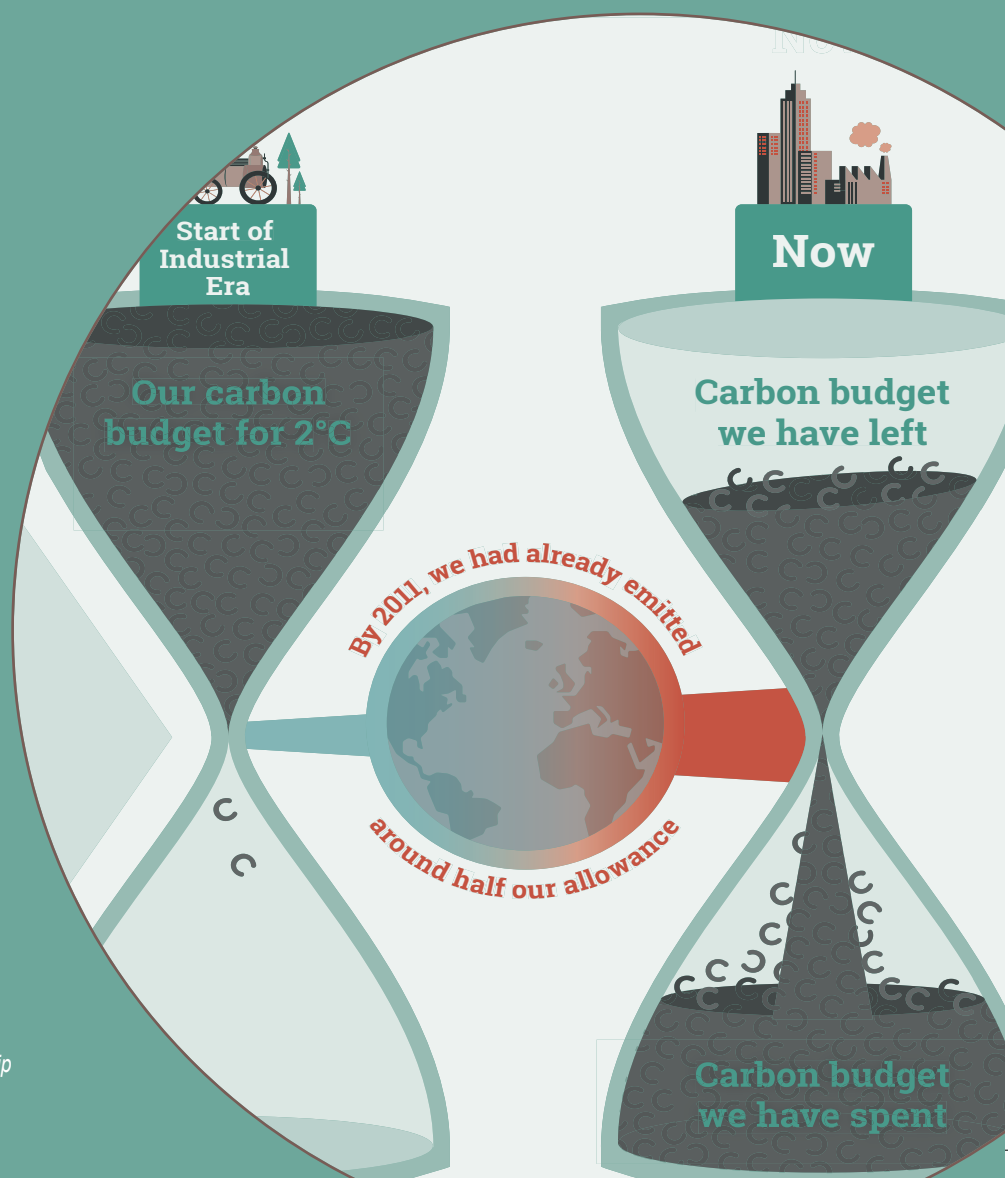


# CLIMATE CHANGE: ACTION, TRENDS AND IMPLICATIONS FOR BUSINESS

The IPCC's Fifth Assessment Report, Working Group 1



UNIVERSITY OF  
CAMBRIDGE

Cambridge Judge Business School  
Cambridge Programme for Sustainability Leadership

# ABOUT THIS DOCUMENT

The Fifth Assessment Report (AR5) from the Intergovernmental Panel on Climate Change (IPCC) is the most up-to-date, comprehensive and relevant analysis of our changing climate.

This document is the second in a series that will synthesize the most pertinent findings of AR5 for specific economic and business sectors. It was born of the belief that businesses could make more use of AR5, which is long and highly technical, if it were distilled into accurate, accessible, timely, relevant and readable summaries.

Although the information presented here is a 'translation' of the AR5's first instalment - *Climate Change 2013: The Physical Science Basis* - it adheres to the rigorous scientific basis of the original source material.

The basis for information presented in this overview report can be found in the fully-referenced and peer-reviewed IPCC technical and scientific background reports at: [www.climatechange2013.org](http://www.climatechange2013.org) and [www.ipcc.ch](http://www.ipcc.ch)

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*Disclaimer:*

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*This family of summaries is not meant to represent the entirety of the IPCC's Fifth Assessment Report (AR5) and they are not official IPCC documents. The summaries have been peer-reviewed by experts both from the business and science communities. The English version constitutes the official version.*

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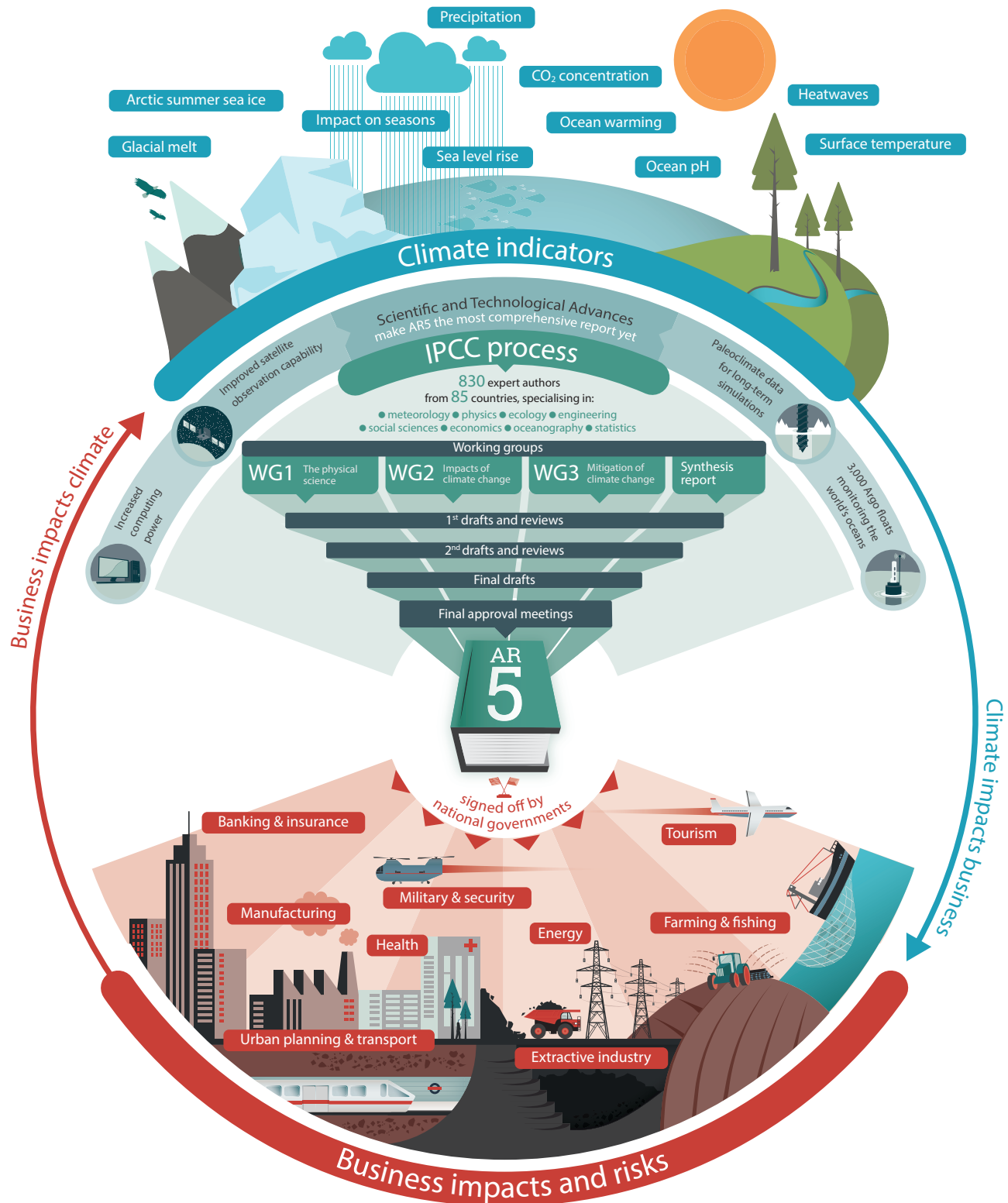
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## The process behind the Fifth Assessment Report (AR5) of the UN's Intergovernmental Panel on Climate Change (IPCC)



## ABOUT AR5

The Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) is the most detailed assessment of climate change ever. It is based on more data, contains more detailed regional projections and is more confident about its conclusions than any global assessment to date. Its contents are highly relevant to business for two reasons: it informs businesses about constraints likely to materialize in the future, for example around natural resources such as water; and governments will use it as a basis for policy-making in areas likely to impact businesses.

AR5 is to be released in several parts through 2013 and 2014. The first - *Climate Change 2013: The Physical Science Basis* - assesses changes observed in the physical environment, factors likely to be driving them, and how different aspects of climate are projected to change by the end of the century under a number of different scenarios for how greenhouse gas emissions could evolve.

Scientific knowledge has increased markedly since the IPCC's Fourth Assessment Report (AR4) was released in 2007, and has strengthened the basis for identifying human activities as the primary driver of climate change.

## KEY FINDINGS

- › Human activities, particularly emissions of carbon dioxide, are causing a **sustained and unequivocal rise in global temperatures**. Despite a very recent slowdown in the rate of rise (thought by AR5 scientists to be due to a number of natural factors), the overall picture is one of continued warming.
- › The rise in global temperatures is causing changes in all geographical regions: **the atmosphere and oceans are warming, the extent and volume of snow and ice are diminishing, sea levels are rising and weather patterns are changing**. Many changes are unprecedented over decades to millennia.
- › **Climate models project continued changes** under a range of possible greenhouse gas emission scenarios over the 21st century. If emissions continue to rise at the current rate, impacts by the end of the century are projected to include a global average temperature 2.6-4.8 degrees Celsius (°C) higher than

*"Each of the last three decades has been successively warmer at the Earth's surface than any other preceding decade since 1850." IPCC, 2013*



present<sup>1</sup>, sea levels 0.45-0.82 metres (m) higher than present and disruption to weather patterns. There is also at least a two-thirds chance of a nearly ice-free Arctic Ocean in summer before mid century.

- › To have a better than two-thirds chance of limiting warming to less than 2°C from pre-industrial levels (**see box on 2°C Target**), the total cumulative carbon dioxide emission from all human sources since the start of the industrial era would need to be limited to about **1,000 gigatonnes of carbon**. About half of this amount had already been emitted by 2011.
- › **Even if emissions are stopped immediately, temperatures will remain elevated for centuries** due to the effect of greenhouse gases from past human emissions already present in the atmosphere. Past, present and future emissions of carbon dioxide represent a substantial multi-century climate change commitment.
- › Limiting temperature rise will require **substantial and sustained reductions** of greenhouse gas emissions.



### 2°C TARGET

To prevent the most severe impacts of climate change, in December 2010, parties to the UN Framework Convention on Climate Change (UNFCCC) agreed to commit to a maximum temperature rise of 2°C above pre-industrial levels, and to consider lowering that maximum to 1.5°C in the near future.

The implication of the AR5 findings is that limiting global temperature rise to 2°C from pre-industrial times requires substantial and sustained global reductions of greenhouse gas emissions.

<sup>1</sup>In this context 'present', is defined as the average for 1986-2005.



## CLIMATE CHANGE

Natural and human factors drive climate change by altering the Earth's energy budget. At present there is a net uptake of the Sun's energy by the Earth system; that is, more energy is entering the Earth system than is being lost back to space. The outcome is an increase in heat energy stored by the Earth. This imbalance is driving the rise in global temperature. AR5 concludes that over 90% of the excess heat is stored in the ocean.



## LIMITING WARMING

AR5 concluded that the total cumulative carbon dioxide emissions since the start of the industrial era would need to be limited to about 1,000 gigatonnes of carbon for emissions from human activities to result in a maximum warming of less than 2°C relative to pre-industrial levels (*see box on 2°C Target on Page 5*). Because about half of this amount had already been emitted by 2011, a significant proportion of climate change is probably irreversible on a human timescale.

The implication of the AR5 findings is that any delay in moving to an emissions pathway consistent with the 2°C warming target is likely to increase the size of emission reductions required in the future. In the real world, however, reductions in emissions take time and there are limits to how fast emissions can be brought down. Postponing emission reductions may make it impossible to meet the internationally agreed 2°C target.



# WHAT CLIMATE CHANGE MEANS FOR BUSINESS

Climate change is a continuing issue for business, governments and all of society. The first instalment of the IPCC's AR5, *Climate Change 2013: The Physical Science Basis*, sets the scientific picture and assesses how the physical environment could change by the end of the century under a range of greenhouse gas emission scenarios. Rising temperatures, rising sea levels, changes in rainfall patterns, disappearing glaciers and acidifying seawater will have direct impacts on some business sectors. The future as seen through the different **RCP scenarios** (see box on Page 11) depends on action to curb greenhouse gas emissions. The less policies change, the greater the climate impacts will be. Major policy change, however, will bring different sets of impacts for business.

The next instalments of AR5, due in March and April 2014, provide the information

businesses need to respond to the costs and opportunities associated with a changing climate. The Working Group 2 (**WGII**) report assesses the impacts of climate change for the economy, the environment and the global population; the **WGIII** report addresses options to mitigate climate change by either cutting greenhouse gas emissions, or by enhancing activities that remove emissions from the atmosphere.



*"Limiting climate change will require substantial and sustained reductions of greenhouse gas emissions." IPCC, 2013*

# PAST & PRESENT CLIMATE CHANGE

Observations, theoretical studies and model simulations indicate an overall warming since the mid-20th century. It is at least 95% certain<sup>2</sup> that human activities have caused more than half of the temperature increase since the 1950s. This warming is responsible for climate change effects worldwide. There is strong evidence that many of the changes taking place within the atmosphere, land, ocean, snow and ice systems (**see Page 9**) are unprecedented over decades to millennia.

The rising levels of greenhouse gases (particularly carbon dioxide) from the burning of fossil fuels and land-use changes (such as deforestation) are in large part driving warming. Natural processes (like changes in solar activity) are responsible for only a very small proportion of recent temperature changes.

Human-driven climate change may be affected by feedbacks within the climate system itself. This is especially the case in the Arctic, where temperatures are rising faster than in any other region.

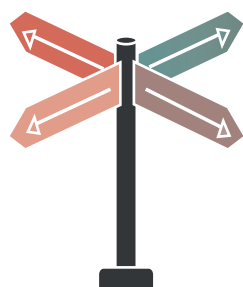
*"It is extremely likely that human influence has been the dominant cause of the observed warming since the mid-20th century." IPCC, 2013*

<sup>2</sup>Certainty has increased from at least 90% certain to at least 95% certain since the IPCC's Fourth Assessment Report (AR4) was released in 2007.

## OBSERVED CHANGES

- › Air temperatures at the land and ocean surfaces are now higher than 100 years ago across almost the entire globe, and the past three decades are warmer than any decade since 1850. Between 1880 and 2012, globally averaged temperatures increased by 0.85°C.
- › Ocean surface waters are much warmer than 100 years ago. The warming is greatest in the upper waters. The upper layer of the ocean is warming at about 0.1°C per decade.
- › The past 50 years have seen changes in many extreme weather and climate events. Some areas are experiencing more heatwaves and/or more heavy rainfall events. Regional trends vary widely.
- › With few exceptions, glaciers worldwide are shrinking. This is also the case for the massive Greenland and Antarctic ice sheets, particularly over the past two decades. The rate of ice loss is increasing.
- › Both the extent and thickness of Arctic sea ice have decreased over the past three decades. It is at least 90% certain that the area covered by sea ice shrank 3.5-4.1% per decade in the period 1979-2012. The particularly rapid retreat in summer sea ice - 9.4-13.6% per decade - may be unparalleled in the past ~1500 years. In contrast, there has been a small overall increase in Antarctic sea ice.
- › The area covered by snow in the Northern Hemisphere each year has shrunk over the past 50 years, especially in spring. Permafrost is thawing in most regions.
- › The Arctic has become substantially warmer over the past 50 years.
- › Global mean sea level rose 0.19 m over the period 1901-2010. The main causes of sea level rise over the past 50 years are ocean warming (water expands as it warms) and melting glaciers and ice sheets. The rate at which global mean sea level is rising has accelerated over the past 200 years.
- › Atmospheric levels of the main greenhouse gases (carbon dioxide, methane, nitrous oxide) have all risen since the start of the industrial era (~1750). By 2011, these greenhouse gases had exceeded pre-industrial levels by about 40%, 150% and 20%, respectively. Current levels are unprecedented in at least the last 800,000 years.
- › The oceans have absorbed about 30% of the carbon dioxide emitted by human activities to date. This is causing ocean acidification.

# FUTURE CLIMATE CHANGE



*Climate Change 2013: The Physical Science Basis* presents a series of near-term and long-term projections of human-induced climate change. These are based on results from complex computer models

developed and operated independently at a large number of research centres around the world. AR5 uses four scenarios to illustrate how the climate is likely to change over the century, depending on future levels of greenhouse gas emissions (**see box on RCP scenarios**). These projections cover changes at the global and regional level and include estimates of how likely the changes are to occur.

Climate change over the next few decades is largely governed by levels of greenhouse gases already in the atmosphere. The amount of mitigation action assumed in scenarios has little impact in the near-term.

In contrast, the trajectory of greenhouse gas emissions (which mainly depends on policy choices made by governments) has a major impact on climate change projected for the mid-21st century and onwards. Although the results from the climate models vary, they all indicate that emissions at or above current

rates would cause changes in all parts of the climate system, some unprecedented in thousands of years. The changes would occur in all geographical regions, and many would continue for hundreds or thousands of years even if emissions were cut to zero.

There is some debate as to whether human influence could trigger an abrupt change in climate, or even force parts of the climate system across critical thresholds or 'tipping points', causing irreversible change. Although scientific studies suggest such events are possible, there is little agreement on how likely they are in the 21st century or what the human consequences would be.



## WARMING SCENARIOS

The rise in global average surface temperature at the land and ocean surface by the end of the 21st century relative to the pre-industrial period is likely to exceed 1.5°C for all **RCP** scenarios except **RCP2.6**. It is likely to exceed 2°C for **RCP8.5** and **RCP6.0**, and more likely than not to exceed 2°C for **RCP4.5**. It is unlikely to exceed 2°C for **RCP2.6**. Warming will continue beyond 2100 under all **RCP** scenarios except **RCP2.6**.



## RCP SCENARIOS

The scenarios of human influence underlying the AR5 projections are known as **RCPs** (Representative Concentration Pathways), because they are expressed in terms of greenhouse gas concentrations (the result of emissions) rather than emission levels. Each **RCP** implies a different amount of human-driven climate change (i.e., each **RCP** results in a different amount of extra heat energy being stored in the Earth system as a result of greenhouse gas emissions). The scenarios are developed using assumptions concerning economic growth, choices of technology and land-use. The scenarios reflect a wide range of possible mitigation actions.

**RCP8.5** assumes a 'business-as-usual' approach. By 2100, atmospheric concentrations of CO<sub>2</sub> are three to four times higher than pre-industrial levels.

**RCP6.0** (medium-high) and **RCP4.5** (medium-low) assume some action to control emissions. These are stabilization scenarios. In **RCP4.5**, CO<sub>2</sub> emissions fall below current levels by 2070 and atmospheric concentrations stabilize by the end of the century at about twice those of the pre-industrial period. In **RCP6.0**, CO<sub>2</sub> emissions continue rising until about 2080; concentrations take longer to stabilize and are about 25% higher than for **RCP4.5**.

**RCP2.6** assumes 'aggressive' mitigation strategies that cause global greenhouse gas emissions to start decreasing after about a decade and to reach near zero levels around 60 years from now. This scenario is unlikely to exceed a 2°C increase in global mean temperature since pre-industrial times.

The number associated with the **RCP** indicates the strength of human-driven climate change by 2100 relative to the pre-industrial period.

# CHANGES PROJECTED FOR THE 21ST CENTURY

- › Depending on the size of emission cuts, the rise in global mean surface temperature in the atmosphere at land and ocean surfaces by the end of the 21st century<sup>3</sup> is more than two-thirds certain to be in the ranges 2.6-4.8°C (**RCP8.5**), 1.4-3.1°C (**RCP6.0**), 1.1-2.6°C (**RCP4.5**), and 0.3-1.7°C (**RCP2.6**).
- › Warming is projected to be greater over land than sea. The Arctic is projected to warm much faster than the global average.
- › It is virtually certain that by the end of the 21st century there will be more unusually hot and fewer unusually cold days almost everywhere. Longer and more frequent heatwaves are more than 90% certain, although unusually cold winters may still occur from time to time.
- › As a generalization, dry areas will become drier and wet areas wetter. Extreme rainfall events are more than 90% certain to become stronger and more frequent in the mid-latitudes and wet tropical areas. It is more than two-thirds certain that the area covered by monsoon systems will get bigger, monsoon rainfall will get stronger, and the monsoon period will get longer. Drought projections are more uncertain.
- › The ocean is projected to warm under all **RCP scenarios**. The strongest warming is projected for surface waters in tropical and Northern Hemisphere sub-tropical regions. In some regions, warming in the top hundred metres could exceed 2.0°C (**RCP8.5, a business-as-usual scenario**) to 0.6°C (**RCP2.6**).

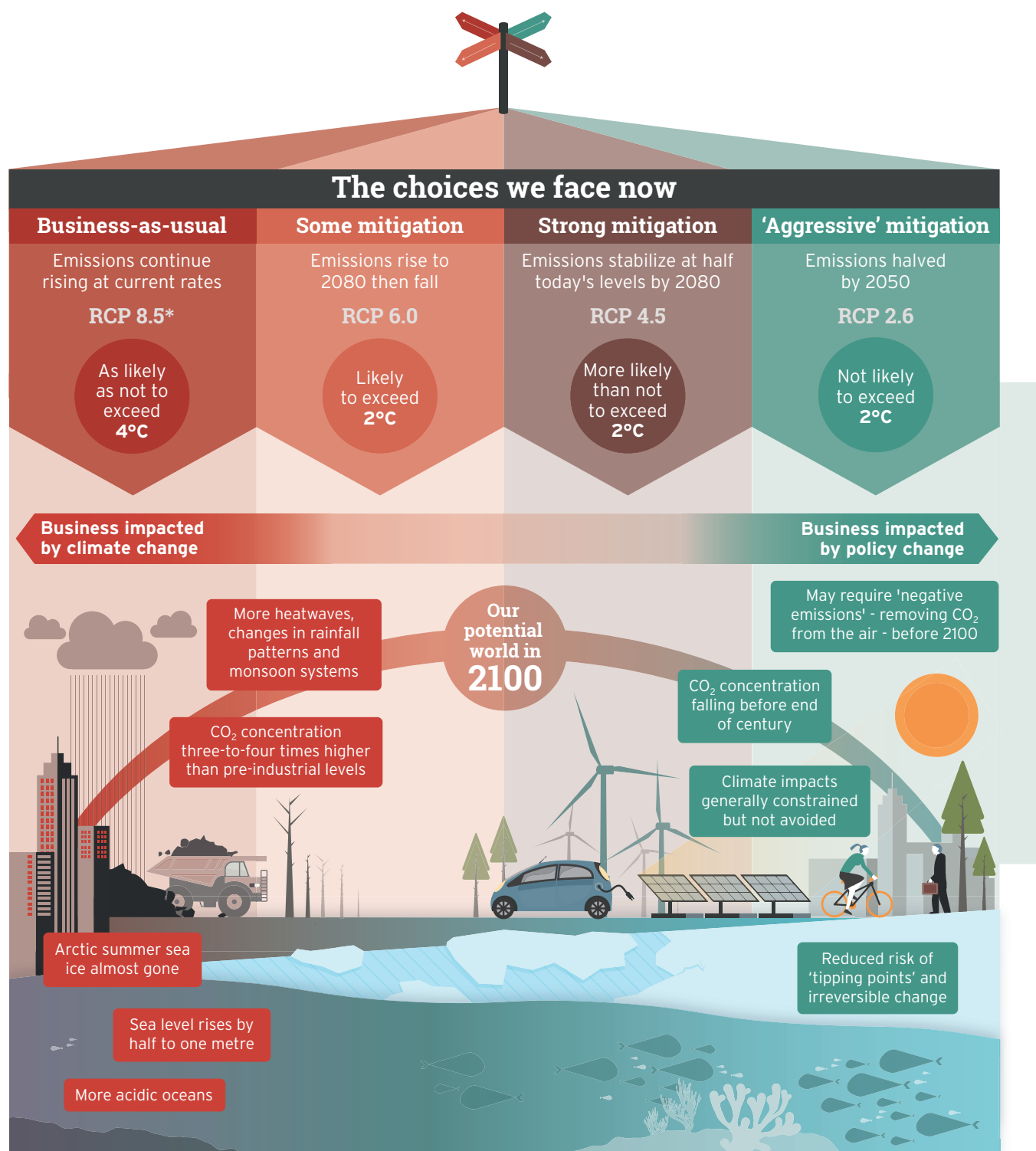
<sup>3</sup>Projected temperature changes are for the period 2081-2100 compared with 1986-2005.

# CHANGES PROJECTED FOR THE 21ST CENTURY

- › Arctic sea ice cover is more than 90% certain to continue shrinking and thinning. Depending on the size of emission cuts, average reductions in sea-ice extent in summer by the end of the 21st century could range from 94% (**RCP8.5**) to 43% (**RCP2.6**). Winter reductions are projected to be lower, ranging from 34% (**RCP8.5**) to 8% (**RCP2.6**). There is a more than two-thirds chance of a nearly ice-free Arctic Ocean in summer before the mid-21st century under **RCP8.5**.
- › Glacier volume is projected to decrease under all scenarios. Net ice loss by 2100 could range from 35-85% (**RCP8.5**) to 15-55% (**RCP2.6**).
- › In the Northern Hemisphere, the snow covered area is projected to continue shrinking. The decrease in spring snow coverage could range from 25% (**RCP8.5**) to 7% (**RCP2.6**). By the end of the 21st century, the area of near-surface permafrost could shrink by 81% (**RCP8.5**) to 37% (**RCP2.6**).
- › Global sea level is projected to continue rising this century. Sea level rise will not be uniform. Depending on the size of emission cuts, by the end of the 21st century the rise has a more than two-thirds chance of being in the ranges 0.45-0.82 m (**RCP8.5**), 0.33-0.63 m (**RCP6.0**), 0.32-0.63 m (**RCP4.5**) or 0.26-0.55 m (**RCP2.6**). The collapse of some sections of the Antarctic ice sheet could cause global sea level to rise substantially above these ranges during the 21st century.
- › Further uptake of carbon by the ocean will increase ocean acidification. Ocean acidification is projected to continue under all RCP scenarios, but to be more severe under high-emission scenarios.

# Carbon crossroads

The Intergovernmental Panel on Climate Change (IPCC) explores four potential futures depending what policies governments adopt to cut emissions



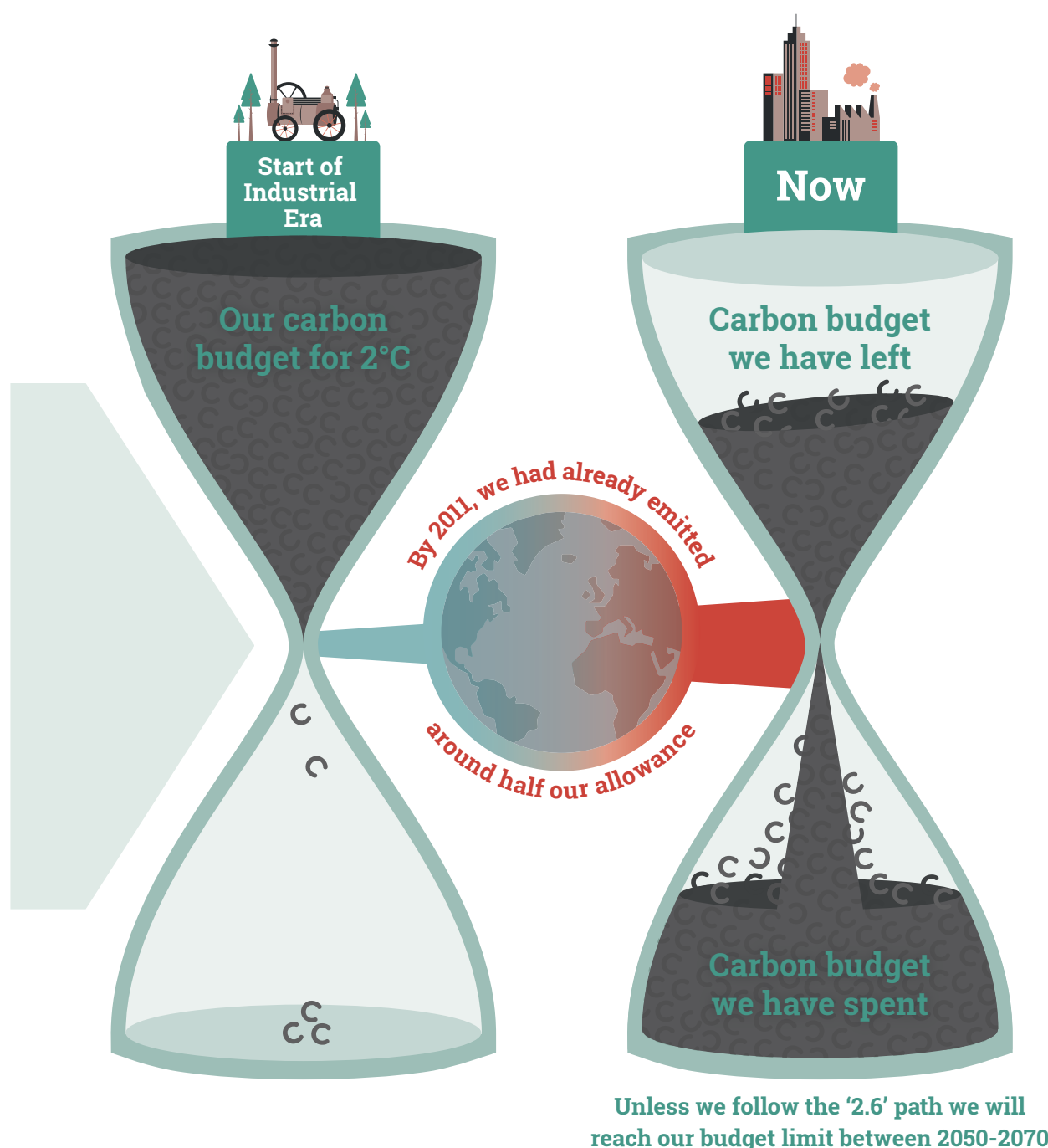
\*The four RCP (Representative Concentration Pathway) scenarios each project a certain amount of carbon to be emitted by 2100, and as a result lead to a different amount of human-driven climate change. Climate change will continue after 2100 and elevated temperatures will remain for many centuries after human CO<sub>2</sub> emissions cease.

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# The pathway to two degrees

Meeting the internationally agreed target of 2°C means spending what remains of our carbon budget wisely\*



\*To have a better than two-thirds chance of limiting warming to less than 2°C from pre-industrial levels, the total cumulative CO<sub>2</sub> emissions since the start of the industrial era would need to be limited to 1,000 gigatonnes of carbon. About half of this amount had already been emitted by 2011. The amount of carbon that can be released would be reduced if concentrations of non-CO<sub>2</sub> greenhouse gases continue to rise. Other factors (for example, the unexpected release of greenhouse gases from permafrost) could also tighten this 'carbon budget'.

For more information: [cpsl.cam.ac.uk](http://cpsl.cam.ac.uk)

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# GLOSSARY

## **Carbon dioxide**

A naturally occurring gas. It is also the main greenhouse gas released from human activities as a by-product of burning fossil fuels (oil, gas and coal), burning biomass, other industrial processes and land-use change.

## **Climate**

The average weather in a given location, averaged over long periods ranging from 30 years to thousands of years. In the wider sense, 'climate' refers to the state of the climate system.

## **Climate change**

Any significant change in climate that persists for an extended period, typically decades or longer.

## **Climate model**

A mathematical representation of the climate system, usually run on a computer. It is based on physical, chemical and biological properties of components of the climate system and their interactions, and is used to study and simulate elements of past, present and/or future climate.

## **Climate system**

The highly complex system comprising the atmosphere, hydrosphere (oceans, seas, rivers, lakes), cryosphere (snow, ice, frozen ground), land surface and biosphere (living organisms). It evolves over time in response to, among other things, volcanic eruptions, solar activity and changes in the composition of the atmosphere through greenhouse gas emissions from human activities.

## **Gigatonne**

1,000,000,000 metric tonnes.

## **Greenhouse gases**

Gases in the atmosphere, of natural and human origin, that absorb and emit thermal infrared radiation. Water vapour, carbon dioxide, nitrous oxide, methane and ozone are the main greenhouse gases in the Earth's atmosphere. Their net impact is to trap heat in the climate system.

## **Greenhouse gas emissions scenario**

A plausible representation of the future pathway of greenhouse gas emissions from human activities based on a set of assumptions, such as economic growth, choices of technology and changes in land-use.

## **Greenhouse gas emissions trajectory**

A projected development in time of greenhouse gas emissions from human activities.

## **Industrial Revolution**

The period of rapid industrial growth with far-reaching social and economic consequences, beginning in Britain around 1750 and spreading to Europe and later to other countries.

## **Mitigation**

Mitigation refers to efforts to reduce or prevent emission of greenhouse gases and can refer to the creation of 'carbon sinks', reservoirs that absorb and store carbon for an indefinite period.

## **Ocean acidification**

A decrease in the pH (i.e. an increase in the acidity) of sea water due to the uptake of carbon dioxide from the atmosphere.

## **Permafrost**

Ground that is frozen for two or more consecutive years.

## **Projection**

A potential future evolution of a quantity or set of quantities, often computed by a model. Projections involve assumptions that may or may not be realized, and are therefore subject to substantial uncertainty; they are not predictions.

## **Scenario**

A plausible and often simplified description of how the future may develop based on a set of assumptions about driving forces and key relationships.

*"Cumulative emissions of CO<sub>2</sub> largely determine global mean surface warming by the late 21st century and beyond. Most aspects of climate change will persist for many centuries even if emissions of CO<sub>2</sub> are stopped. This represents a substantial multi-century climate change commitment created by past, present and future emissions of CO<sub>2</sub>." IPCC, 2013*

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