Restoring the Carbon Balance- Session 1: The Budget Imperative

Dave Biello
Science Curator
Ted Talks

Edward Saltzberg, Ph.D.
Managing Director
Security & Sustainability Forum

ASU LightWorks
ARIZONA STATE UNIVERSITY

SECURITY & SUSTAINABILITY FORUM
Convening Global Experts to Guide Decision Making

Arizona State University

Restoring the Carbon Balance Series

ASU LightWorks
ARIZONA STATE UNIVERSITY

Webinar Schedule

LightSpeed Solutions
Secure Energy • Sustainable Fuels

- **February 1** – Restoring the Carbon Balance Webinar 2: The Technologies (Registration open)
- **March 2017** – Restoring the Carbon Balance Webinar 3: Policies, Financing, Regulations (Registration opens soon)

1. Follow "Restoring the Carbon Balance" at

www.lightspeedsolutions.org

Register, Watch Recordings, Access Collateral Material

2. Participate in the Discussions

Join: **The Future of Sustainable Fuels LinkedIn Group**

the center for negative carbon emissions

Agenda

Introduction: Dave Biello

Presentations:

- Jeffrey Sachs
- John Shepherd
- Kevin Anderson
- Klaus Lackner (for the discussion)

Discussion Moderated by Dave Biello

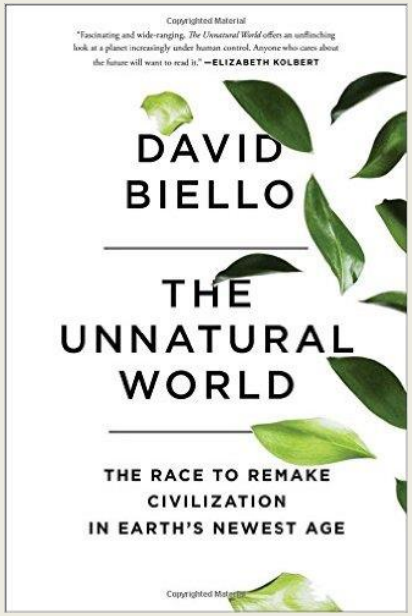
Audience Q&A: *Use the box in the go to Webinar window*

Summary

(Please Take the Brief Exit Survey)

Moderator

David Biello has been covering energy and the environment for nearly a decade. David is the Science Curator at Ted Talks and for the last four years was an associate editor at *Scientific American*. He is working on a documentary with Detroit Public Television on the future of electricity.



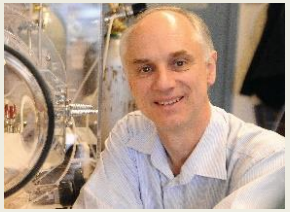
https://www.amazon.com/Unnatural-World-Remake-Civilization-Earths/dp/1476743908

Panelists

John Shepherd, Emeritus Professor of Earth System Science in the Ocean and Earth Science department of the University of Southampton, UK, and chair of the Royal Society's 2009 study of Geoengineering

Kevin Anderson, Professor of Energy and Climate Change in the School of Mechanical, Aeronautical and Civil Engineering at the University of Manchester

Jeffrey Sachs, Columbia University Professor of Economics, leader in sustainable development, senior UN advisor, bestselling author, syndicated columnist and former Director of Columbia University's Earth Institute.



Klaus Lackner, Director of Arizona State University's Center for Negative Climate Emissions and Professor at the School of Sustainable Engineering

Jeffrey Sachs

Columbia University Professor of Economics, leader in sustainable development, senior UN advisor, bestselling author, syndicated columnist and former Director of Columbia University's Earth Institute.

Climate Change: *the Factor Forty Problem*

Why we shall probably need negative emissions technologies

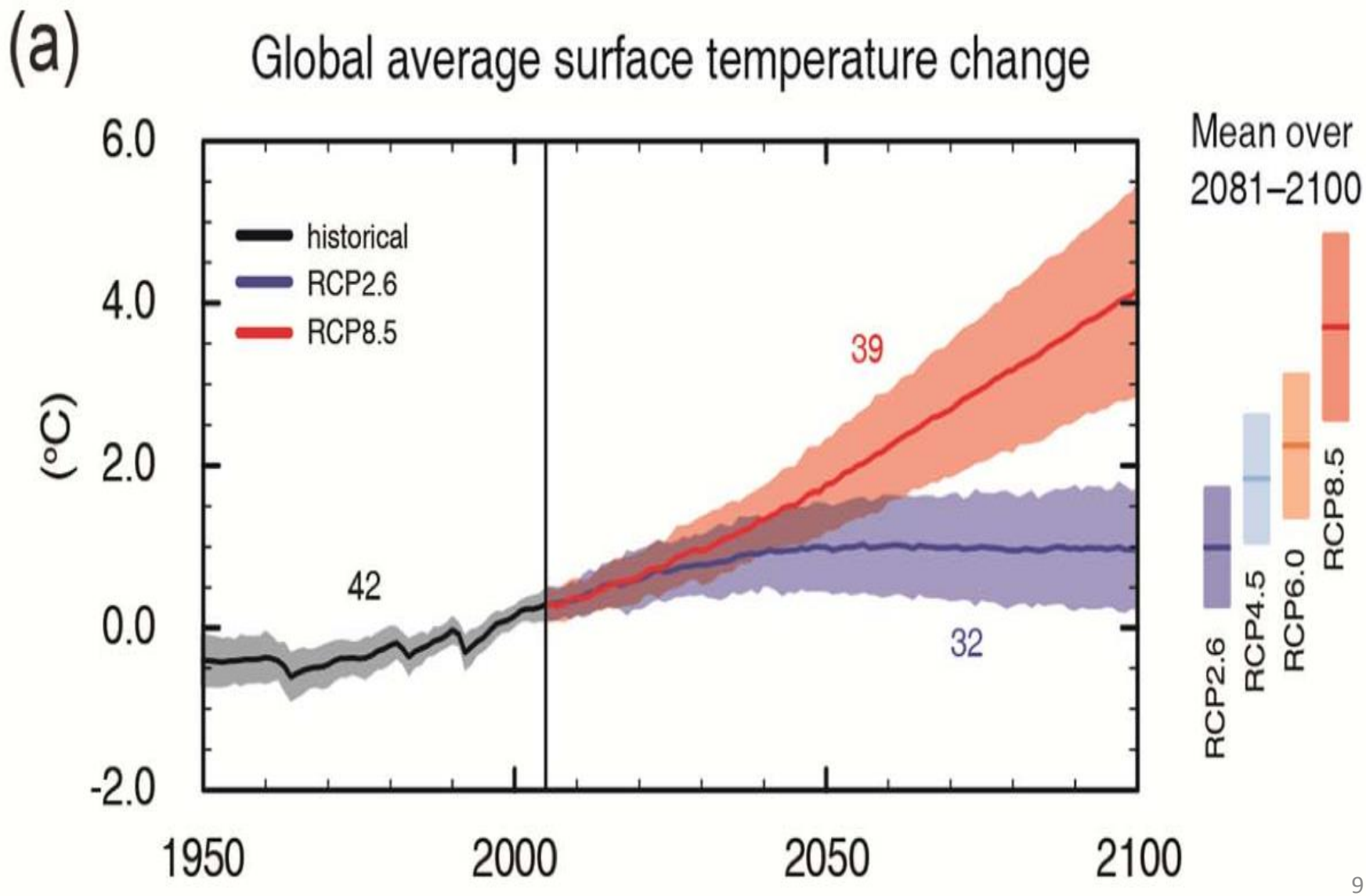
John Shepherd

School of Ocean & Earth Science
National Oceanography Centre
University of Southampton, UK

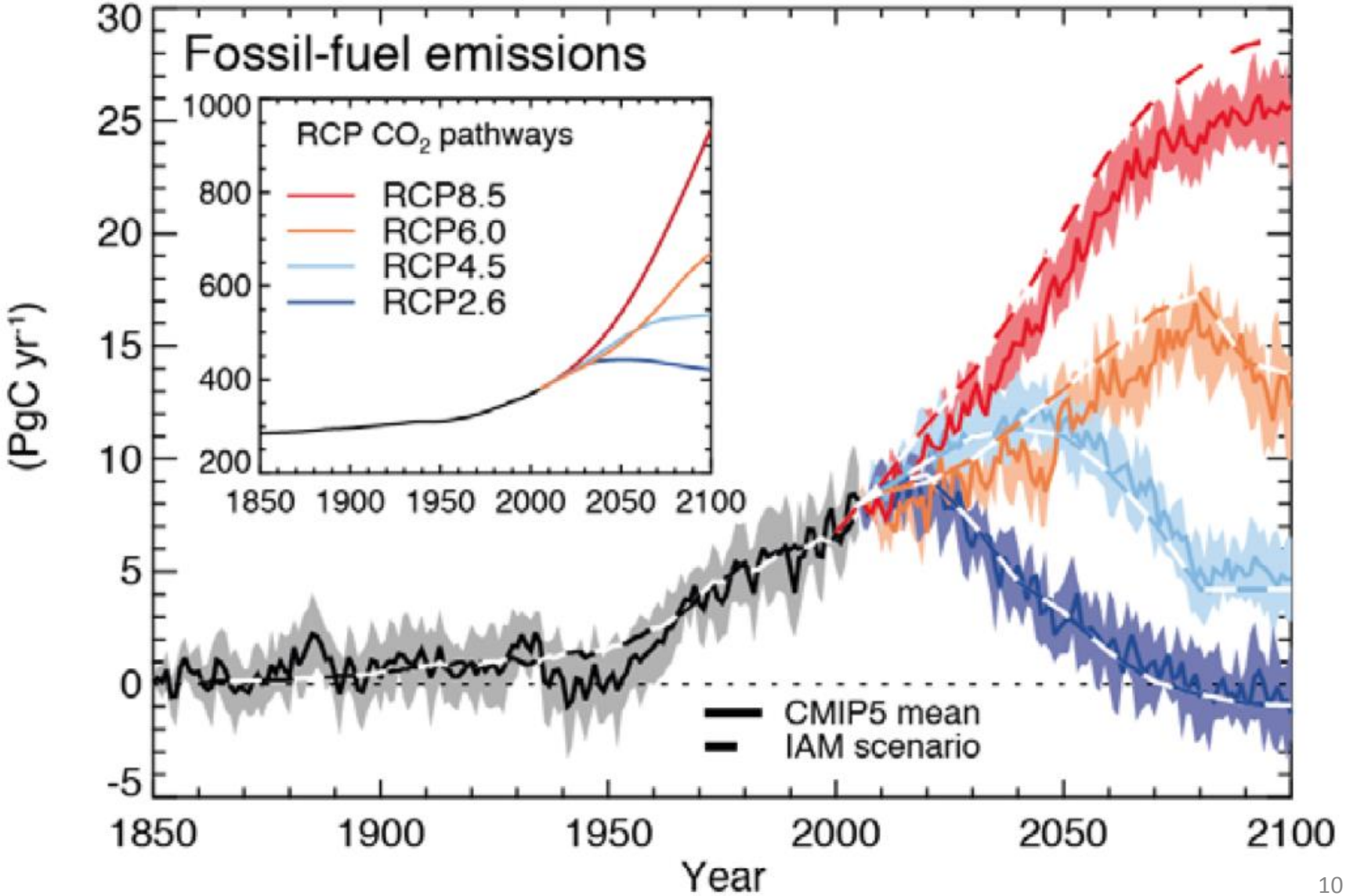
The Earth System and the carbon cycle

- **Carbon in the system**
  - The **atmosphere**, the **surface ocean** and the living **terrestrial biosphere** (land plants) contain **comparable amounts of CO_2**
  - There is **quite a bit more in soils** (dead plants)
  - **Most of the available CO_2 is in the deep ocean** (as sodium bicarbonate)
  - The ocean is dominant in the long term…
  - and **the ocean is the ultimate sink** for CO_2
- **Man has perturbed the system**
  - By burning fossil fuels, and by deforestation
  - Injecting an **extra 10 GtC/yr** into the atmosphere
  - Upsetting the natural balance of the system
- **It will take a very long time to recover (millennia)**

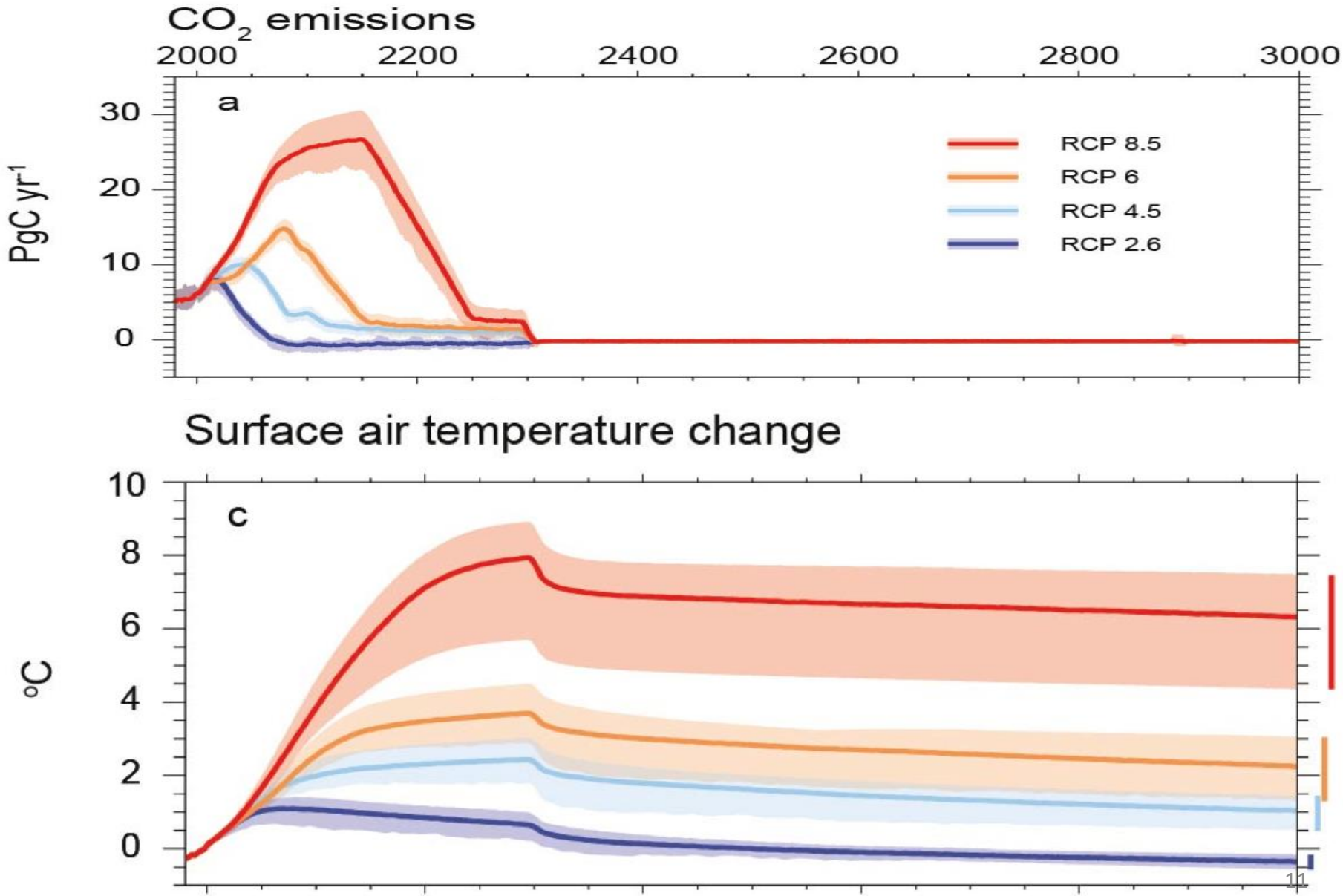
IPCC AR5 Temperature Projections



IPCC AR5 Emissions Scenarios



IPCC AR5: very long-term simulations



Summary: Climate in the future

- to restrict global warming to no more than **a few °C** over the next few centuries
  - e.g. **to stabilise temperature** anywhere near the internationally agreed maximum level of **2 °C**
- **Global CO_2 emissions** will need to be reduced
  - to a level around that of the Ocean Sink, PDQ
  - i.e. to about 2 Gt(C) per year, ASAP
  - **i.e. to less than 20%** of their current global level
  - and to zero thereafter (by ca 2100)
- to achieve this is a ***massive*** challenge…
- In fact it is a **Big, Hard,** and **Long-term Problem**
- i.e. it is very difficult for politicians (!)

Mitigating Global Warming : The Big Picture

- Reducing **global** emissions ***by*** 80% :i.e. by **a factor of 5**
- with population growth (global) : **another factor of 2**
- and increased energy use (per capita) in the developing world (to EU level only) : **a further factor of 5**…
- Altogether we need a **factor of 50** of decarbonisation
  - (of economic activity, globally)
- Need energy efficiency, renewables (etc) : maybe we can achieve a **Factor 4** (Weizsacker, Lovins & Lovins, 1994)
- There is ***still*** a mismatch by **a factor > 10**
- Is there any hope of closing the gap ???
- ***Maybe…***

What we need to achieve

- **Say, 50% reduction in *global* total emissions by 2050**
- **This means ~ 2% per year reductions, globally**
- **Each year, every year**, for the foreseeable future
  - (say the next 100 years)
- Compared with ~ 3% per year ***increases*** recently
- **More** (80%, at ~ -4% per year) for the UK & Europe
- **Even more** (90%, at ~ -5% per year) for the USA (etc)
- And ***even more still, if we delay*** taking action…
    - 20 years delay makes it **twice as hard**

Ways and Means: “Mitigation”

We need **energy conservation & efficiency and low carbon sources of energy**

to allow **decarbonisation of the electricity supply** (& transport…)

- **Renewables are excellent** (but not yet enough)
  - Offshore wind, solar PV & thermal, marine (waves & tides)…
- **Nuclear fission** is available now
- **Nuclear fusion** will probably work (eventually)
  - good for electricity (and for hydrogen ?)…
  - but not much good for road transport & aviation !
- **NB: Hydrogen** is only a carrier
  - it still needs a primary low-carbon energy source
  - (e.g. **solar** or **nuclear** power…)
- Meanwhile, we shall also need **Carbon Capture & Storage**

For shipping, low-carbon technologies already exist!

But for aviation, they do not

The way forward ?

- We should rapidly ***develop & implement*** large-scale
  - **Decarbonisation of the electricity supply**
  - **Including CO_2 sequestration (CCS) technology**
  - **Use of bio-fuels for transport (?)**
- It will take a long time..., so **we should start real soon**
  - the energy industry could and should take a lead…
- We should also ***actively research***
  - **Climate Intervention (Geoengineering) methods**
    - including CDR (Negative Emissions Technologies)
  - **Solar** (and/or nuclear) **generation of hydrogen**
- But we need ***education*** <u>and</u> ***economic incentives*** <u>and</u> ***regulation*** to make things happen

We also need a shift in public & political opinion : by ***education*** ?

Low Carbon Transportation...

A possible solution by Emily Boon & Fenella Martin
Class 4DS, Forres Sandle Manor School

Geoengineering

a.k.a. Climate Intervention or Climate Remediation

- **If we fail to mitigate emissions enough…**
- and/or **adaptation is too difficult & expensive…**
- and/or **the impacts of climate change are too painful…**
- we may need **Geoengineering**
- **i.e. Deliberate and large-scale intervention in the Earth's climate system**
  - in order to moderate global warming
- Various schemes, such as
  - **albedo modification** ("sunshade" methods): (SRM)
  - **removal of CO_2** from the atmosphere (CDR)

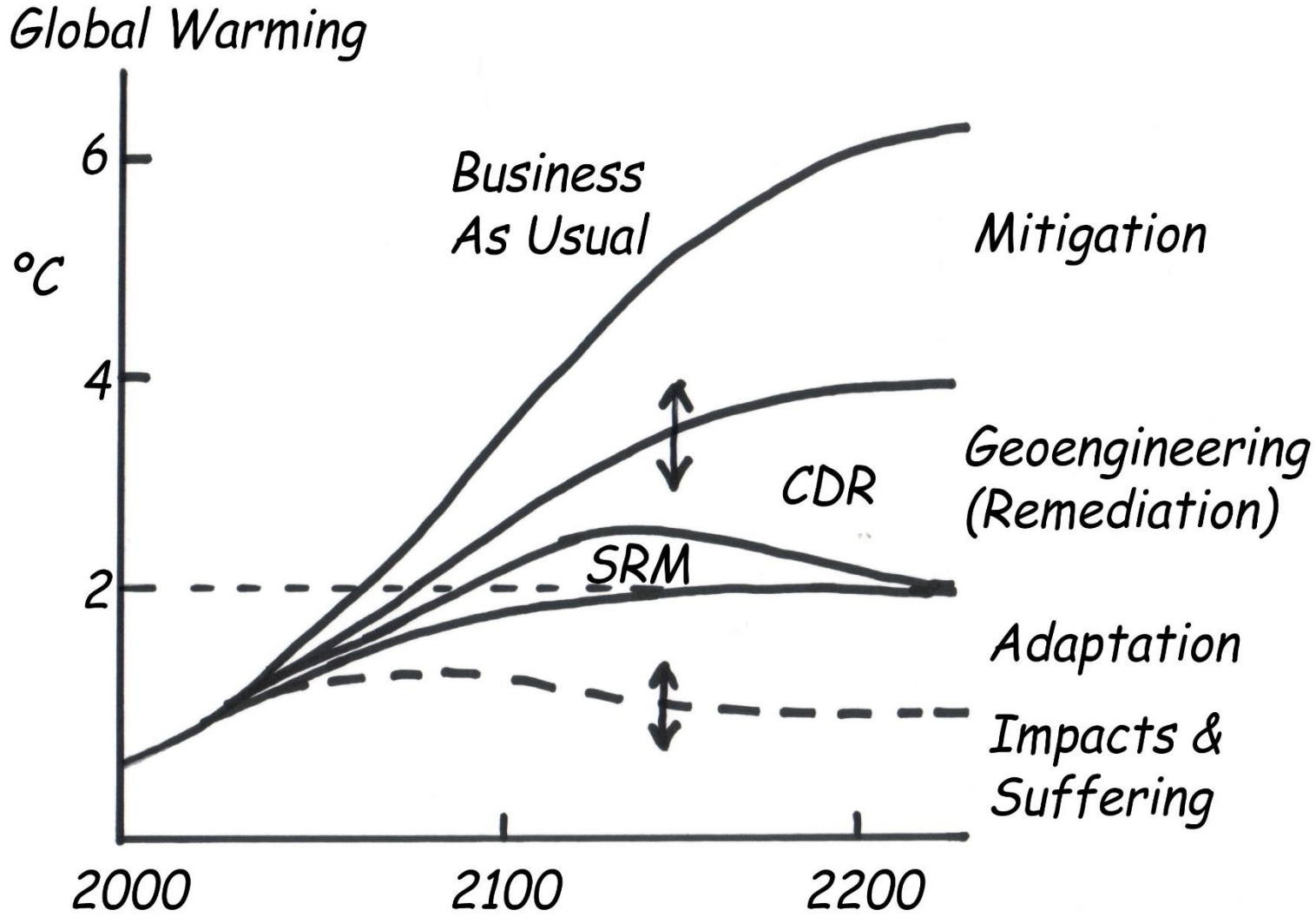
Climate Intervention: the two main methods

- **Solar Radiation Management** (SRM)
  - E.g. mirrors in space, stratospheric aerosols, cloud albedo enhancement, white roofs…
- **Carbon Dioxide Removal** (CDR)
  - E.g. ocean fertilisation, engineered CO2 capture from air (DAC), enhanced weathering, biochar…
- these differ greatly in many respects, **especially the timescale to have an effect…**
  - **SRM works fast**: within a year or two
  - **CDR is slow**: takes many decades…
- **NB:** Need a **few W/m^2**, or ~ **10 GtC/yr for 100 years**
- *[Note: one could possibly also remove other greenhouse gases, but there are no credible proposals to do this at present]*

Carbon Dioxide Removal (NETS) methods

- **Afforestation**
  - Cheap, low-tech, but => land-use conflicts & v. insecure
- **Biomass Energy with CCS (BECCS)**
  - Cheap, low-tech, but => land-use conflicts, & needs CCS
- **Biochar**
  - Mod. cost, mod. tech, good for soils (?) but => land-use conflicts, & why not burn the charcoal (instead of mining coal) ?
- **Ocean fertilisation** (using iron or macronutrients)
  - Cheap (for Fe), but not very effective & major ecosystem disruption
- **Enhanced ocean upwelling/mixing** (ineffective, CO_2 back-flux)
- **Engineered Direct CO_2 capture from air**
  - "Encapsulated" but probably costly, energy/water use & needs CCS
- **Enhanced weathering** (Olivine or lime, on soils or oceans)
  - Very secure, mod. ecosystem effects (?), but massive material use

Responses to Climate Change: the four-fold way
Mitigation, Adaptation, Geoengineering & Suffering



Conclusions re CDR/NETs

- Would be ***useful*** anytime (if & when affordable)
- Likely to be ***necessary*** for the "end-game": later this century
  - To supplement the declining ocean sink
  - To deal with intractable sources of emissions
    - Aviation & agriculture
  - To replace SRM (if we have had to deploy it)
  - To ***reduce*** atmospheric CO_2 again (to 450 or 350 ppm)
    - if we only manage to stabilise at too high a level…
- Need ***sustained*** RD&D, starting right away, because
  - Long lead time (several decades) for deployment
  - Slow acting even when deployed at scale
- **Not a credible substitute for emissions reduction**

Climate change & 2 °C: is the Parisian emperor naked?

twitter: **@KevinClimate**

web: kevinanderson.info

Kevin Anderson
Professor of Energy & Climate Change

MANCHESTER 1824
The University of Manchester

UPPSALA UNIVERSITET

Tyndall°Centre®
for Climate Change Research

Conclusions

- Fund R&D & demonstration of negative emission technologies (NETs)
- BUT … Mitigate emissions today as if they will not work
- Marshall-style construction plan of very low CO_2 energy supply
- Stringent & tightening energy efficiency regulations
- Tailor policies towards the behaviours of high-carbon emitters (cut of 30% in 1 yr)
- However, still too late for carbon budgets for 1.5°C
- A chance of 2°C remains – just – but demands a rapid 'paradigm shift'
- Relying on NETs/SRM is a moral hazard
- If NETs work – perhaps they'll compensate for carbon cycle feedbacks

  … or maybe reduce the temperature rise to 1.5°C
- If we rely on them & they fail at scale - we'll have locked in 3°C, 4°C or more

Backdrop to **Paris** *(& latest **IPCC** reports)*

- The mitigation message has changed little in the last **twenty five** years
- Annual emissions **~60% higher** than at time of the first report in **1990**

- Abject failure of the International community
- Wealthy nations have demonstrated no meaningful leadership

		2014	Pre-financial crisis	tonnes CO_2 per person
Since 1990:	**USA**	up ~20%;	**up ~30%**	19
	EU	down ~10%	**up ~5%**	9
	Japan	no change	**up ~20%**	11
	China	*3 fold rise*	***~1.75x***	*7*

Litany of ruses to avoid difficult mitigation

- Offsetting
- Clean development mechanism (CDM) – state-sanctioned offsetting
- Focus on long-term (2050) targets rather than carbon budgets
- Weak trading (EUETS) – excess of permits to minimise price signals
- Offshoring of heavy industries by wealthy nations
- Negative emission technologies
- Geo-engineering the planet

We have & continue to try anything other than actual mitigation

Paris Agreement sets our mitigation commitment

… "hold the increase in global average temperature to ***well below 2°C*** *above pre-industrial levels and pursue* ***efforts*** *to limit the temperature increase to* ***1.5°C"***

… to ***undertake rapid reductions*** *in accordance with the* ***best science*** *… and on the* ***basis of equity***

IPCC's carbon budget **ranges** for 1.5 & 2°C

Table 2.2 | Cumulative carbon dioxide (CO_2) emission consistent with limiting warming to less than stated temperature limits at different levels of probability, based on different lines of evidence. *{WGI 12.5.4, WGIII 6}*

Cumulative CO_2 emissions from 1870 in $GtCO_2$									
Net anthropogenic warming [a]	<1.5°C			<2°C			<3°C		
Fraction of simulations meeting goal [b]	66%	50%	33%	66%	50%	33%	66%	50%	33%
Complex models, RCP scenarios only [c]	2250	2250	2550	2900	3000	3300	4200	4500	4850
Simple model, WGIII scenarios [d]	No data	2300 to 2350	2400 to 2950	2550 to 3150	2900 to 3200	2950 to 3800	n.a. [e]	4150 to 5750	5250 to 6000
Cumulative CO_2 emissions from 2011 in $GtCO_2$									
Complex models, RCP scenarios only [c]	400	550	850	1000	1300	1500	2400	2800	3250
Simple model, WGIII scenarios [d]	No data	550 to 600	600 to 1150	750 to 1400	1150 to 1400	1150 to 2050	n.a. [e]	2350 to 4000	3500 to 4250
Total fossil carbon available in 2011 [f]: 3670 to 7100 $GtCO_2$ (reserves) and 31300 to 50050 $GtCO_2$ (resources)									

IPCC's carbon budget **ranges** for 1.5 & 2°C

- Range reflects: scientific uncertainty; probabilities; non-CO_2 GHG assumptions
- Rightly excludes some important carbon-cycle feedbacks
- Overall feedbacks are likely to reduce available carbon budgets
- But they are insufficiently quantified to be included in the models

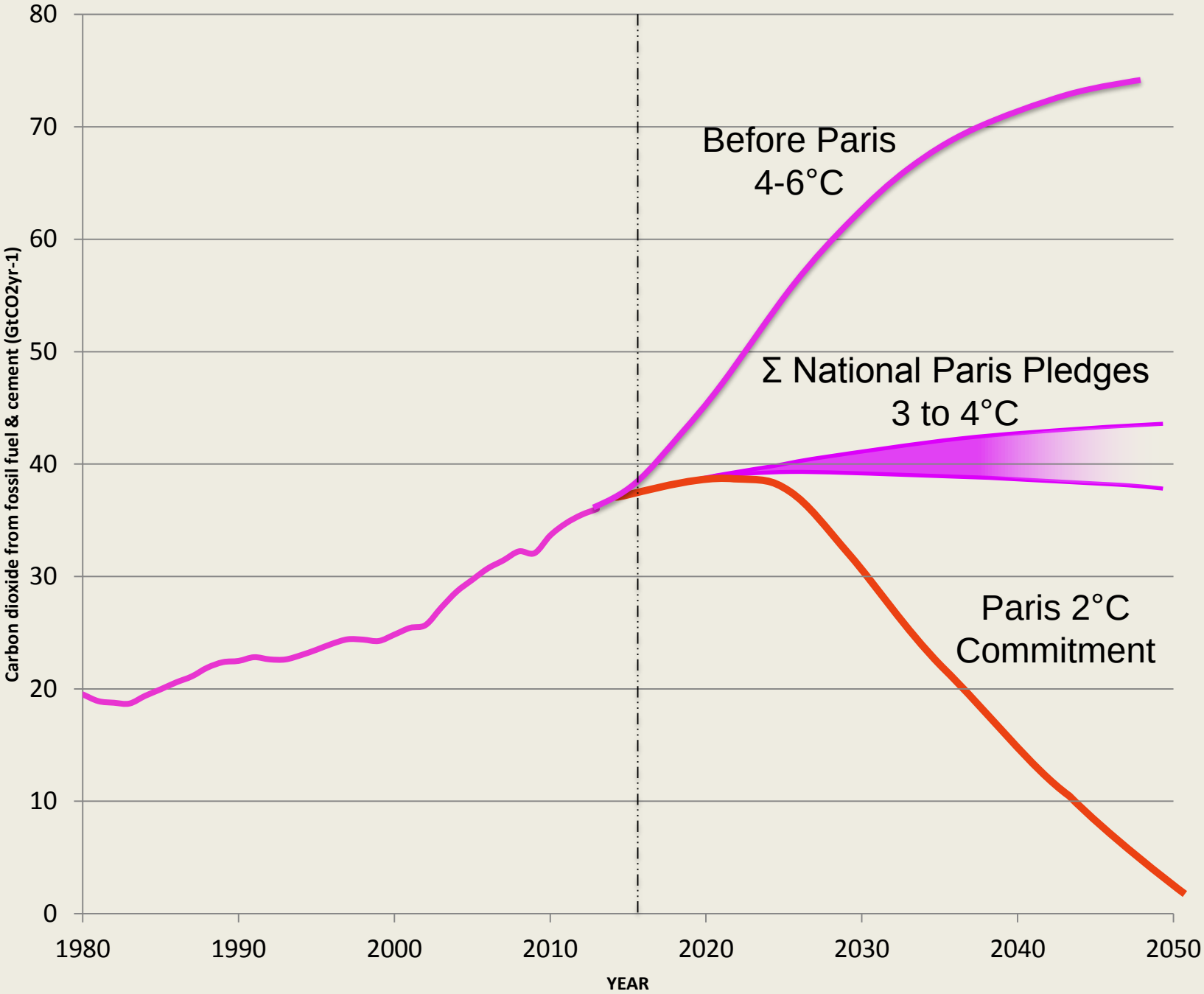
My focus is on energy-related CO_2 emissions

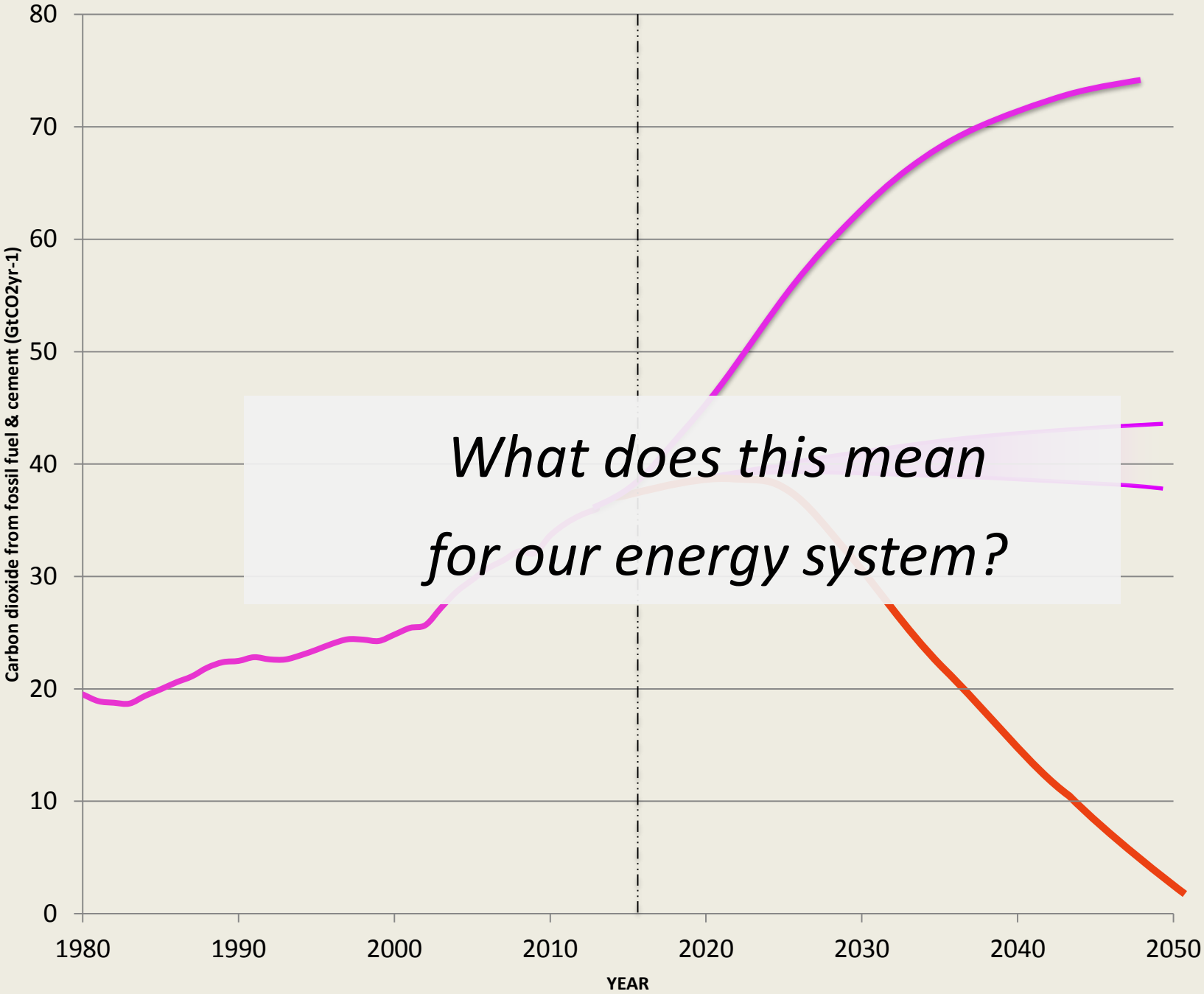
Very optimistic allowance for:

1) deforestation & landuse cumulative CO_2

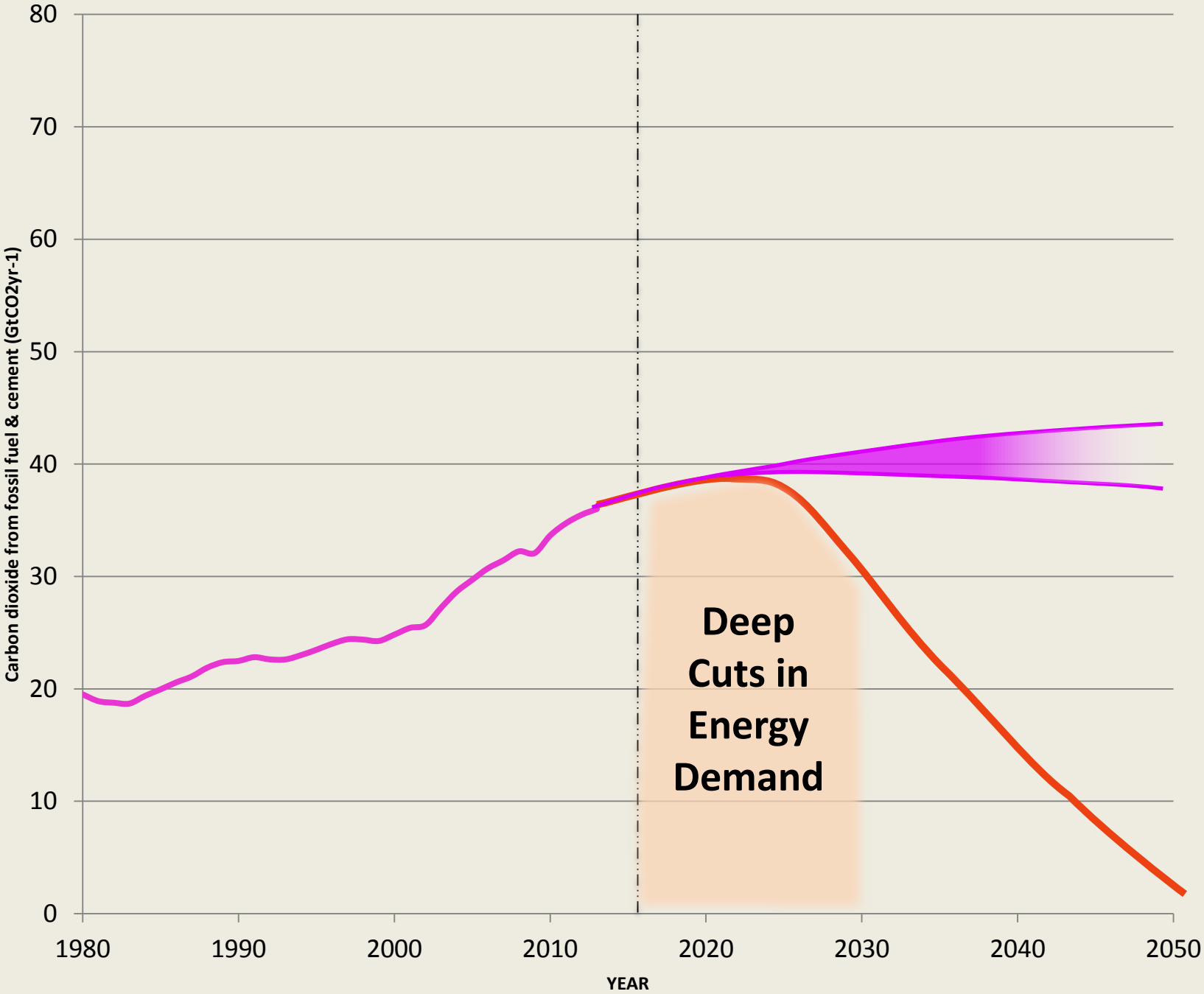
2) industrial process cumulative CO_2 (principally cement & steel)

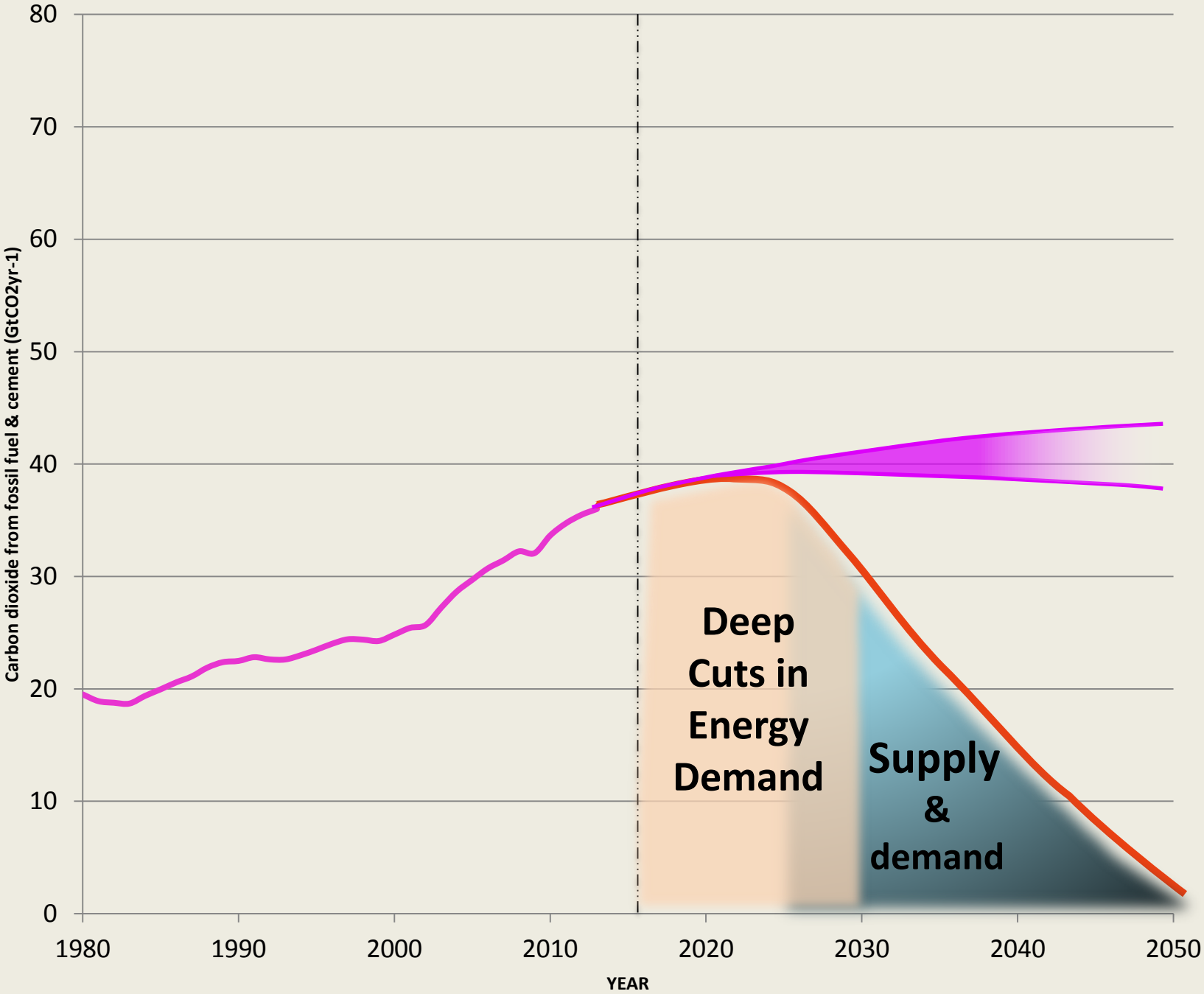
Thinking of this graphically…

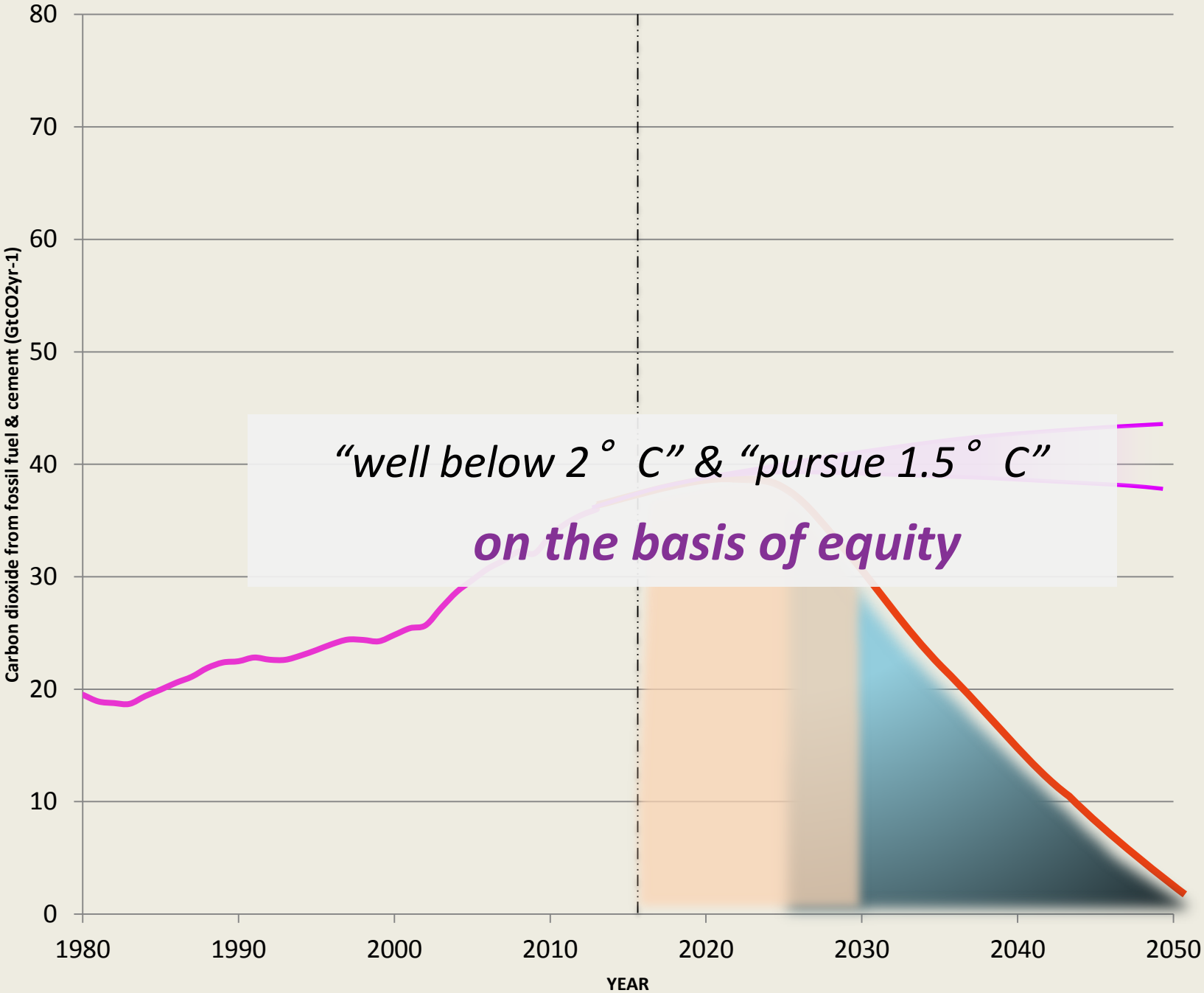

Before Paris
4-6°C
Σ National Paris Pledges
3 to 4°C
Paris 2°C
Commitment
Carbon dioxide from fossil fuel & cement (GtCO2yr-1)
YEAR
0
10
20
30
40
50
60
70
80
1980
1990
2000
2010
2020
2030
2040
2050



What does this mean for our energy system?


80
70
60
50
40
30
20
10
0
Carbon dioxide from fossil fuel & cement (GtCO2yr-1)
1980
1990
2000
2010
2020
2030
2040
2050
YEAR
Deep Cuts in Energy Demand


80
70
60
50
40
30
20
10
0
Carbon dioxide from fossil fuel & cement (GtCO2yr-1)
1980
1990
2000
2010
2020
2030
2040
2050
YEAR
Deep Cuts in Energy Demand
Supply & demand


80
70
60
50
40
30
20
10
0
Carbon dioxide from fossil fuel & cement (GtCO2yr-1)
1980
1990
2000
2010
2020
2030
2040
2050
YEAR
"well below 2° C" & "pursue 1.5° C"
on the basis of equity

Returning to IPCC's Carbon budgets

In 3 to 13 years we'll use all the 1.5°C energy-CO_2 budget

Pledges not reviewed in depth till 2023

… from a budget perspective

Is it is now too late for 1.5°C?

And for energy & 2°C:

- Poorer & less-industrialised nations: *zero-CO_2 energy by* ***~2050***

  Peak in 2025, 10% p.a. mitigation from 2035

- Wealthy industrialised nations: *zero-CO_2 energy by* ***~2035***

  >10% p.a. mitigation from 2017

How can this fit with the Paris euphoria?

… by pulling a rabbit from the magician's hat

… by pulling a rabbit from the magician's hat

Negative emissions technologies (NETs)

i.e. suck CO_2 directly from the atmosphere by 2030 & beyond

Virtually all IPCC scenarios for 2°C include huge uptake of BECCS

(biomass energy with carbon capture and storage – the NET dominating models)

- planting 1 to 3x the area of India
- year after year; decade after decade, continue beyond 2100
- store 100s of billions of tonnes of CO_2
- securely underground for 1000s of years

Or the equivalent of adding another biosphere!

+

… absorbs ½ of anthropogenic annual CO_2

i.e. oceans & plants absorbs ~20GtCO_2/yr.

BECCS is set to absorb 10 to 20GtCO_2/yr

i.e. up to another planet's worth of biospere

So Paris, some Academics & Politicians …

- rather than **we** focus on urgent & deep mitigation now

  - *with challenging political, economic & personal repercussions for **us***

  … we prefer to rely on

- **tomorrow's generation** & speculative negative emission technologies

  - *sucking 100s billions of tonnes of CO_2 directly from the air in the future*

Deep endemic bias …

- We embrace highly uncertain NETs

  - as they **extend** the available carbon budgets

  - & reduce and delay the need for strong mitigation

… and

- Conveniently ignore similarly uncertain carbon-cycle feedbacks

  - as they **reduce** the available carbon budget

  - and & make mitigation harder

Without *'NETs'* …

is 2°C possible?

Hypothesis: yes *… just*

- Technology
  - Supply: decadal timeframe
  - Demand: near term options
- **Equity: immediate & near-term**

Technology:

Supply: delivering **zero** carbon energy

- *cannot exploit ~80% of known fossil fuel reserves*
- *CCS: not viable as LCA emissions too high (100+gCO_2/kWh)*
- *massive electrification: from 20% to 80%+ of energy*
- *many affordable very-low CO_2 options (esp. at low discount rate)*

Demand: use less energy to deliver the same services

- *technically: power down demand by 50-70% in 10yrs*
- *US energy/capita is 125% higher than the UK & 115% higher than Switzerland*

Beyond technology

Put simply:

Technology (supply & demand) alone cannot deliver on the Paris budgets

Rapid & deep changes in *what we do, how we do it & how often we do*

is now critical

EQUITY: extreme CO_2 asymmetry

~50% of global CO_2 comes from ~**10%** of the population

Top 1% of US emitters (~3.4 million people)

… have CO_2 footprints

2500x higher than bottom 1% globally (~70 million)

EQUITY: extreme CO_2 asymmetry

… if the top 10% of global emitters

were to reduce their carbon footprint

to the level of a typical EU citizen

Global CO_2 emissions would be cut ~33%

So, who is in this key 10% group?

So, who is in this key 10% group?

So, who is in this key 10% group?

So, who is in this key 10% group?

So, who is in this key 10% group?

EQUITY: frames a new agenda for mitigation

- Most of the 7.4 billion have little scope to reduce emissions
- There is huge asymmetry in responsibility
- Rapid & near-term reduction in CO_2 from top 10% of emitters
- Real opportunity for leading by example
- And thereby catalysing system-change

Climate Change demands System Change

Interpreting Paris through the **logic of carbon budgets** begs fundamental questions of our **norms & paradigms**

- *Marshall-style transition in supply technologies*
- *stringent efficiency programme on end-use technologies*
- *transition in physical & institutional Infrastructures*
- *profound shift in behaviour & practices*
- *development of cogent economic models*
- *much more inclusive values*
- *serious consideration of inter/intra generational equity*

Climate Change *is* System Change

But which 'System' will **we** choose?

Selfish

- continue with our insincere platitudes on actual mitigation today
- ignore the poor & climatically vulnerable
- and bequeath our own children a rapidly changing climate

Progressive

- demonstrate courage and integrity
- begin **immediate**, deep and system-wide mitigation
- and shape a new and prosperous post-carbon society

Thank you

twitter: **@KevinClimate**

web: kevinanderson.info

Kevin Anderson
Professor of Energy & Climate Change

MANCHESTER 1824
The University of Manchester

UPPSALA UNIVERSITET

Tyndall°Centre®
for Climate Change Research

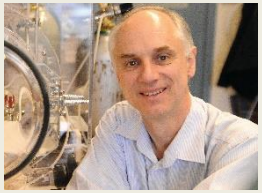
Discussion

John Shepherd
john_g_shepherd@mac.com

Jeffrey Sachs
sachs@ei.columbia.edu

Kevin Anderson
kevin.anderson@manchester.ac.uk

Dave Biello
dbiello@ted.com



Klaus Lackner
Klaus.Lackner@asu.edu

Arizona State University

Restoring the Carbon Balance Series

ASU LightWorks ARIZONA STATE UNIVERSITY

Webinar Schedule

LightSpeed Solutions Secure Energy • Sustainable Fuels

- **February 1** – Restoring the Carbon Balance Webinar 2: The Technologies (Registration open)
- **March 2017** – Restoring the Carbon Balance Webinar 3: Policies, Financing, Regulations (Registration opens soon)

1. Follow "Restoring the Carbon Balance" at

www.lightspeedsolutions.org

Register, Watch Recordings, Access Collateral Material

2. Participate in the Discussions

Join: **The Future of Sustainable Fuels LinkedIn Group**

the center for negative carbon emissions

Upcoming Webinars

SSF Webinar Schedule

Register at: **www.ssfonline.org**

More SSF Webinars Coming Up:

- **December 22, 2016** - Lancet Countdown on Health and Climate Change
- **January 18** - Why Companies Should Care About Diversity

Join SSF to receive updates and registration info on upcoming programs!

Thank you for attending! A recording of this webinar and the slide presentation will be available soon in the SSF Archives at www.ssfonline.org.

(and please take the brief exit survey)