climate change

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drivers of change climate change

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Andrew Peterman, Harriet O'Brien, Stephen Fraser,
Bernadette Middleton, all Arup workshop participants, and
all contributing photographers

Printing and packaging
1st-Packaging, printed in 2017

climate change

social

food supply

what will you eat?

Feeding the planet's anticipated 9.7bn inhabitants in 2050 will require a 50% increase in food production over current rates, while predicted climate change conditions may reduce crop yields by over 25% in the same period. —World Bank (2016)

food supply

The warming climate will reduce global yields of staple grains such as wheat, rice and maize. Low latitudes will be severely impacted, while higher-latitude regions will benefit from longer and warmer growing seasons (Fig 1). These shifts in food production will exacerbate existing imbalances between the developed and developing worlds.

More than 1bn people rely on seafood as a major source of protein, and 90% of the people who derive their livelihoods from fishing live in developing, low-latitude regions (Fig 2). The climate change-driven 'tropicalisation' of mid/high latitude systems is fundamentally altering ocean habitats, prompting a migration of ocean species towards the poles.

Regional agro-ecosystems are dependent upon local conditions; changes in climate upset the regional balance of flora and fauna, impacting productivity. The direct effects of climate change (e.g. temperature and water availability) on food production can be modeled, but indirect effects, such as changes in disease vectors, pollinator relationships, and invasive species are difficult to quantify. Uncertainty over production yields is compounded by a projected increase in the frequency and severity of extreme weather events and droughts.

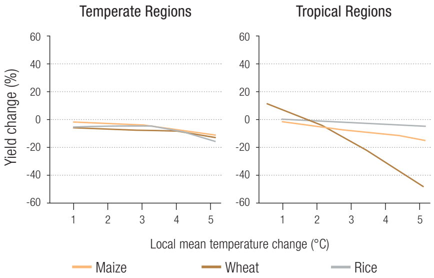

Fig 1: Temperature stimulated crop yield change
[IOP Science, 2014]

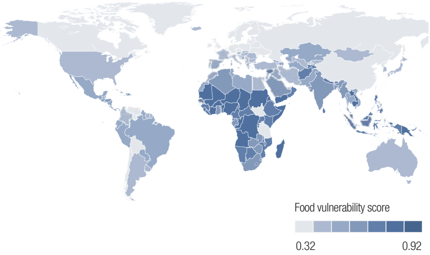

Fig 2: Locations where food supplies are vulnerable to climate change
[Notre Dame Global Adaptation Index, 2015]

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mobility patterns

will you own a car?

Helsinki is aiming to make car ownership entirely obsolete by 2025, by combining public and private transportation with responsive technology.
—Delivering on Digital (2016)

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mobility patterns

Mobility patterns reflect how often we (and our goods) travel, how far we travel, and by what means. The transportation sector accounts for 23% of all energy-related greenhouse gas emissions, and over 50% of primary oil consumption. Transport's share of domestic emissions is as large as 30% in some high-income nations, and less than 3% in developing nations where mobility for many is limited to walking and cycling (Fig 1).

In densely populated urban areas, per capita emissions are lower, due to the viability of mass transit and non-motorized travel. For example, 1,175 cites worldwide employ bike-sharing schemes, and 206 cities use rapid-transit bus systems. Nonetheless, the share of emissions from motorized transport is on the rise, due to sprawling land use and increased private vehicle ownership. From 1970 to 2010, global emissions levels due to road traffic increased by nearly 200% (Fig 2).

Several factors are colliding to reshape mobility patterns around the globe. Mobile-phone ownership is on track to reach 70% globally by 2020, a technological shift that has enabled the rise of car-sharing schemes in cities from San Francisco to Beijing. Automated transport is also on the rise; Google, Uber and Volvo are pioneering self-driving vehicles, and both Helsinki and Las Vegas have adopted automated bus systems.

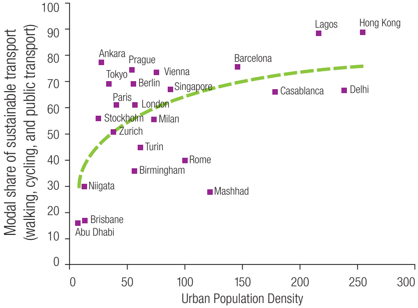

Fig 1: Sustainable transport share by population density
[UITP, 2015]

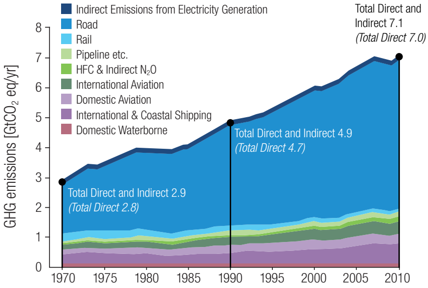

Fig 2: Greenhouse gas emissions by mode of transport
[IPCC, 2014]

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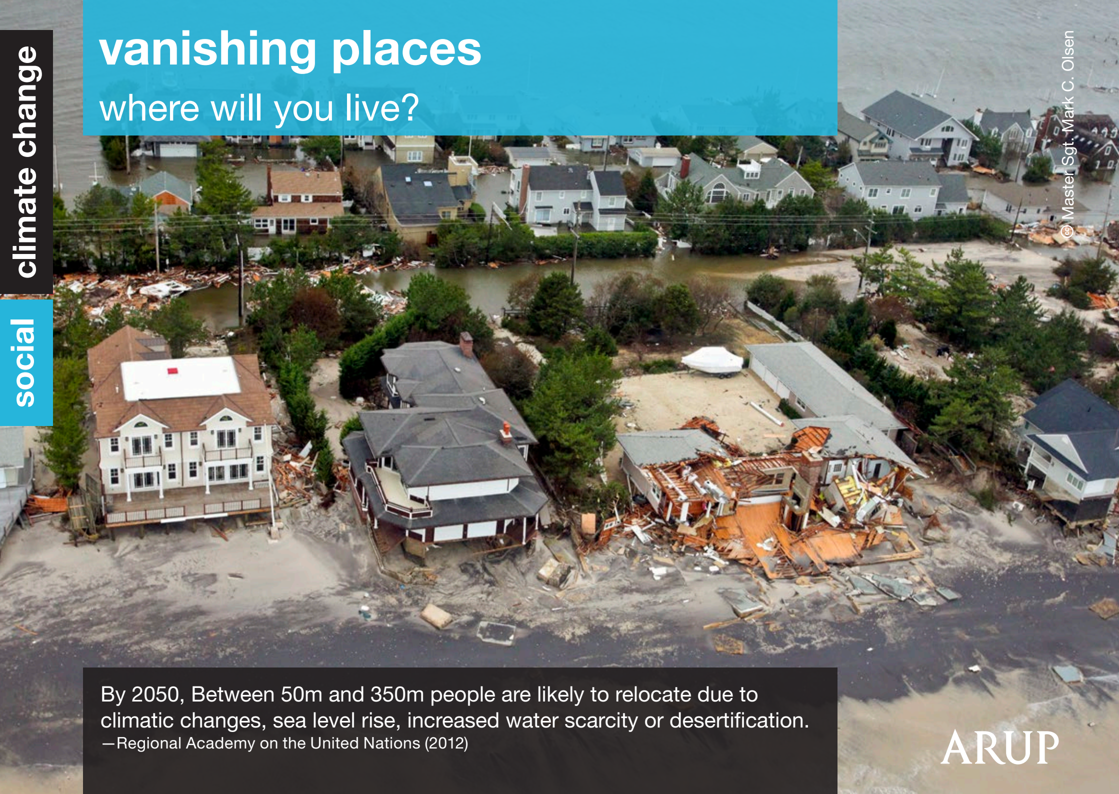
vanishing places

where will you live?



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By 2050, Between 50m and 350m people are likely to relocate due to climatic changes, sea level rise, increased water scarcity or desertification.
—Regional Academy on the United Nations (2012)

vanishing places

Sea levels are currently rising faster than at any time in the last 22 years (Fig 1). Scientists predict an additional rise of between 0.9–1.2m by 2100. With nearly half of the world's population located within 150km of a coastline, global sea level rise and coastal erosion will dramatically impact where people can live. Port cities such as Alexandria, Barranquilla and New York are already imperiled by rising sea levels; in the near future, near-coastal cities where flood risk has not been a historical concern will also feel these impacts.

Areas further inland are also vulnerable; 12m hectares of land are lost to desertification and drought annually. Under IPCC's high emissions scenario, dryland biomes are projected to increase by 24% by 2100, to cover 56% of the planet's total land area (Fig 2). Persistent anthropogenic degradation of drylands, caused by deforestation, overgrazing and unsustainable agriculture, will intensify the effects of climate change. Today, over 38% of the global population lives in a dryland biome. As a result of desertification, 50 million people may be displaced within the next 10 years, a figure estimated to reach 135m people by 2045.

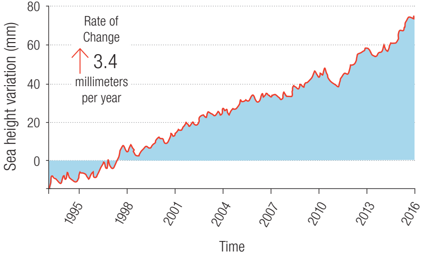

Fig 1: Sea level rise — rate of change per year
[NASA, 2016]

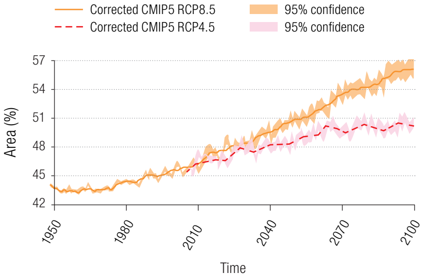

Fig 2: Percent global cover of dryland biome under RCP 8.5 and 4.5 projections
[Nature, 2015]

climate change

social

consumption

how much carbon do you consume?

13.2 tonnes of materials are required to supply the goods and services consumed per person per year in the EU. In the UK the number is 8.9 tonnes, 0.5 tonnes more than Spain. Finland and Estonia consume more than 30 tonnes of materials per person. —ONS UK (2016)

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consumption

Household consumption is responsible for more than 60% of global greenhouse gas emissions and 50–80% of all land, material and water use. 80% of these impacts result from supply chains, rather than individual behaviour such as driving or taking long showers. Average global carbon footprint per capita is 3.4 tonnes CO_2 equivalent, ranging from over 18 tonnes in the US to 1.8t in China, and even less in developing countries (Fig 1).

Historically, emissions have increased with economic growth, suggesting that emissions reductions will impede markets. However, 21 countries have demonstrated sustained decoupling of growth from emissions over a 14-year period. The UK cut CO_2 emissions by 24% between 2000 and 2014, while GDP grew by 27%. As a result, the nation's carbon intensity — CO_2 emissions per unit of GDP — dropped 40%.

Improving the useful life of manufactured products is one effective path to meeting increasing consumer demand while staying within emission targets. Lifecycle energy analysis — a calculation of the total emissions generated over an object's life from manufacturing to disposal — can encourage the development of products with longer useful lives, as well as more efficient production methods (Fig 2).

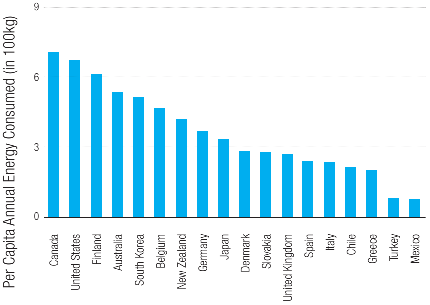

Fig 1: Municipal Waste Generation
[OECD, 2015]

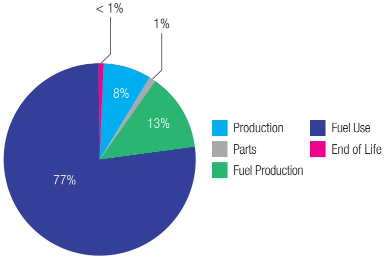

Fig 2: Life cycle GHG emissions analysis of passenger cars
[European Environment Agency, 2010]

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health threats

will the climate make you ill?

The World Health Organisation estimates that diseases associated with anthropogenic warming and precipitation trends of the past three decades already claim more than 150,000 lives each year. —WHO (2014)

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health threats

Warming global temperatures contribute to both direct impacts on human health and economic consequences from a rising number of vector-borne diseases, including dengue fever, Lyme disease, malaria, and Zika virus. The geographic range of disease-carrying insects is expanding due to rising temperatures; in addition, climate change-driven rainfall, flooding and humidity patterns result in expanded breeding environments for these insect vectors.

In 2015, approximately 3.2bn people — nearly half the world's population — were at risk of malaria. Recently, University of Michigan ecologists determined that temperature directly affects the spread of malaria; average numbers of reported cases increase in warmer years and decrease in cooler ones. This relationship results in millions of additional infections per year for every 1°C rise in global temperature. Similarly, people living in large parts of Europe and the mountainous regions of South America — too cold today to support mosquito populations year-round — will within decades face outbreaks of dengue fever, for which no vaccine or treatment is available (Fig 1).

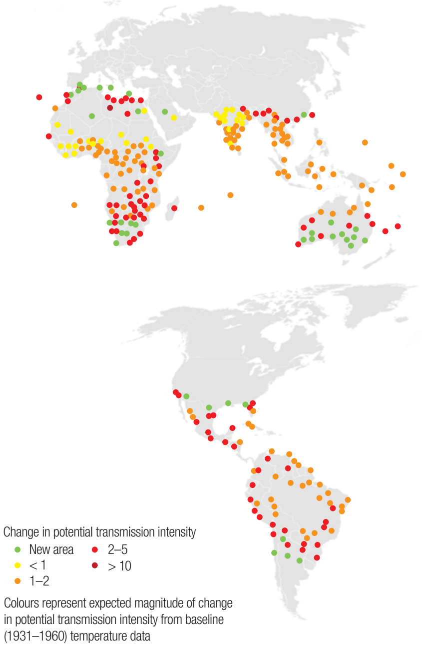


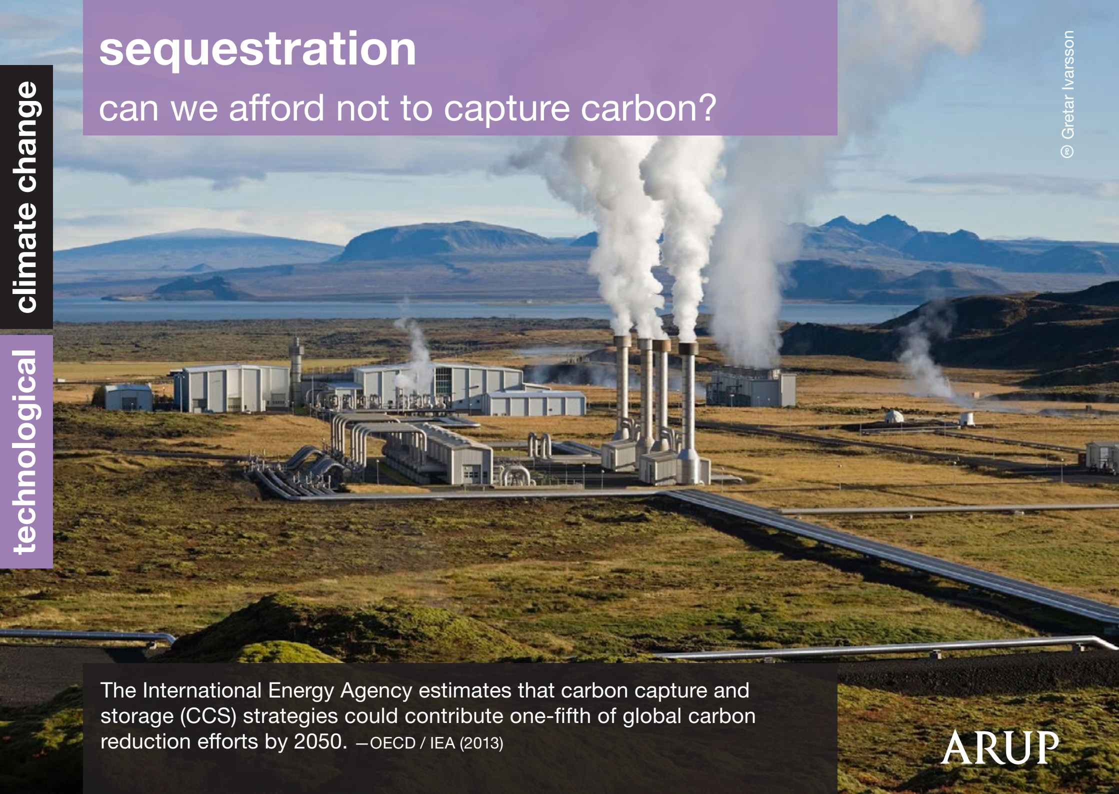
Fig 1: Projected dengue distribution for 2050 (2°C warming scenario)
[Nature Reviews Microbiology, 2015]

climate change

technological

sequestration

can we afford not to capture carbon?



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The International Energy Agency estimates that carbon capture and storage (CCS) strategies could contribute one-fifth of global carbon reduction efforts by 2050. —OECD / IEA (2013)

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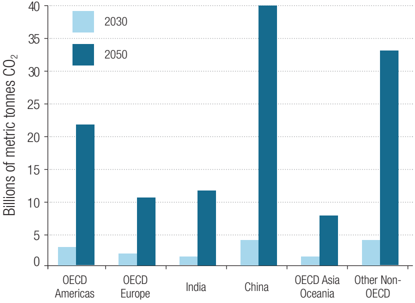
sequestration

Carbon sequestration may provide a path to stabilising atmospheric CO_2 levels while continuing to use fossil fuels, by recapturing and storing emitted carbon before it can enter the atmosphere. Nations around the world have set ambitious carbon-capture goals; OECD nations aim to capture between 3–5 billion metric tonnes of CO_2 by 2030, increasing to an average 15bn metric tonnes by 2050, while China hopes to capture 40bn metric tonnes of carbon in the same timeframe (Fig 1).

Proposed methods of sequestration include soil carbon enrichment and carbon capture and storage (CCS). Soil enrichment using charcoal-enriched ‘synthetic terra preta’ soils can contain 2.5 times the carbon of natural soil and may help mediate the worldwide decline in soil fertility.

CCS is a longer-term strategy to store carbon emitted by fossil fuel driven power stations. In this process, CO_2 is removed from a power station’s exhaust stream, liquefied, and injected into the porous rock strata of an aquifer or disused oil field (Fig 2). It is estimated that the deep aquifers of the world’s sedimentary basins alone have a potential total storage capacity of between 1,000 and 10,000 gigatons of carbon — between 100 and 1,000 years of CO_2 emissions at present day rates.



OECD – Organization for Economic Cooperation and Development, which includes 34 member countries

Fig 1: Long-term carbon capture goals
[MIT Technology Review, 2012]

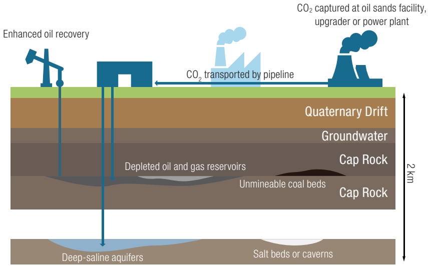


Fig 2: Geologic sequestration of CO_2
[CO_2 Solutions, 2014]

climate change

technological

technology lock-in

do you invest in the right solutions?

The fossil-fueled power plants built in 2012 alone will emit some 19 billion tons of CO_2 over their expected 40-year lifetime, more than the annual emissions of all operating fossil-fueled power plants in 2012.
—World Bank (2015)

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technology lock-in

Technology lock-in is an institutional resistance to replacing existing systems, standards and practices with newer, more efficient designs. Short-term systemic and sunk cost economic considerations tend to drive technology lock-in.

Systemic technology lock-in can be seen in fuelling infrastructures designed for fossil fuel powered vehicles. This established system creates a barrier to the market entry of alternative fuel vehicles; the economic benefits of a network of alternative fuel stations are considerable, but require the presence of a large number of electric vehicles on the road. (Fig 1). Each electric vehicle manufacturer benefits from the successes of its competitors, as the total volume of EVs on the road will strengthen the network of charging stations (Fig 2).

Sunk cost technology lock-in concerns existing systems that are economically and environmentally costly to run, but difficult to replace. Despite the economic costs of CO_2 emissions and the availability of more efficient technologies, coal-fired power stations remain in operation simply because they are “built and paid for”. Addressing technology lock-in requires sustained strategic vision, and can be difficult to justify for cities whose budgets naturally focus on shorter-term solutions.

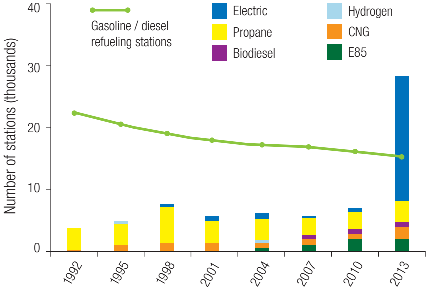


Fig 1: US alternative refuelling stations compared to all refuelling stations
[Scientific American, 2015]

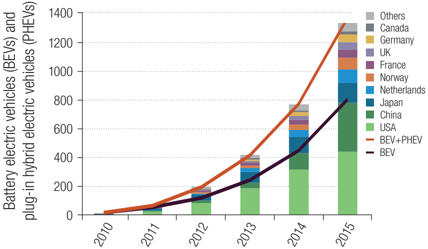


Fig 2: Global electric car stock, 2010–2015
[IEA, 2016]

climate change

technological

geoengineering

can we control the climate?

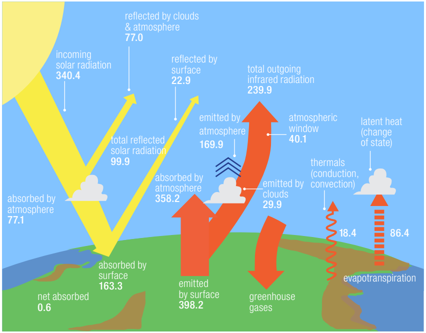
Los Angeles County is spending US$550,000 a year on cloud seeding to increase rainfall, a method estimated to provide drinking water for 36,000 people. —San Diego Union Tribune (2016)

geoengineering

It is now understood that during the industrial period human beings inadvertently altered the climate via aerosol pollution; an increase in carbon-based greenhouse gases (GHG) traps heat near the earth's surface, gradually raising global temperatures. This effect is magnified by a simultaneous decrease in polar sea ice, reducing the amount of sunlight reflected into space (Fig 1). A question now under consideration is how large-scale climate manipulation projects (geo-engineering) could reverse or slow these warming trends.

Proposals to reduce the concentration of GHG focus on increasing uptake of these gases into natural carbon sinks such as trees and water. One concept suggests intensifying ocean absorption of carbon by increasing the productivity of marine life, accomplished by adding nutrients to ocean water, thus stimulating plankton growth.

Approaches to reducing the amount of received sunlight on earth include constructing orbital mirrors to create a 'reflective shield' (Fig 2), increasing ocean cloud cover via spray-based cloud seeding, and artificially polluting the upper atmosphere with sulfur dioxide aerosols to mimic the reflectivity of volcanic ash.



All values are average Wm^2 flux based on ten years of data

Fig 1: Earth's energy budget
[NASA, 2014]

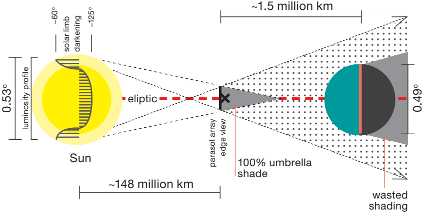


Fig 2: Space mirrors could provide the total planetary electrical demand projected for the year 2050
[Ultimax, 2014]

climate change

technological

decarbonisation

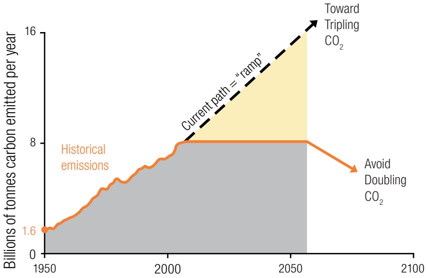
when will we be carbon neutral?

CO_2 stays in the atmosphere for hundreds, if not thousands, of years. Stabilizing climate change to within 2°C above preindustrial temperatures would require bringing net carbon emissions to zero by 2100.
—World Bank (2015)

decarbonisation

Decarbonisation is the process of decoupling economic growth and energy supply from greenhouse gas emissions. The first step in this process is improving efficiency and conservation measures. For buildings or vehicles, the second step is often to switch fossil fuel use to electricity use (e.g. replacing a gas water heater with an electric heat pump water heater). Transitioning to electricity alone, however, does not reduce emissions unless that electricity is carbon free.

The third step is electricity sector decarbonisation, which involves replacing fossil fuel-based emissions sources (such as coal-fired power plants) with carbon-free sources. This shift away from fossil fuels to carbon-free electricity will lead to a doubling of the share of electricity in final energy consumption to more than 40% by 2050. Fuel switching is one of eight strategies required for ‘stabilization wedges’, a framework for minimising carbon emissions with currently available technology (Fig 1 & 2). When the stabilisation triangle was first introduced in 2004, seven wedges were needed; lack of emission reductions since 2004 has necessitated the identification of two additional wedges.



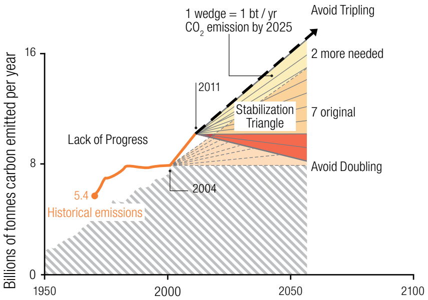


Fig 1 & 2: Carbon stabilization wedges in 2004 and 2011, Pacala & Socolow

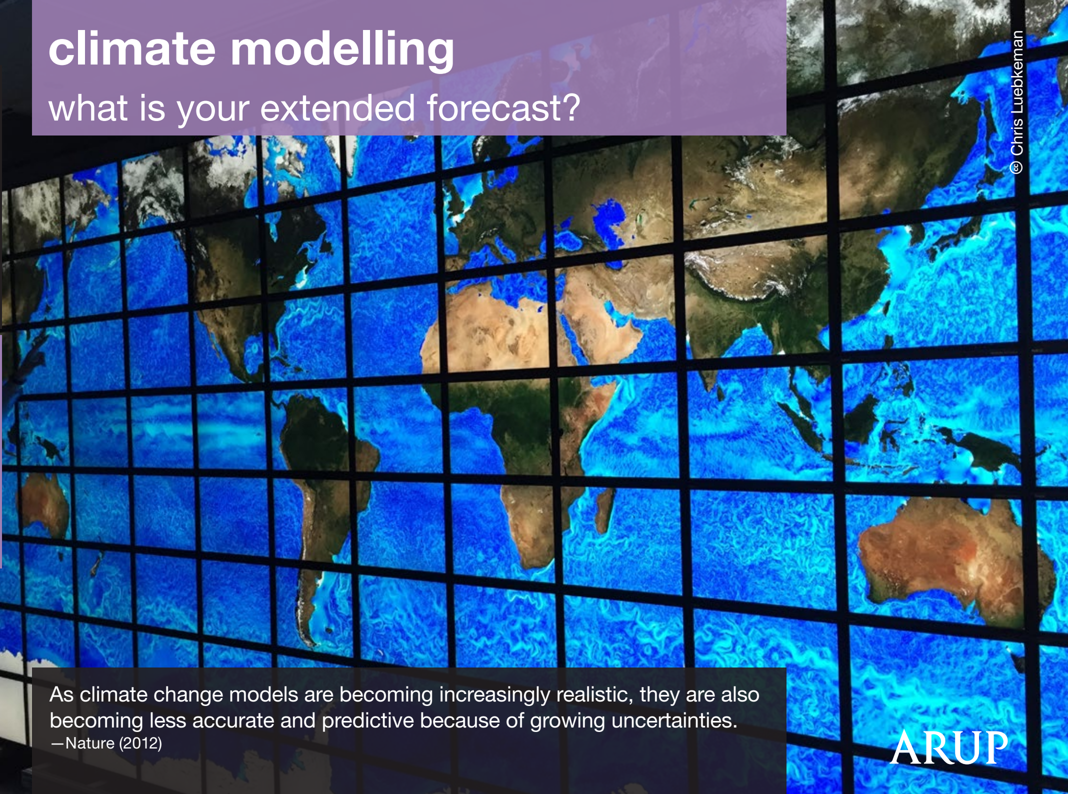
[Princeton, 2015]

climate change

technological

climate modelling

what is your extended forecast?



As climate change models are becoming increasingly realistic, they are also becoming less accurate and predictive because of growing uncertainties.
—Nature (2012)

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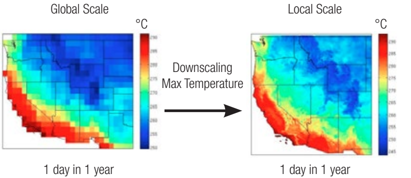
climate modelling

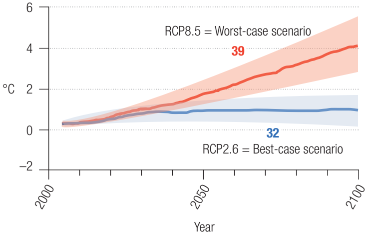
Climate models make quantitative projections of future climate change under different greenhouse gas (GHG) emissions scenarios. The most sophisticated of these models are called global circulation models (GCM). GCM models simulate both the physics and chemistry of the global climate system, including atmospheric and oceanic circulation patterns, effects of clouds, land and sea ice, and the effects of GHG and aerosols in the atmosphere. Engineers and planners are now using downscaled GCM data to inform design decisions for more climate responsive and resilient buildings and infrastructure (Fig 1).

The Intergovernmental Panel on Climate Change (IPCC) reviews the science and projections of climate models. In 2014, the IPCC reported that global temperatures will rise between 0.3°C and 1.7°C in the best-case scenario (RCP 2.6) and between 2.6°C and 4.8°C in the worst-case scenario (RCP 8.5) (Fig 2). This range is partly due to uncertainty around future GHG emissions and partly from scientific uncertainties in the models. Projected global temperature changes are much larger at the poles than the tropics. Climate models also focus on changes in rainfall, snow and frost, wind speeds and sea-level rise.



This process translates information from coarse to fine resolution.

Fig 1: Downscaling climate data
[Conservation Biology Institute, 2016]



Representative Concentration Pathways (RCPs) are GHG trajectories used by the IPCC for policy-based modeling. RCP 2.6 assumes that global annual GHG emissions peak between 2010-2020, followed by substantial subsequent declines. RCP 8.5 assumes a continued rise in emissions throughout the 21st century.

Fig 2: Global average surface temperature change
[IPCC, 2014]

ecosystems valuation
what are our ecosystems worth?
climate change
economic
Beekeepers across the US saw a 44% decline in their honeybee colonies from 2015-2016, putting $15bn worth of pollinated food crops in jeopardy.
—Bee Informed Partnership (2016)
ARUP

ecosystems valuation

Ecosystems are critical to society, contributing fresh food, water, climate regulation, soil formation and nutrient cycling. Human existence depends on “natural capital,” yet estimating its benefit is difficult and often overlooked in economic decision-making. Ecosystem valuations assess the financial worth of these services, allowing the benefits of natural systems to be compared alongside those of traditional commodities and understood as valuable assets.

Over one-third of food production on the planet depends on insect pollinators, whose estimated economic value is more than US$170bn (Fig 1). Bee populations are sensitive to temperature rise, and are severely impacted by climate change. Global warming is pushing bees into higher elevations and toward the poles (Fig 2), leading to a loss in bee distribution and a potential decline in plant reproduction.

Ecosystem valuation techniques are becoming increasingly sophisticated. Such assessments encourage greater understanding of the complex interdependencies between nature and human life, further enhancing our capabilities to model, manage and protect the natural environment.

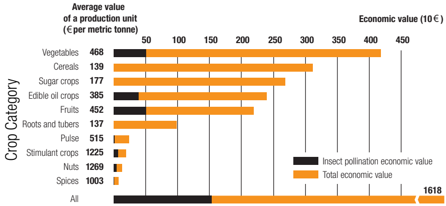


Fig 1: Global economic impact of insect pollination on agricultural production
[United Nations Environment Program, 2009]

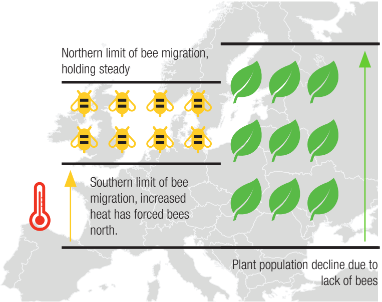


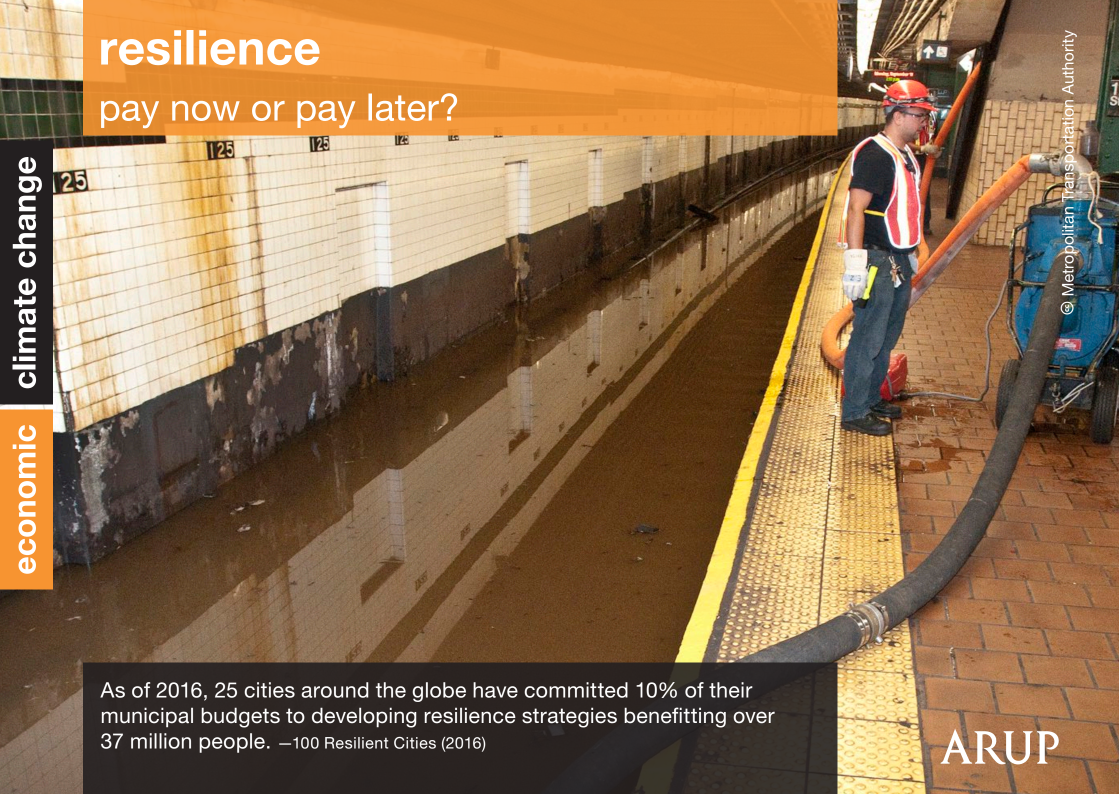
Fig 2: Migrating patterns of bees and other pollinators
[Live Science, 2015]

resilience

pay now or pay later?

climate change

economic



As of 2016, 25 cities around the globe have committed 10% of their municipal budgets to developing resilience strategies benefitting over 37 million people. —100 Resilient Cities (2016)

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resilience

Resilience is the capacity of people, cities and the built environment to survive and thrive when encountering natural and human pressures. Resilience is both proactive and reactive; it must recognize the complex and interdependent effects of climate change. Individuals, communities and systems use resilience to adapt and grow in the face of shocks (e.g. earthquakes, floods and storms), as well as chronic stressors (e.g. unemployment, social unrest and ongoing water shortages).

Since 1900, worldwide economic losses due to natural disasters have been increasing (Fig 1), with 30% of global losses due to flooding, 26% from earthquakes and 19% from storm damage. Hurricane Katrina, which made landfall in the southern US in 2005, was the most destructive weather event in US history (Fig 2). Nearly 2000 people died as a result of the storm, which caused US$108 million in damages, flooded 80% of the city of New Orleans and displaced over 1m residents of the Gulf Coast region. It is estimated that by 2050, between US$66–$106bn worth of US coastal property will be below sea level.

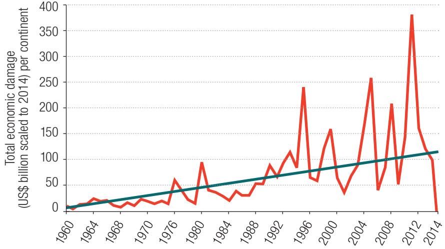

Fig 1: Global total natural disaster induced economic damage 1950–2015
[Emdat, 2015]

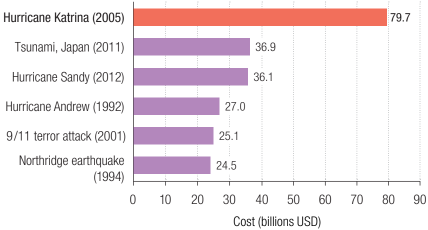

Fig 2: Catastrophes with highest insurance costs 1970–2015
[Swiss Re, 2015]

climate change

economic

carbon finance

would you invest?

In 2015, global carbon markets were valued at US$48bn (US$34bn in emission trading schemes and US$14bn in carbon taxes) covering 12%, or 7 gigatonnes, of annual GHG emissions.
—World Bank Carbon Pricing Watch (2015)

carbon finance

Carbon finance is the system of assigning a market value to fixed amounts of CO_2 emission reductions. This value is determined by the cost to a party of achieving a given reduction in emissions, compared to the cost of paying another party to achieve the same reduction elsewhere. The rationale behind this strategy is that in either case, the same net reduction in carbon is achieved.

Substantial progress in carbon pricing has been made since the introduction of emissions trading schemes under the 2005 Kyoto Protocol. In 2015, 20 sub-national jurisdictions, 39 countries and 450+ companies established carbon pricing, representing almost 25% of global greenhouse gas (GHG) emissions (Fig 1). Combined carbon pricing systems represent 12% of annual global GHG emissions and over half of the emissions in participating jurisdictions. Growth in the emissions market is projected to drive a 500% increase the price per tonne of CO_2 by 2050 (Fig 2).

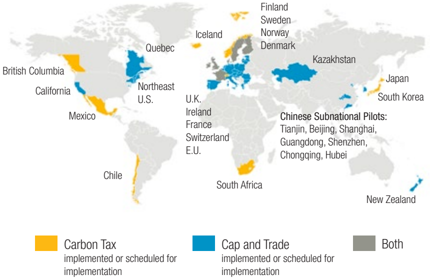

Fig 1: Carbon pricing programs around the world
[World Resource Institute, 2015]

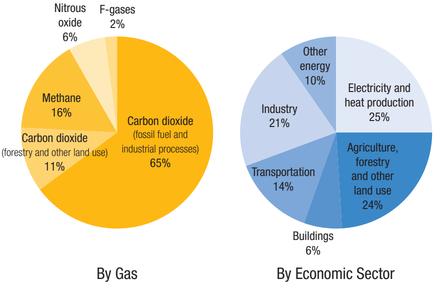

Fig 2: Global greenhouse gas emissions
[US Environmental Protection Agency, 2014]

business opportunities

how will your business profit?

climate change

economic

S&P 500 companies that are actively managing and planning for climate change secure an 18% higher return on investment than companies that aren't — and 67% higher ROI than companies who refuse to disclose their emissions. —CDP (2014)

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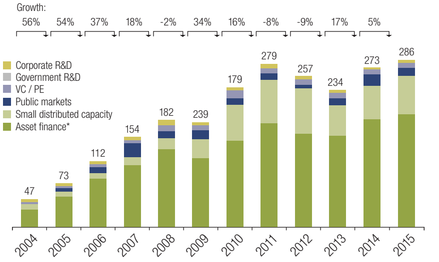
business opportunities

Companies are realizing the business and market differentiation opportunities of climate change. A recent Carbon Trust study found that while 76% of executives believe the impacts of climate change present a potential risk to their businesses, a higher proportion (84%) believe that climate change represents increased opportunity in the future.

Eco-innovation, investment and resilient business models are on the rise (Fig 1), and are projected to drive further economic opportunity. Growth in eco-patents outpaced all other patent applications in many countries, with China, India and Korea leading the way (Fig 2). A new global index of companies leading the way in climate change mitigation outperformed the Bloomberg World Index by 9.6% between 2010 and 2014. These firms reported that investments to cut CO_2 led to average emissions reductions of 9% per company, while achieving an average internal rate of return of 57% per project. Carmaker General Motors redesigned delivery routes and switched deliveries from road to rail, helping cut emissions by 244,000 metric tons a year and saving the company US$287m.



*Asset finance volume adjusts for re-invested equity.
Total values include estimates for undisclosed deals

Fig 1: New investment in renewables 2004–2015
[UNEP, 2016]

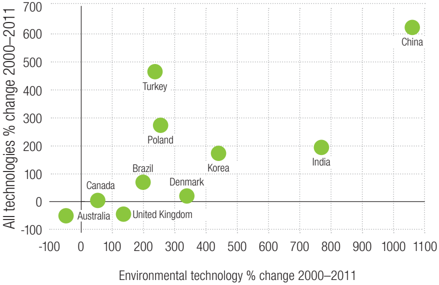


Fig 2: Environmental patents vs all technological patents
[OECD, 2016]

climate change

economic

accumulated risk

can we insure against the ripple effect?

climate change

economic

Average global economic losses from weather-related events jumped from US$50bn annually in the 1980s to nearly US$200bn in the last decade. Estimates suggest losses from investment assets as a result of climate change will reach US$143tr by 2100. —IPCC (2012), The Economist (2015)

accumulated risk

Accumulated risk occurs when a disaster triggers a series of compounding consequences, resulting in amplified impacts. One example of this 'ripple effect' is the 2011 Tohoku earthquake, tsunami and nuclear incident in Japan. Effects of the 9.0-magnitude earthquake included nearly 16,000 deaths, 2,590 missing persons, US$220bn in damages, and a significant tourism decline nationwide. Follow-on losses cost US$55m in California, US$30m in Hawaii, and US $6m in Chile, crossing economic, cultural and geographic divides.

Many people, businesses and countries rely on insurance to protect against the economic hazards of extreme weather. Insurance industry research has found that the frequency and severity of extreme weather events has increased in recent years, leading to an increase in claims (Fig 1). In 2014, the world experienced 336 disaster events, up from 150 in 2003.

The insurance industry is keenly aware of the changing nature of climate risks and the associated increase in climate-related financial losses (Fig 2). Some insurers are raising premiums and cancelling policies in high-risk areas, while others are choosing to promote climate risk reduction and resilience strategies, including green infrastructure and catastrophe modelling.

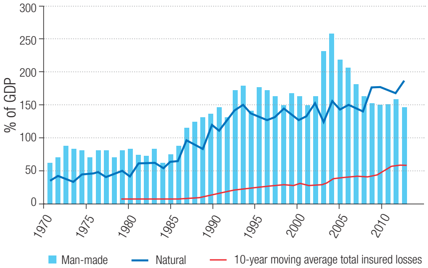


Fig 1: Catastrophic events over time
[Swiss Re, 2015]

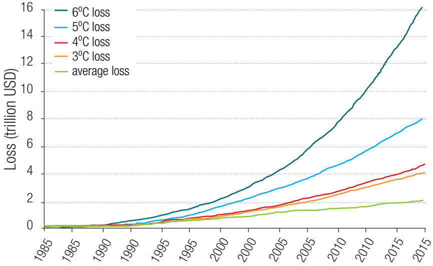


Fig 2: Projected global financial loss due to climate change
[The Economist, 2015]

climate change

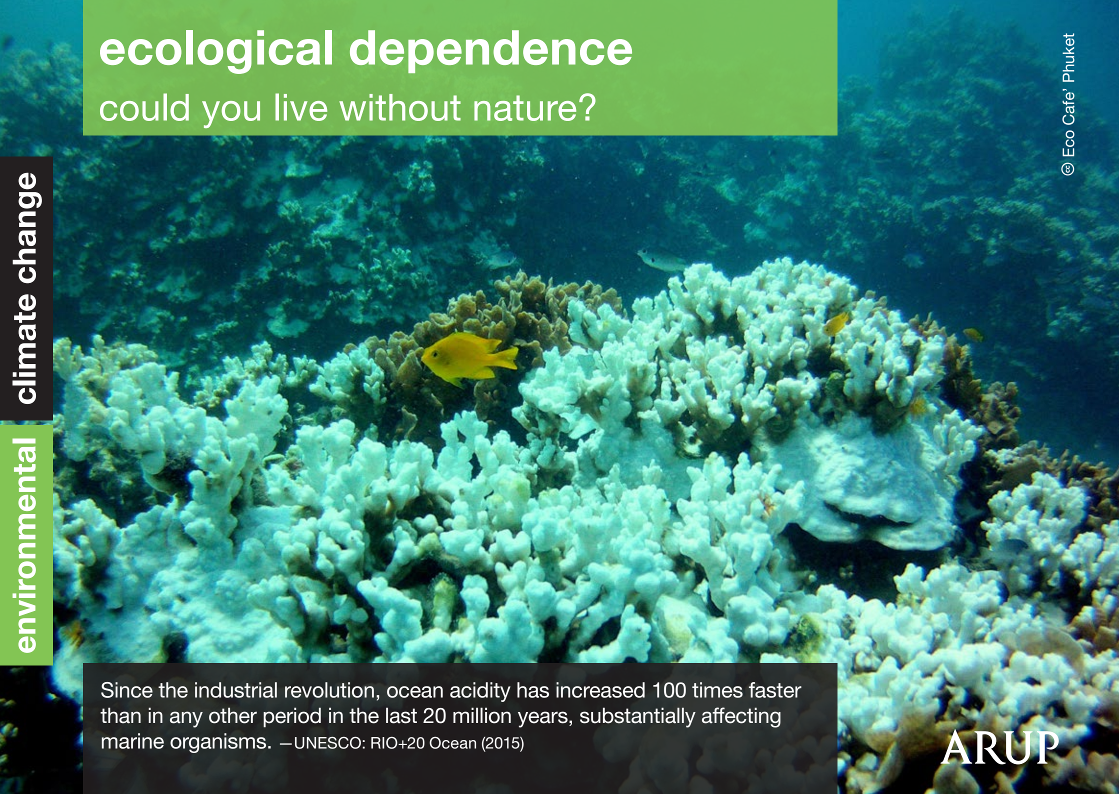
economic

ecological dependence

could you live without nature?

climate change

environmental



Since the industrial revolution, ocean acidity has increased 100 times faster than in any other period in the last 20 million years, substantially affecting marine organisms. —UNESCO: RIO+20 Ocean (2015)

ARUP

ecological dependence

Anthropogenic CO_2 emissions have resulted in increased absorption of atmospheric CO_2 in the world's oceans. As a result, ocean acidity has risen 30%, with predictions indicating these levels may rise by 150% by the end of the 21st century. Research has shown that the changing chemical composition of the ocean is inhibiting marine organisms' ability to build reefs through shell calcification (Fig.1). Declines in reef stability and longevity affect marine food webs, species composition, and ultimately the entire ocean ecosystem.

Reef-building tropical and subtropical corals are among the species worst affected by the combined stresses of ocean warming, acidification, overfishing and pollution. In the last 30 years, the world's coral reef cover has diminished by 50%, with 75% of remaining reef systems threatened. Nearly 25% of aquatic species rely heavily on the 1% of ocean covered by coral reefs.

The state of our oceans is of worldwide concern, but particularly so in the developing world, where local populations rely heavily on the sea (Fig 2). Stocks of the most widely-used food fish — tuna, mackerel and bonito — have fallen by 74%, endangering global food security. Evidence shows that effective management can successfully rebuild fish stocks.

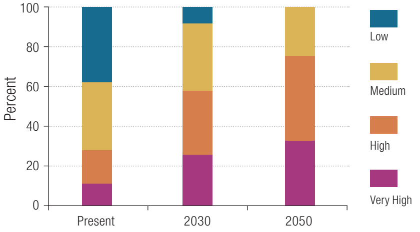


Fig 1: Present and projected global coral reefs at risk
[WRI, 2012]

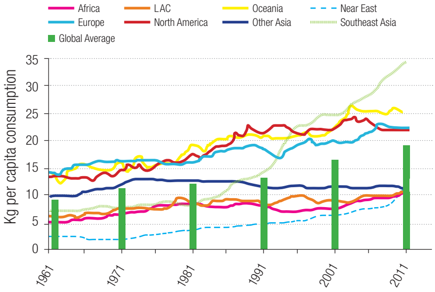


Fig 2: Regional evolutions of fish consumption per capita
[Commitee on World Food Security, 2014]

climate change
environmental

tipping points

can we reverse endangerment?

climate change

environmental

Estimates put the current loss rate of plant and animal species at between 1,000 to 10,000 times higher than Earth's natural extinction rate.
—World Wildlife Fund (2016)

tipping points

When a climate system reaches its ‘tipping point’ (the threshold at which the future state of a system is irreversibly altered) drastic change becomes a permanent condition. Extra-systemic climate ‘forcing factors’ are often the initial drivers of climate change; these include declines in surface reflectivity (albedo), and human-induced aerosol emissions. As these forcing factors increase in frequency and severity, the process accelerates, leading to irreversible and catastrophic developments. Polar ice loss, ocean circulation shifts, rapid methane release, rainforest deforestation, weather instability and the mass extinction of marine and terrestrial species are potential tipping points, endangering earth’s ecosystem as a whole (Fig 1).

Biologists believe we may be entering a sixth mass extinction — the first such extinction caused by a species (humans). Data indicates that one in six extant species may vanish as a result of anthropogenic climate change over the next century. Since 1500AD, more than 750 species have become extinct; as of 2014, another 5,552 are threatened (Fig 2). The World Wildlife Fund estimates that over 50% of Emperor and Adélie penguins will disappear by 2050 if global temperatures continue to increase above pre-industrial levels (2°C).

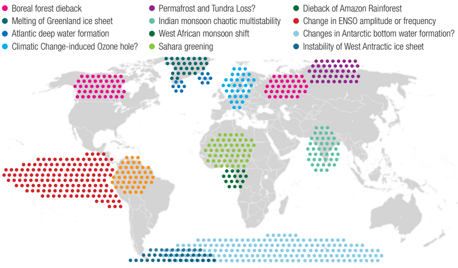


Fig 1: Potential tipping elements in the earth system
[C2ES, 2014]

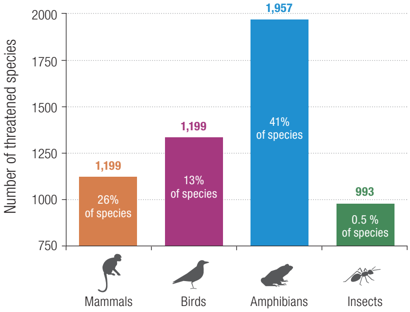


Fig 2: Existing species threat of extinction
[Nature, 2014]

climate change

environmental

forest loss

how much do trees matter?

© Tony Hisgett

More than 18m hectares of tree cover was lost worldwide in 2014, at a rate of 34 hectares per minute. This total is equivalent to a land area twice the size of Portugal. —UN-REDD (2016)

ARUP

forest loss

Tree cover loss (TCL) refers to removal of trees regardless of cause; this includes deforestation, forest fires and natural loss. From 2001-2014, the highest TCL occurred in Russia (41m hectares), Brazil (38m) and Canada (31m) (Fig 1). Russia and Canada's boreal forests experienced heavy loss due to a combination of timber harvesting, fires and climate change. Brazil's losses were due to agriculture-driven deforestation.

Humans clear forests on a massive scale for timber, agriculture, mining and urbanization. Globally, agriculture accounts for 80% of deforestation. In Asia and Latin America, timber extraction accounts for over 70% of tree removal. In Africa, deforestation is primarily a result of fuel wood collection and charcoal production.

While tropical tree loss is greatest overall, boreal forests have experienced the steepest increase in annual loss since 2011. These forests are experiencing more fires now than in any period over the past 10,000 years. While forest regeneration is possible, it is a very slow process that can take centuries. Forests and vegetation absorb 30% of CO_2 emissions. Researchers predict that climate change will increase boreal wildfire frequency, further intensifying greenhouse gas emissions as stored carbon is released into the atmosphere.

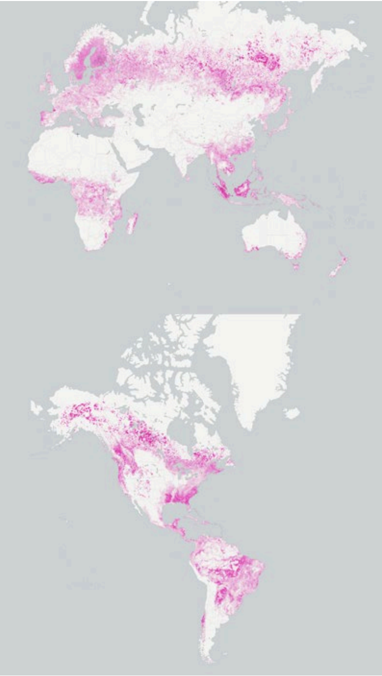


Fig 1: Portion of forest loss 2001–2014
[Global Forest Watch, 2016]

climate stress

how vulnerable are you?

climate change

environmental

Australia has experienced a 40% increase in bushfires since 2008, with an average of 4,595 fires per week in 2013. —Royal Society Publishing (2016)

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climate stress

Climate stress is the combined physical, chemical and biological constraint on ecosystem productivity. Stressors result from natural factors (e.g. excessive temperatures, moisture or solar radiation) and human activities, which disrupt environmental quality and ecosystem integrity. Worsening conditions lead to increasing scarcity of environmental resources; this chronic, compounding resource unavailability degrades a system's capacity to function.

Since the 1880s, Earth's temperature has risen 0.87°C. As global temperatures continue to rise, heat waves typically striking once every 20 years could become annual events across 60 percent of Earth's land surface by 2075 (Fig 1). The NPCC predicts that in New York City, annual mean temperatures could increase by 2.3–3.2°C by the 2050s and 2.9–4.8°C by the 2080s. Global temperatures are expected to rise by 1.5°C–2°C by 2050.

Reduced rainfall and higher temperatures are increasing both fire-prone weather conditions and ignition sources, leading to a 19% increase in fire season length worldwide (Fig 2). In the US, California's fire season — linked to poor air quality, increased heat threats and local economic losses — now encompasses the entire calendar year.

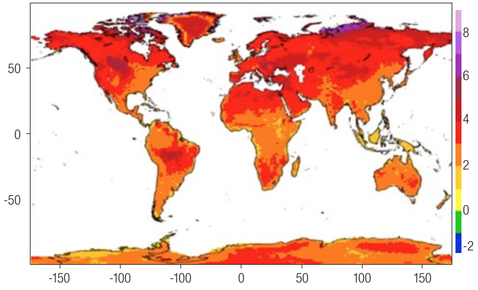


Fig 1: Change in heat wave intensity by 2075 expressed as the greatest increase in minimum temperatures over 3-day periods.
[Climate Change, 2016]

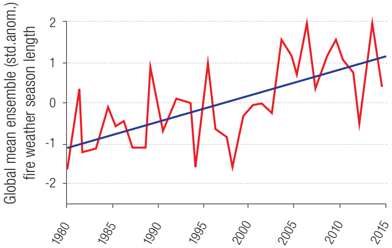


Fig 2: Length of global fire seasons 1980–2015
[Nature Communication, 2015]

climate change

environmental

the big thaw

how high could the seas rise?

© Kimberly Vardeman

Global CO_2 concentrations have not exceeded 300 parts per million (ppm) in the last 800k years. Today, concentrations are 407ppm (2016) and could reach as high as 935 ppm by 2100 at current emissions rates. Present levels are already sufficient to gravely accelerate the melting of all ice in Greenland.
—U.S. Global Change Research Program (2014)

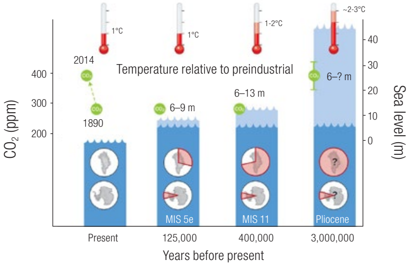
ARUP

the big thaw

One of the most tangible impacts of global warming is the widespread disappearance of land and sea ice. Global sea warming, and expanding waters, account for one-third of universal sea-level rise, while the remaining two-thirds is a result of melting ice sheets in Greenland, Antarctica and mountain glaciers. Extreme projections of polar ice sheet melting anticipate a resultant rise in sea levels of over 6 meters by the end of this century (Fig 1).

Satellite observation of Arctic sea ice has shown that the ice is diminishing at a rate of 13.4% per decade relative to the 1981 to 2010 average; 2015 holds the record for the lowest summer ice coverage since 1979 (Fig 2). This trend also occurs on land; the US Geological Society found that glaciers within Wyoming's Glacier National Park have declined from an estimated 150 in 1850 to just 25 in 2010.

Ice cover reduction contributes to sea level rise and loss of both water habitats and freshwater supply. Cascading effects include reduced reflection of solar radiation, increased global heat absorption, increased methane and carbon dioxide release from melting permafrost, and changes to oceanic circulation and global weather patterns.



Peak global mean temperature, atmospheric CO_2, maximum global mean sea level (GMSL), and source(s) of meltwater.Light blue shading indicates uncertainty of GMSL maximum. Red pie charts over Greenland and Antarctica denote fraction (not location) of ice retreat.

Fig 1: Sea level rise projections based on historical ice loss and CO_2 data
[Science Magazine, 2015]

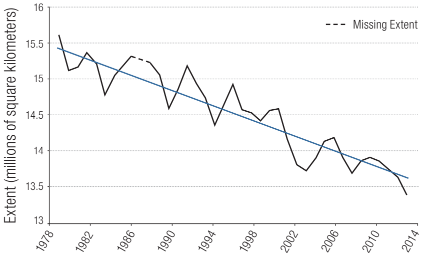


Fig 2: Arctic sea ice loss 1979–2013
[U.S. Global Change Research Program, 2013]

long-term planning

which future should we prepare for?

climate change

political

Even under a rapid climate change scenario, the Maeslant storm surge barrier in Rotterdam will only remain effective until 2070.
—Rotterdam Climate Initiative

ARUP

long-term planning

The costs of climate change, in terms of policy action or inaction, cannot be quantified within a typical 2–6 year electoral cycle. Thus, decisionmakers motivated by legitimate short-term challenges are not incentivised to “pay now” to address future problems. This near-sighted approach will lead to significant economic losses, as preventative climate action measures are projected to be 20 times more cost-effective than reacting after impacts have occurred.

Some cities are beginning to plan for climate resilience, but even the most forward-thinking municipal administrations are not looking past 2070, despite the anticipated escalation of warming beyond 2100 (Fig 1) and the likelihood of cities existing for hundreds of years (Fig 2). Tangible efforts to lengthen planning timescales are emerging. Sweden, for example, has appointed a Minister of the Future, to expand the long-term horizon of government planning. In British Columbia, 160 citizens chosen at random for a single, non-renewable term have been asked to reform the electoral system in the long-term public interest, free from the pressures of an electoral cycle.

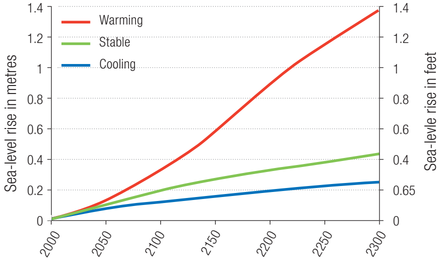


Fig 1: Sea-level rise anomaly from thermal expansion
[OLCF, 2013]

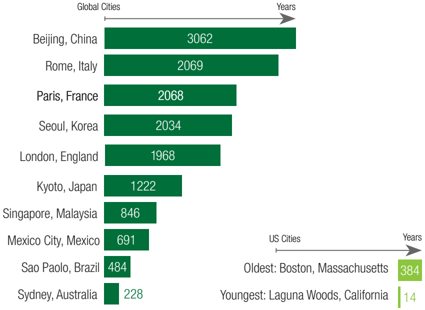


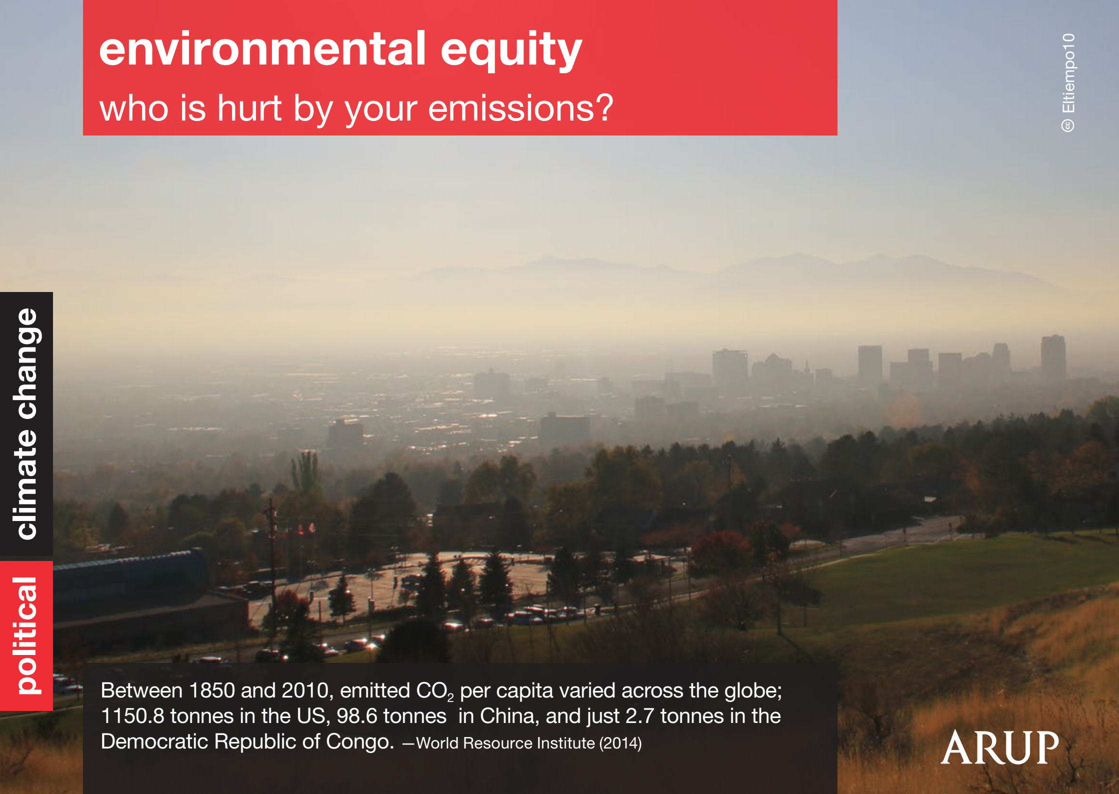
Fig 2: Oldest and youngest US cities compared to global cities
[European Economic Review, 2014, Wikipedia, 2016]

environmental equity

who is hurt by your emissions?

climate change

political



Between 1850 and 2010, emitted CO_2 per capita varied across the globe; 1150.8 tonnes in the US, 98.6 tonnes in China, and just 2.7 tonnes in the Democratic Republic of Congo. —World Resource Institute (2014)

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environmental equity

Environmental equity is the development, implementation and enforcement of environmental policies ensuring that nations with little economic or political clout are not made to bear a disproportionate share of harmful pollution effects. Wealthier countries are often leading carbon emitters, while poorer nations and lower income demographics generally emit significantly less carbon yet suffer the most from climate change impacts. One step toward more universal equity is a process of the UN Framework Convention on Climate Change, allowing nations to propose climate action plans tailored to local economic and demographic trends, while aligning with collective guidelines.

In 2013, the top three emitting regions accounted for over half of global CO_2 emissions, with China responsible for 29% (10.3bn tonnes), the US 15% (5.3bn), and the WU and the EU 11% (3.7bn) (Fig 1). In 2014, China's per capital emission levels exceeded mean EU levels for the first time in history (Fig 2). Projected effects of high emissions include decreased agricultural yields, harm to human health and lower worker productivity. The 2014 economic damage of these emissions, known as the *social cost of carbon*, was estimated between US$37 and US$200 per tonne.

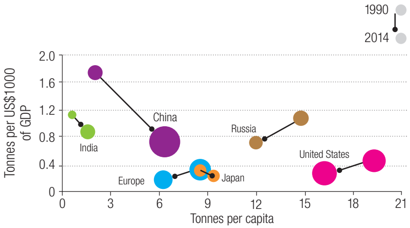

Fig 1: Energy-related C0$_2$ emissions per capita by region
[International Energy Agency, 2015]

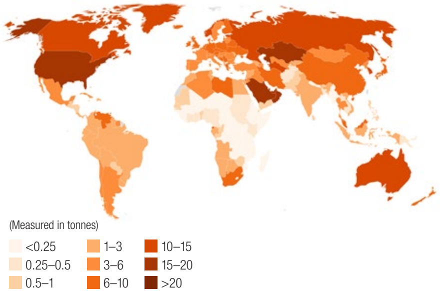

Fig 2: Comparing climate equity, CO_2 per person
[Carbon Map, 2016]

climate change

political

destabilisation

how are you connected?

climate change

political

In 2014, an average of 36 people per minute, 19.3m from 100 countries, were displaced from their homes due to weather-related and geophysical hazards. —iDMC (2015)

ARUP

destabilisation

Destabilisation is the imbalancing of functioning civil, national and social systems; climate change-related conditions can generate resource shortages, conflicts and mass migrations that contribute to and accelerate instability. Desert and mountainous regions are particularly susceptible to conflicts stemming from changes in water and food supply, as well as from weaknesses in energy infrastructure. Effects of such conflicts can worsen living conditions for populations already under stress, further compounding destabilisation.

Destabilisation due to natural disasters continues to increase. Between 2008 and 2014, 72,500 people on average were displaced each day (Fig 1). Forced human migration has global-scale effects, as these populations tend to relocate into unfamiliar regions. The risk of instability and consequent displacement is greatest in regions where national and civil institutions are less able to manage climate and disaster impacts. Natural disasters in China, India and the Philippines accounted for 15 of the 20 largest displacements in 2014 (Fig 2). While there can be positive economic aspects to refugee influx, the large-scale presence of refugees places heavy burdens upon receiving communities.

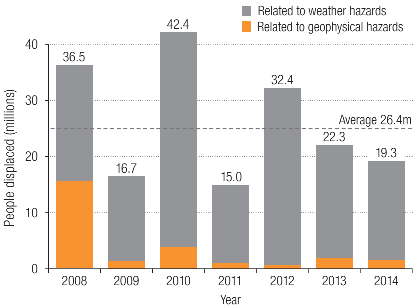

Fig 1: Disaster induced displacement, 2008–2014
[iDMC, 2015]

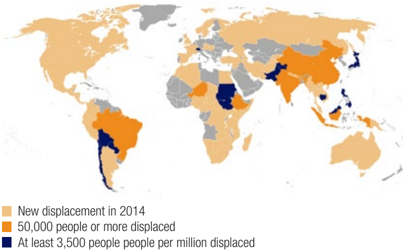

Fig 2: Disaster induced displacement by country
[iDMC, 2015]

emission targets

do you know yours?

climate change

political

In 2015, 177 nations became signatories to the UN COP21 Paris Agreement. Twice as many as the Kyoto Protocol at COP3 in 1997. —United Nations (2016)

ARUP

emission targets

Emission targets establish greenhouse gas (GHG) reduction goals, often in terms of dates and percentage reduction below past GHG levels (Fig 1). Many emission targets are voluntary and not legally binding; Buenos Aires, Cape Town, Melbourne, and San Francisco have all voluntarily set ambitious reduction trajectories. Even past treaties that appear legally binding, such as the 1997 Kyoto Protocol, have allowed signatory countries to exit their agreements (e.g. Canada); viewed in this light, Kyoto was essentially a voluntary treaty. Voluntary goals can be quite effective: most Kyoto signatory countries met and in some cases exceeded their emission targets from 2008 to 2012.

The challenge of making progress towards and ultimately achieving an emissions target can vary by scale and compliance mechanism (Fig 2). Bhutan committed to the most ambitious emission targets at COP21 in Paris. Bhutan's forests sequester 6.4m tonnes of CO_2 each year; as the country only emits 2.2m tonnes annually, it is at present carbon negative. Most countries produce significantly greater emissions and have fewer natural carbon sinks, and thus must resort to tougher enforcement mechanisms, including complex energy regulations.

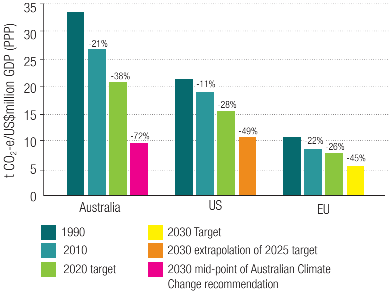

Fig 1: Comparing emission targets for 1990–2030
[Australian Government, 2015]

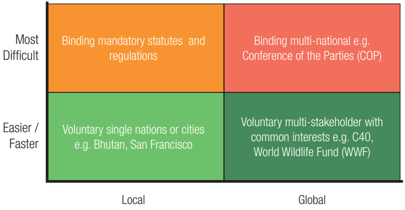

Fig 2: Emission target examples: from local to global; from easier to most difficult
[Arup, 2016]

governance

who will take the lead?

climate change

political

45% of cities set and enforce their own climate action policies, putting them in a unique position to take effective action. As cities are responsible for 70% of total greenhouse gas emissions, urban policy changes can have a profound global impact. —C40 (2015) and Nature (2012)

governance

Governments seeking to effectively legislate climate action face a fundamental challenge: greenhouse gases (GHG) know no boundaries. Nations emit varying levels of GHG into the atmosphere, yet the adverse impacts of these emissions on the ecosystem are felt by all.

While national governments can regulate large-scale emissions from industry and vehicles, cities are increasingly leading climate action commitments (Fig 1). Climate change solutions often emerge at a city level prior to their national or regional adoption.

Cities can effect change through service operation, funding access, policy development, and goal promotion (Fig 2). Research shows that how cities use their power and resources is more important than their actual ownership of assets or functions. Cities are the front line on deployment of transportation systems, management of population density, and enforcement of building performance standards. Cities with shorter mayoral terms, directly elected mayors, and non-hierarchical structures tend to be more successful in delivering climate action. Tokyo emits 55% less carbon per capita than Japan at large, as does Rio de Janeiro (72% fewer emissions) when compared to Brazil at large.

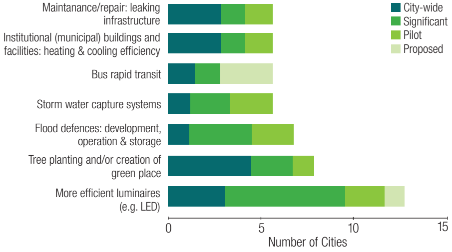

Fig 1: City actions to reduce emissions and mitigate climate change
[C40, 2015]

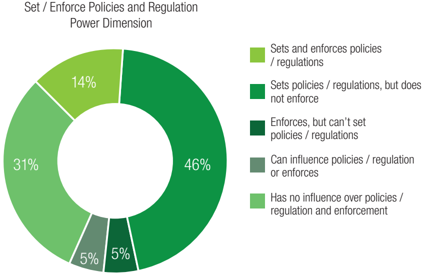

Fig 2: Cities' ability to set, enforce policies and regulation
[C40, 2015]

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