UNIVERSITÄT LEIPZIG

# Decarbonizing the Global Energy Supply System: Options and Cost-effective Strategies

Annual Meeting of the German Physical Society, Erlangen, 6.3.2018

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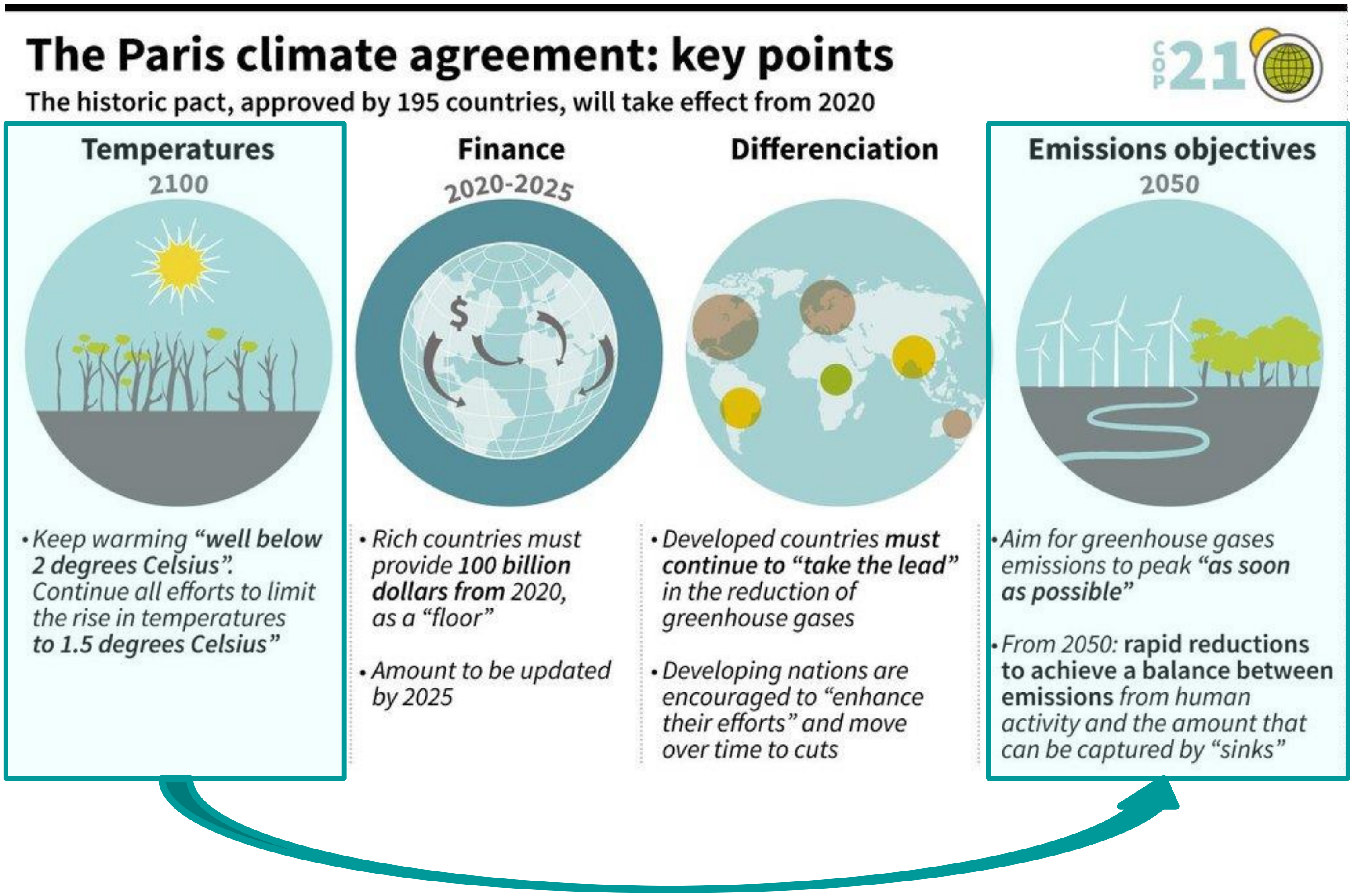
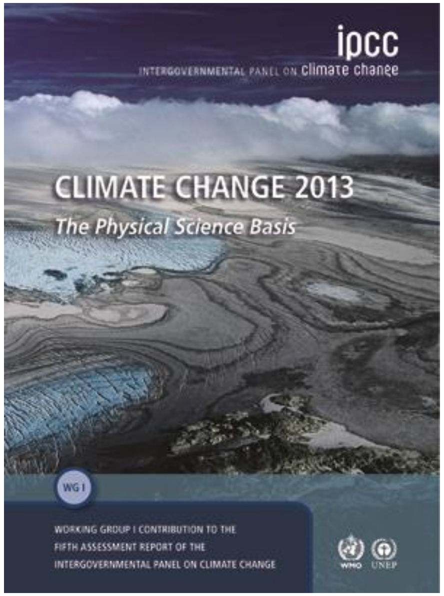
Chair for Energy Management and Sustainability, University of Leipzig
Director, Institute for Infrastructure und Resources Management – IIRM
Coordinating Lead Author of the Chapter on Energy Systems, WG III, IPCC AR5

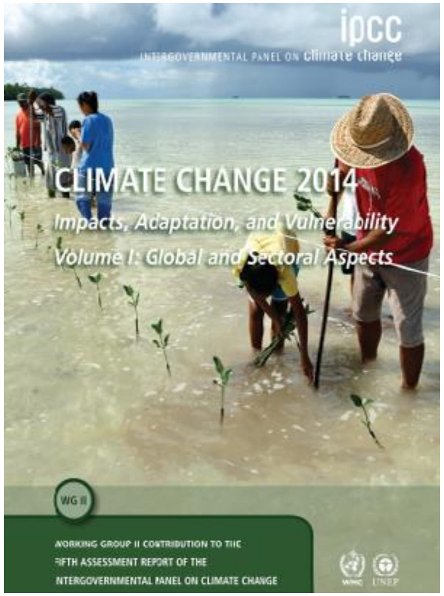
# UNFCCC COP 21 Paris



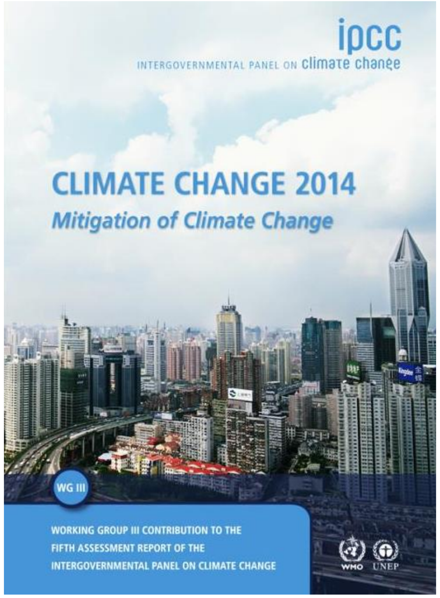
# The 5th IPCC Assessment Report: the threat of climate change and options to mitigate it




Working Group I:
Science of Climate Change




Working Group II:
Climate Impacts




Working Group III:
Mitigation

IPCC
INTERGOVERNMENTAL PANEL ON climate change

# CLIMATE CHANGE 2014

## *Mitigation of Climate Change*

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**Prof. Dr. Thomas Bruckner**

Coordinating Lead Author

Chapter “Energy Systems”



Working Group III contribution to the
IPCC Fifth Assessment Report


WMO UNEP

1 Summary for Policymakers

1 Technical Summary

16 Chapters

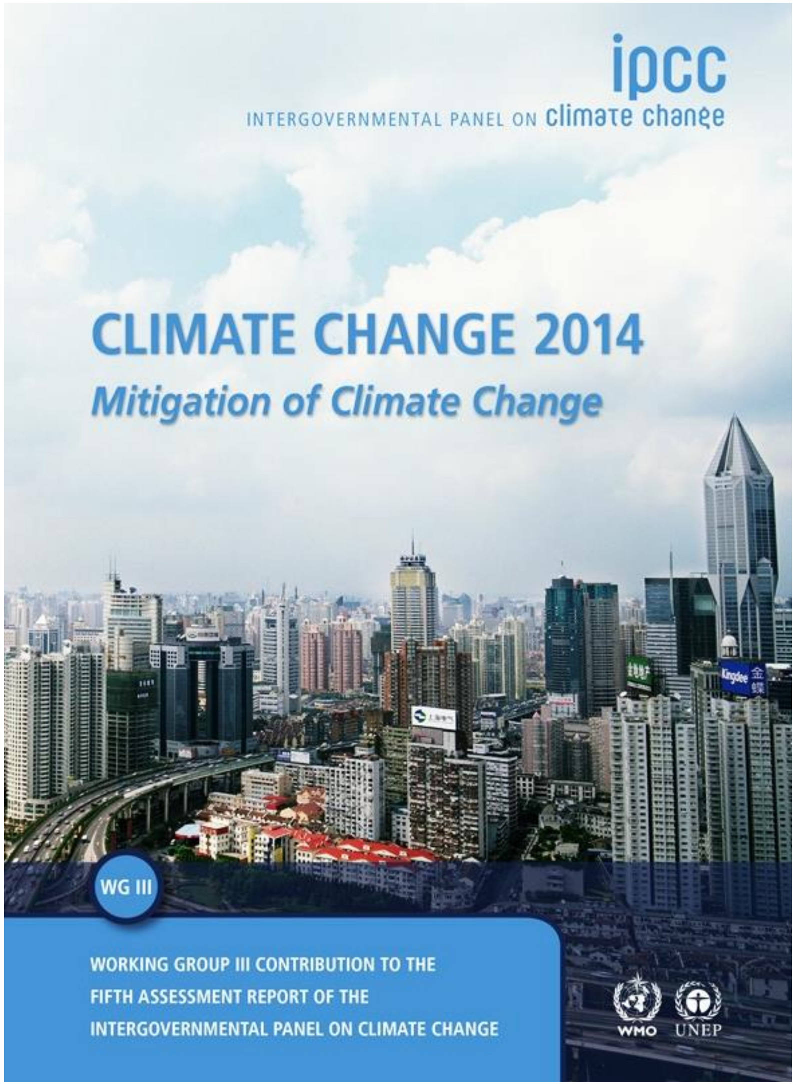
235 Authors

800+ Reviewers

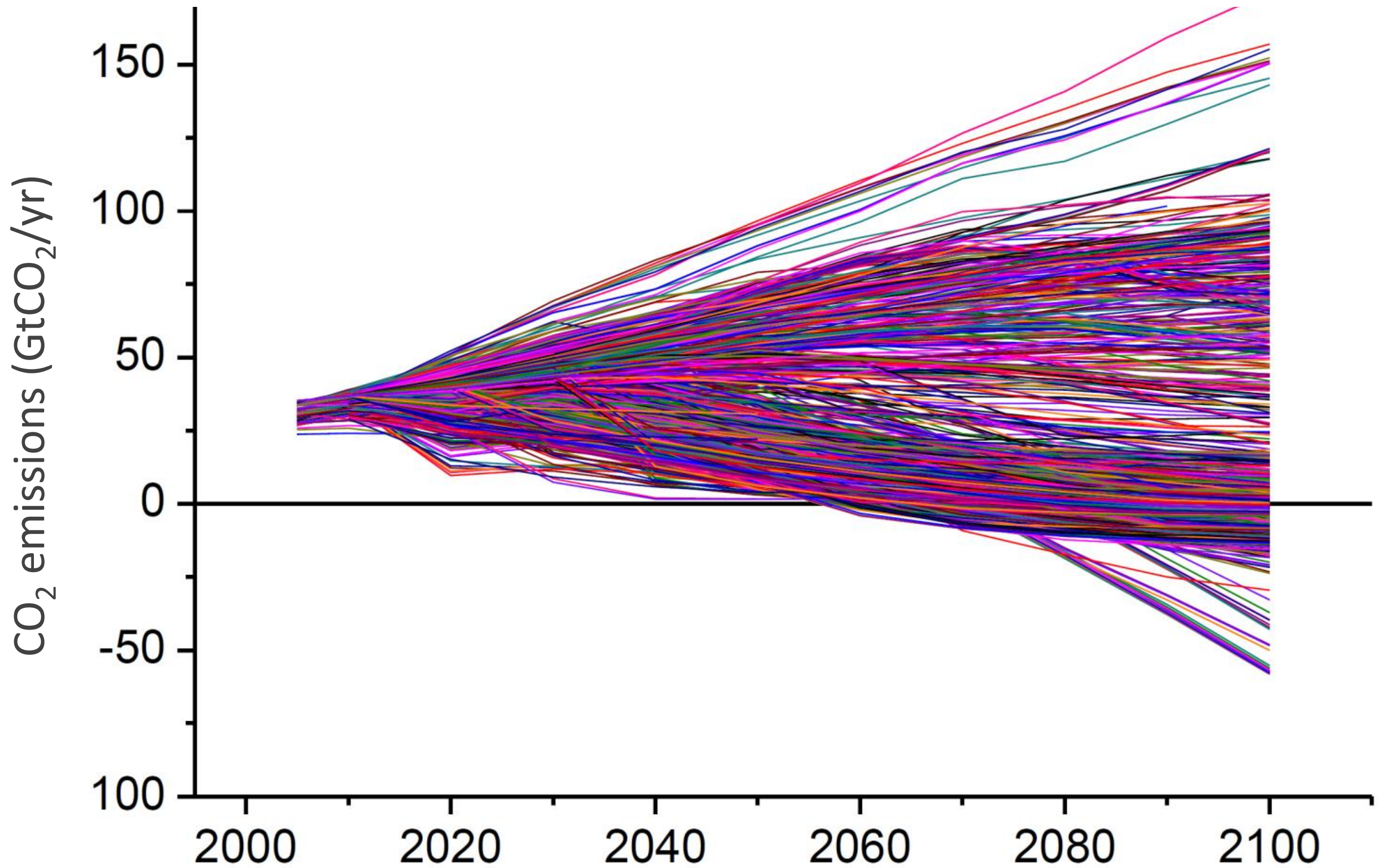
Close to 1500 pages

Close to 10,000 references

Database with 1200 scenarios

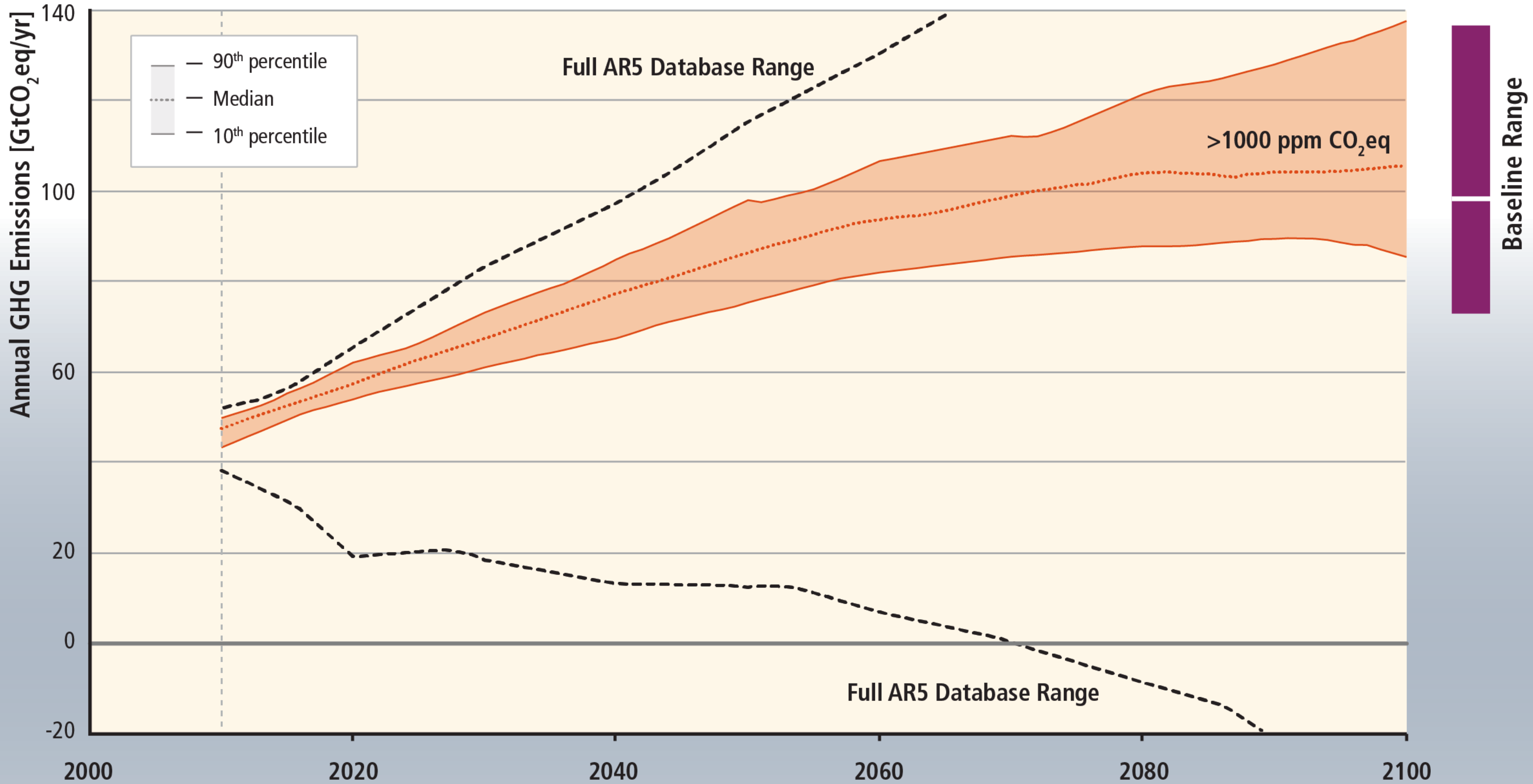


# The IPCC AR5 WG III scenario database



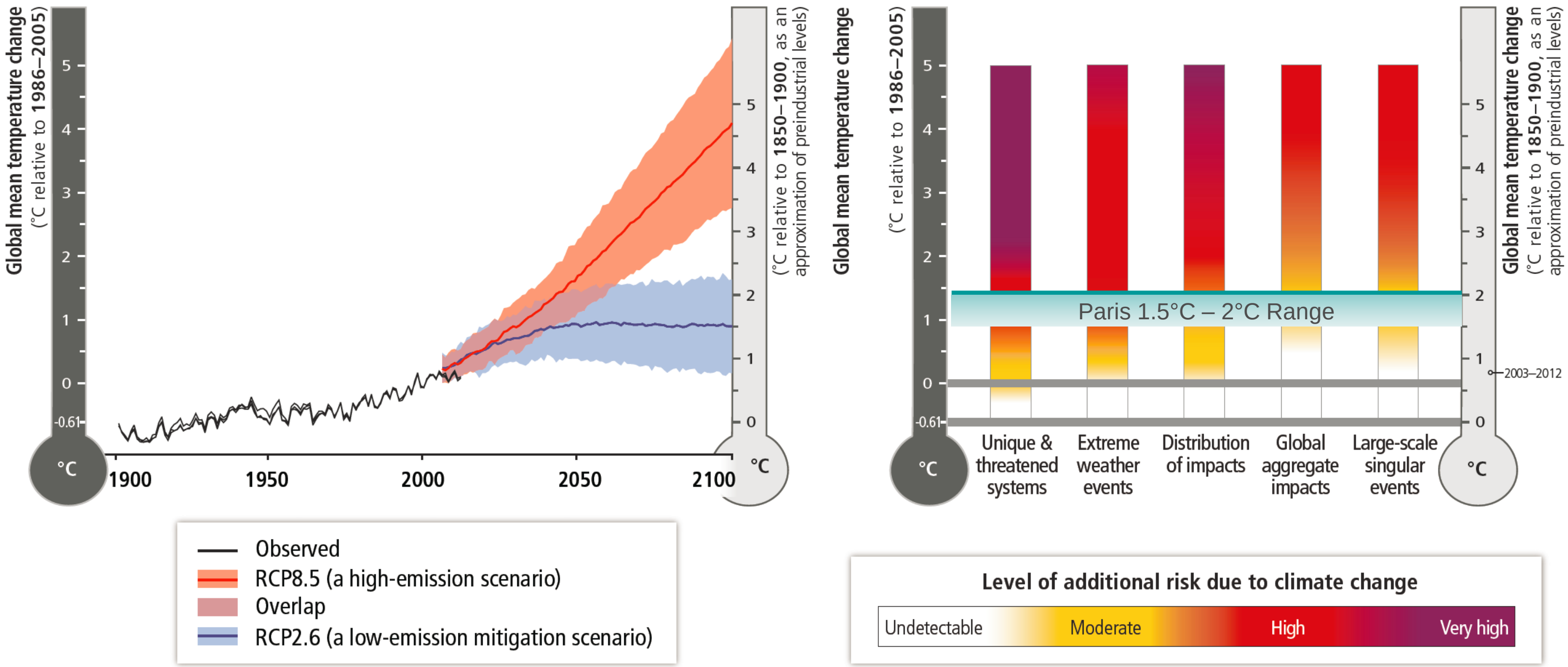

Source: D. van Vuuren, V. Krey: Transformation pathways and limiting warming to specific levels, notably a global mean warming of 2°C or 1.5°C relative to pre-industrial levels. http://unfccc.int/science/workstreams/the_2013-2015_review

# In the business-as-usual scenarios, greenhouse gas emissions and associated concentrations are expected to grow




Source: IPCC, AR 5, WG III, based on Figure 6.7

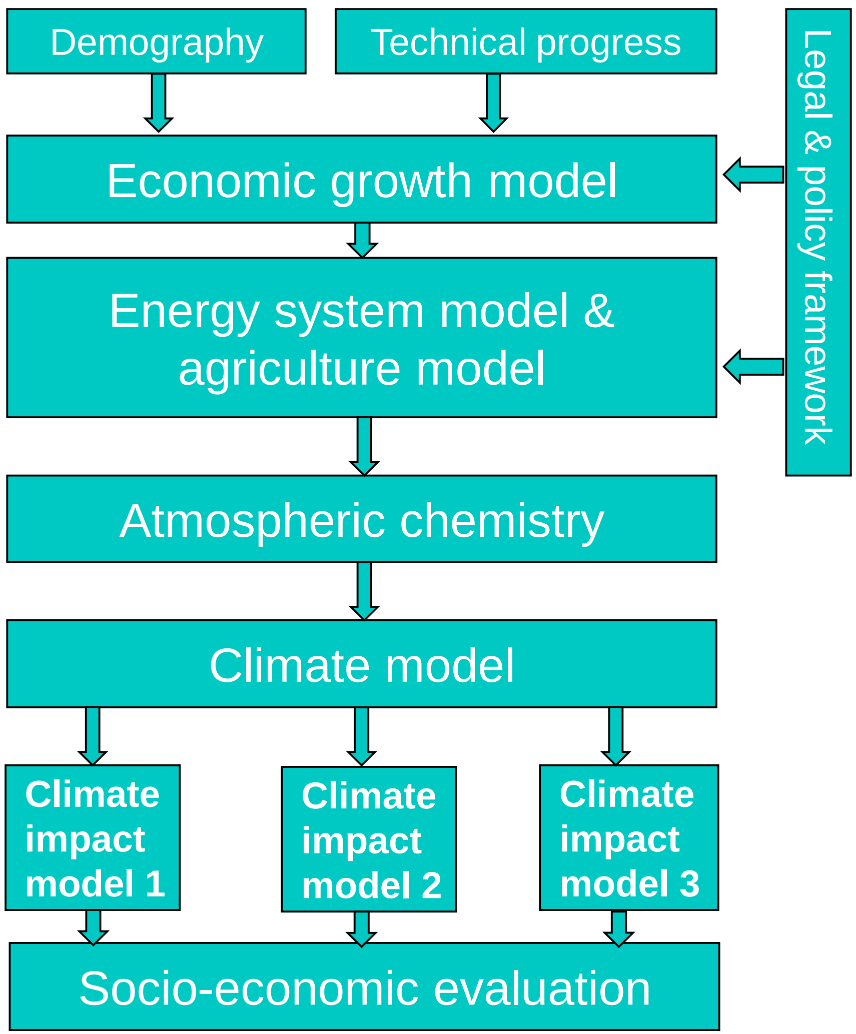
# Normative setting: limiting global climate change to stay below 2°C in order to avoid intolerable risks

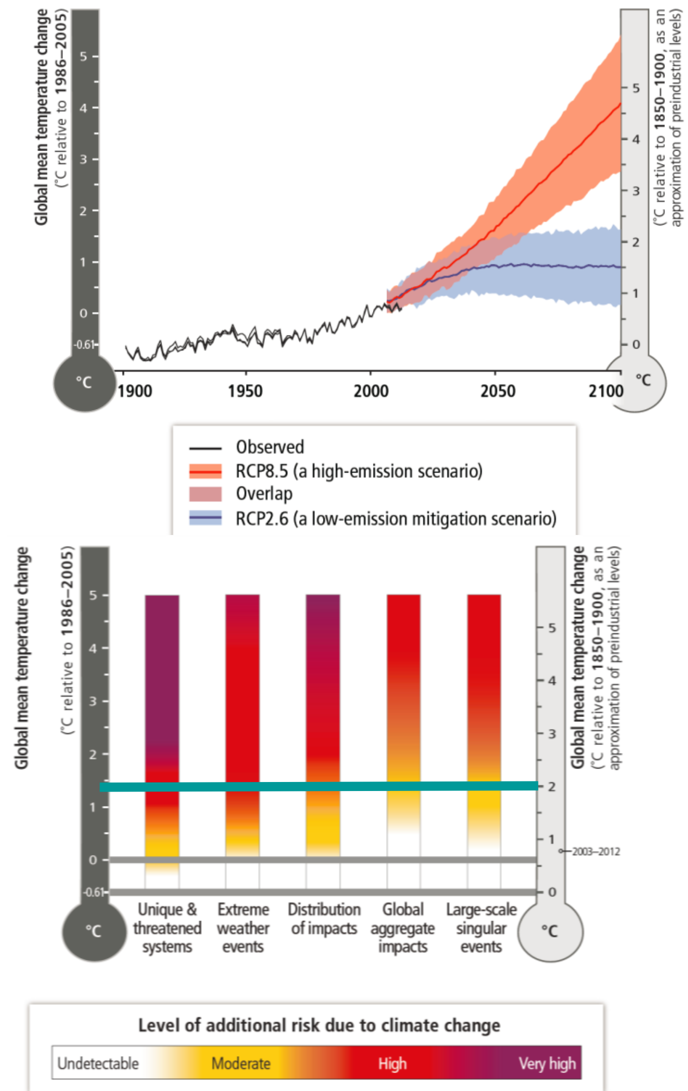



**Assessment Box WG2 SPM.1 Figure 1**: A global perspective on climate-related risks. Risks associated with reasons for concern are shown at right for increasing levels of climate change. The color shading indicates the additional risk due to climate change when a temperature level is reached and then sustained or exceeded. Undetectable risk (white) indicates no associated impacts are detectable and attributable to climate change. Moderate risk (yellow) indicates that associated impacts are both detectable and attributable to climate change with at least medium confidence, also accounting for the other specific criteria for key risks. High risk (red) indicates severe and widespread impacts, also accounting for the other specific criteria for key risks. Purple, introduced in this assessment, shows that very high risk is indicated by all specific criteria for key risks.

Source: IPCC, AR 5, WG II, SPM.1 Figure 1

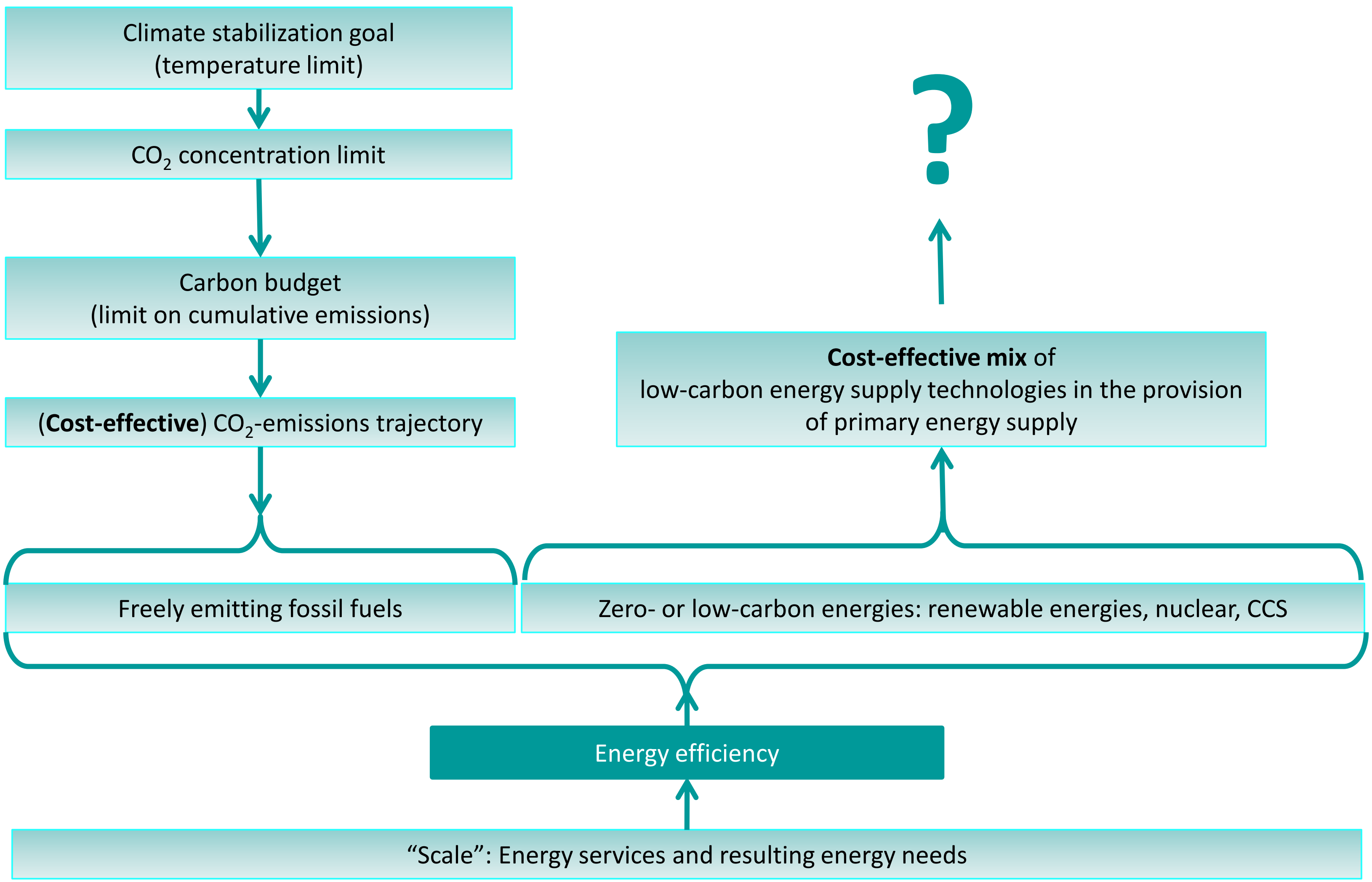
# Scenario analysis using integrated assessment (simulation-) models



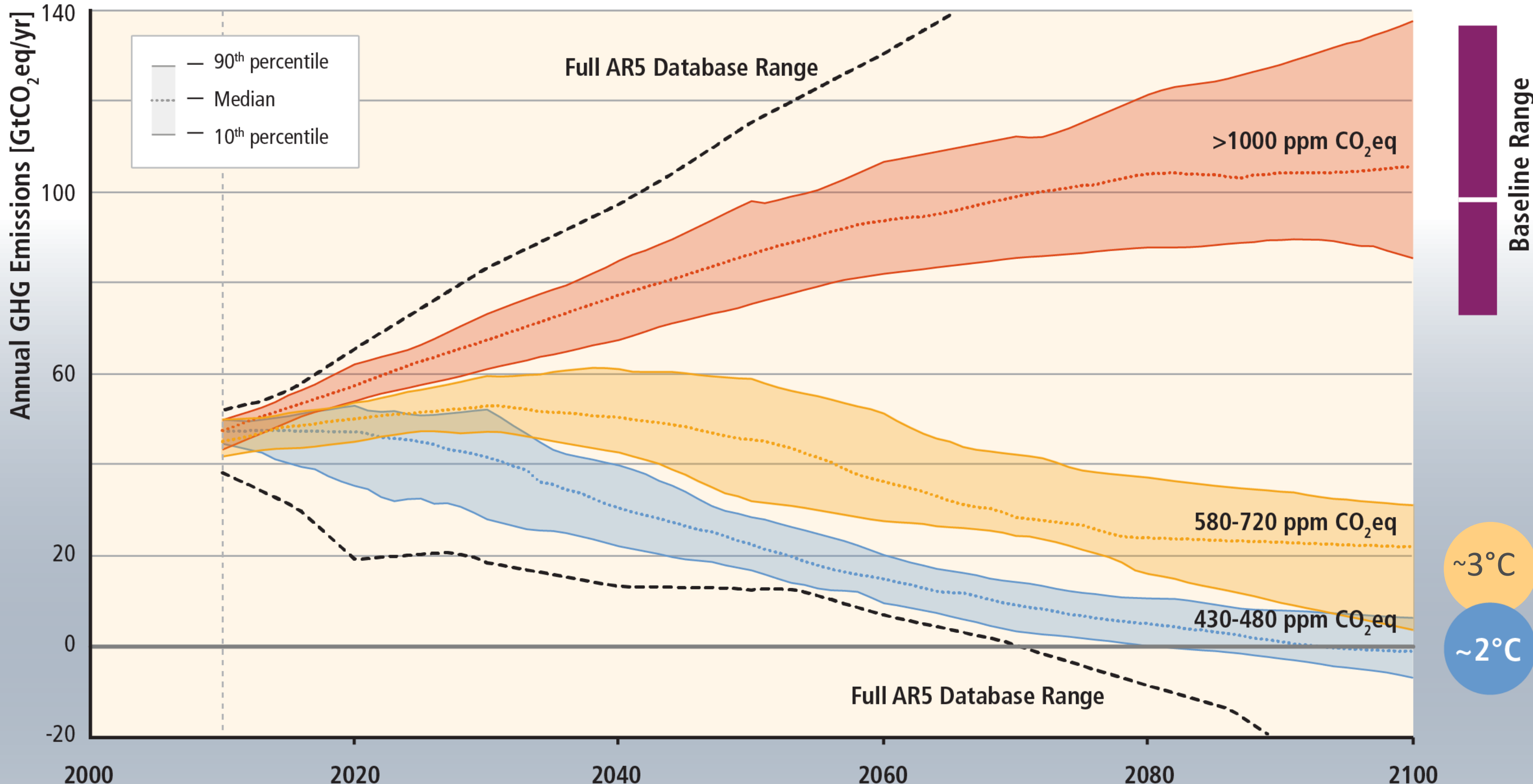

Source: Left-hand side: T. Bruckner, IIRM, Leipzig University, own illustration;
Right-hand side: IPCC, AR 5, WG II, SPM.1 Figure 1

# Low-carbon energy supply and climate change mitigation



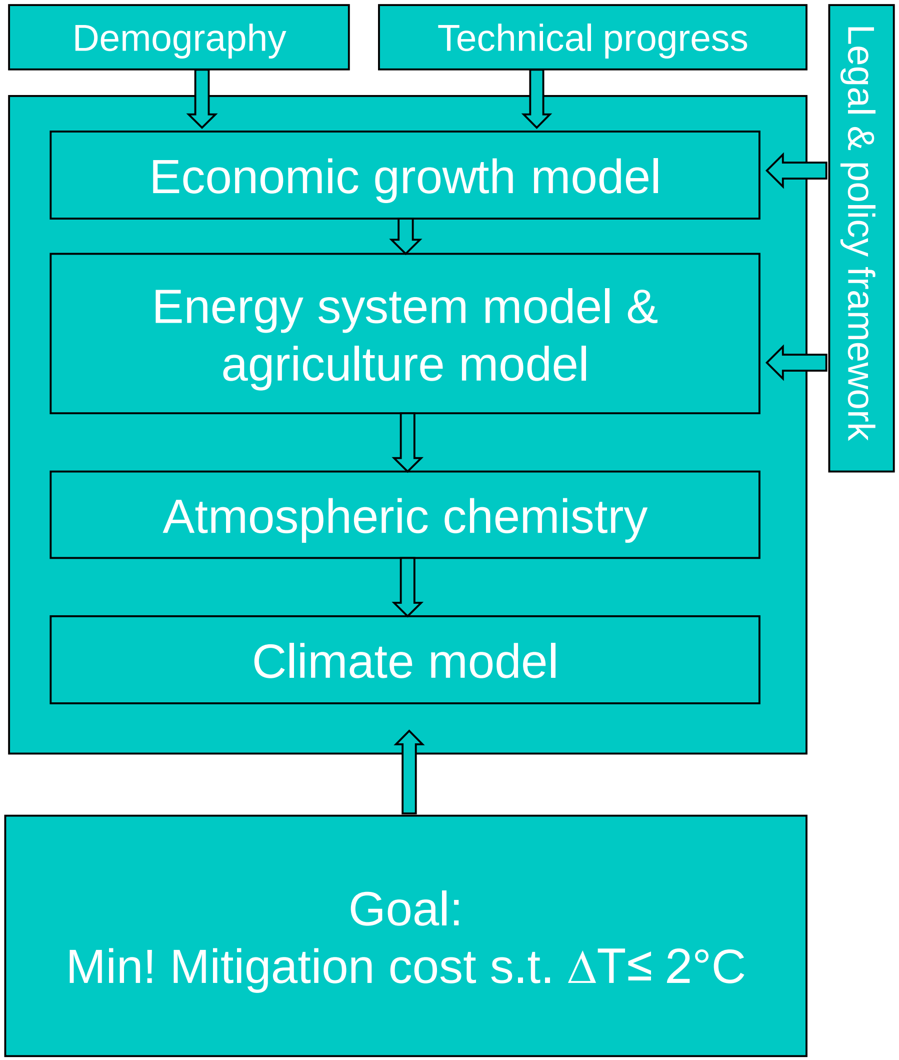

Source: IPCC, SRREN, Chapter 1, 2011

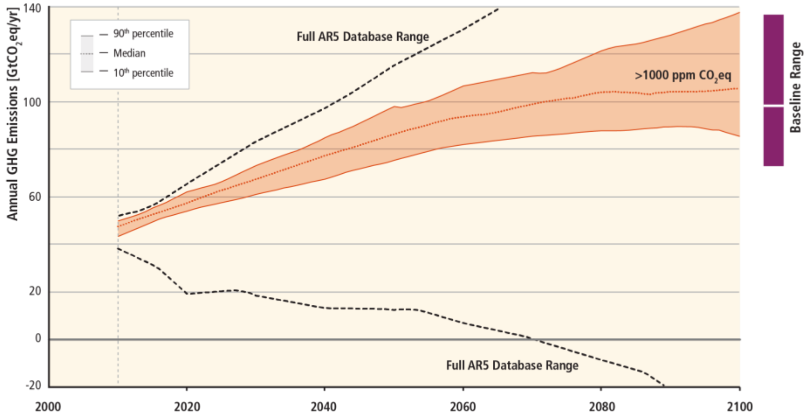
# Stabilization of atmospheric concentrations requires moving away from the baseline – regardless of the mitigation goal.



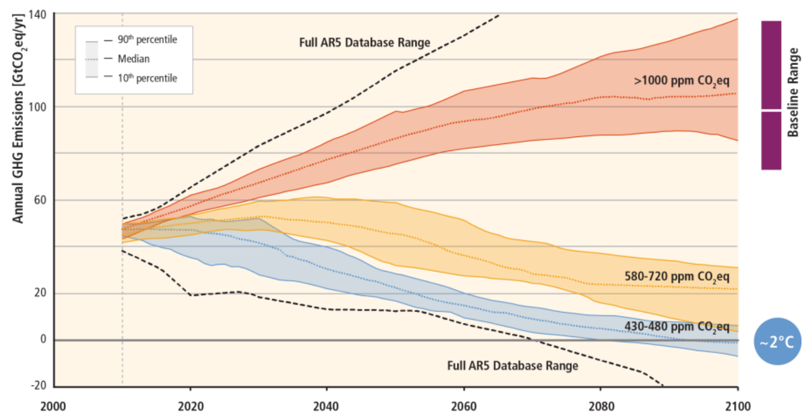

Source: IPCC, AR 5, WG III, based on Figure 6.7

# Cost-effectiveness analysis using integrated assessment (optimization-) models



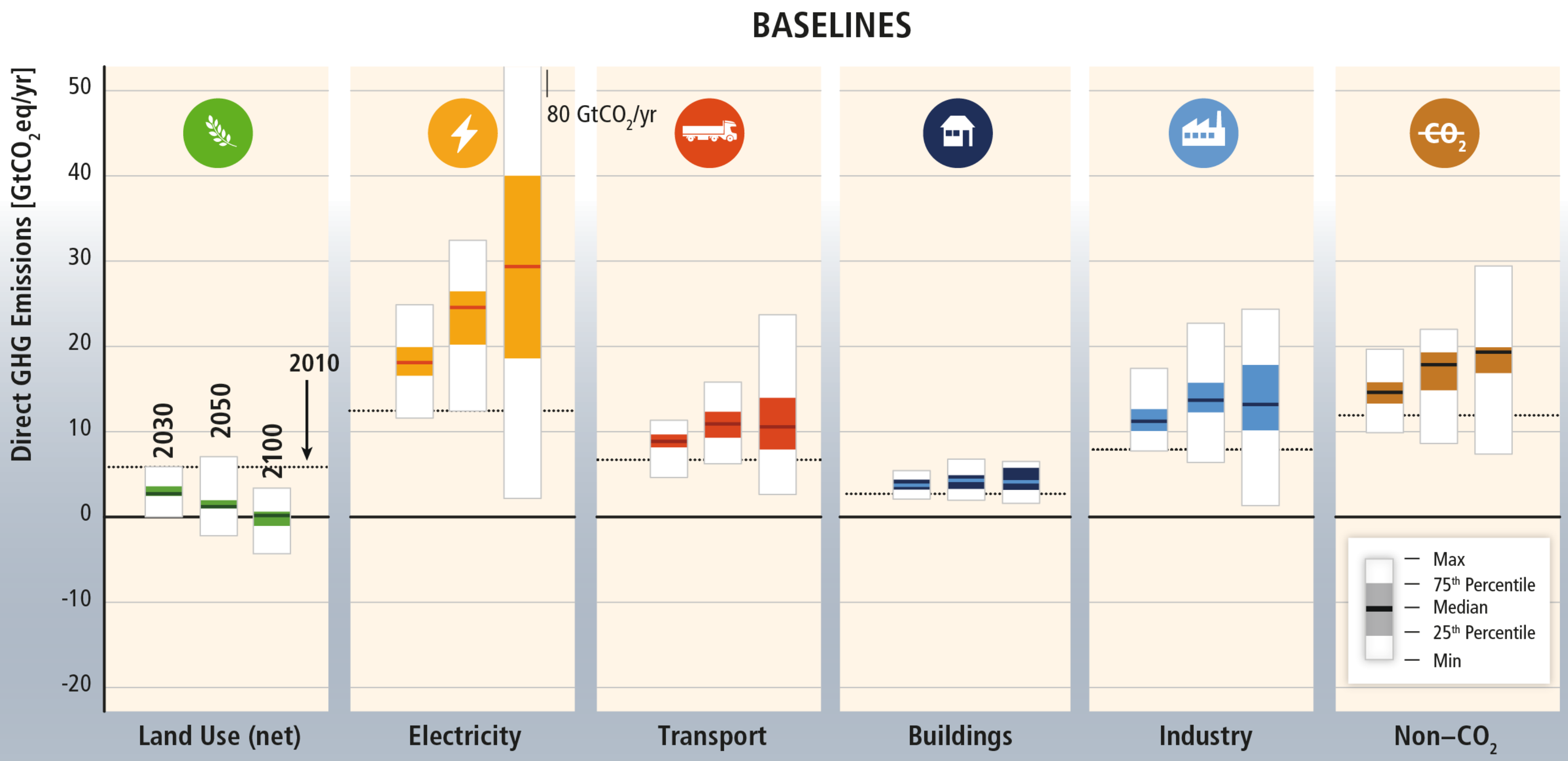

Business-as-usual (e.g. optimal growth)




Cost-effective emission reduction paths

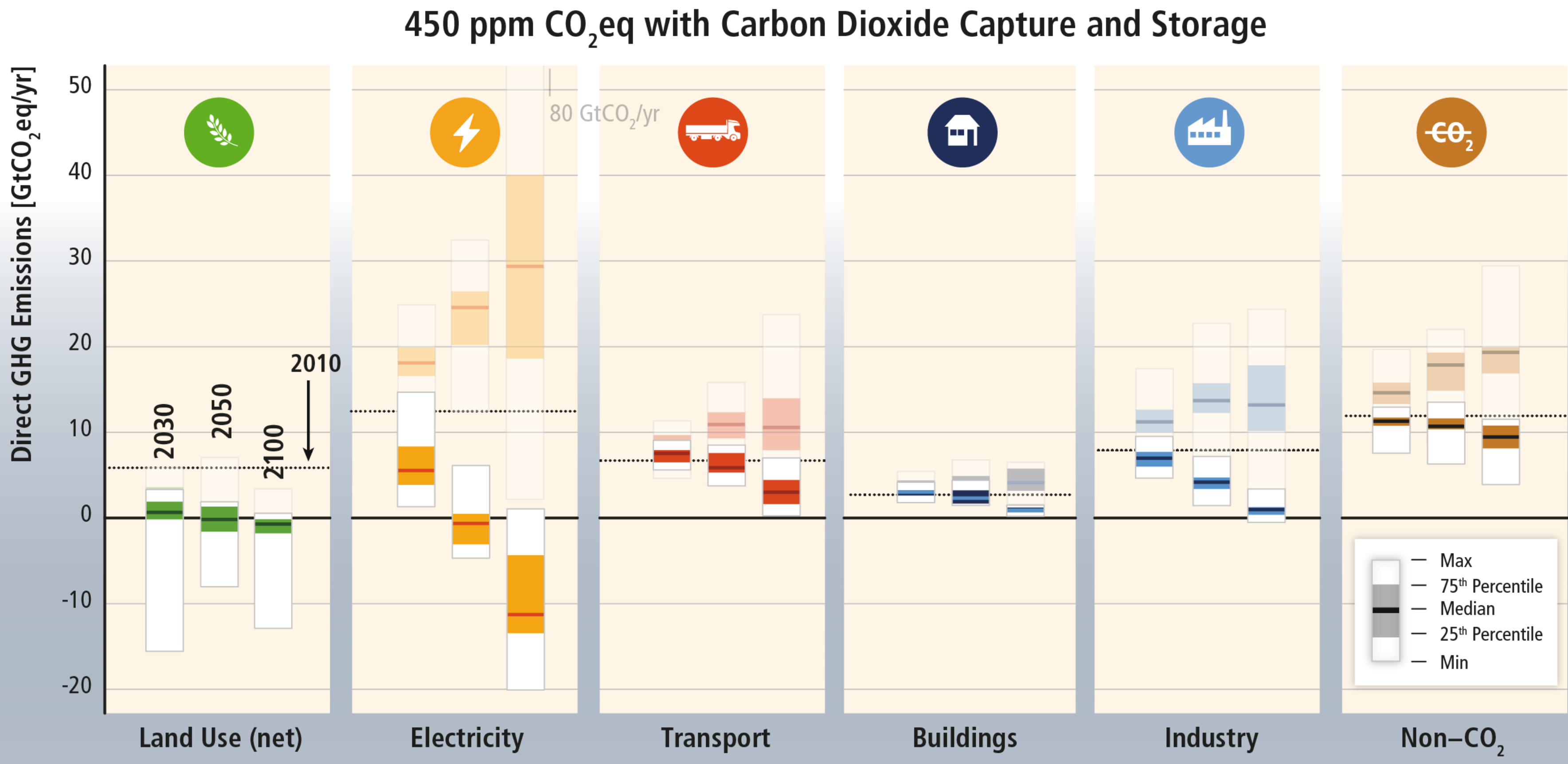
Source: Left-hand side: T. Bruckner, IIRM, Leipzig University, own illustration; right-hand side: IPCC, AR 5, WG III, Figure 6.7.

# Baseline scenarios suggest rising GHG emissions in all sectors, except for $CO_2$ emissions from the land-use sector.



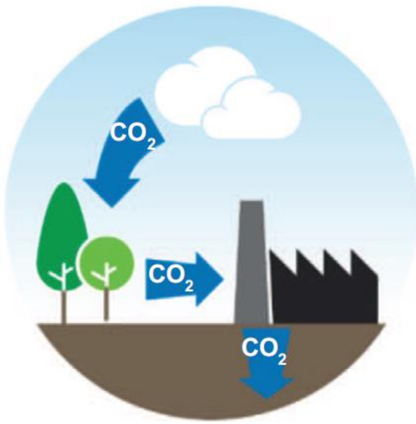

Source: IPCC, AR 5, WG III, based on Figure TS.15

# Mitigation requires changes throughout the economy. Systemic approaches are expected to be most effective.



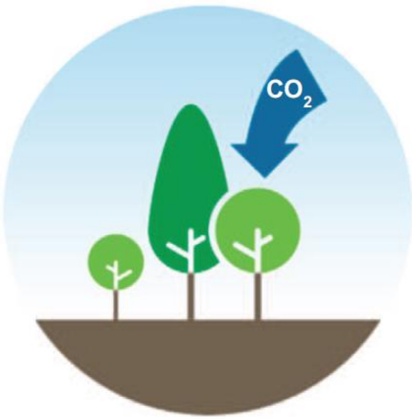

Source: IPCC, AR 5, WG III, based on Figure TS.17

# Negative emissions?
# Carbon dioxide removal (CDR)




**Bioenergy with carbon capture and sequestration (BECCS)**

Plants turn $CO_2$ into biomass, which is then combusted in power plants, a process that is ideally $CO_2$ neutral. If CCS is applied in addition, $CO_2$ is removed from the atmosphere.

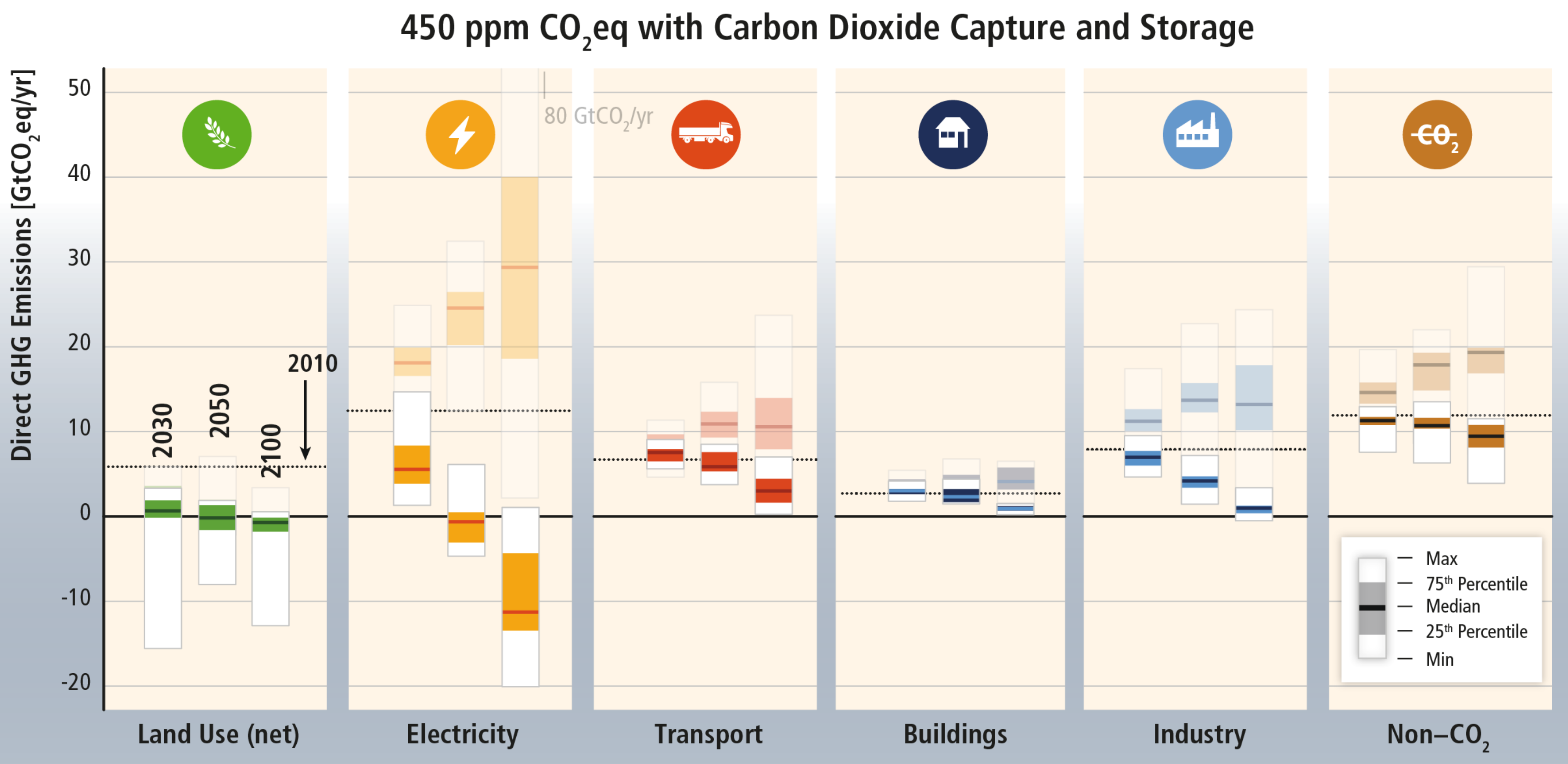



**Afforestation and reforestation**

Additional trees are planted, capturing $CO_2$ from the atmosphere as they grow. The $CO_2$ is then stored in living biomass.

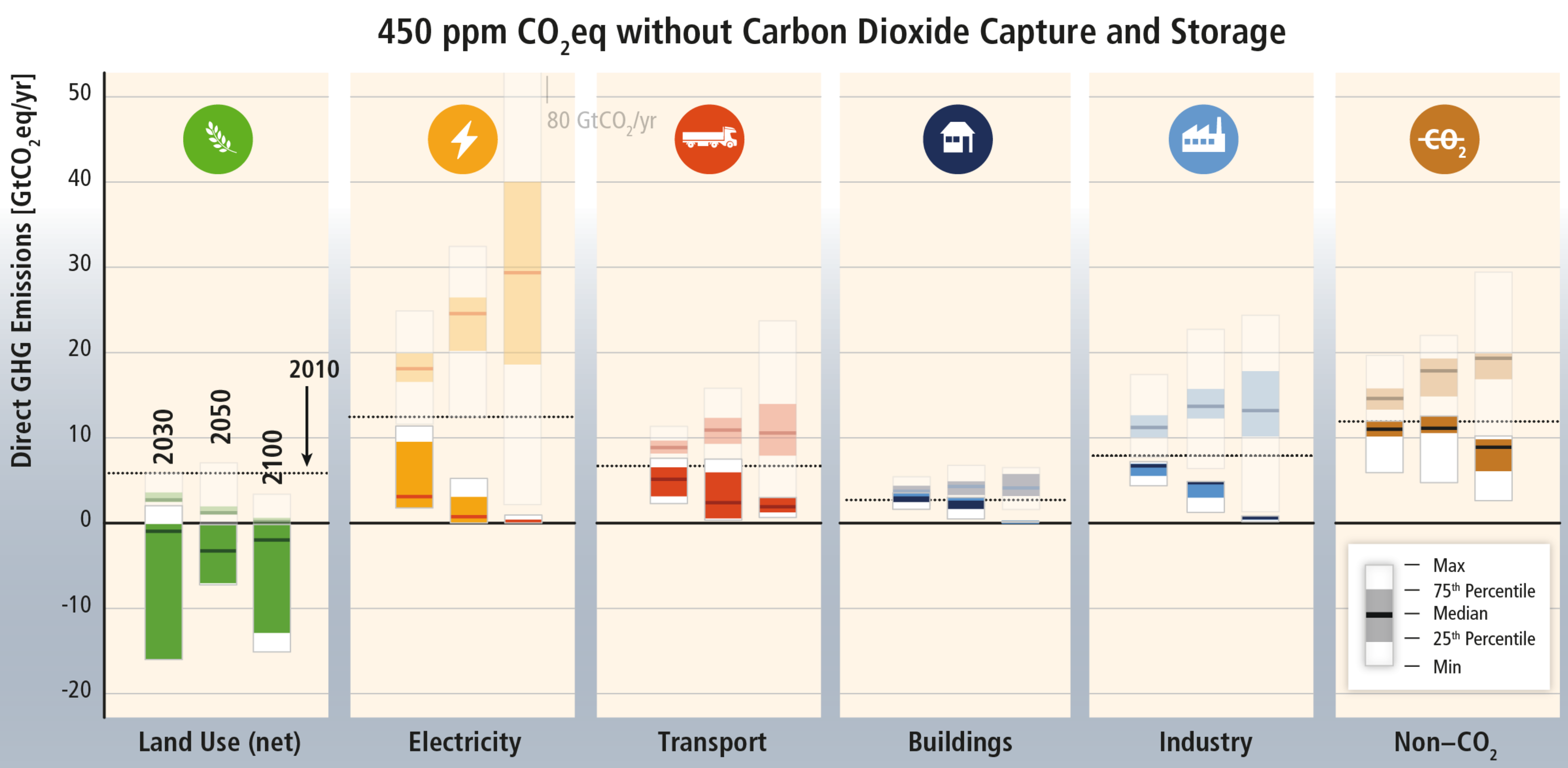
Source: J. Minx, W. Lamb, M. Callaghan, L. Bornmann, S. Fuss: Fast growing research on negative emissions, Environ. Res. Lett. 12 (2017).

# Mitigation requires changes throughout the economy. Systemic approaches are expected to be most effective.



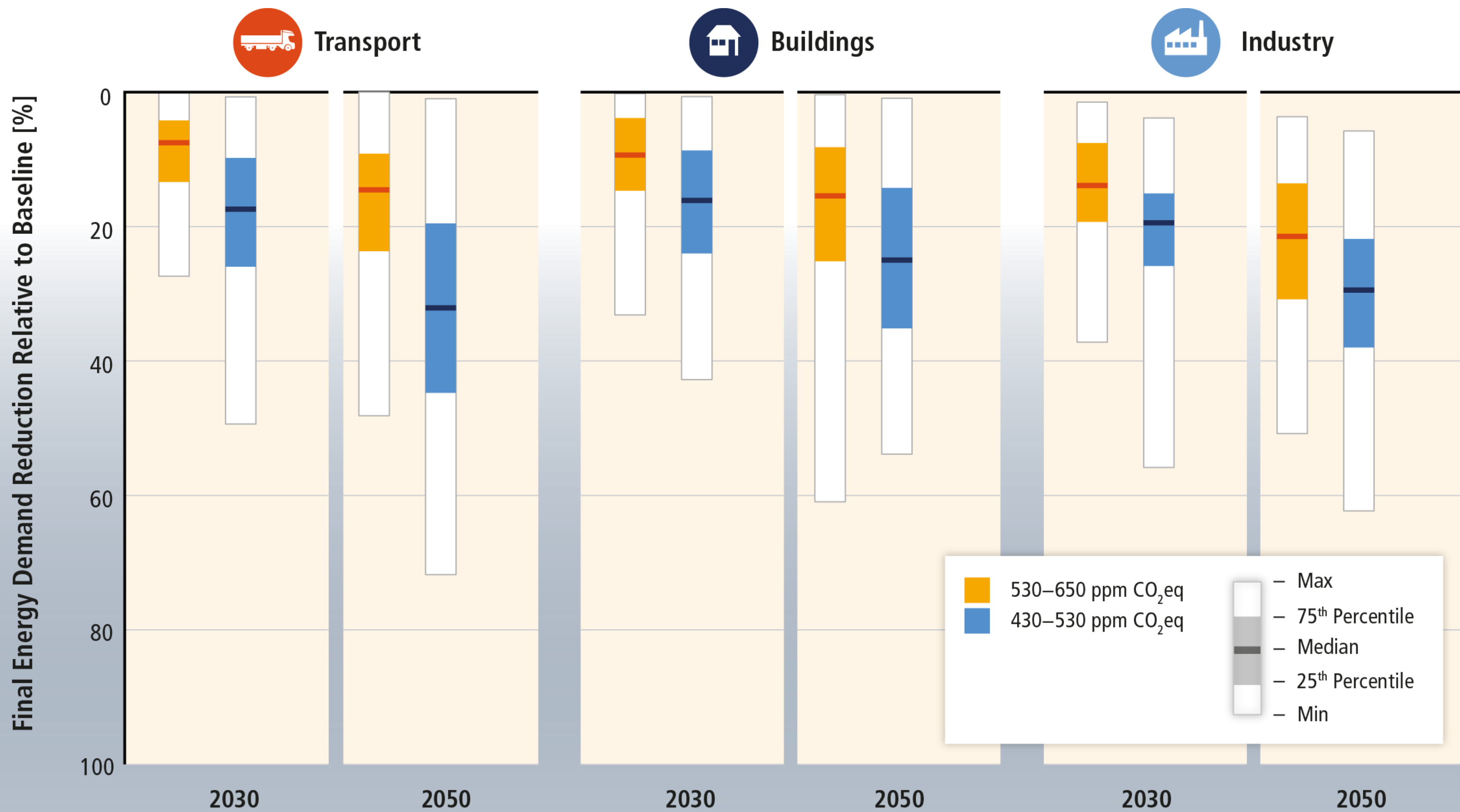

Source: IPCC, AR 5, WG III, based on Figure TS.17

# If CCS is not applied in the energy sector, negative emissions from changes in land-use play an important role



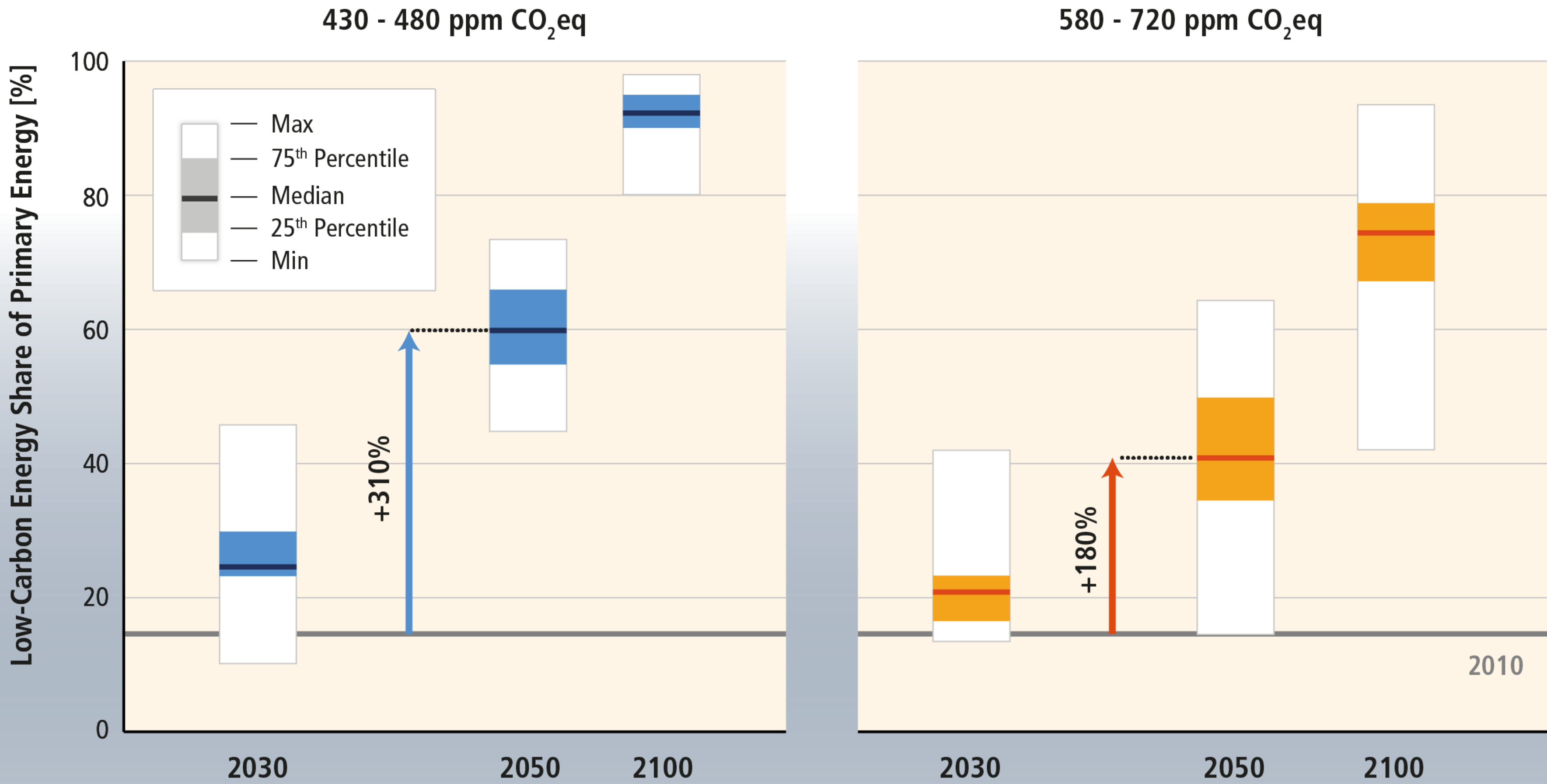

Source: IPCC, AR 5, WG III, based on Figure TS.17

# 1st pillar: final energy demand reduction (energy efficiency improvements and behavioral changes)




Source: IPCC, AR 5, WG III, based on Figure 6.37

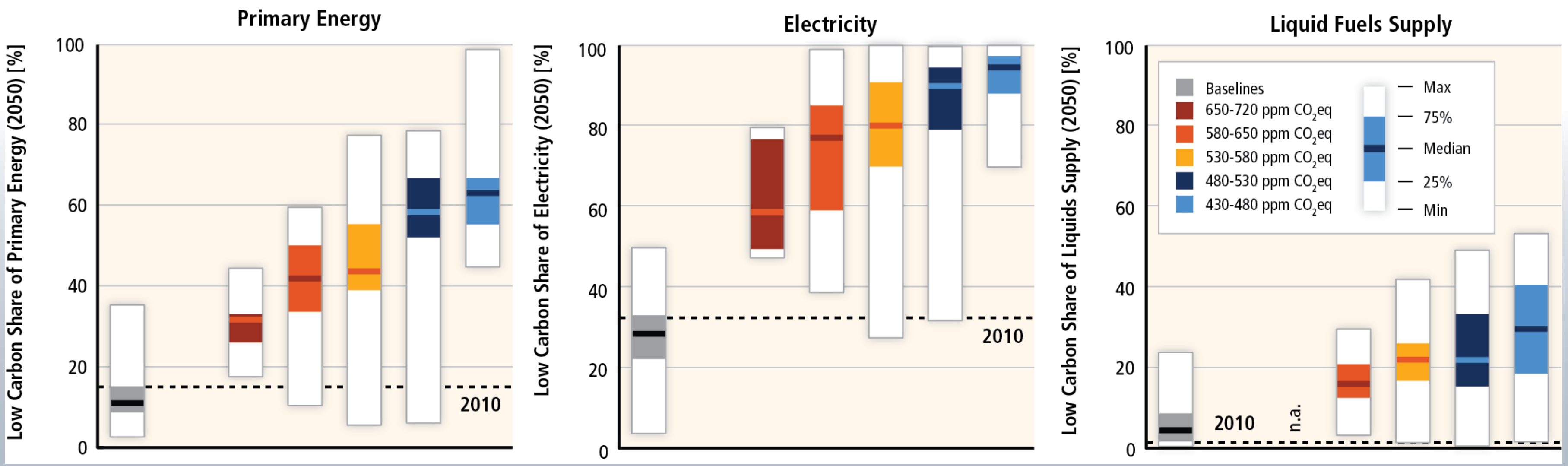
# 2nd pillar: upscaling of low-carbon technologies (renewable energies, CCS, and/or nuclear energy)




Source: IPCC, AR 5, WG III, based on Figure 7.16

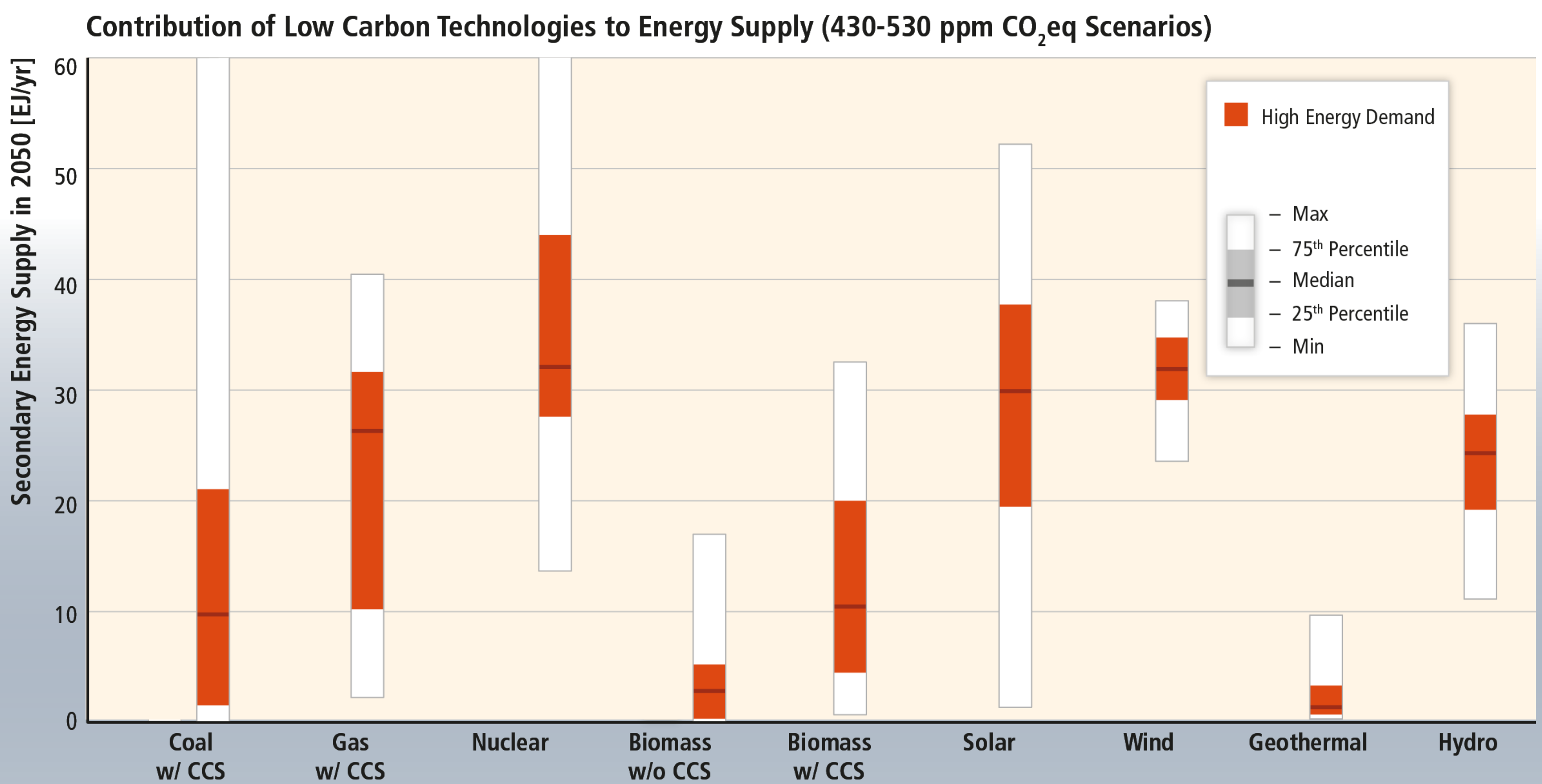
# Decarbonizing electricity generation is a key component of cost-effective mitigation strategies

Share of low-carbon energy in total primary energy, electricity and liquid supply sectors for the year 2050.



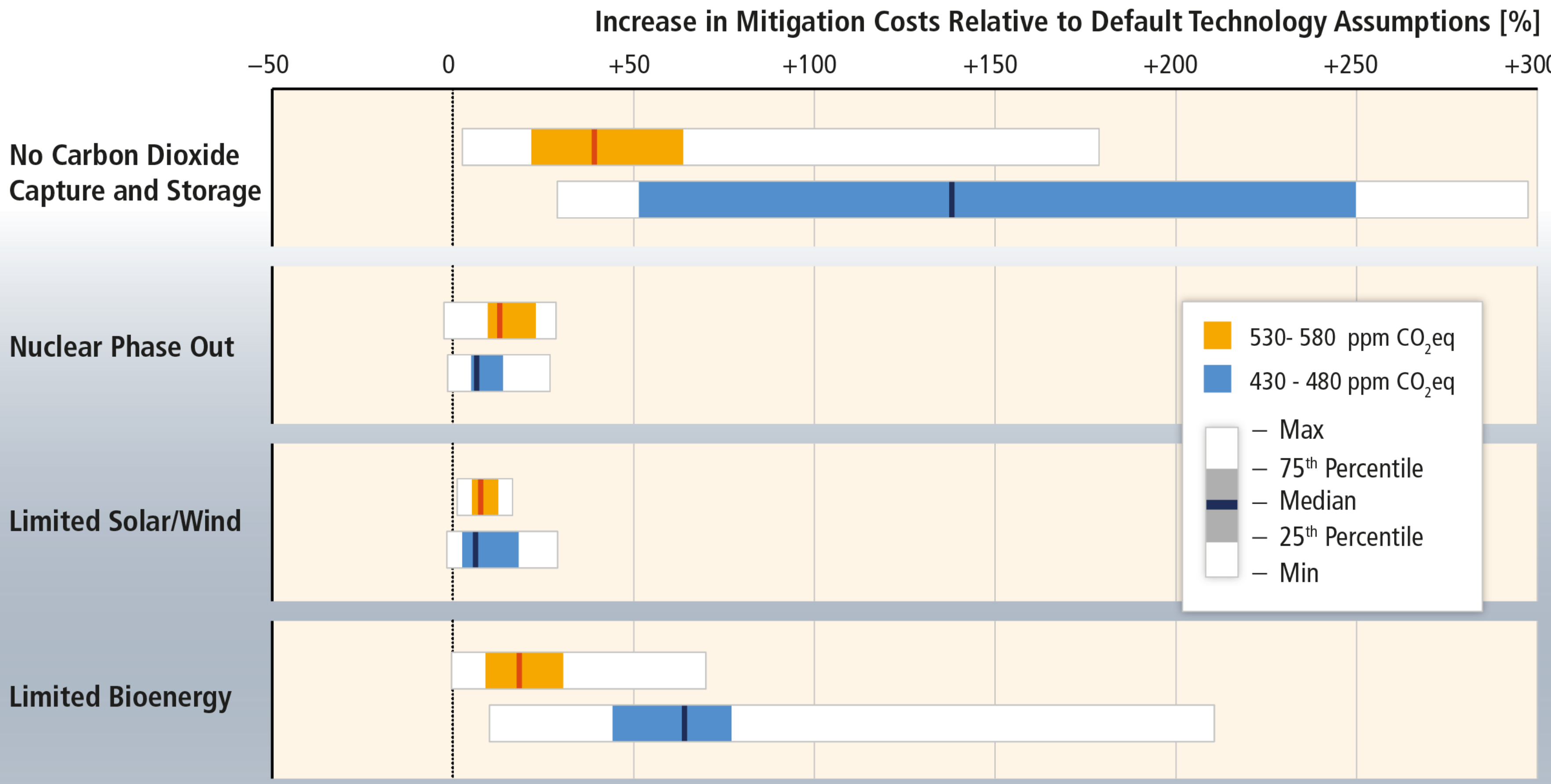

Source: IPCC, AR5, WG III, Figure 7.14

# Decarbonization of energy supply is a key requirement for limiting warming to 2°C. The technologies are available.



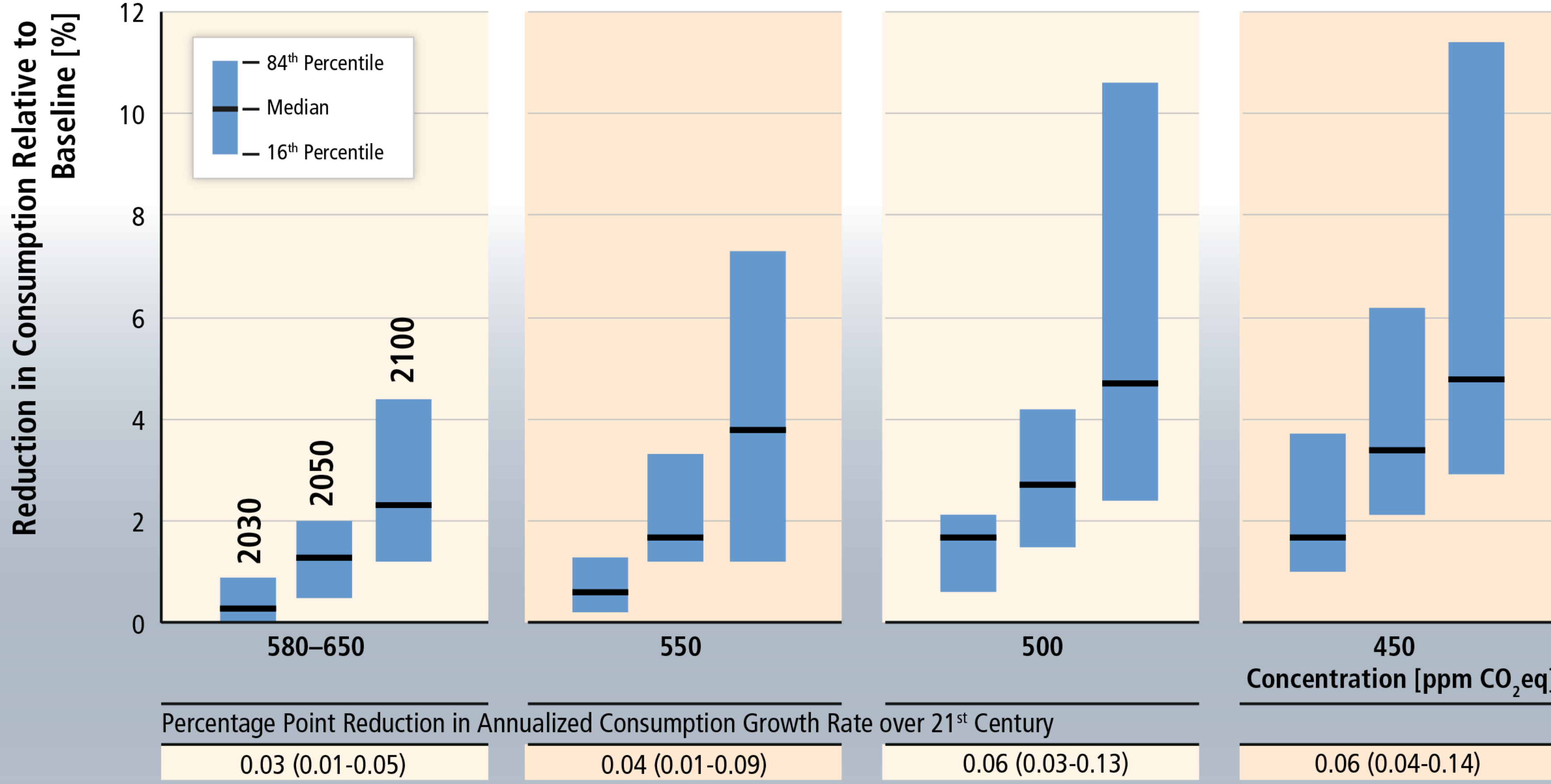

Source: IPCC, AR 5, WG III, based on Figure 7.11

# Technological limitations can increase mitigation costs, but the increase in cost differs depending on the restricted technology



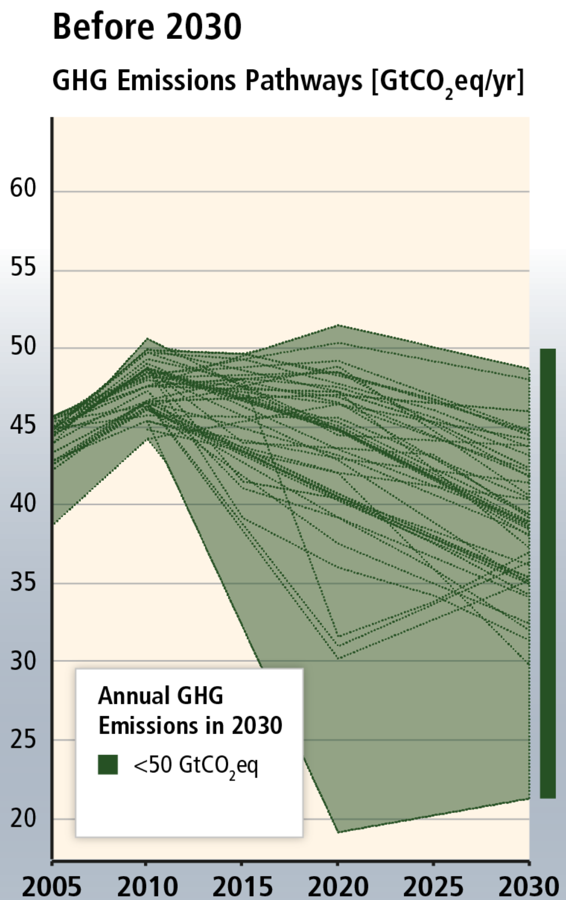

Source: IPCC, AR 5, WG III, based on Figure 6.24

# Mitigation will affect consumption, but the associated costs are small compared with its expected growth (300-900%/century)




Source: IPCC, AR 5, WG III, based on Table SPM.2

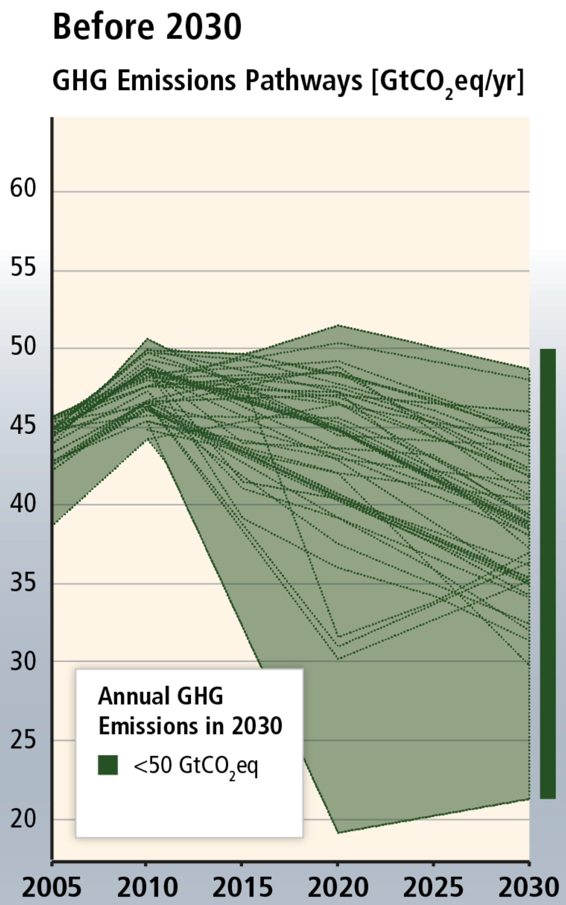
# The "immediate action" scenarios shown make it at least *about as likely as not* that warming will remain below 2°C

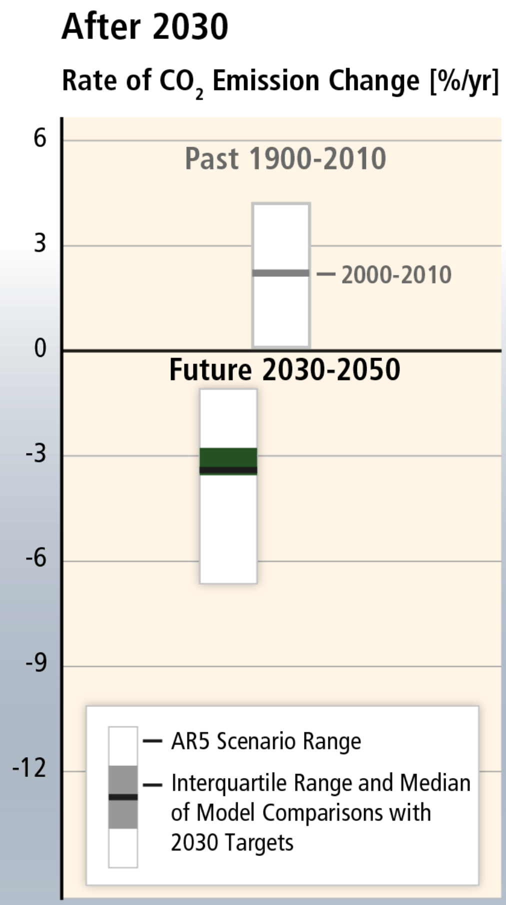



"Immediate Action"

Source: IPCC, AR 5, WG III, based on Figures 6.32 and 7.16

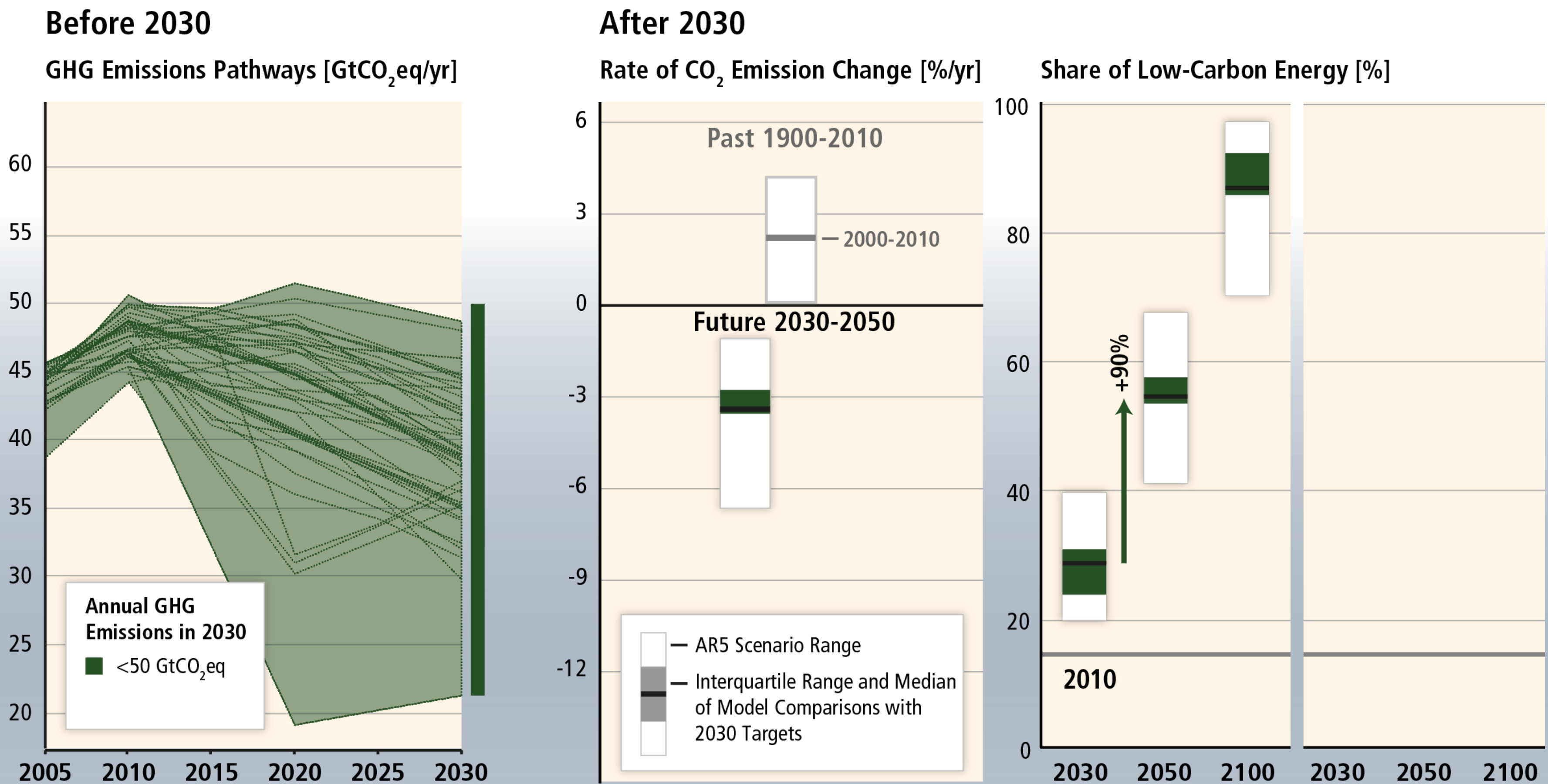
# Still, between 2030 and 2050, emissions would have to be reduced at an unprecedented rate...



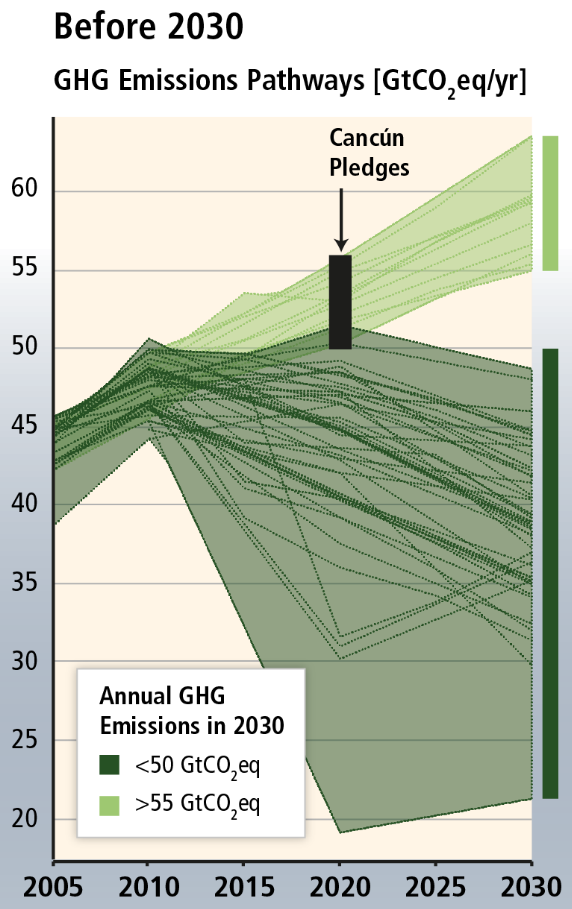

Source: IPCC, AR 5, WG III, based on Figures 6.32 and 7.16

# ...implying a rapid scale-up of low-carbon energy.




Source: IPCC, AR 5, WG III, based on Figures 6.32 and 7.16

# Delaying emissions reductions increases the difficulty and narrows the options for mitigation.




"Delayed Mitigation"

"Immediate Action"

Source: IPCC, AR 5, WG III, based on Figures 6.32 and 7.16

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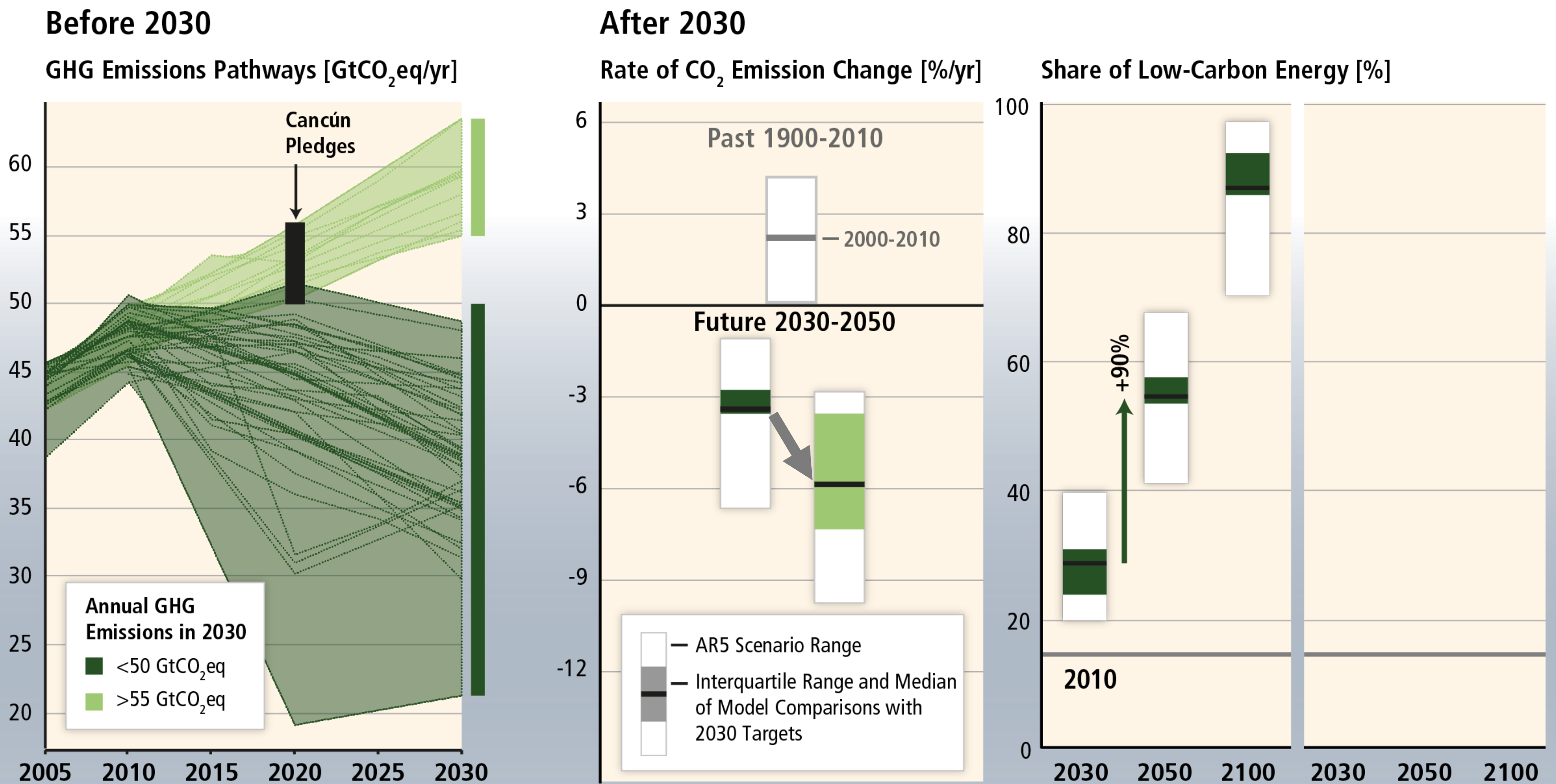


Source: IPCC, AR 5, WG III, based on Figures 6.32 and 7.16

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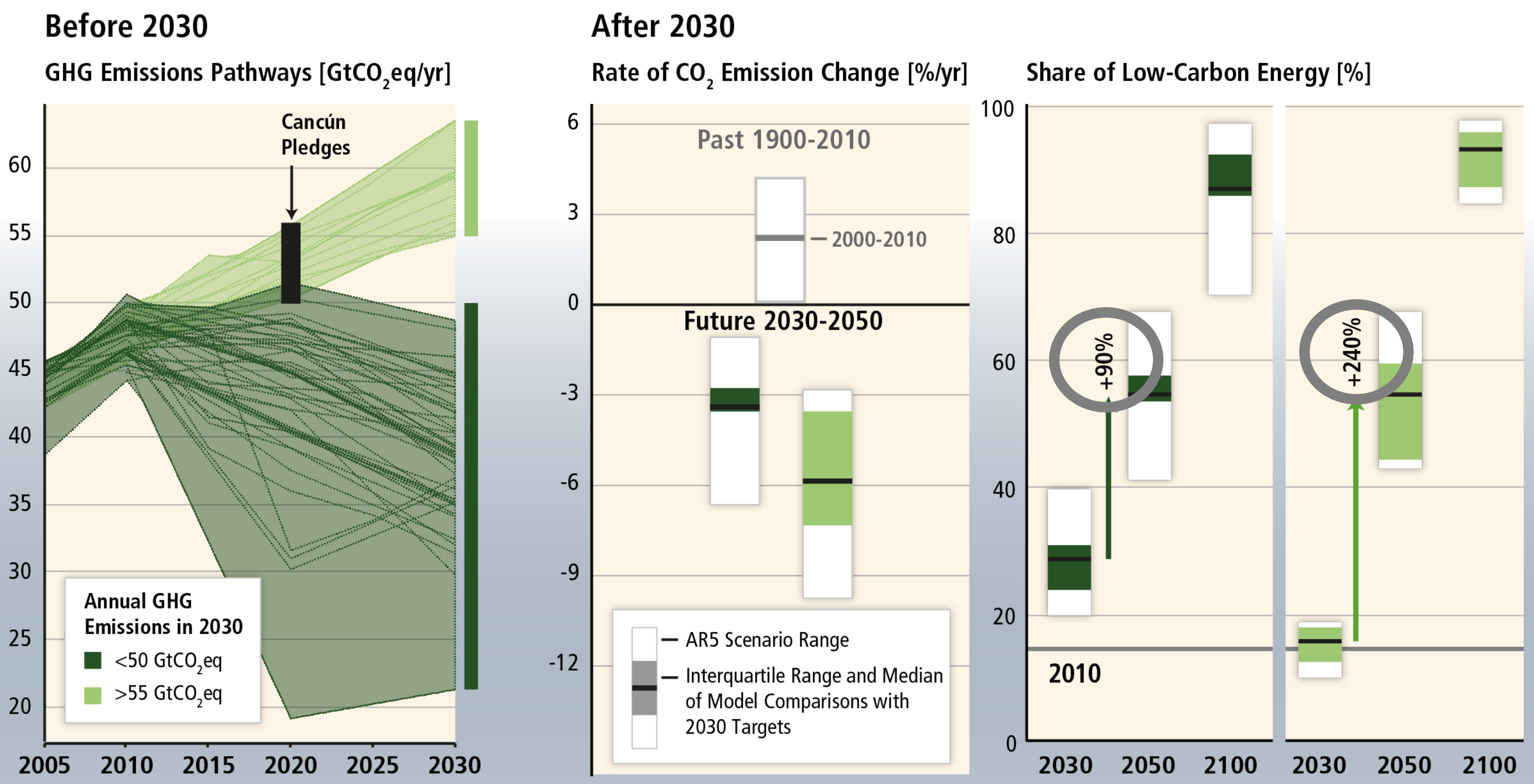
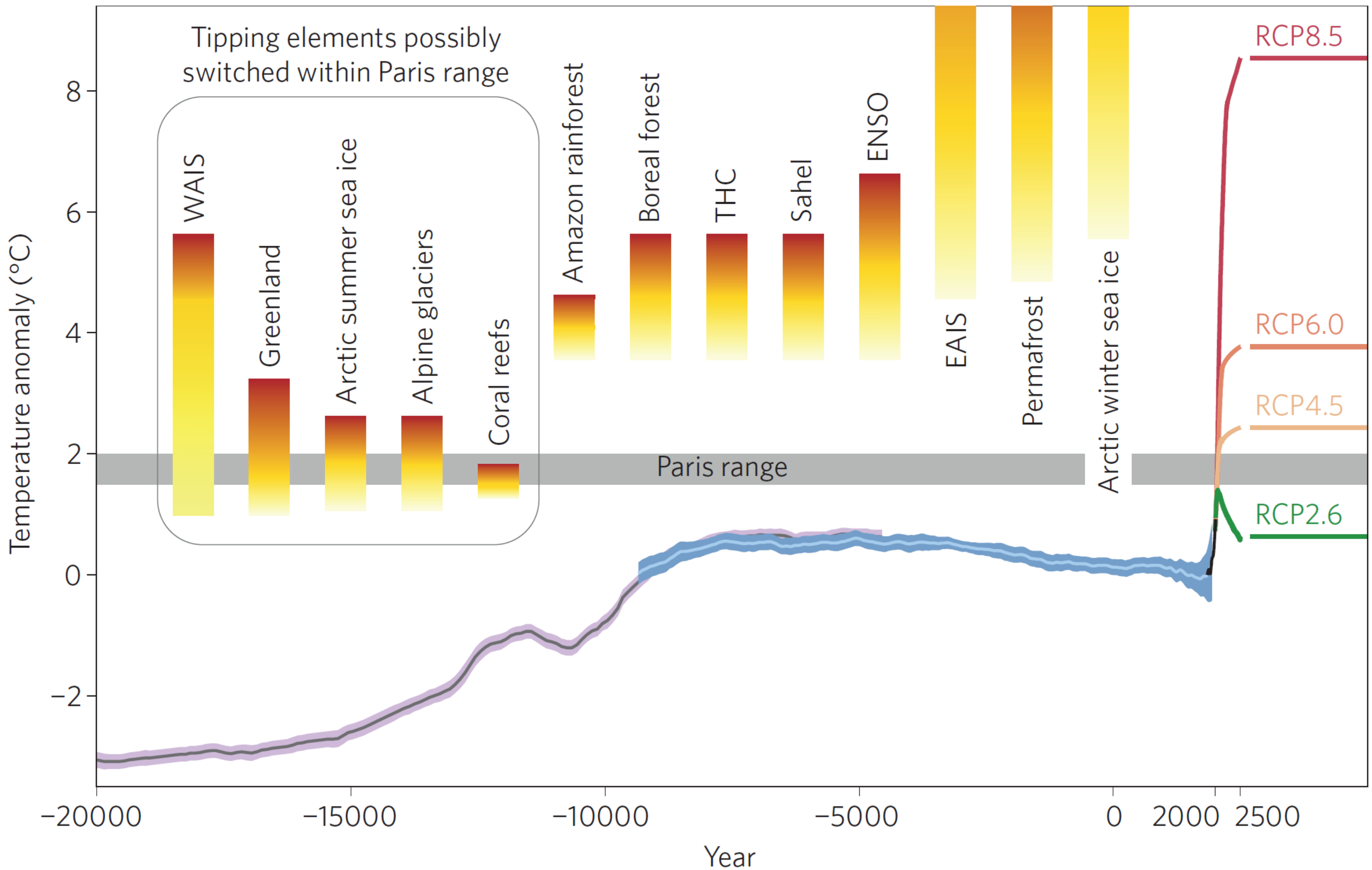



Source: IPCC, AR 5, WG III, based on Figures 6.32 and 7.16

# From 2°C towards 1.5°C




Source: H.-J. Schellnhuber, S. Rahmstorf, R. Winkelmann: Why the right climate target was agreed in Paris, Nature Climate Change, 2016.

# COP 21 in Paris and the shift from 2°C → 1.5°C temperature limit

**Article 2 of the Paris Agreement**

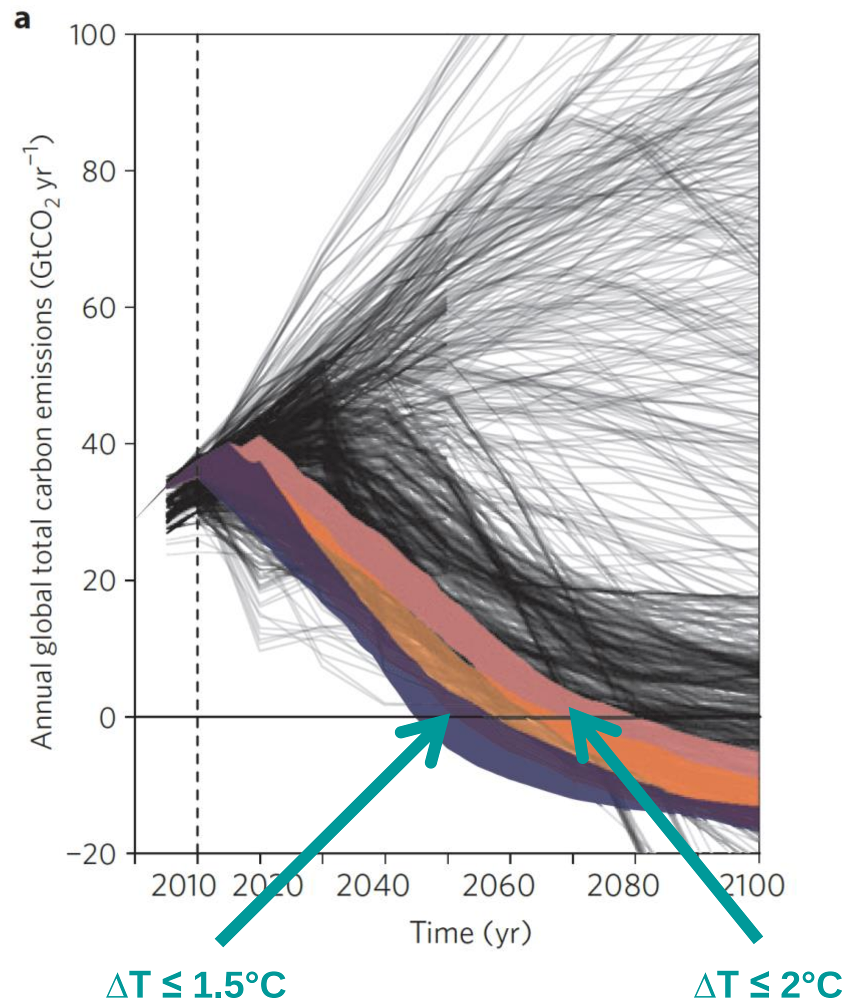
“This Agreement, in enhancing the implementation of the Convention, including its objective, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.”

| | Cumulative $CO_2$ emissions from 2011 in $GtCO_2$ | | | | | |
|---|---|---|---|---|---|---|
| Net anthropogenic warming [a] | <1.5°C | | | <2°C | | |
| Fraction of simulations meeting goal [b] | 66% | 50% | 33% | 66% | 50% | 33% |
| Complex models, RCP scenarios only [c] | 400 | 550 | 850 | 1000 | 1300 | 1500 |

Source: IPCC, AR5, SYR (2014), Table 2.2.

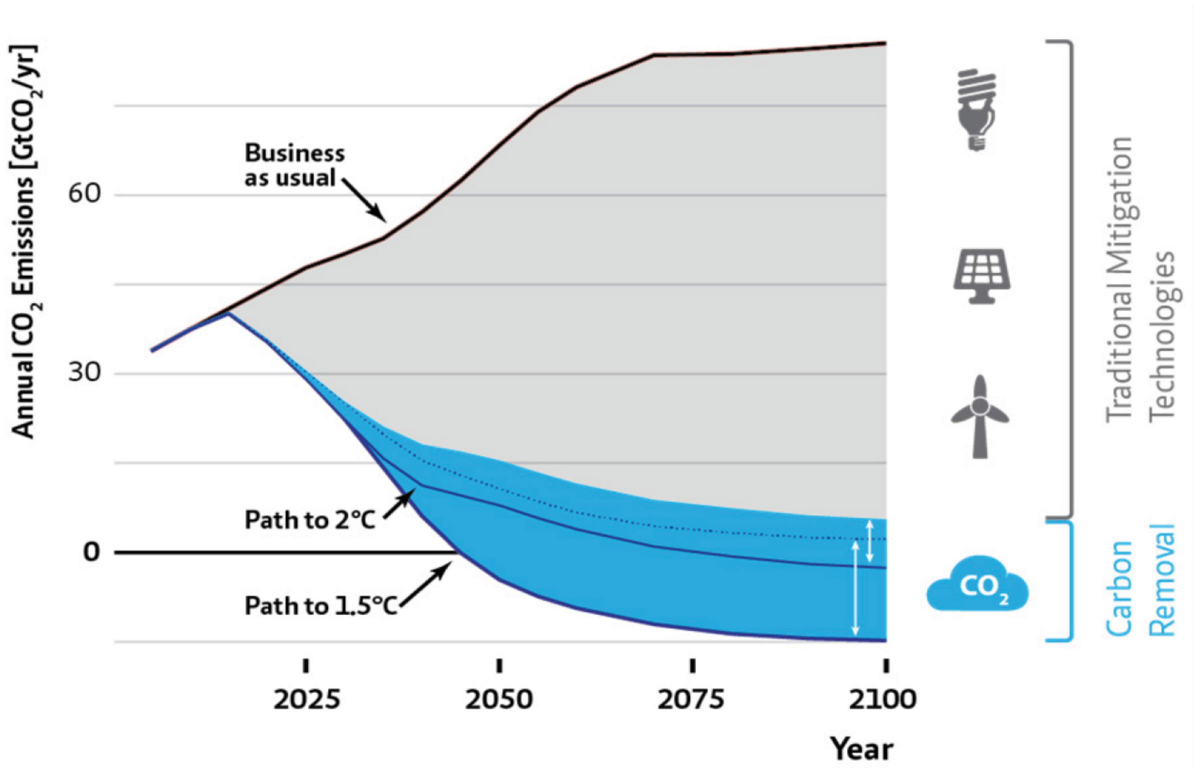
# Moving from ΔT ≤ 2°C➔ 1.5°C




J. Rogelj et al.: Energy system transformations for limiting end-of-century warming to below 1.5 °C. Nature Climate Change 5, 519–527 (2015)

# Moving from ΔT ≤ 2°C → 1.5°C

## How to keep global warming below 1.5 or 2 degrees Celsius:




Mercator Research Institute on Global Commons and Climate Change (MCC): Betting on negative emissions Potentials and uncertainties of new technologies to reduce the world's carbon debt, MCC Policy Brief 2, 2016.

# Moving from 2°C → 1.5°C

**Table 1 | Key characteristics of 1.5 °C scenarios and comparison with 2 °C scenarios.**

| Key 1.5 °C characteristic | Detailed qualification |
|---|---|
| $CO_2$ reductions beyond global net zero emissions. | 1.5 °C-consistent scenarios reach net zero carbon emissions globally by mid-century, 10–20 yr earlier than in scenarios consistent with only 2 °C, and show net negative emissions in the 2050–2100 period, which is not a requirement for 2 °C-consistent scenarios. |
| Additional GHG reductions mainly from $CO_2$. | The mitigation potential of non-$CO_2$ GHGs is often already exhausted by mitigation action for keeping warming to below 2 °C. Therefore, additional reductions in 1.5 °C scenarios are mainly from $CO_2$. |
| Rapid and profound near-term decarbonization of energy supply. | 1.5 °C scenarios require a decarbonization of energy supply that is more rapid and profound than in 2 °C-consistent scenarios. Early $CO_2$ reductions in 1.5 °C-consistent scenarios are achieved through early reductions in the power sector (Supplementary Fig. S6). |
| Greater mitigation efforts on the demand side. | By mid-century, mitigation efforts in the industry, buildings and transport sectors lead to significantly lower emissions from these sectors. |
| Energy efficiency improvements are a crucial enabling factor for 1.5 °C. | Energy efficiency plays a critical role in low stabilization scenarios in general. Most 1.5 °C scenarios assume energy use per unit of GDP to decrease at a faster pace than historically observed, for example, owing to dedicated energy efficiency policies. In addition, there are substantial climate-policy-induced demand reductions, which are greater in 1.5 °C than in 2 °C scenarios owing to the more stringent emissions constraints. |
| Higher mitigation costs. | Aggregated long-term mitigation costs are higher, for example up to two times when comparing corresponding 1.5 °C and 2 °C scenario pairs. The effect on near-term costs is greater. |
| Comprehensive emission reductions need to be implemented in the coming decade. | The window of emissions in 2030 that still keeps the option open to limit warming to below 1.5 °C by 2100 is much lower and substantially smaller than the corresponding window for 2 °C-consistent scenarios. Diverting investments towards low-carbon technologies in the coming decade is therefore critical. |

J. Rogelj et al.: Energy system transformations for limiting end-of-century warming to below 1.5 °C. Nature Climate Change 5, 519–527 (2015)

# Policy implications

Deutscher Bundestag
11. Wahlperiode

Drucksache 11/8030

24. 05. 1990

Sachgebiet 2129

## Dritter Bericht

**der ENQUETE-KOMMISSION**
**Vorsorge zum Schutz der Erdatmosphäre**

**zum Thema**
**Schutz der Erde**

### 3.4 Globale Eindämmung des zusätzlichen Treibhauseffekts

Wenn ein Schutz vor den Folgen des zusätzlichen Treibhauseffektes gewährleistet sein soll, muß eine Obergrenze für den Anstieg der Temperatur festgelegt werden. Im ersten Bericht der Kommission wird es auf der Grundlage der vorhandenen Erkenntnisse zum Schutze der Ökosysteme für notwendig erachtet, daß eine mittlere globale Rate des Temperaturanstiegs von 0,1°C pro Dekade möglichst nicht überschritten wird. Das bedeutet bis zum Ende des nächsten Jahrhunderts eine Erwärmungsobergrenze von etwa 2°C gegenüber dem vorindustriellen Wert. Ziel der Eindämmung des zusätzlichen Treibhauseffektes muß es deshalb sein, daß die über den gesamten Modell-Unsicherheitsbereich von 1,5°C bis 4,5°C berechnete globale Erwärmung bis zum Jahre 2100 unterhalb der 2°C-Obergrenze bleibt.

**Reduktionsziele der Enquete-Kommission zur Verminderung der energiebedingten $CO_2$-Emissionen bis zu den Jahren 2005 und 2050.**

Angaben in Prozent, bezogen auf die Emissionen der jeweiligen Ländergruppen im Jahr 1987

| Ländergruppen | Reduktionsziele, in %, bezogen auf die Emissionen der Ländergruppen im Jahr 1987 | |
|---|---|---|
| | bis 2005 mindestens | bis 2050 mindestens |
| westliche und östliche Industrieländer zusammen ... | −20 | −80 |
| wirtschaftsstarke westliche Industrieländer mit derzeit besonders hohen Pro-Kopf-Emissionen .... | −30 | −80 |
| Europäische Gemeinschaften insgesamt .......... | −20 bis −25 | −80 |
| Entwicklungsländer zusammen .................. | +50 | +70 |
| weltweit .................................. | − 5 | −50 |

Source: Deutscher Bundestag, 1990

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