

**“New Energy for Czechia” Roundtable
Prague, 5 April 2019**

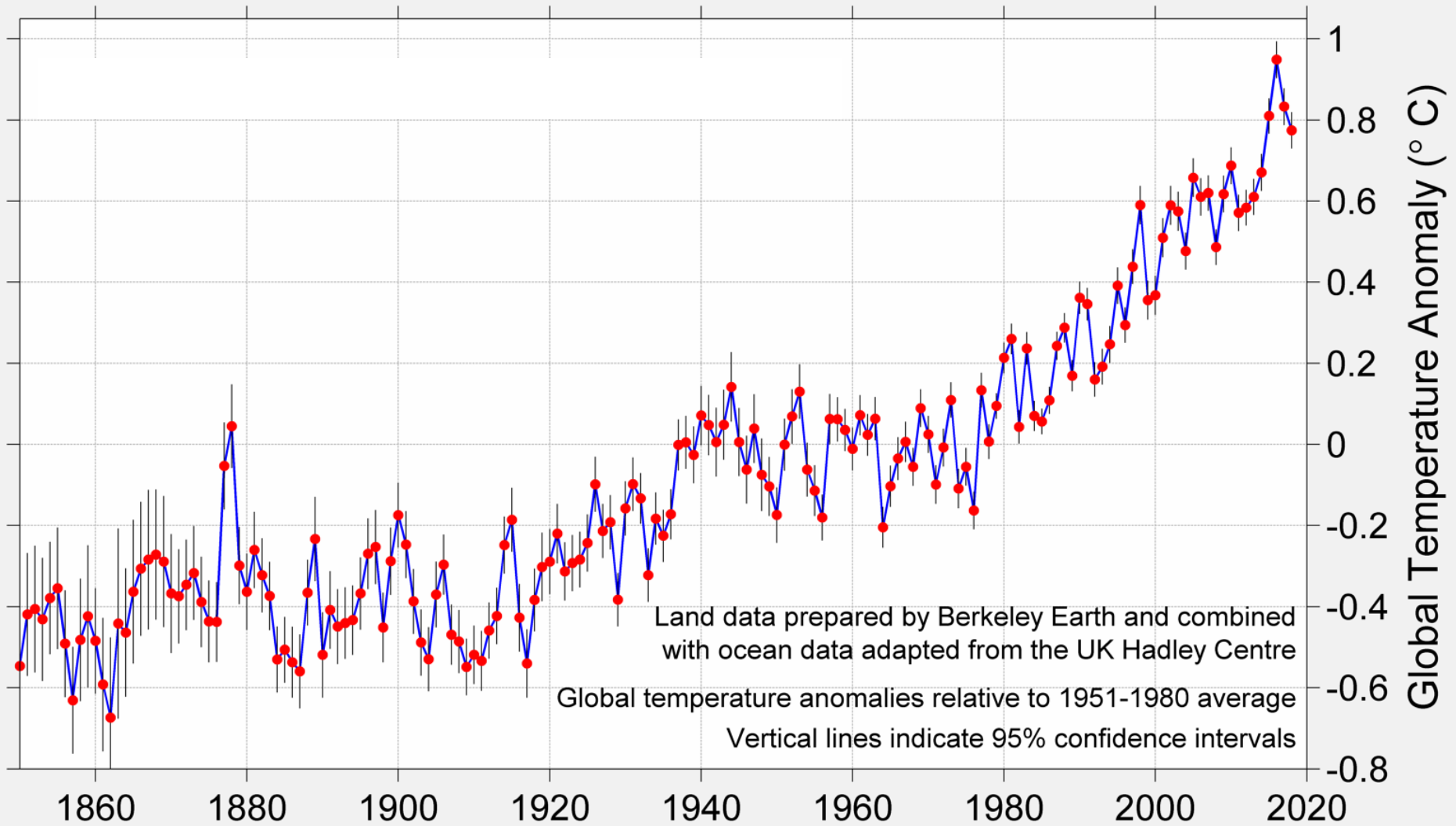
The Climate Challenge and the Great Transformation

Professor H. J. Schellnhuber CBE

Director Emeritus, Potsdam Institute for Climate Impact Research

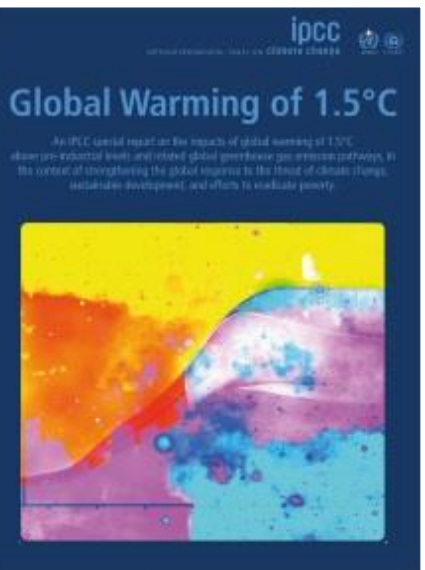


Global Mean Temperature 1850-2018



Global Warming of 1.5°C

#SR15



IPCC @IPCC_CH Folgen

"Every half degree of warming matters" said IPCC Chair, Hoesung Lee on the Special Report on Global Warming of 1.5°C #SR15 #climatechange #ipcc #ParisAgreement



0:36 18.7 Tsd. Aufrufe

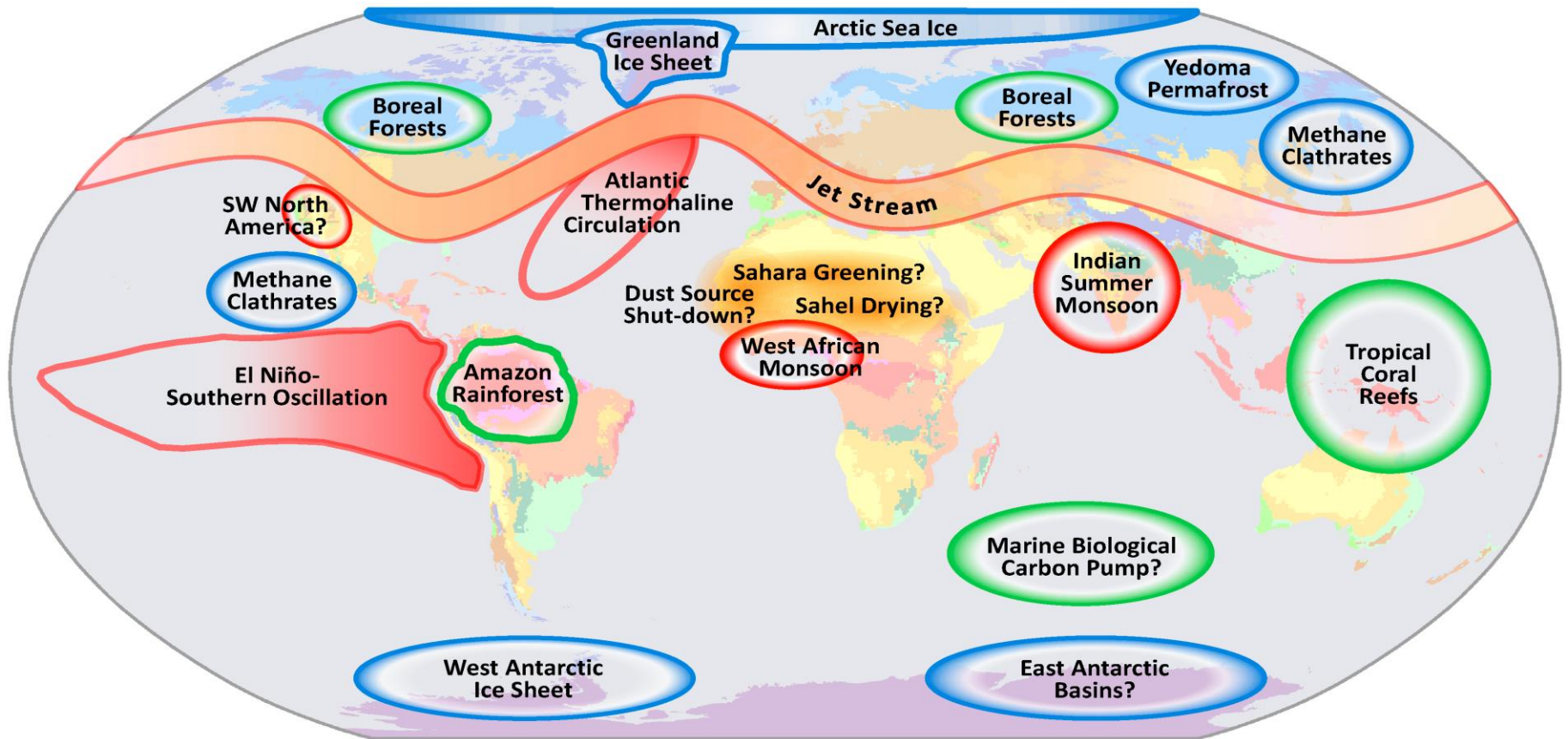
15:00 · 8. Okt. 2018

482 Retweets 585 „Gefällt mir“-Angaben

16 482 585



Looming Risks: Tipping Elements in the Earth System



- Cryosphere Entities
- Circulation Patterns
- Biosphere Components

Köppen Climate Classification



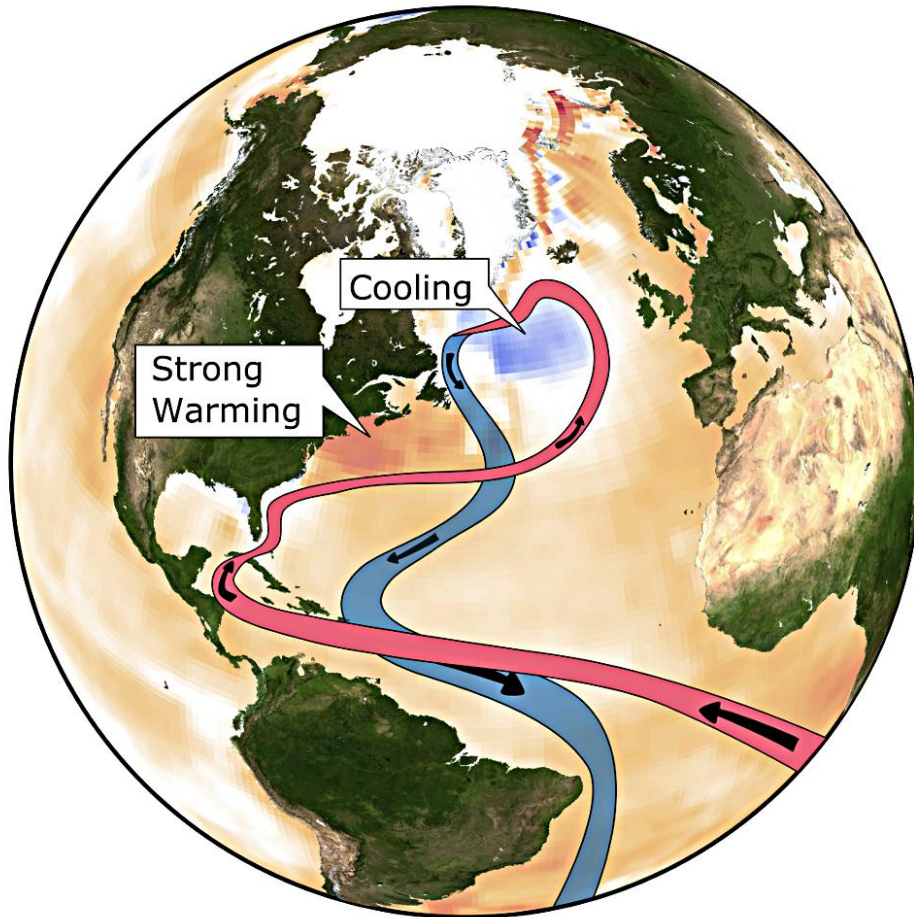
Stronger Evidence for a Weaker Atlantic Overturning

<https://doi.org/10.1038/s41586-018-0006-5>

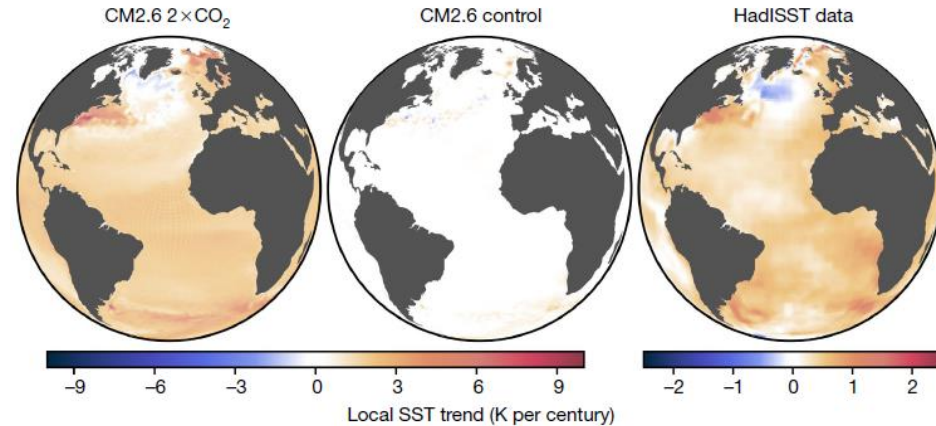
Observed fingerprint of a weakening Atlantic Ocean overturning circulation

L. Caesar^{1,2*}, S. Rahmstorf^{1,2*}, A. Robinson^{1,3,4,5}, G. Feulner¹ & V. Saba⁶

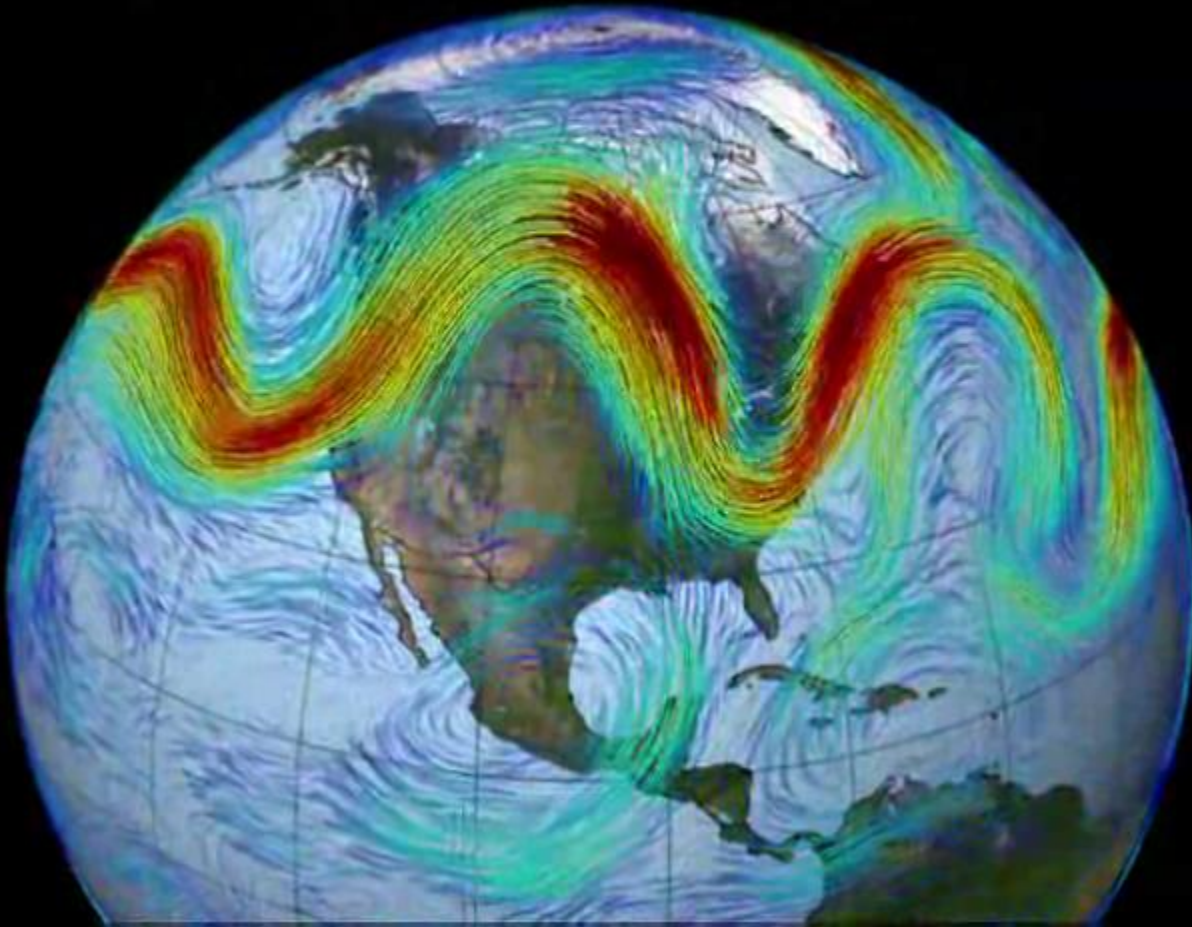
The Atlantic meridional overturning circulation (AMOC)—a system of ocean currents in the North Atlantic—has a major impact on climate, yet its evolution during the industrial era is poorly known owing to a lack of direct current measurements. Here we provide evidence for a weakening of the AMOC by about 3 ± 1 sverdrups (around 15 per cent) since the mid-twentieth century. This weakening is revealed by a characteristic spatial and seasonal sea-surface temperature ‘fingerprint’—consisting of a pattern of cooling in the subpolar Atlantic Ocean and warming in the Gulf Stream region—and is calibrated through an ensemble of model simulations from the CMIP5 project. We find this fingerprint both in a high-resolution climate model in response to increasing atmospheric carbon dioxide concentrations, and in the temperature trends observed since the late nineteenth century. The pattern can be explained by a slowdown in the AMOC and reduced northward heat transport, as well as an associated northward shift of the Gulf Stream. Comparisons with recent direct measurements from the RAPID project and several other studies provide a consistent depiction of record-low AMOC values in recent years.



Observed temperature change since 1870 (°C)



Meandering of the Jet Stream



Animation

NASA Goddard Space Flight Center

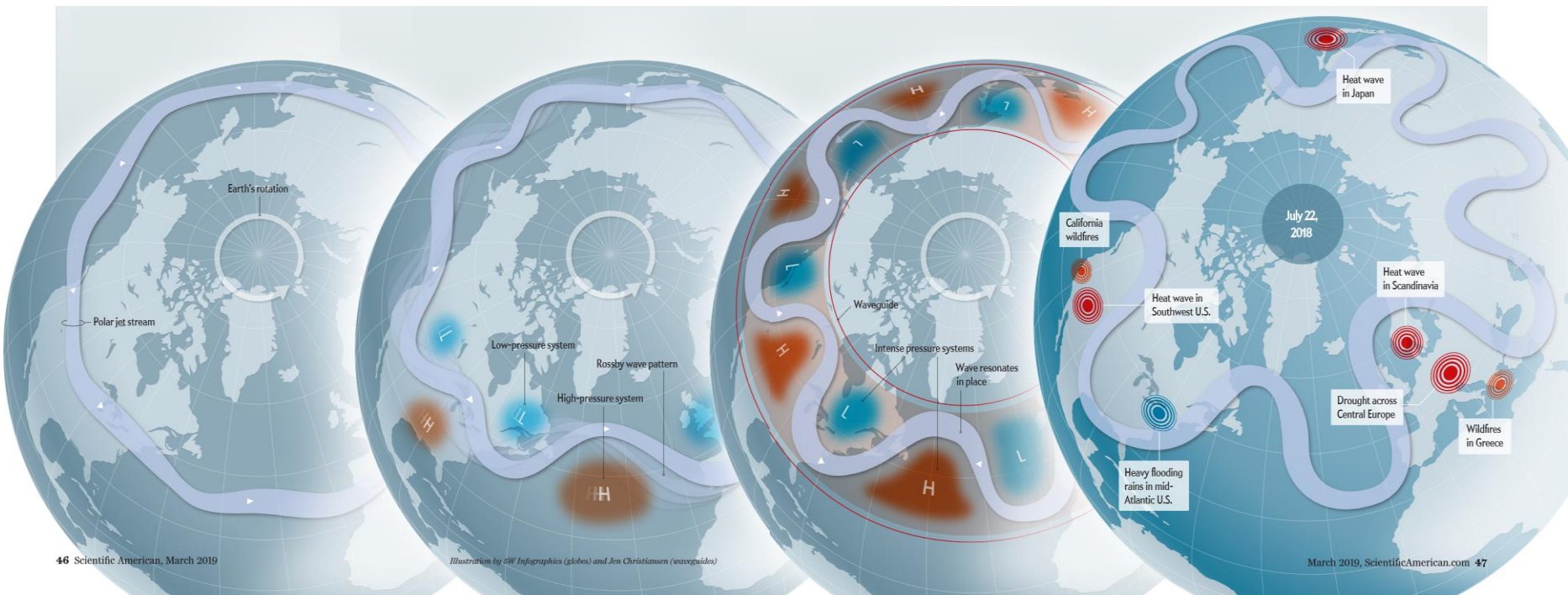
Pethoukov-Effect: Rossby waves related to extreme weather events

Polar jet stream

Bends create low-pressure and high-pressure systems

Formation of Rossby waves

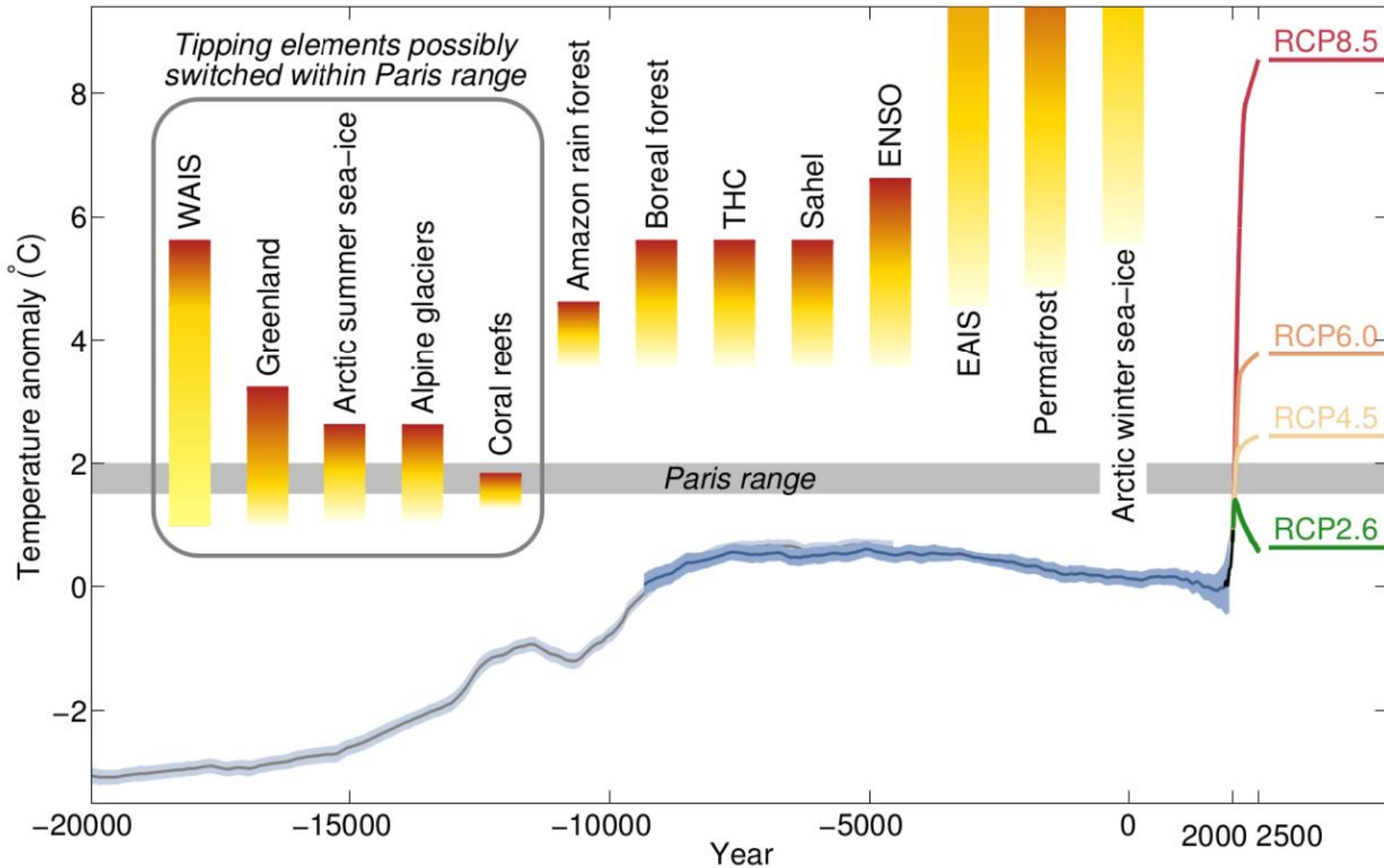
Extreme weather events (e.g. 2018)



Pethoukov et al., PNAS, 2013

Graphic: Mann, M., Scientific American, 2019

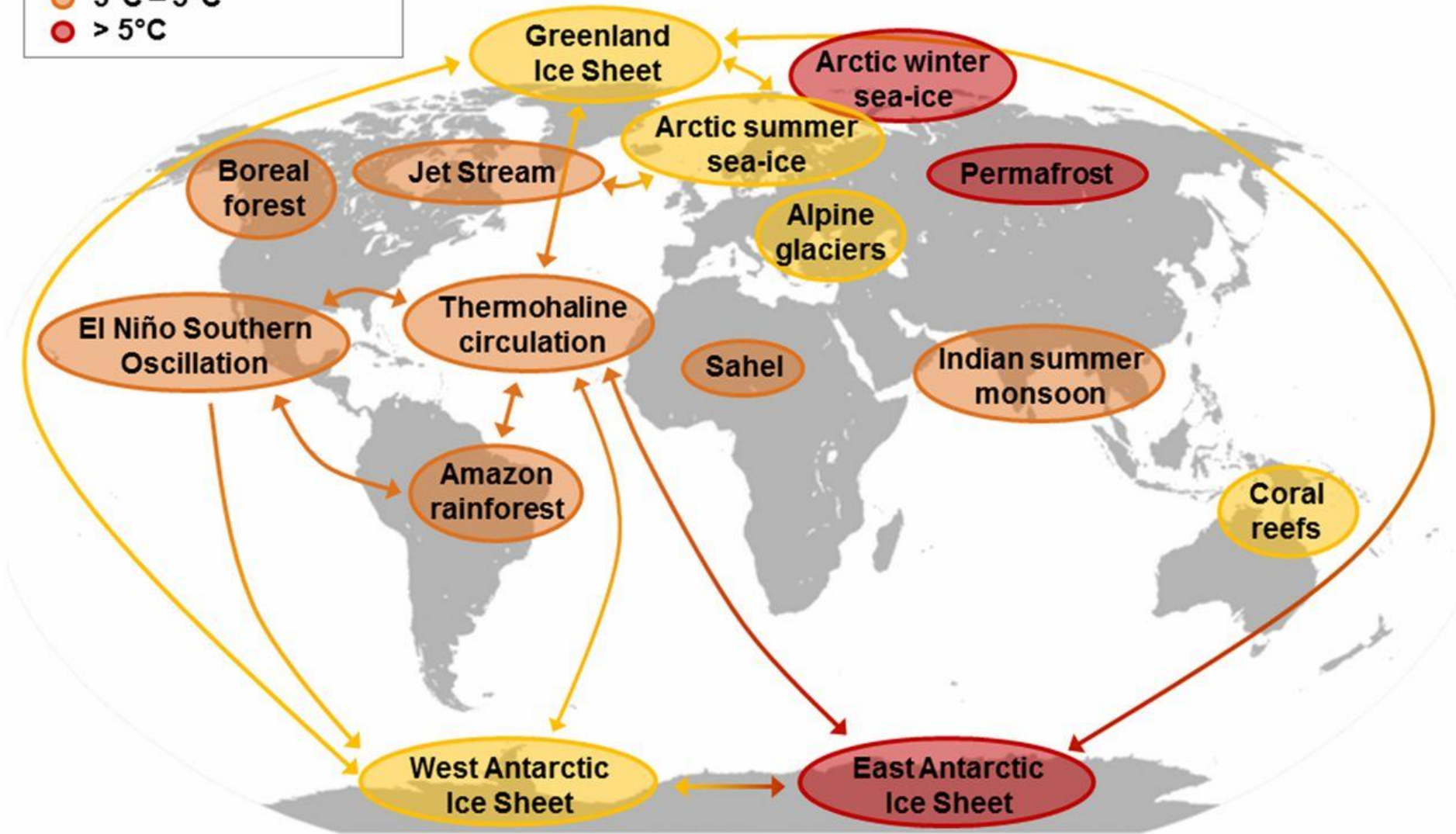
Tipping Points Related to 2°C-Guardrail



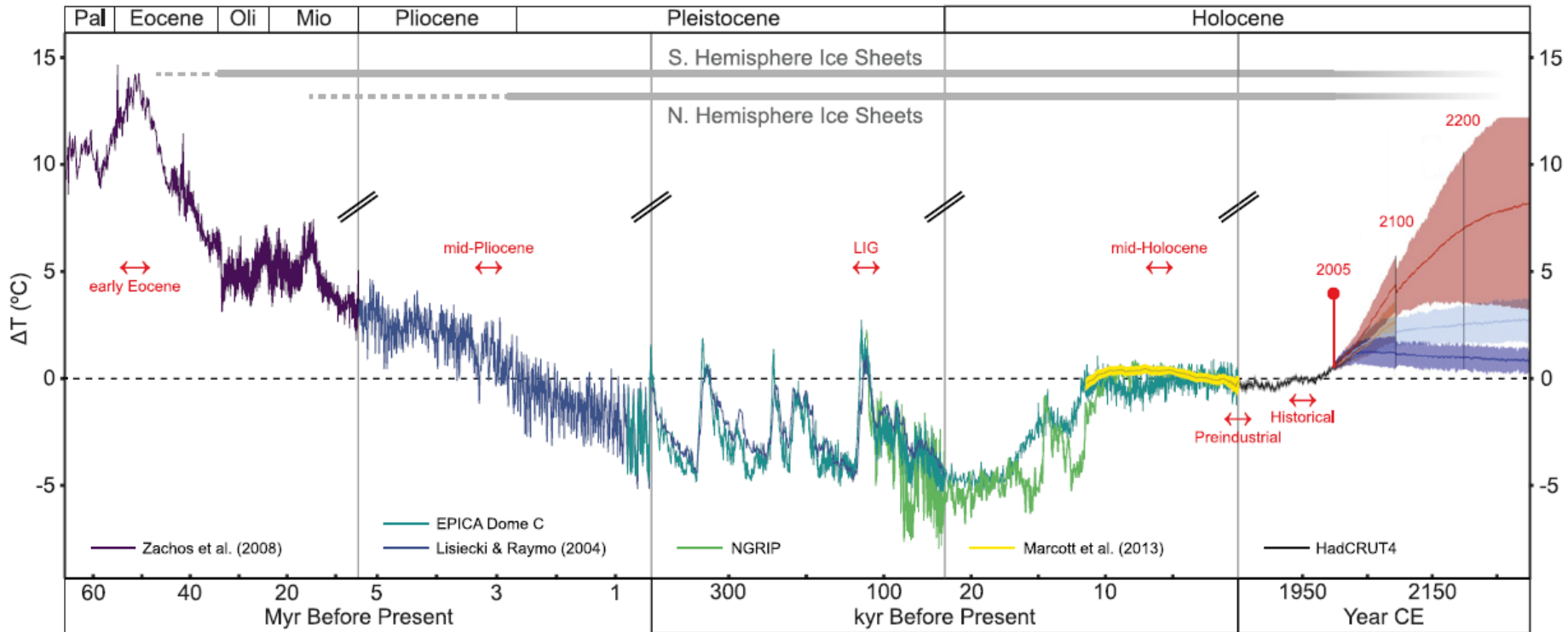
Global Map of Potential Tipping Cascades

Tipping elements at risk:

- 1°C – 3°C
- 3°C – 5°C
- > 5°C



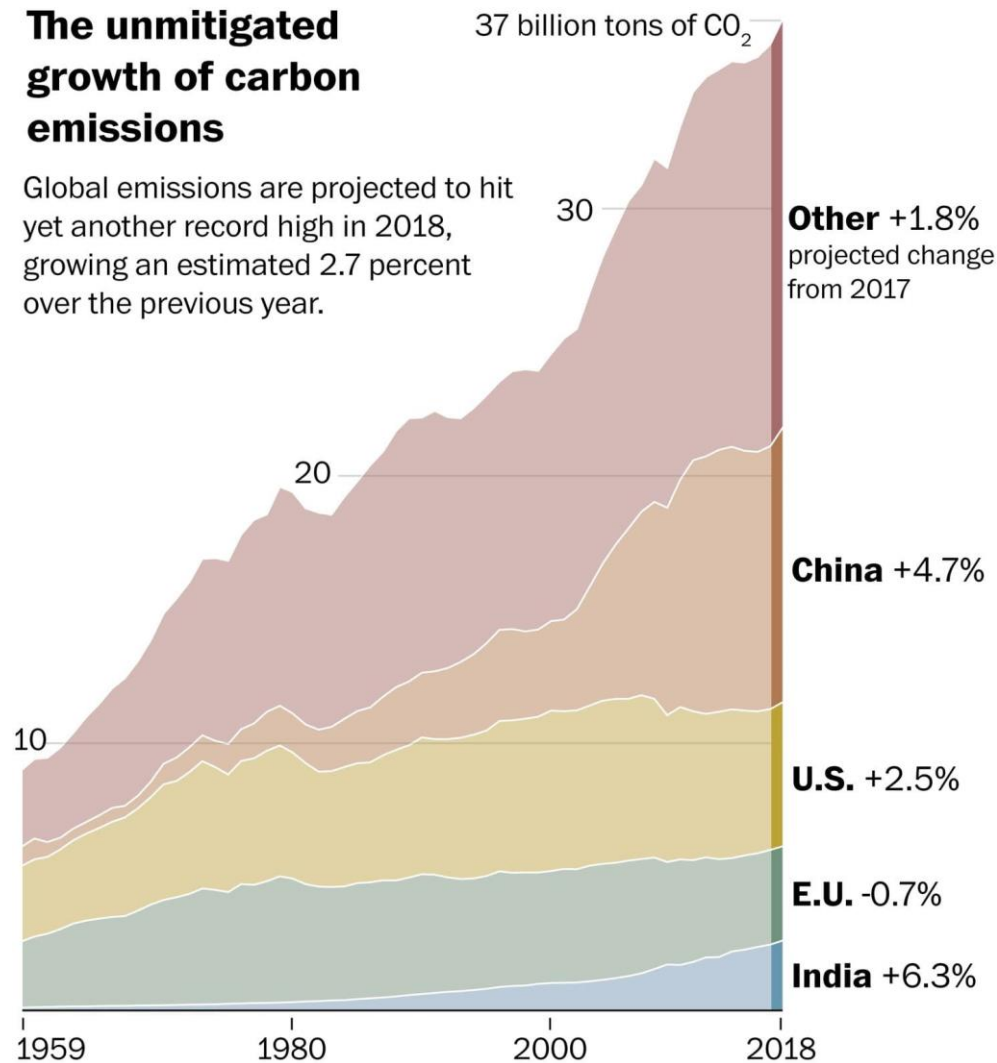
Temperature Trends for the Past 65 Ma and Potential Geohistorical Analogs for Future Climates



'We are in trouble'. Global carbon emissions reached a record high in 2018

The unmitigated growth of carbon emissions

Global emissions are projected to hit yet another record high in 2018, growing an estimated 2.7 percent over the previous year.



Figures show emissions from fossil fuels and industry, which includes cement manufacturing but not deforestation.

Policies of China, Russia and Canada threaten 5C climate change, study finds

Ranking of countries' goals shows even EU on course for more than double safe level of warming



The Guardian 16 November 2018

nature
COMMUNICATIONS

ARTICLE

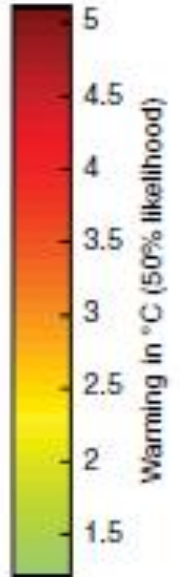
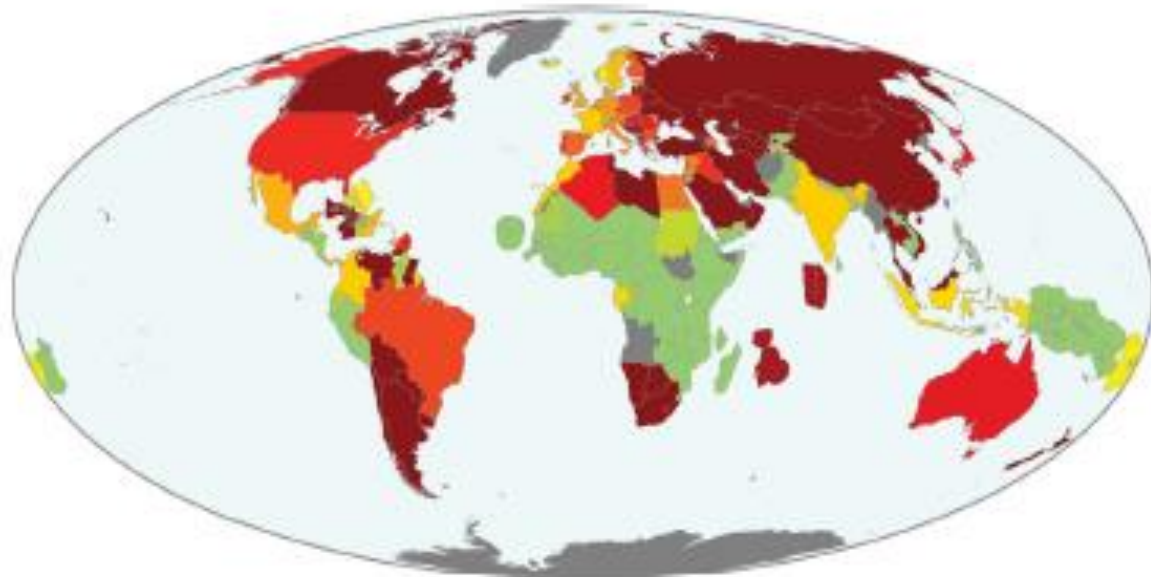
DOI: 10.1038/s41467-018-07223-9

OPEN

Warming assessment of Paris Agreement emissions

Yann Robiou du Pont¹ & Malte Meinshausen¹

Under the bottom-up architecture of the Paris Agreement (NDCs). Current NDCs include inconsistent w...
Determined Cont...
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2.3 °C. Tigh...
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WBGU

German Advisory Council on Global Change

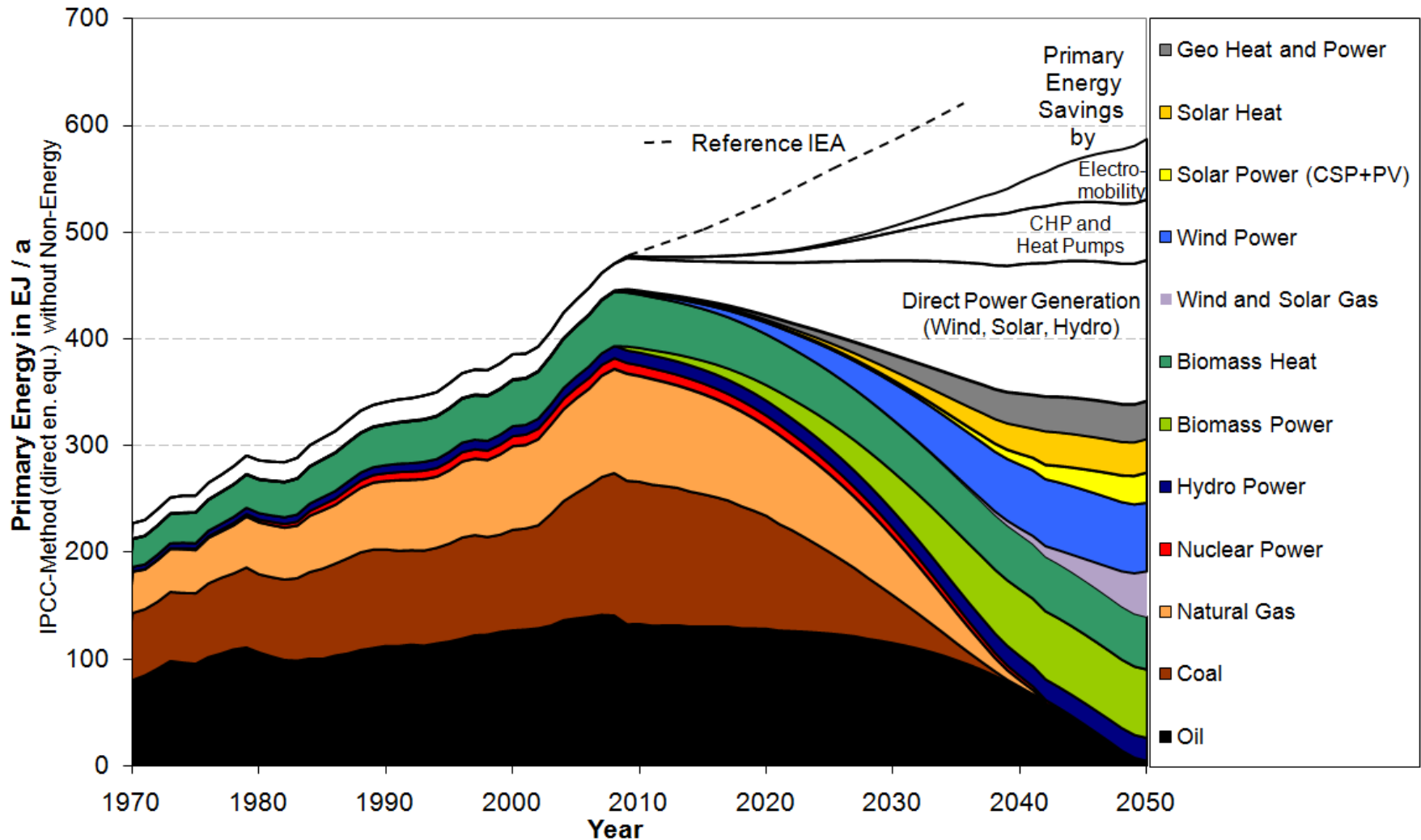
Summary for
Policy-Makers

World in Transition A Social Contract for Sustainability



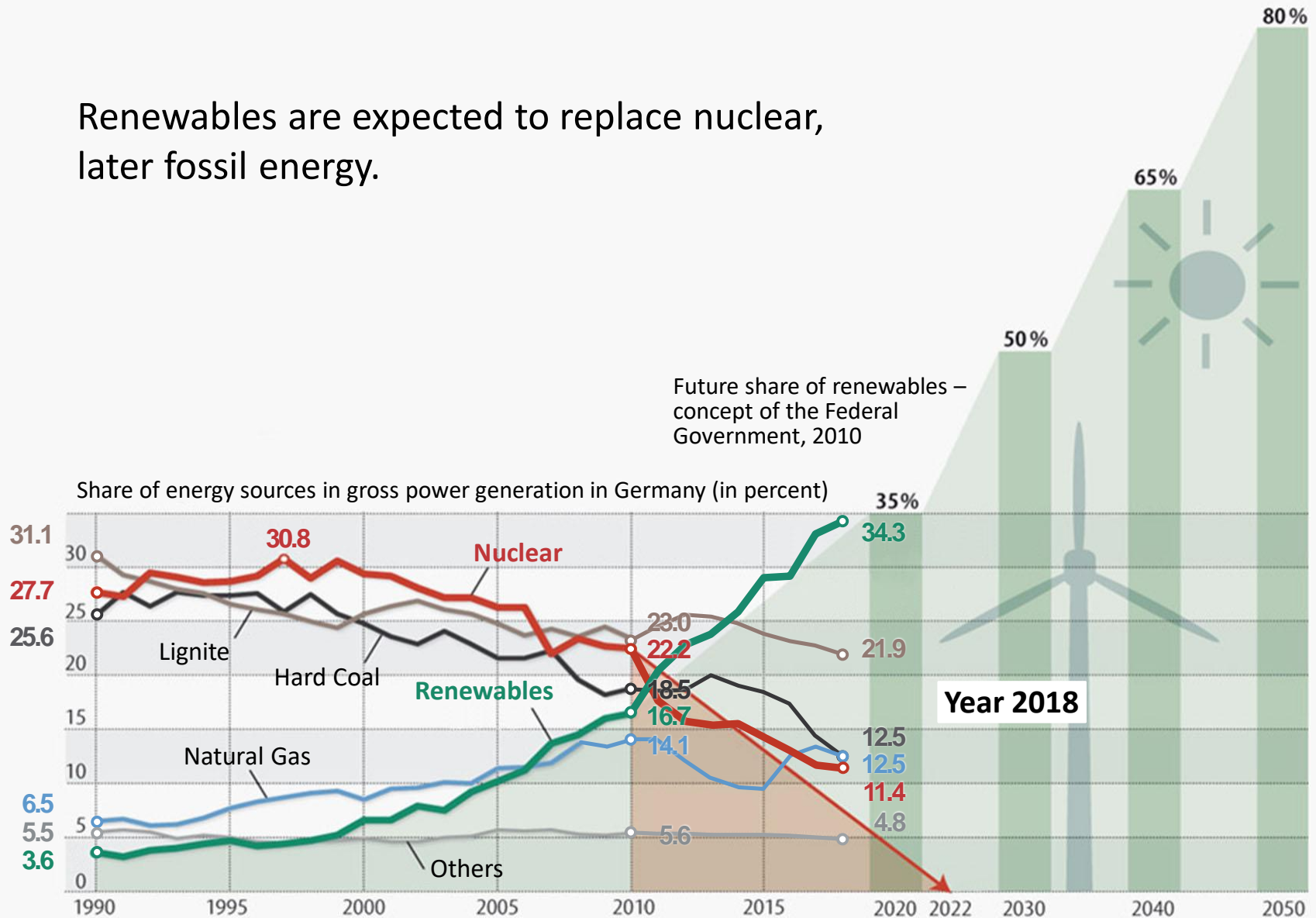
WBGU Vision of Global Energy Revolution

Development of the primary energy demand between 1970 and 2050



“Energiewende“ in Germany

Renewables are expected to replace nuclear, later fossil energy.



Quellen: Bundesregierung; Bundesumweltministerium; Umweltbundesamt; Statistisches Bundesamt; Statistische Landesämter; Bundesanstalt für Geowissenschaften und Rohstoffe; Deutsche Energie-Agentur (dena); eigene Berechnungen

Aktualisierung bis 2019 durch PIK nach BMWi: Zahlen und Fakten – Energiedaten (2019).

German Commission Designing Coal Phase-out



1

Einsetzung der Kommission Wachstum, Strukturwandel und Beschäftigung

Die Politik der Bundesregierung dient der Schaffung von Vollbeschäftigung und gleichwertigen Lebensverhältnissen in ganz Deutschland. Um dies zu erreichen, ist es erforderlich, den in vielen Bereichen stattfindenden Strukturwandel aktiv und umfassend zu begleiten, um so Wachstum und Beschäftigung insbesondere in den betroffenen Regionen zu stärken.

Die Bundesregierung bekennt sich zu den national, europäisch und im Rahmen des Pariser Klimaabkommens vereinbarten Klimaschutzzielen bis zum Jahre 2050. Der Klimaschutzplan der Bundesregierung aus dem Jahre 2016 beschreibt hierzu den schrittweisen Weg in Richtung einer weitgehend treibhausgasneutralen Wirtschaft und Gesellschaft in Deutschland bis Mitte des Jahrhunderts. Insbesondere werden durch den Klimaschutzplan für die einzelnen Sektoren (Energie, Industrie, Gebäude, Verkehr, Landwirtschaft) konkrete Minderungsziele für das Jahr 2030 festgelegt. Dabei werden wir das Ziel, geeignete Maßnahmen sicherzustellen, um die Erreichung dieser Ziele aus Versorgungssicherheit, Umweltverträglichkeit und Wirtschaftlichkeit einhalten.

Mit der Umsetzung des Klimaschutzplanes wird sich der Strukturwandel in vielen Regionen und Wirtschaftsbereichen beschleunigen, insbesondere im Sektor der Energieerzeugung. Die damit einhergehenden Veränderungen dürfen nicht einseitig zu Lasten der kohlestromerzeugenden Regionen gehen, müssen vielmehr Chancen für eine nachhaltige wirtschaftliche Dynamik mit qualitativ hochwertiger Beschäftigung eröffnen. Diese wollen wir aktiv nutzen und so Strukturbrüche sowie Einschränkungen der internationalen Wettbewerbsfähigkeit vermeiden.

Die Bundesregierung setzt deshalb eine Kommission „Wachstum, Strukturwandel und Beschäftigung (WSB)“ ein, die bis zum Ende dieses Jahres konkrete Vorschläge erarbeiten soll. Zu ihrem Auftrag gehört insbesondere die Erarbeitung eines Aktionsprogrammes mit folgenden Schwerpunkten:

1. Schaffung einer konkreten Perspektive für neue, zukunftssichere Arbeitsplätze in den betroffenen Regionen im Zusammenwirken zwischen Bund, Ländern, Kommunen und wirtschaftlichen Akteuren (z.B. im Bereich Verkehrsinfrastrukturen, Fachkräfteentwicklung, unternehmerische Entwicklung, Ansiedlung von Forschungseinrichtungen, langfristige Strukturentwicklung).

Zu Mitgliedern der Kommission

Vorsitzende
 Matthias Platzeck
 Ronald Pofalla
 Prof. Dr. Barbara Praetorius
 Stanislaw Tillich

2. Entwicklung eines Instrumentariums für Strukturwandel, Sozialpolitik und Klimaschutz zusammen mit der Bundesregierung

3. Dazu gehören auch nationale Förderinstrumente von der Bundesregierung in den betroffenen Regionen ein Fonds für Strukturwandel einzusetzen.

4. Maßnahmen, die das Ziel erreichen, einschließlich dem Klimaschutzplan der Bundesregierung aus dem Jahre 2030 gegenüber dem Jahr 2030 die Kommission gezielte Maßnahmen für die Umsetzung des Klimaschutzplans zu erarbeiten.

5. Darüber hinaus ein Plan der Kohleverstromung, notwendige rechtliche und strukturelle Begleitmaßnahmen zu erarbeiten.

6. Ebenso Maßnahmen zur Erreichung des 40% Ziels. Hierzu wird die Größe der zu erwartenden Kohleerzeugung im Jahr 2017 veröffentlicht.

Mitglieder
 Prof. Dr. h.c. Jutta Allmendinger
 Antje Grothues
 Gerda Hasselfeldt
 Christine Hertrich
 Martin Kaiser
 Steffen Kampeter
 Stefan Kappler
 Prof. Dieter Kempf
 Stefan Körzell
 Michael Kreuzberg
 Dr. Felix Matthes
 Claudia Nemat
 Prof. Dr. Kai Niebert
 Prof. Dr. Annkatrin Niebuhr
 Reiner Priggen
 Katherina Reiche
 Gunda Röstel
 Andreas Scheidt
 Prof. Dr. Hans Joachim Schellnhuber
 Dr. Eric Schweitzer
 Michael Vassiliadis
 Prof. Dr. Ralf Wehrspohn
 Hubert Weiger
 Hannelore Wodtke

Als Personen mit Rede-, aber ohne Deutschen Bundestages benannt:

Andreas G. Lämmel, MdB
 Dr. Andreas Lenz, MdB
 Dr. Matthias Miersch, MdB

Die Kommission WSB legt ihre Arbeitsergebnisse in schriftlichen Berichten an den Staatssekretärsausschuss nieder. Ihre Empfehlungen für Maßnahmen sowie zu sozialen und strukturellen Entwicklungen der Braunkohleregionen sowie zu ihrer finanziellen Absicherung legt die Kommission WSB bereits Ende Oktober 2018 schriftlich vor. Ihre Empfehlungen für Maßnahmen zum Beitrag der Energiewirtschaft, um die Lücke zur Erreichung des 40 Prozent-

German Commission

Designing Coal Phase-out



The Commission's pensum:

- 16 full-time meetings over half a year
- Hearings of more than 60 experts
- Three journeys to the districts
- 21 hours of final negotiations

The Commission's results:

- Exit of coal-fired power stations until 2038, optionally 2035
- Agreement on phase-out pathway:
 - 2022: 15 GW lignite + 15 GW hard coal (minus 12,7 GW compared to 2017)
 - 2030: 9 GW lignite + 8 GW hard coal (aiming for a continuous reduction pathway starting 2022)
- Extensive support of affected states: €40 billion over 20 years
- Extensive measures for employees and, as far as possible, conjoint solutions with power station operators
- Considerable electricity price compensation



CLIMATE POLICY

A roadmap for rapid decarbonization

Emissions inevitably approach zero with a “carbon law”

By **Johan Rockström**,¹ **Owen Gaffney**,^{1,2}
Joeri Rogelj,^{3,4} **Malte Meinshausen**,^{5,6}
Nebojsa Nakicenovic,⁴ **Hans Joachim Schellnhuber**^{1,5}

pose framing the decarbonization challenge in terms of a global decadal roadmap based on a simple heuristic—a “carbon law”—of halving gross anthropogenic carbon-dioxide (CO₂) emissions every decade. Comple-

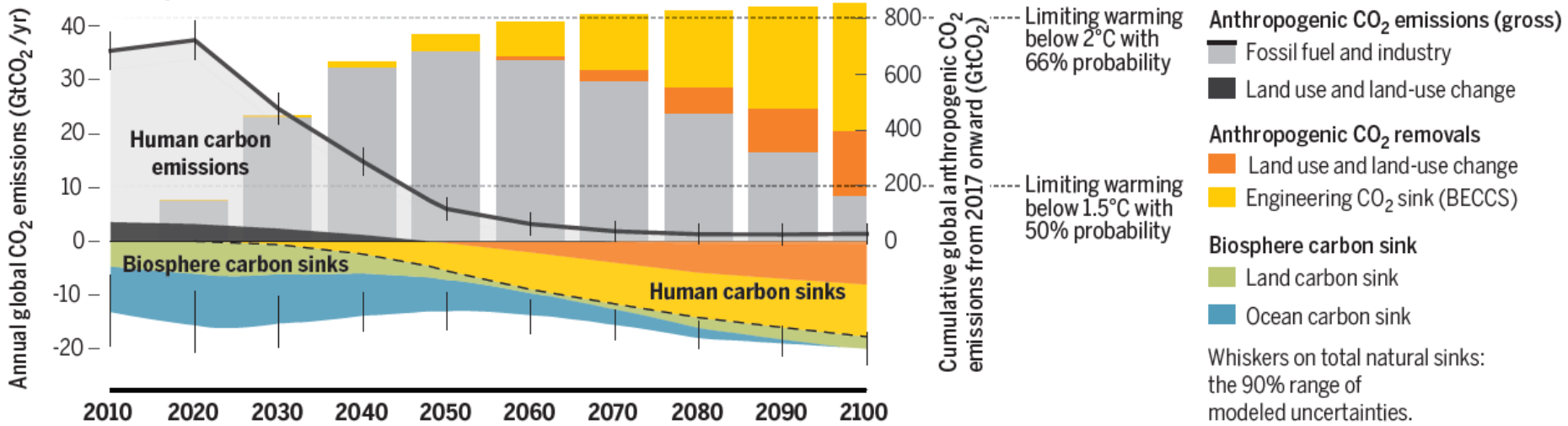
The road to global decarbonization must involve renewable energy, as from these wind turbines in Germany, and improved transportation technologies.

sistent with the trajectory of the past decade (see the figure, bottom left). All sectors (e.g., agriculture, construction, finance, manufacturing, transport) need comparable transformation pathways. In addition, in the absence of viable alternatives, the world must aim at rapidly scaling up CO₂ removal by technical means from zero to at least 0.5 GtCO₂/year by 2030, 2.5 by 2040, and 5 by 2050. CO₂ emissions from land-use must decrease along a nonlinear trajectory from 4 GtCO₂/year in 2010, to 2 by 2030, 1 by 2040, and 0 by 2050 (see the figure, bottom right). The endgame is for cumulative CO₂ emissions since 2017 to be brought back from around 700 GtCO₂ to below 200 GtCO₂ by the end of the century (see the figure, top) and atmospheric CO₂ concentrations to return to 380 ppm by 2100 (currently at 400 ppm).

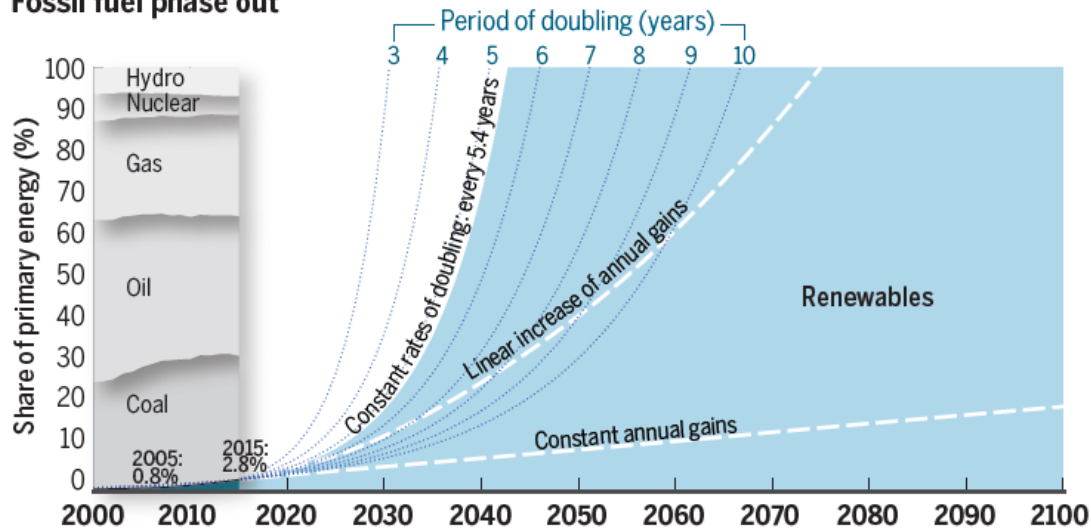
Roadmaps are planning instruments, linking shorter-term targets to longer-term goals. They help align actors and organizations to investigate technological and institutional breakthroughs to meet a collective challenge. An explicit carbon roadmap for halving anthropogenic emissions every decade, codesigned by and for all industry sectors, could help promote disruptive, nonlinear technological advances toward a zero-emissions world. The

The Transformation Roadmap

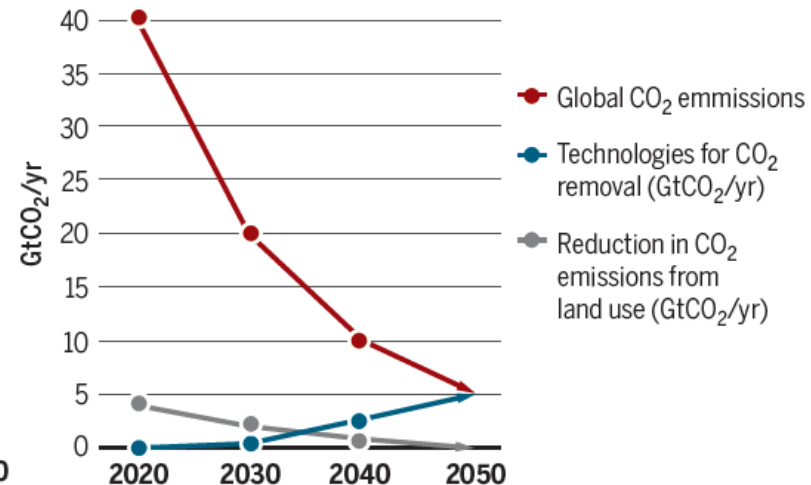
Decarbonization pathway consistent with Paris agreement



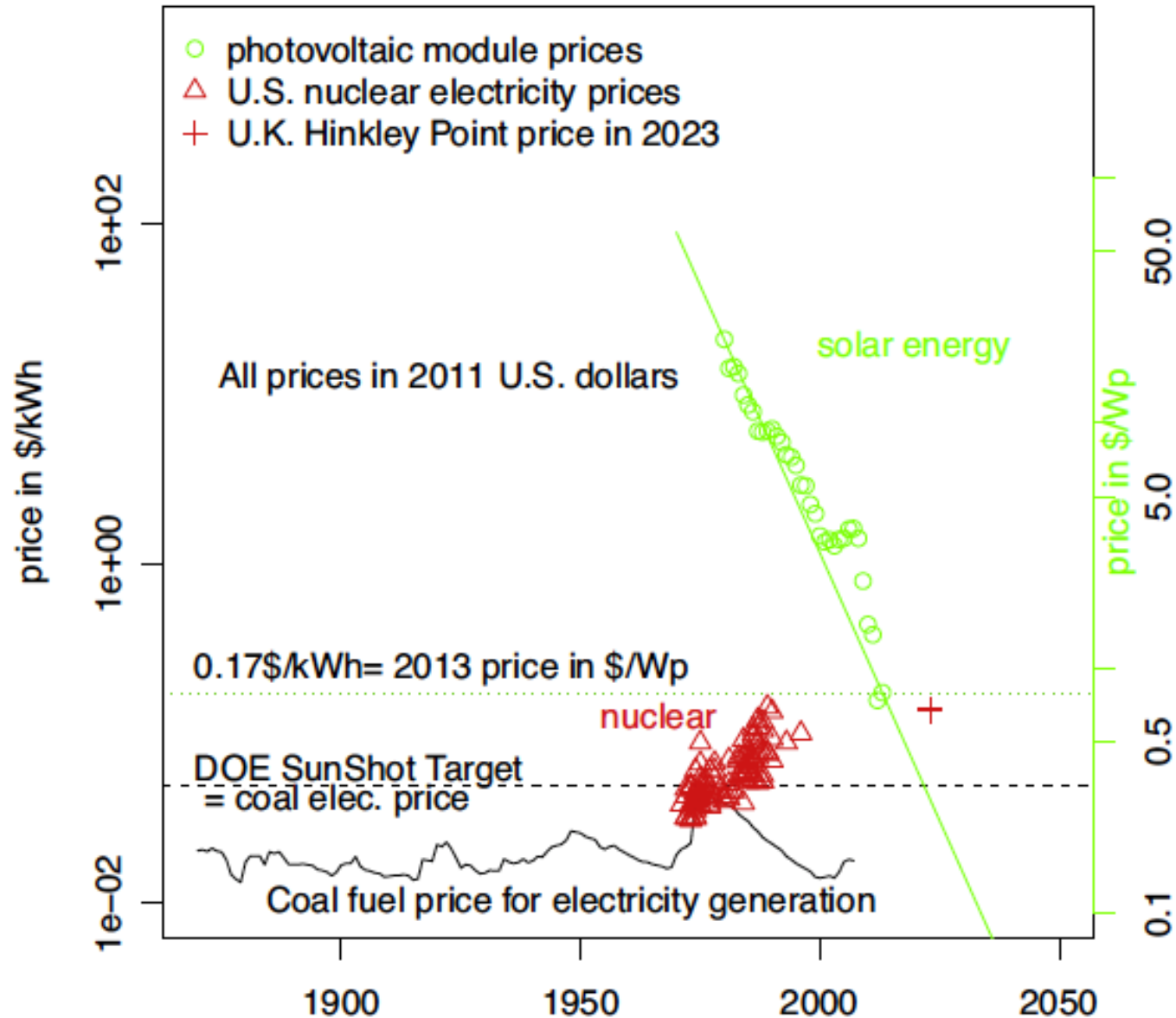
Fossil fuel phase out



Global carbon law guiding decadal pathways

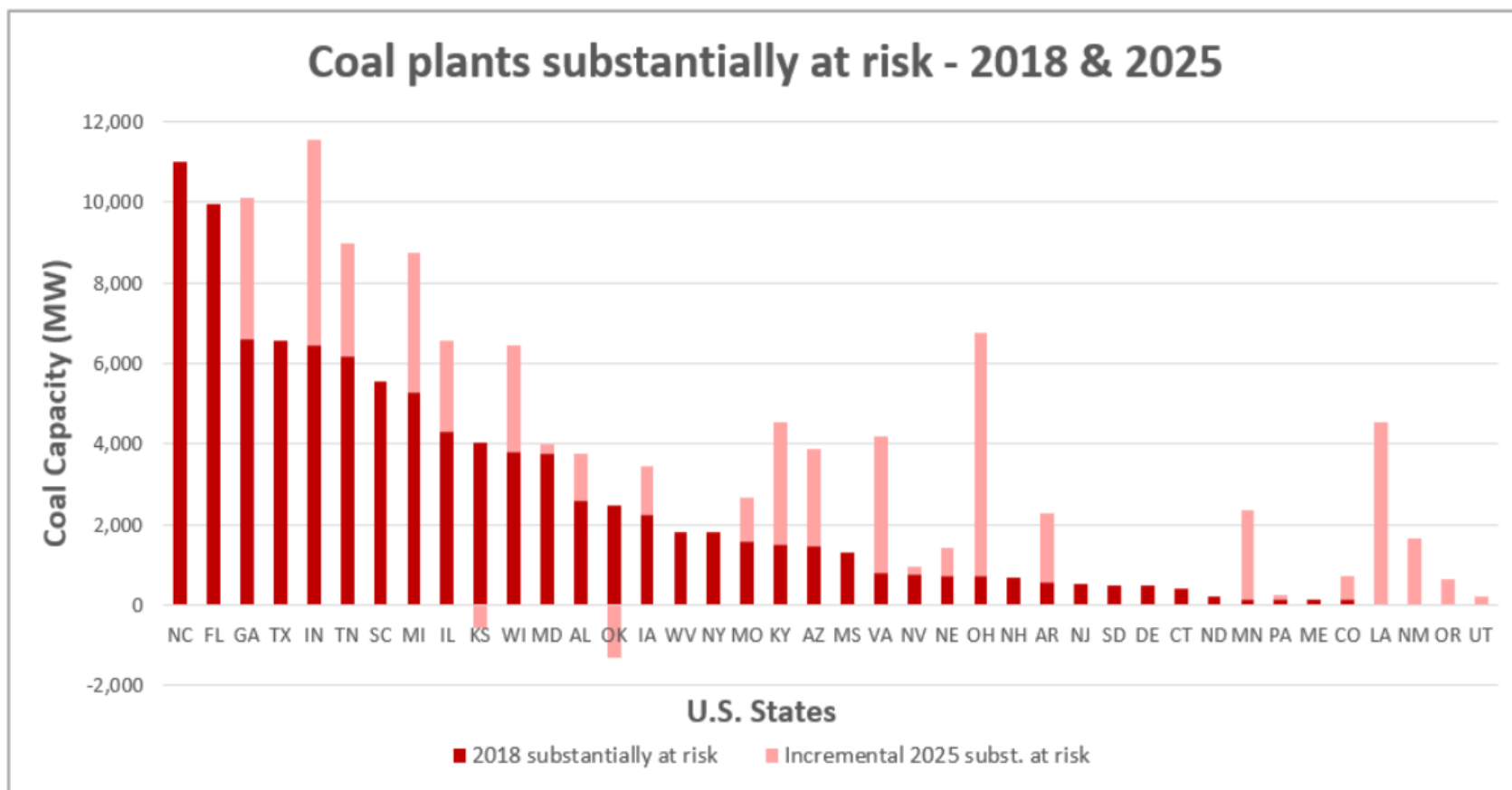


Technologies Beat Commodities – Renewables Will Win (But Not Fast Enough)



'Coal is on the way out': study finds fossil fuel now pricier than solar or wind

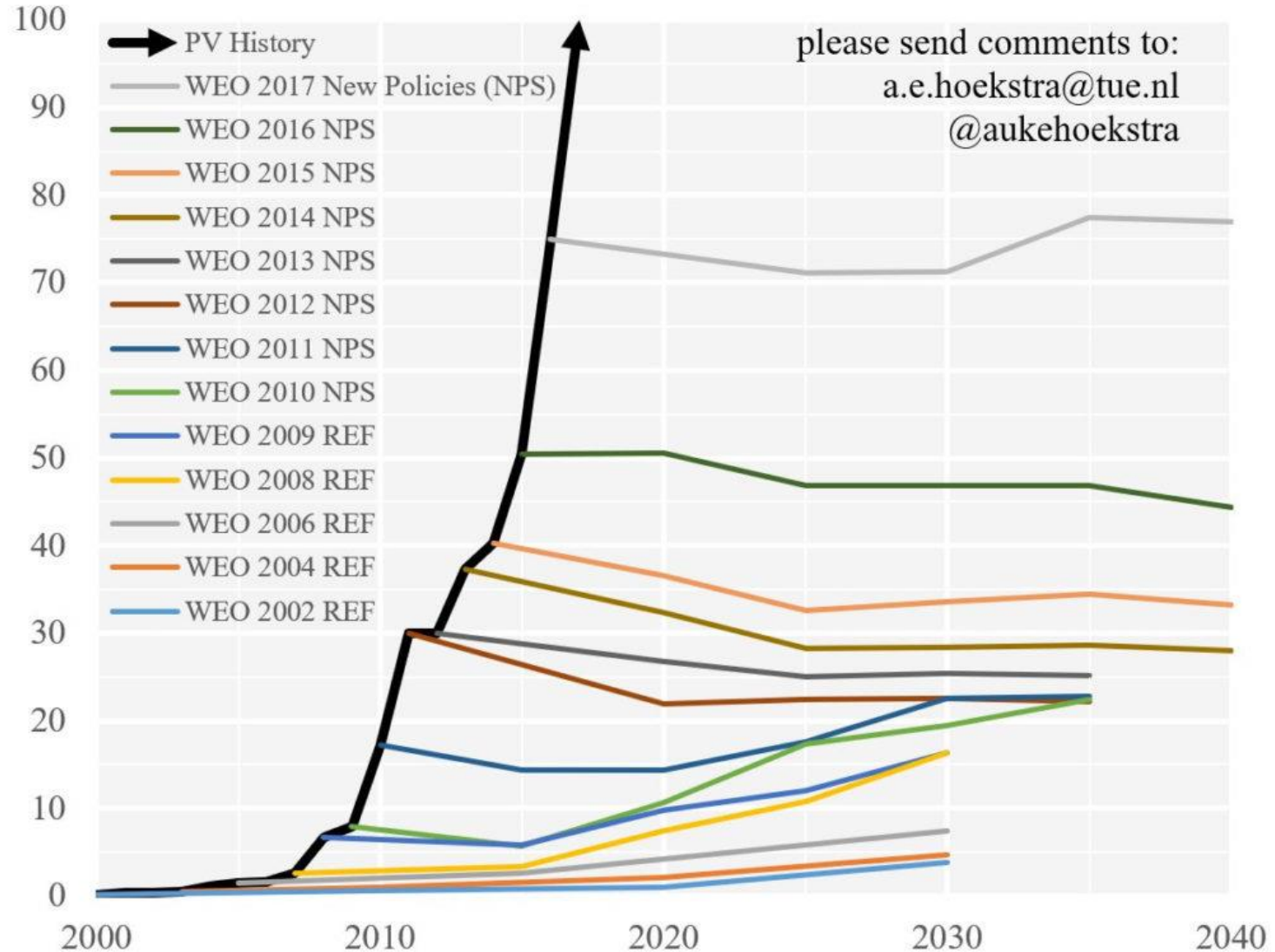
Around 75% of coal production is more expensive than renewables, with industry out-competed on cost by 2025



Real Photovoltaics Development vs. IEA Projections

Annual PV additions: historic data vs IEA WEO predictions

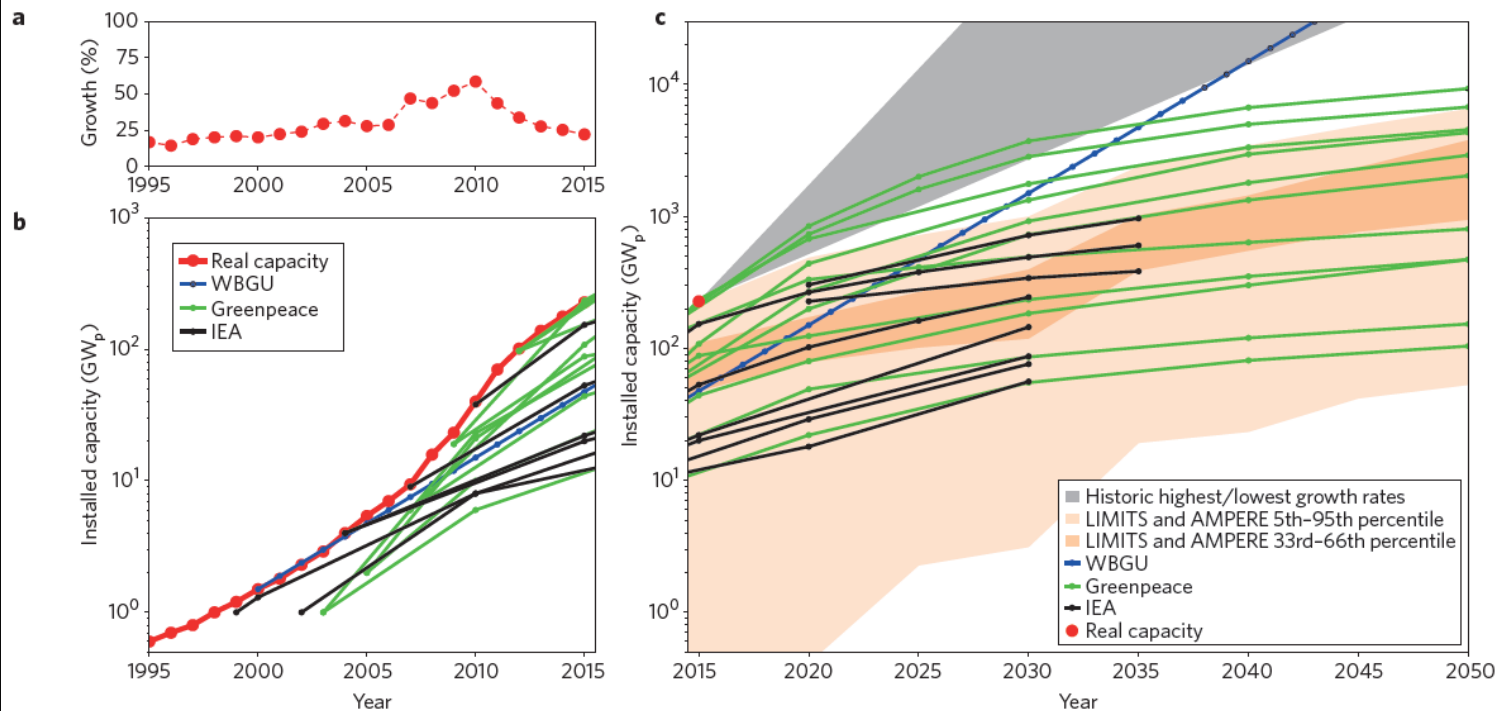
In GW of added capacity per year - source International Energy Agency - World Energy Outlook



The underestimated potential of solar energy to mitigate climate change

Felix Creutzig^{1,2*}, Peter Agoston¹, Jan Christoph Goldschmidt³, Gunnar Luderer⁴, Gregory Nemet^{1,5} and Robert C. Pietzcker⁴

The Intergovernmental Panel on Climate Change's fifth assessment report emphasizes the importance of bioenergy and carbon capture and storage for achieving climate goals, but it does not identify solar energy as a strategically important technology option. That is surprising given the strong growth, large resource, and low environmental footprint of photovoltaics (PV). Here we explore how models have consistently underestimated PV deployment and identify the reasons for underlying bias in models. Our analysis reveals that rapid technological learning and technology-specific policy support were crucial to PV deployment in the past, but that future success will depend on adequate financing instruments and the management of system integration. We propose that with coordinated advances in multiple components of the energy system, PV could supply 30–50% of electricity in competitive markets.



Growth in PV capacity and scenario projections.

The Future of Solar Energy: Worldwide Innovation Projects

Cochin International Airport, India



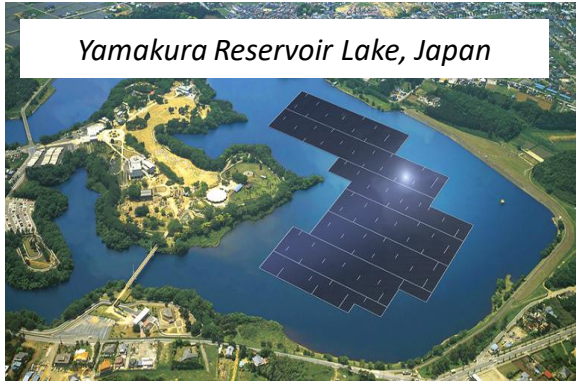
Blackfriars Bridge, London, UK



Riyuetan-Weipai-Building, China



Yamakura Reservoir Lake, Japan



Solar Farm, Punjab, India



Solar Farm, Noor, Morocco

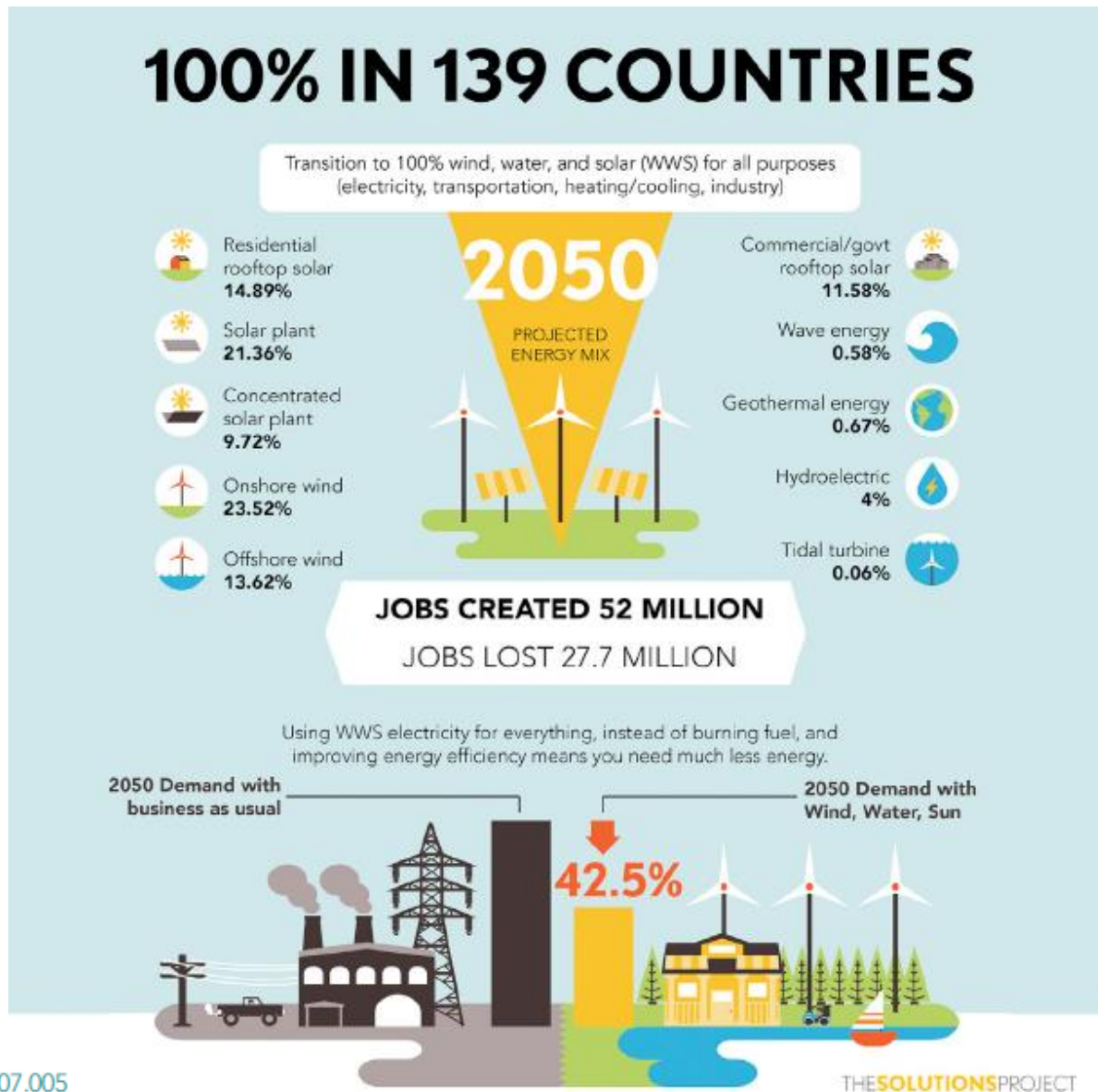


Train Tunnel, Holland-Belgium



100% Clean and Renewable Wind, Water, and Sunlight All-Sector Energy Roadmaps for 139 Countries of the World

Mark Z. Jacobson,^{1,5,*} Mark A. Delucchi,² Zack A.F. Bauer,¹ Savannah C. Goodman,¹ William E. Chapman,¹ Mary A. Cameron,¹ Cedric Bozonnat,¹ Liat Chobadi,³ Hailey A. Clonts,¹ Peter Enevoldsen,⁴ Jenny R. Erwin,¹ Simone N. Fobi,¹ Owen K. Goldstrom,¹ Eleanor M. Hennessey,¹ Jingyi Liu,¹ Jonathan Lo,¹ Clayton B. Meyer,¹ Sean B. Morris,¹ Kevin R. Moy,¹ Patrick L. O'Neill,¹ Ivalin Petkov,¹ Stephanie Redfern,¹ Robin Schucker,¹ Michael A. Sontag,¹ Jingfan Wang,¹ Eric Weiner,¹ and Alexander S. Yachanin¹





FINAL REPORT

of the High-Level Panel
of the European Decarbonisation
Pathways Initiative



SYSTEM UPLOADING

Research and
Innovation

High-Level Panel of the European Decarbonisation Pathways Initiative (HLP-EDPI)



EU Commissioner
Carlos Marín Brindley



HLP-EDPI
Chair Michael Schellnhuber



Peter Thimann



Catia Bastioli



Paul Ekins



Beata Jaczewska



Barbara Kux



Laurence Tubiana

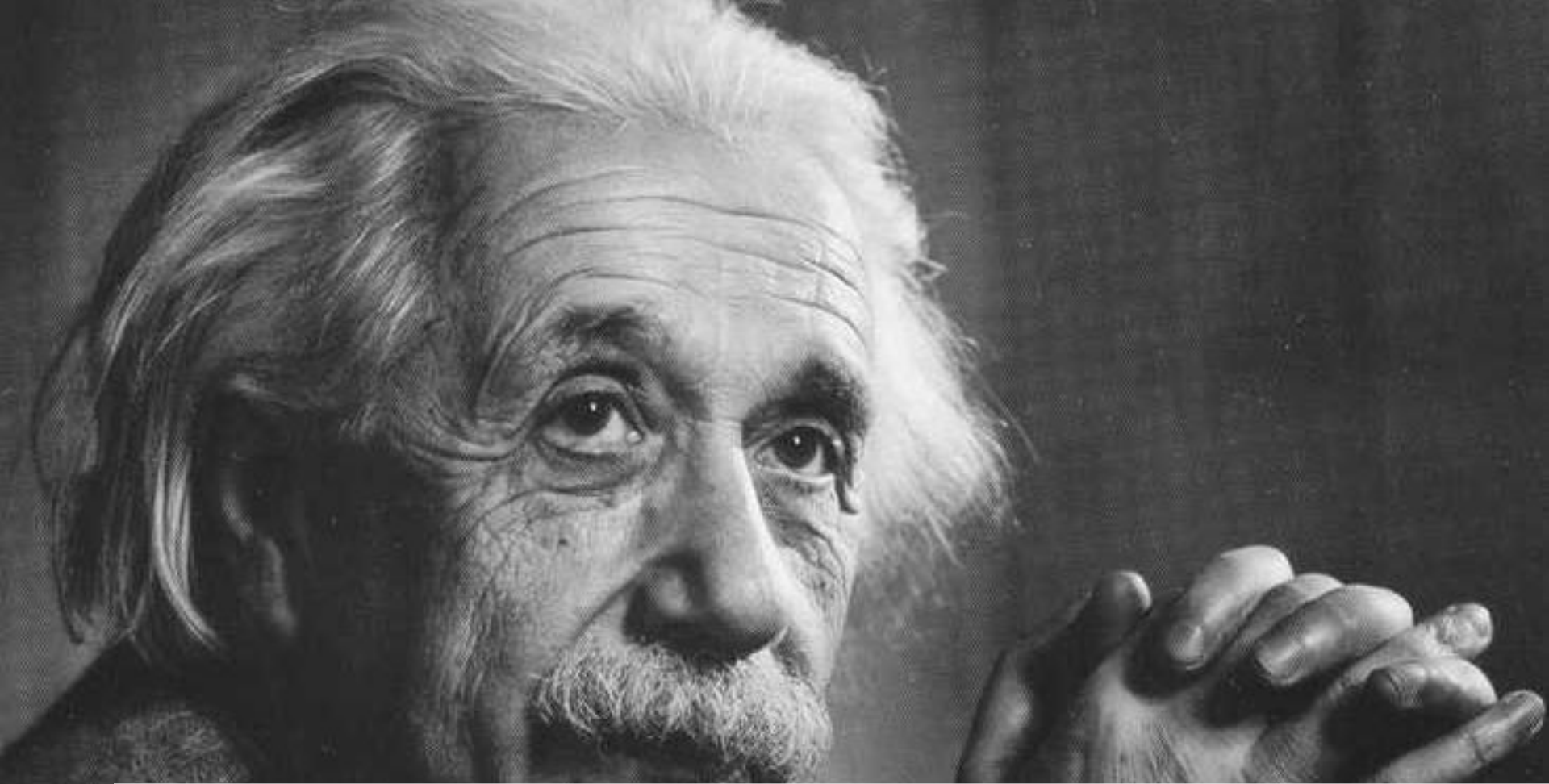


Maria van der Hoeven



Karin Wanngard

Transition Super-Labs!!!



The significant problems we face cannot be solved at the same level of thinking we were at when we created them.

Albert Einstein

Towards Deep Machine Learning

Proc. Natl. Acad. Sci. USA
Vol. 79, pp. 2554–2558, April 1982
Biophysics

J.J. Hopfield, *PNAS*, 1982

Neural networks and physical systems with emergent collective computational abilities

(associative memory/parallel processing/categorization/content-addressable memory/fail-soft devices)

J. J. HOPFIELD

Division of Chemistry and Biology, California Institute of Technology, Pasadena, California 91125; and Bell Laboratories, Murray Hill, New Jersey 07974

Contributed by John J. Hopfield, January 15, 1982

ABSTRACT Computational properties of use to biological organisms or to the construction of computers can emerge as collective properties of systems having a large number of simple equivalent components (or neurons). The physical meaning of content-addressable memory is described by an appropriate phase space flow of the state of a system. A model of such a system is given, based on aspects of neurobiology but readily adapted to integrated circuits. The collective properties of this model produce a content-addressable memory which correctly yields an entire memory from any subpart of sufficient size. The algorithm for the time evolution of the state of the system is based on asynchronous parallel processing. Additional emergent collective properties include some capacity for generalization, familiarity recognition, categorization, error correction, and time sequence retention. The collective properties are only weakly sensitive to details of the modeling or the failure of individual devices.

Spin-glass models of neural networks, Amit, Gutfreund and Sompolinsky *Phys. Rev. A*, 1985

PHYSICAL REVIEW A

VOLUME 32, NUMBER 2

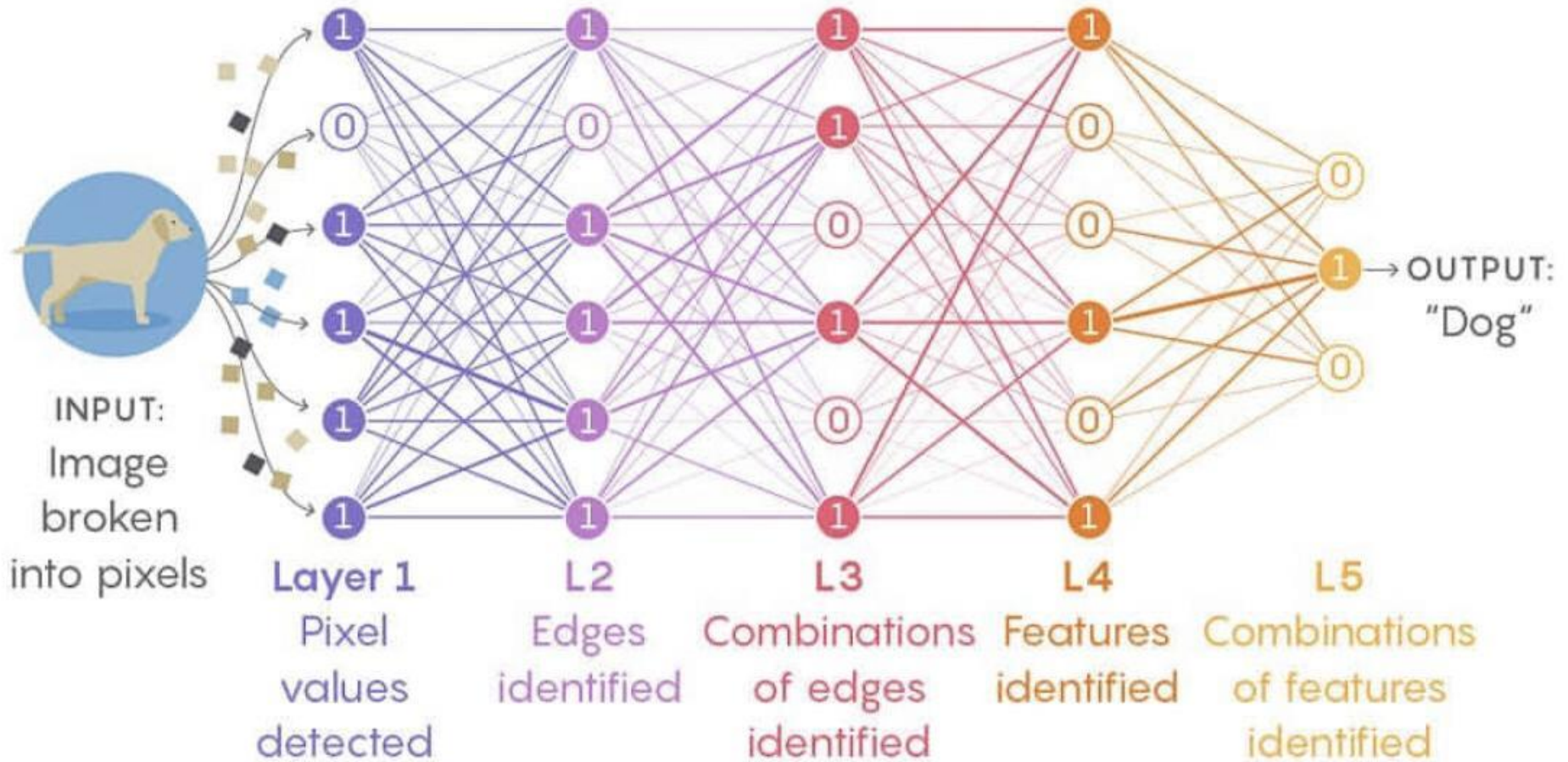
AUGUST 1985

Spin-glass models of neural networks

Daniel J. Amit and Hanoach Gutfreund
Racah Institute of Physics, Hebrew University, 91904 Jerusalem, Israel

H. Sompolinsky
Department of Physics, Bar-Ilan University, 52100 Ramat-Gan, Israel
(Received 22 March 1985)

Two dynamical models, proposed by Hopfield and Little to account for the collective behavior of neural networks, are analyzed. The long-time behavior of these models is governed by the statistical mechanics of infinite-range Ising spin-glass Hamiltonians. Certain configurations of the spin system, chosen at random, which serve as memories, are stored in the quenched random couplings. The present analysis is restricted to the case of a finite number p of memorized spin configurations, in the thermodynamic limit. We show that the long-time behavior of the two models is identical, for all temperatures below a transition temperature T_c . The structure of the stable and metastable states is displayed. Below T_c , these systems have $2p$ ground states of the Mattis type: Each one of them is fully correlated with one of the stored patterns. Below $T \sim 0.46T_c$, additional dynamically stable states appear. These metastable states correspond to specific mixings of the embedded patterns. The thermodynamic and dynamic properties of the system in the cases of more general distributions of random memories are discussed.



Mastering the game of Go without human knowledge

David Silver^{1*}, Julian Schrittwieser^{1*}, Karen Simonyan^{1*}, Ioannis Antonoglou¹, Aja Huang¹, Arthur Guez¹, Thomas Hubert¹, Lucas Baker¹, Matthew Lai¹, Adrian Bolton¹, Yutian Chen¹, Timothy Lillicrap¹, Fan Hui¹, Laurent Sifre¹, George van den Driessche¹, Thore Graepel¹ & Demis Hassabis¹

A long-standing goal of artificial intelligence is an algorithm that learns, *tabula rasa*, superhuman proficiency in challenging domains. Recently, AlphaGo became the first program to defeat a world champion in the game of Go. The tree search in AlphaGo evaluated positions and selected moves using deep neural networks. These neural networks were trained by supervised learning from human expert moves, and by reinforcement learning from self-play. Here we introduce an algorithm based solely on reinforcement learning, without human data, guidance or domain knowledge beyond game rules. AlphaGo becomes its own teacher: a neural network is trained to predict AlphaGo's own move selections and also the winner of AlphaGo's games. This neural network improves the strength of the tree search, resulting in higher quality move selection and stronger self-play in the next iteration. Starting *tabula rasa*, our new program AlphaGo Zero achieved superhuman performance, winning 100–0 against the previously published, champion-defeating AlphaGo.

Source: Silver et. al 2017



Image: DeepMind Technologies Ltd

The Telegraph 18 OCTOBER 2017

AlphaGo Zero: Google DeepMind supercomputer learns 3,000 years of human knowledge in 40 days

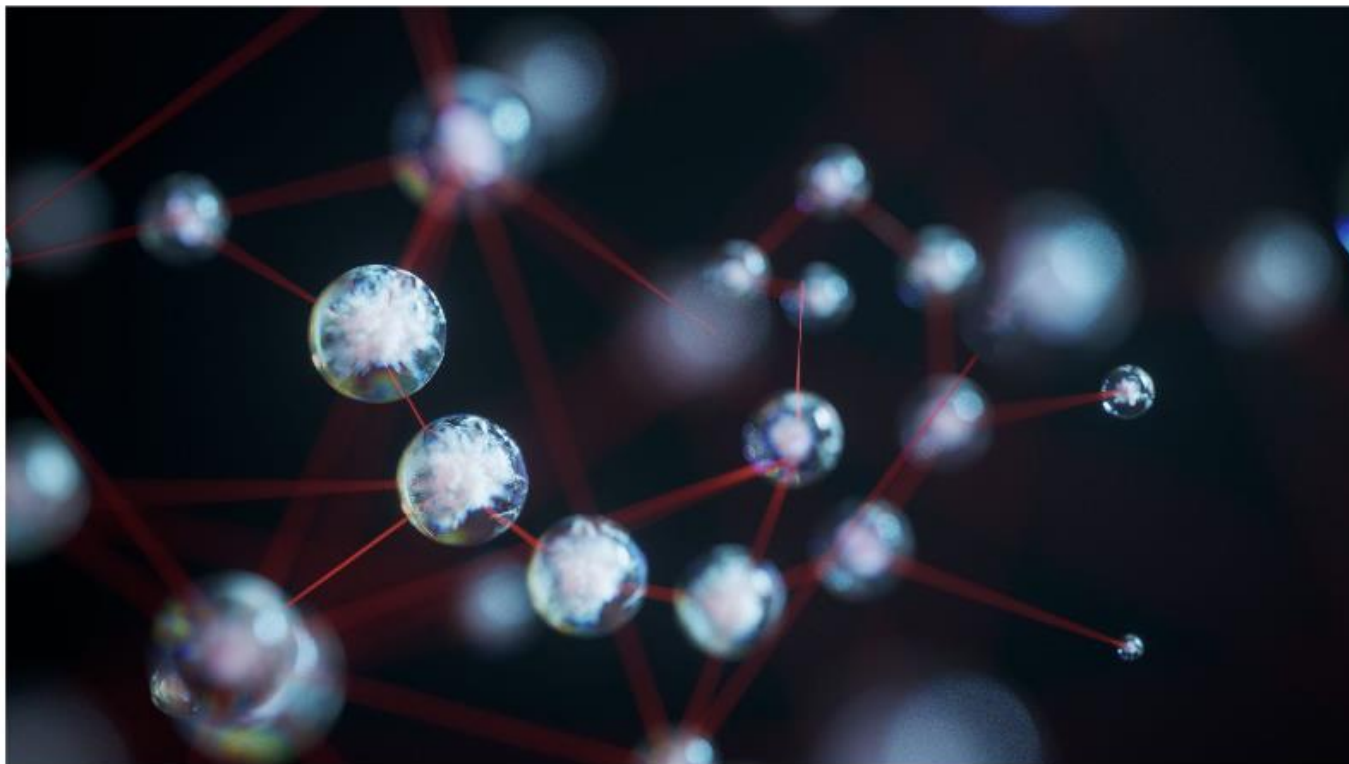
Fusion of Neural Networks and Quantum Computing



By George Musser

Job One for Quantum Computers: Boost Artificial Intelligence

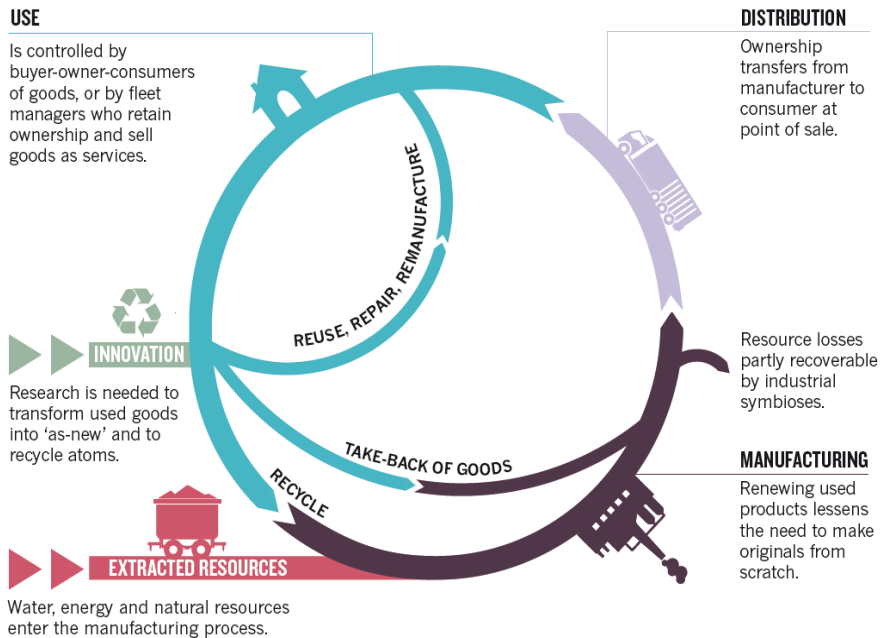
The fusion of quantum computing and machine learning has become a booming research area. Can it possibly live up to its high expectations?



The Dream of a Digital Circular Economy

CLOSING LOOPS

Using resources for the longest time possible could cut some nations' emissions by up to 70%, increase their workforces by 4% and greatly lessen waste.



- 3-D Printing
- The Internet of Things
- Automation of Production
- Automation of Deconstruction

(Stahel, 2016)

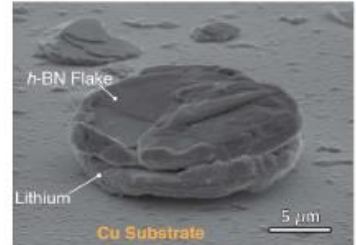
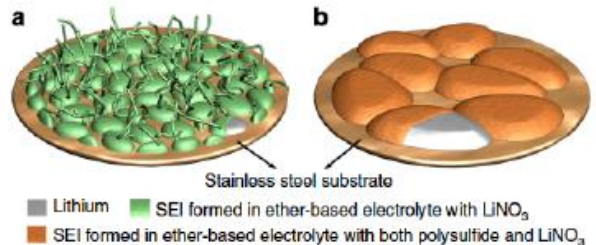
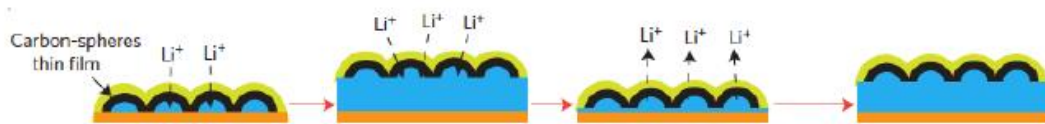
➔ More Efficiency

➔ Less Material and Energy Usage

➔ Better Monitoring of Material Flows

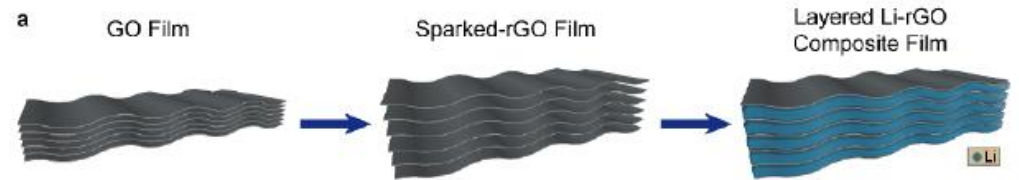
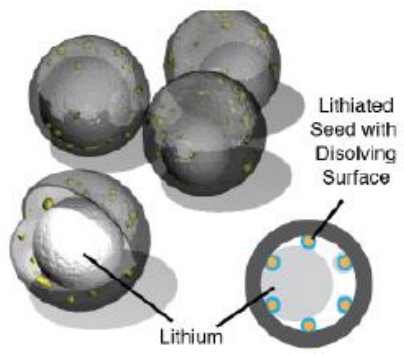
Li Metal Anode: Holy Grail of Batteries

Materials for a Stable Interface



Prof. Steven Chu

Materials for a Stable Host



Costing the Earth: Construction and Concrete



© Omar Chatrivala/flickr

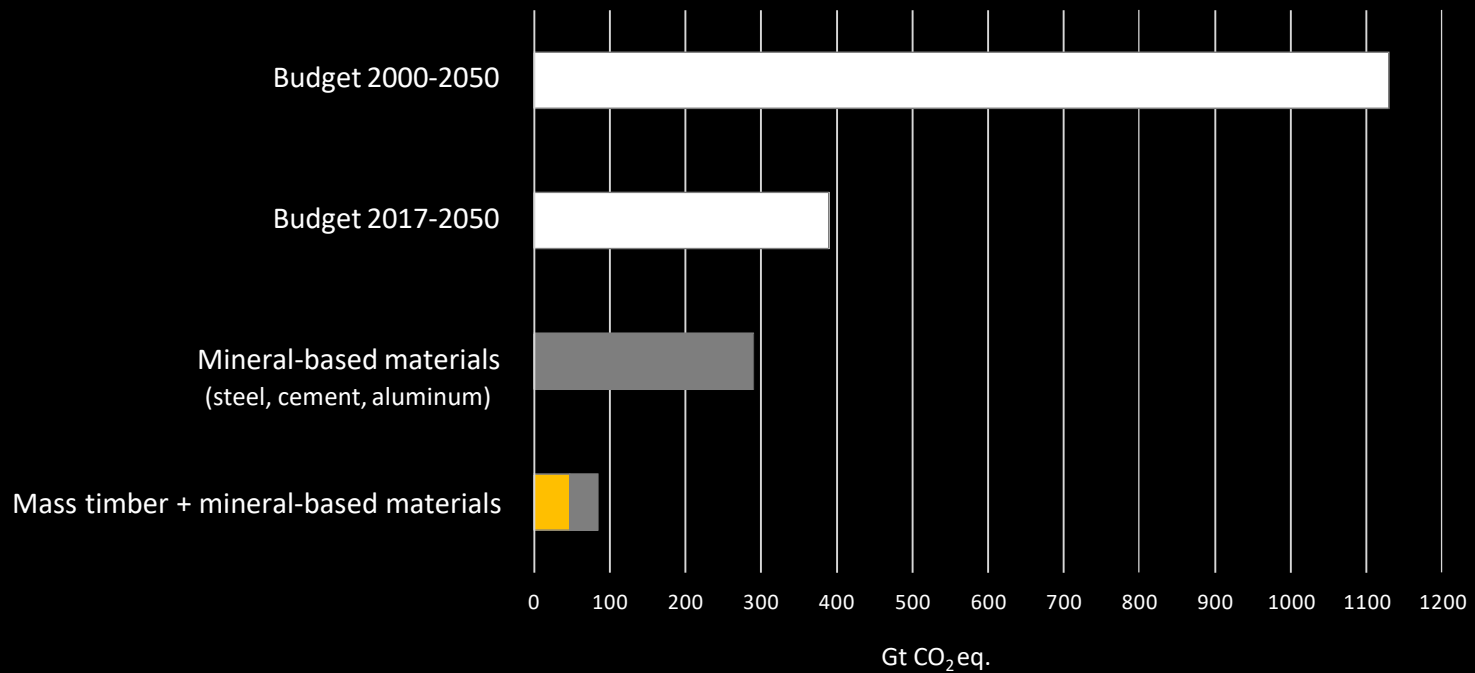
- Global construction until 2050 will require the same amount of infrastructure as has been built since 1850.
- This will use up most of the CO₂ budget (1.5°C), if conventional materials like concrete are used.
- In China alone more cement was used from 2008–2010 than during the entire 20th century in the USA.

→ **Climate change mitigation will be decided in the cities.**

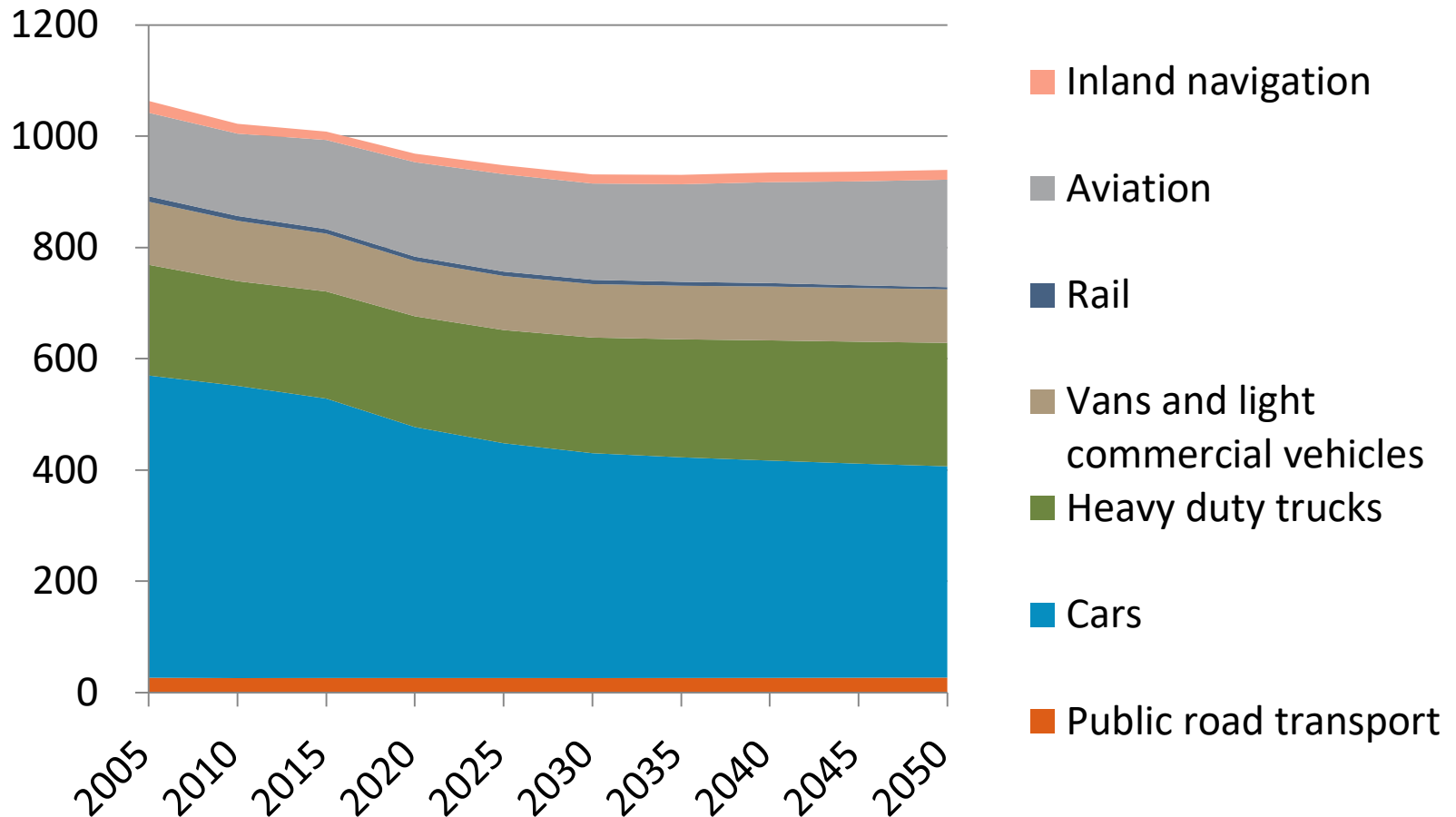


Biomass-based Materials in Construction

Greenhouse Gas Emissions (Gt CO₂ eq.)

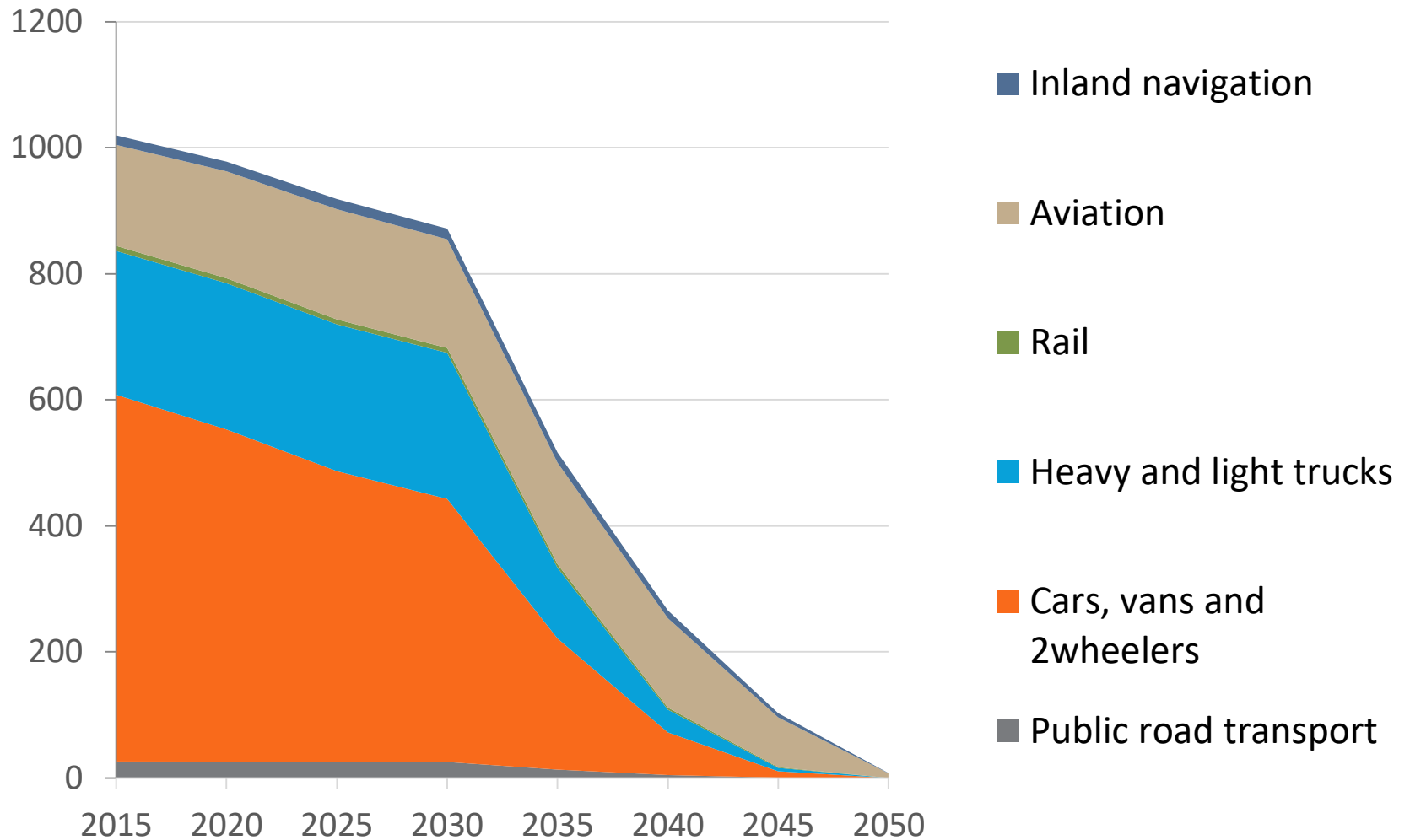


Evolution of EU-28 national CO₂ emissions until 2050 by mode in the Reference scenario 2016



Source: Final Report, High-Level Panel of the European Decarbonisation Pathways Initiative, 2018

Evolution of the EU-28 transport sector CO₂ emissions in a 100% transport decarbonisation scenario



Source: Final Report, High-Level Panel of the European Decarbonisation Pathways Initiative, 2018

The European High-Speed Train Network: A Patchwork Rug!

