

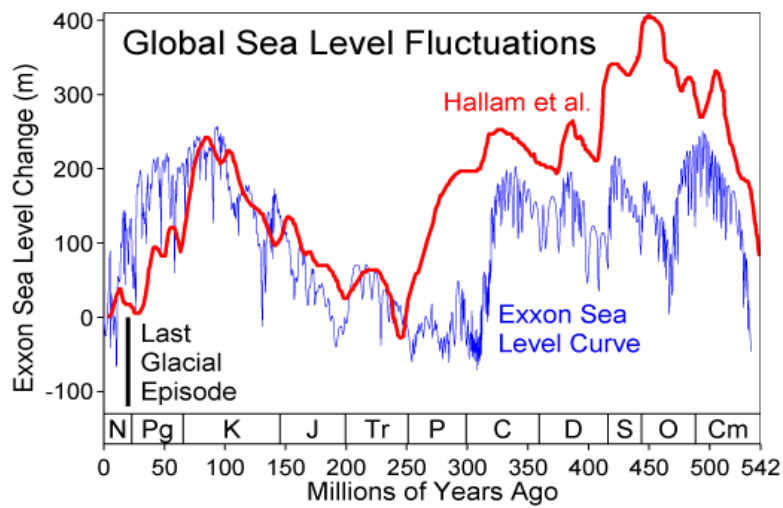
## climate change – resilience

# climate change

Climate has always changed but not previously as a result of human activity



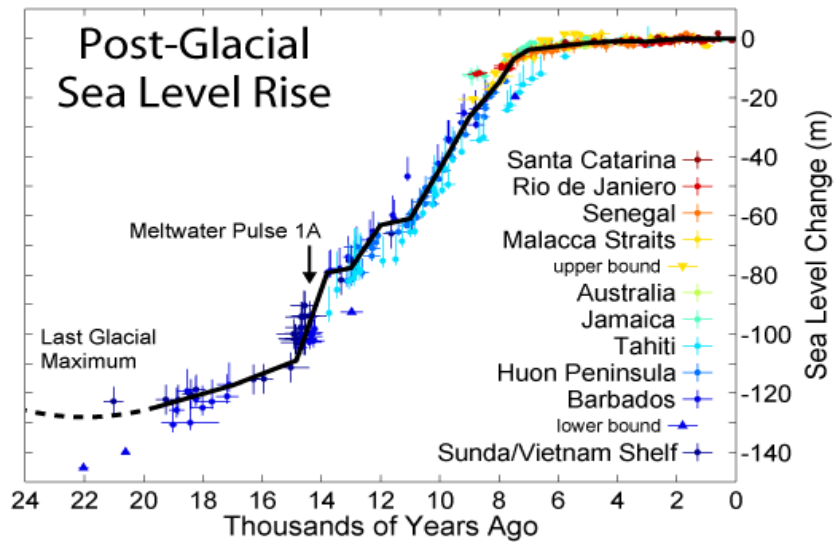
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[Acknowledgement <http://www.globalwarmingart>]



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[Acknowledgement <http://www.globalwarmingart>]



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## Human-induced climate change

'...carbon dioxide gas already released by human activities — such as through the burning of fossil fuels — will continue to contribute to global warming and sea level rise for the next millennium.'

UNITED NATIONS INTER-GOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC) 2007

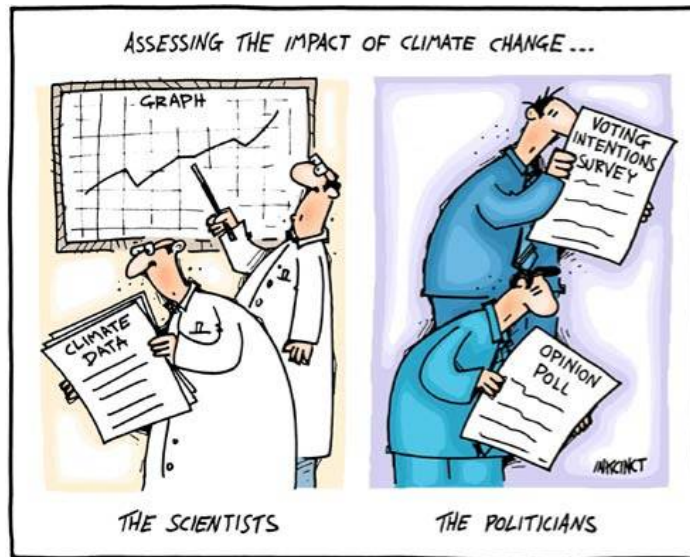


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## What is the challenge we have to respond to?

- Adapting to a changing climate
- Reducing emissions
- Getting funded
- Getting re-elected?



© John Ditchburn 19/02 2007 098



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## Climate change challenge part 1 – mitigation FEB 2005 IPCC

- Development is a driver of human-induced climate change
- Climate Change affects development – often in a negative way
- Adaptation and Mitigation are strongly linked to development paths
- Key is to make development more sustainable rather than think about a more theoretical sustainable development



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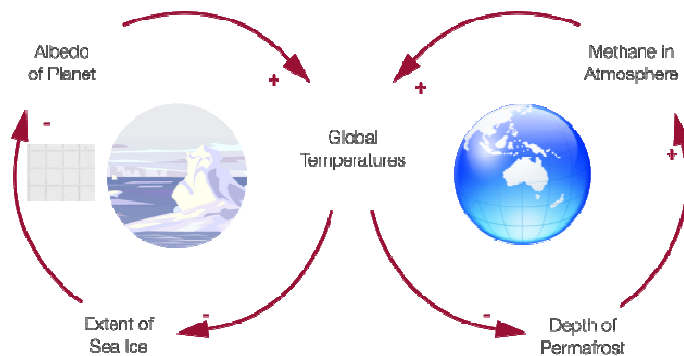
## Climate change challenge part 2 – adaptation

IPCC Copenhagen discussions suggest that a 4 deg C temperature rise might be a more appropriate adaptation policy driver than the 2 deg C target now underpinning mitigation policy



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## reinforcing causal loops



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**tolerable or not  
tolerable?**

**resilient  
infrastructure?**



© John Ditchburn 29/08 2006 438



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# set the infrastructure imperative

- How vulnerable are the current systems?
- Can we adapt existing infrastructure?
- Can we design-in resilience?
- Can we mitigate the impact of change on our existing infrastructure?
- Do we need to operate our infrastructure in a different way?
- Do we need to think differently?
- What about society?
- What about the environment?
- What will it cost?
- Should we manage asset systems not just assets?



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**one of two  
dimensions  
of resilience:**

Recovery ("As you were!")  
Adaptation or transformation



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**another of two dimensions of resilience:**

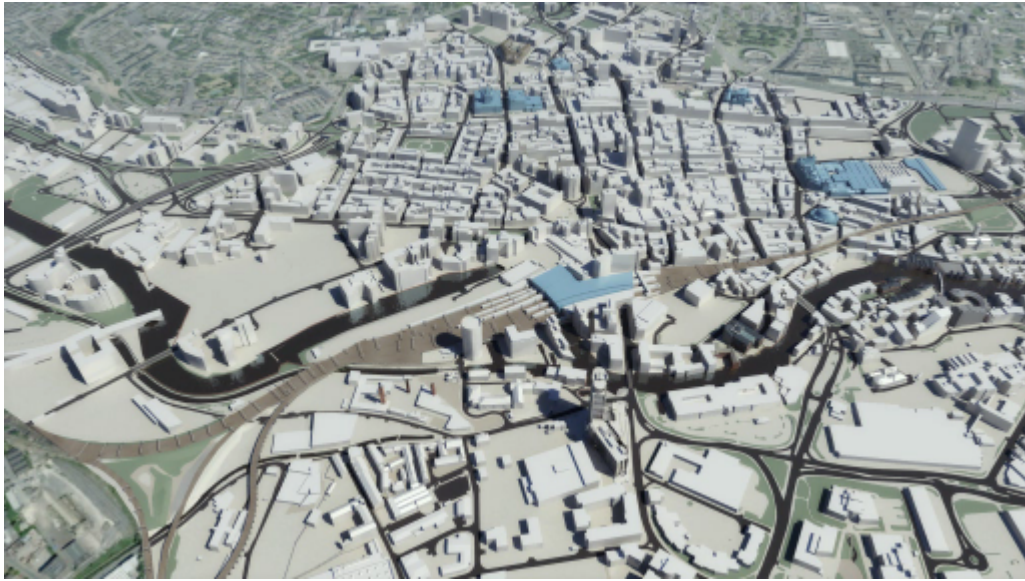
**Shock change**  
**Cumulative incremental change**

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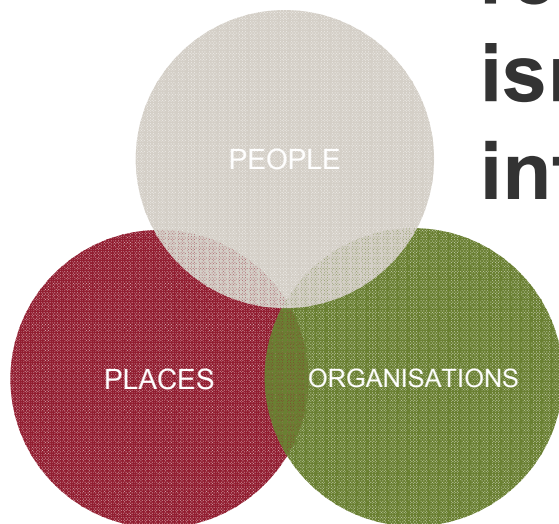
# two dimensions

	Major Events	Regular Events
	<b>SHOCK CHANGES</b>	<b>CUMULATIVE INCREMENTAL CHANGE</b>
<b>RECOVERY</b>	A major flood event leads to a major clean up operation where buildings are reinstated behind higher flood defences.	An increase in average daily temperature changes seasonal water demand patterns which leads to changes in catchment management to match supply with the new demand.
<b>ADAPTATION OR TRANSFORMATION</b>	A major flood event leads to redesign of buildings, with lower levels for non-essential use and electrical circuits placed above future potential flood levels.	An increase in average daily temperature leads to changes in predicted water demand and demand management is implemented rather than matching demand automatically.

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# resilience isn't just for infrastructure

Co-dependent with

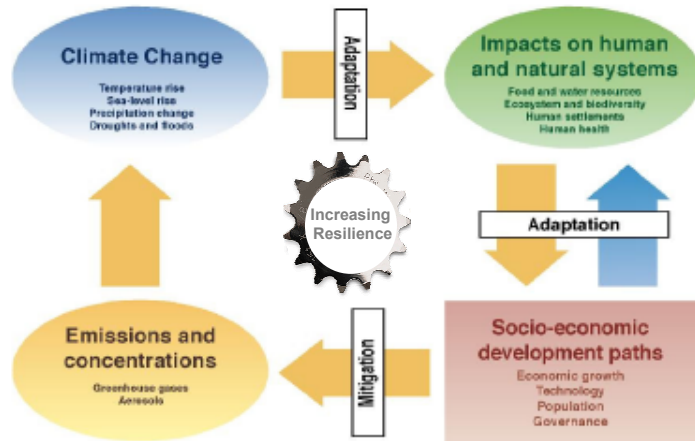
- People
- Places
- Organisations



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# adapted from ipcc

Feb 2005



FEB 2005

## IPCC

- Integrate climate change into development strategies
- Make development climate friendly (with low Green House Gas emission economies)
- Climate-proofing (resilience against climate variability and climate change)
- Enhance capacity for adaptation and mitigation



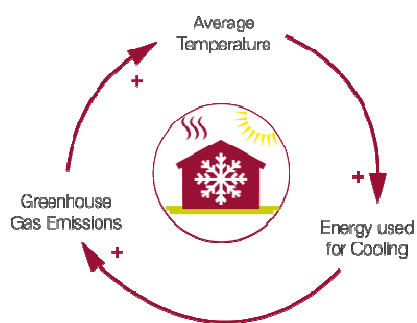
# priorities

We cannot do everything at once  
Do we understand how different infrastructure is vulnerable to different impacts?

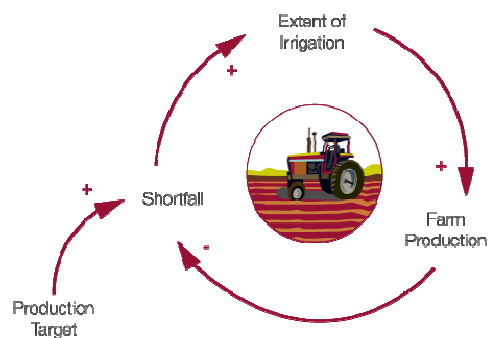
	INCREASE IN AVERAGE DAILY TEMPERATURE	INCREASE IN FREQUENCY OF EXTREME WEATHER EVENTS	CHANGES IN RAINFALL PATTERNS (WETTER WINTERS, DRIER SUMMERS)	SEA LEVEL RISE
ROAD				
RAIL				
WATER				
ICT				
ETC.				

# causal loops

- We need to monitor progress
- We need to learn as we go



a) Positive Feedback

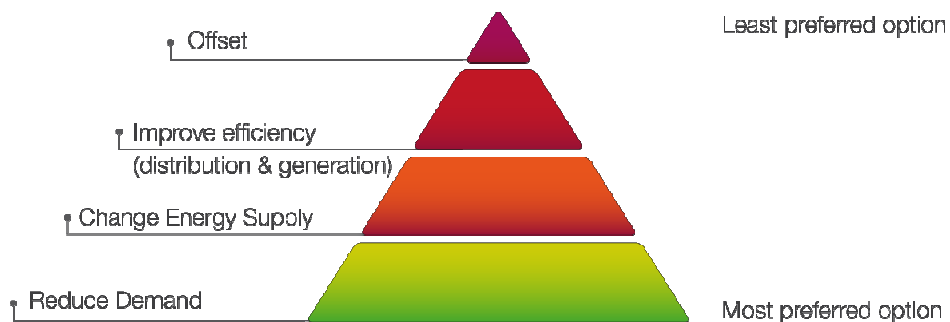


b) Negative Feedback



# industry needs...

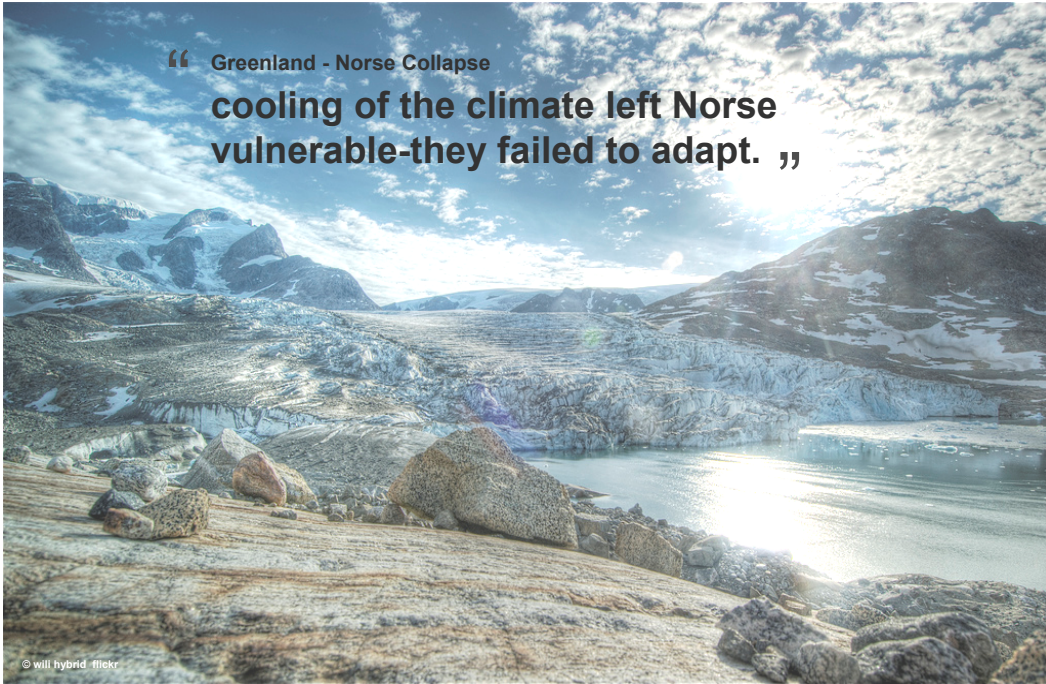
- To un-learn linear thinking and think differently
- To accept that the future will not simply be a continuation of the past
- To develop approaches to risk management that allow for uncertainty
- To understand some of the possible futures our infrastructure must serve



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“ Greenland - Norse Collapse  
 cooling of the climate left Norse  
 vulnerable-they failed to adapt. ”

© will hybrid flickr



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Greenland

## Norse collapse

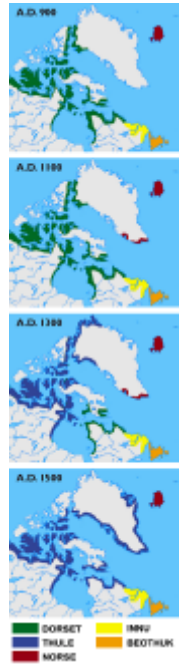
- Norse settled from Iceland in 984AD during relatively mild climatic period – lasted nearly 500 years
- A complex economy developed to survive using traditional Norse practices but resulting in significant environmental impacts.
- Society was ruled by religious chiefs with total control.
- The annual hunt was dedicated to gathering goods desirable in Europe for export, **not valuable food**.
- Norse had **increasingly violent relations with the Inuit**, some men were killed.
- Cooling of the climate left Norse vulnerable – they **failed to adapt**.
- A **reduction in demand** for goods in Europe and an increase in sea ice led to the **end of many trade links**
- **Famine** ensued and settlements were gradually abandoned around 1300AD
- 1350 'Little Ice Age'
- Last record of Norse settlement is 1408



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# Greenland

## Inuit thrive



- Inuit **extend** their **hunting grounds**
- Inuit **extend** their **low density colonisation** into Greenland as Norse retreat
- Inuit **adapt to changing climate** and **thrive** on the change
- Inuit have a **resilient societal infrastructure** and superior technology **adapted to the climate** challenges
- Inuit **populations expanded** to NW Greenland from Canada around 1200AD
- **Norse leave** in 1408
- Inuit have **never experienced warfare** other than skirmishes with the Norse
- Inuit **live within environmental limits** and **have a safe, healthy and just society**
- Their development is **sustainable**

# Thank you

Any questions?

