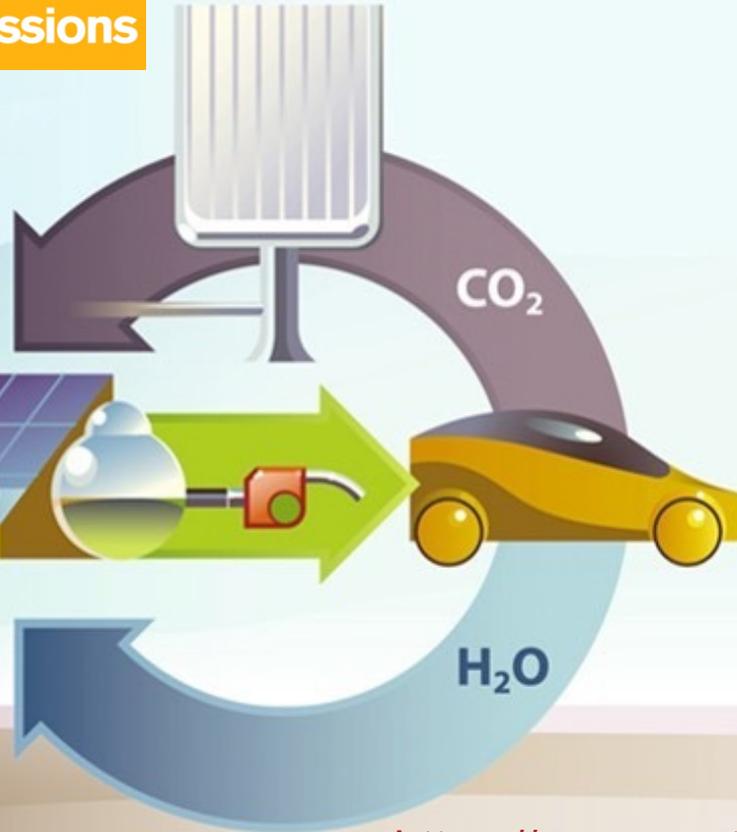


the center for negative carbon emissions

ASU IRA A. FULTON SCHOOLS OF  
engineering

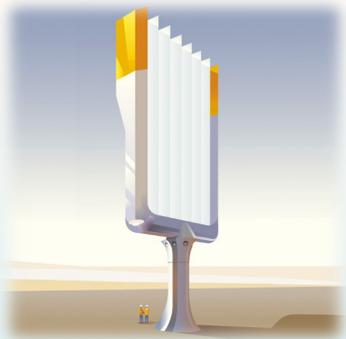
IPCC  
Reflections



<https://www.youtube.com/watch?v=4dHjCjrYcfs>

# Reflections on IPCC Perspectives

Klaus S Lackner  
November 2022



# The IPCC shaped the climate discussion

## The IPCC **does not**

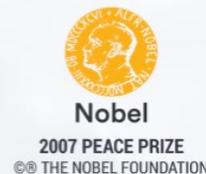
- perform scientific research
- make policy
- advocate for policies

## The IPCC **does**

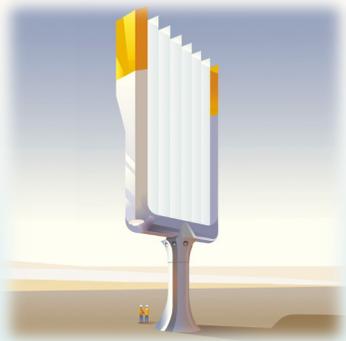
- assess the state of science
- address topics by request
- reflects established science
- reflects consensus

**Zeitgeist matters**

The Intergovernmental Panel on Climate Change (IPCC) is the United Nations body for assessing the science related to climate change.

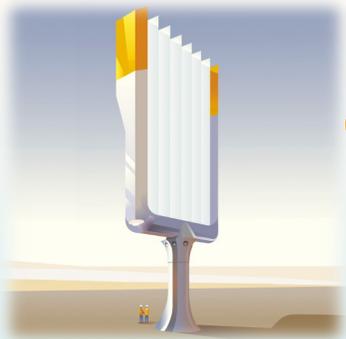


From: [www.ipcc.ch](http://www.ipcc.ch)



# IPCC Reports

- **Roughly every five years the IPCC issues a climate report**
  - Working Group I: The Science
  - Working Group II: Impacts
  - Working Group III: Mitigation
- **Every so often the IPCC is asked to assess specific questions**
  - The report on Carbon Dioxide Capture and Storage
  - The report on 1.5° warming
  - Ocean and Cryosphere
  - Guidelines for National Greenhouse Gas Inventories
  - Special Report on Emissions Scenario



# The Science is Settled!

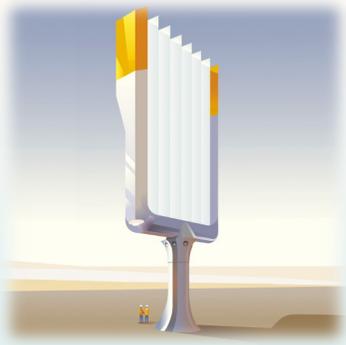
- **The IPCC statements become more unequivocal**

**1992**

The size of this warming is broadly consistent with predictions of climate models, but it is also of the same magnitude as natural climate variability. Thus, the observed increase could be largely due to this natural variability, alternatively this variability and other human factors could have offset a still larger human-induced greenhouse warming. The unequivocal detection of the enhanced greenhouse effect from observations is not likely for a decade or more.

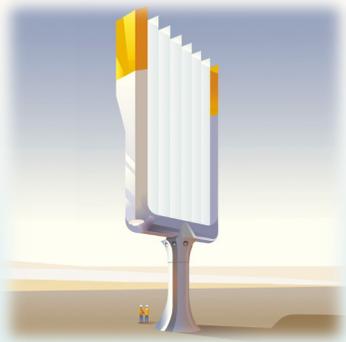
**2021**

From a physical science perspective, limiting human-induced global warming to a specific level requires limiting **cumulative** CO<sub>2</sub> emissions, reaching at least net zero CO<sub>2</sub> emissions, along with strong reductions in other greenhouse gas emissions. Strong, rapid and sustained reductions in CH<sub>4</sub> emissions would also limit the **warming effect resulting from declining aerosol pollution** and would improve air quality.



# IPCC Reports drive policy

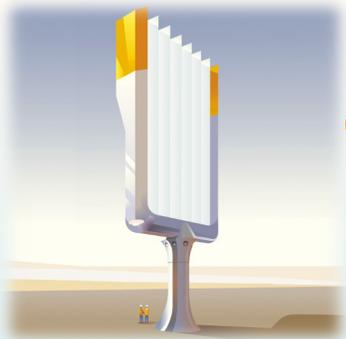
- **1988 Toronto**
  - Formation of the IPCC
- **1992 Rio Agreement**
  - The United Nations Framework Convention on Climate Change
  - Stabilize greenhouse gas concentration in the atmosphere at a level that prevents dangerous anthropogenic interference
- **1996 Berlin**
  - The first Conference of the Parties COP 1
- **1996 Kyoto**
  - The Kyoto Treaty
- **2015 Paris**
  - Setting the 1.5 degree target
  - Nationally determined contributions
  - Resulted in the highly influential IPCC special report on 1.5 degree warming
- 2021/22 Glasgow/Sharm el-Sheikh (COP 26/27) ???



# IPCC: Climate Change is Real and Dangerous

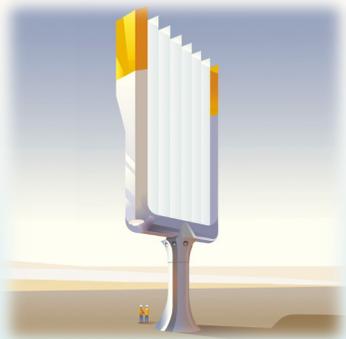
- **Threshold is 1.5°C warming**
  - Too late to hold the line
- **Threshold is less than 450 ppm of CO<sub>2</sub> in the air**
  - About 12 years away
- **The world has a finite Carbon Budget**
  - Dealing with other greenhouse gases is helpful

**We live in an overshoot world!**



# The importance of greenhouse gases

- **Climate change is driven by greenhouse gas concentrations in the air**
  - Main emitters are fossil fuels, cement, Agriculture
- **The IPCC has a long list of greenhouse gases**
  - They differ in strength and longevity
- **Water is not considered a greenhouse gas**
  - Too short-lived
  - Instead, it amplifies the effect of the greenhouse gases



# Global Warming Potential

	Lifetime (years)		GWP <sub>20</sub>	GWP <sub>100</sub>	GTP <sub>20</sub>	GTP <sub>100</sub>
CH <sub>4</sub> <sup>b</sup>	12.4 <sup>a</sup>	No cc fb	84	28	67	4
		With cc fb	86	34	70	11
HFC-134a	13.4	No cc fb	3710	1300	3050	201
		With cc fb	3790	1550	3170	530
CFC-11	45.0	No cc fb	6900	4660	6890	2340
		With cc fb	7020	5350	7080	3490
N <sub>2</sub> O	121.0 <sup>a</sup>	No cc fb	264	265	277	234
		With cc fb	268	298	284	297
CF <sub>4</sub>	50,000.0	No cc fb	4880	6630	5270	8040
		With cc fb	4950	7350	5400	9560

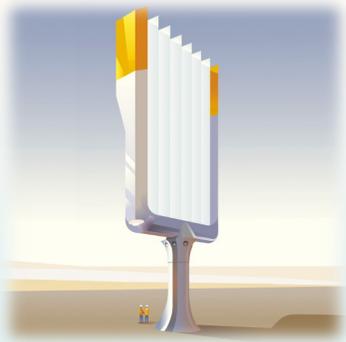
GWP: Global Warming Potential

GTP: Global Temperature Potential

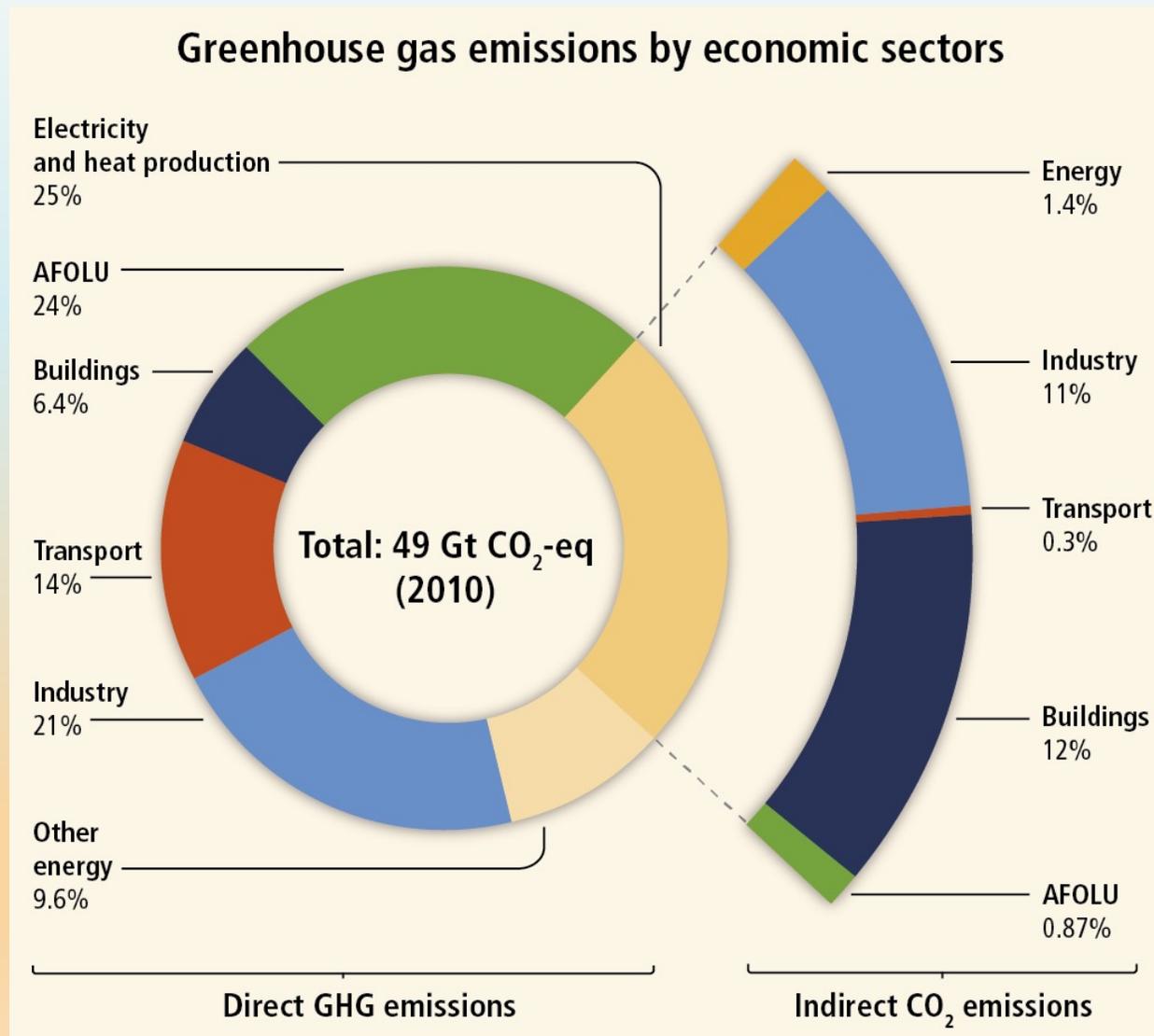
cc fb: climate-carbon feedback

CF-11: CCl<sub>3</sub>F forbidden by the Montreal Protocol  
because it destroys ozone

Myhre, G., D. Shindell, F.-M. Bréon, W. Collins, J. Fuglestedt, J. Huang, D. Koch, J.-F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura and H. Zhang, 2013: Anthropogenic and Natural Radiative Forcing. In: *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

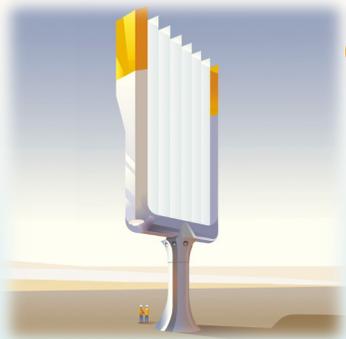


# Not all emissions can be easily avoided



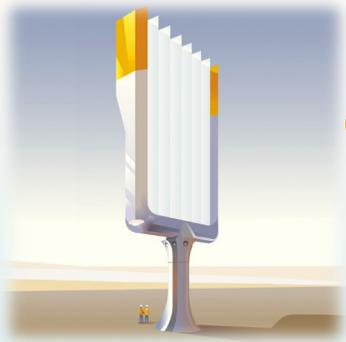
Direct air capture can deal with any and all CO<sub>2</sub> emissions

Figure from IPCC Report: AR5 Synthesis Report, Figure 1.07-01



# The importance of methane in the IPCC report

- **Strong forcing factor**
  - 100 times stronger than CO<sub>2</sub> by mass
- **But very short lifetime**
  - methane decays in a decade, mainly into CO<sub>2</sub>
- **How to compare?**
  - IPCC uses a 100 year time frame
  - Discounting the distant future



# This is beginning to change in AR6

- **Stock problem vs Flow Problem**
  - Compare the integral of CO<sub>2</sub> with the rate of methane!
  - Very different balance

**This is the basis for carbon accounting rather than greenhouse gas accounting**

Published in the Proceedings of the Global Warming and Energy Policy Conference, Fort Lauderdale, B. N. Kursunoglu, S. L. Mintz and A. Perlmutter eds. (2000).

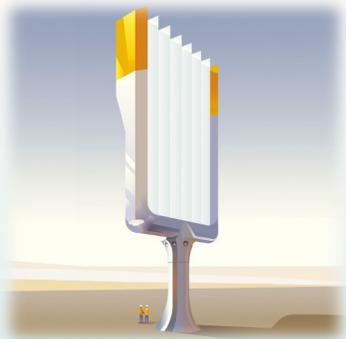
**FREE-MARKET APPROACHES TO CONTROLLING  
CARBON DIOXIDE EMISSIONS TO THE  
ATMOSPHERE**

**A discussion of the scientific basis**

Klaus S. Lackner, Richard Wilson and Hans-Joachim Ziock\*

**1. Introduction**

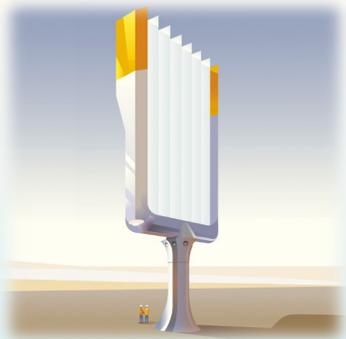
Human activities are changing the Earth on a global scale affecting virtually every region and every ecosystem [1]. Not all changes have been intentional or for the better. A case in point is the emission of greenhouse gases. There is a growing consensus that



# Carbon is the driver of climate change

- **Balancing the carbon budget is very different from methane mitigation**
- **Zero carbon will more or less fix climate**
- **Zero methane will not**
- **Constant carbon emissions will drive continued climate change**
- **Constant methane emissions will not**

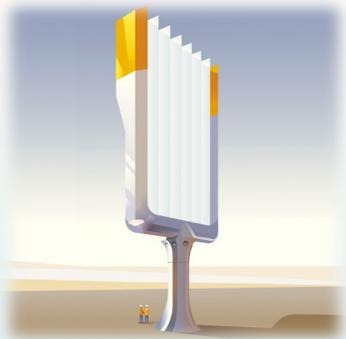
The lifetime of CO<sub>2</sub> in the atmosphere is not a simple first order decay constant  
The longer one waits the longer the lifetime of the remainder



# Impact times

- **Proportional to CO<sub>2</sub> emissions**
- **Temperature stay up for a millennium**
- **Ocean acidification lasts for 10s of thousands of years**

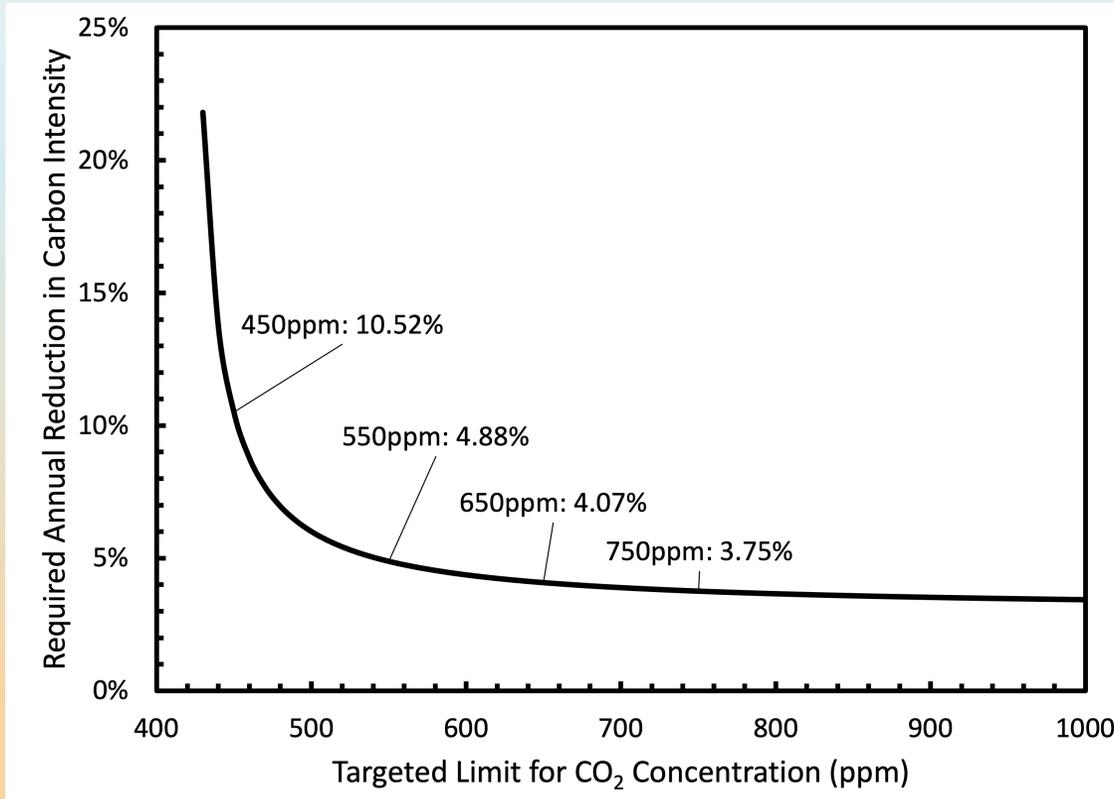
Intergenerational equity combined with the principle of polluter-pays suggests that extraction of fossil carbon must pay for the virtually permanent removal of all carbon extracted



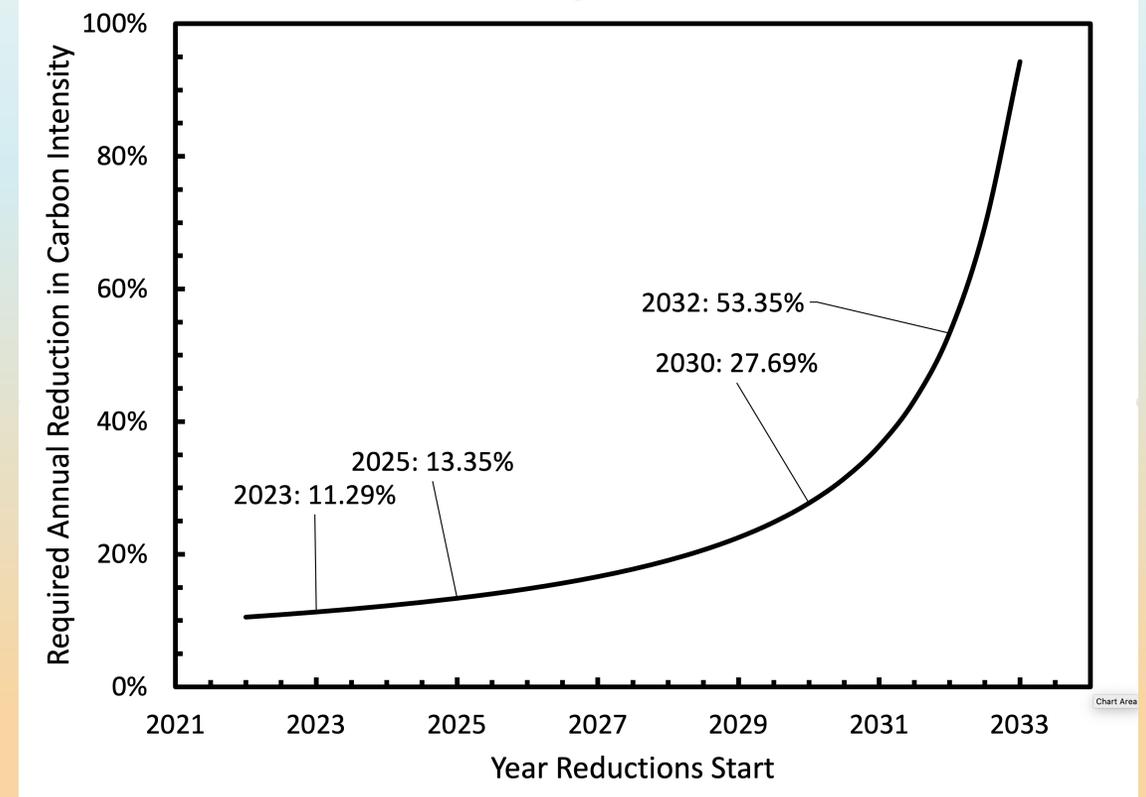
# Economy must decarbonize fast

## Reducing Carbon Intensity to zero

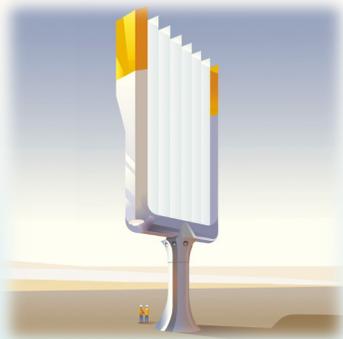
Overcoming 3% growth  
(economic + population)



Required annual reduction in carbon intensity to limit CO<sub>2</sub> levels to  $x$  starting in 2022



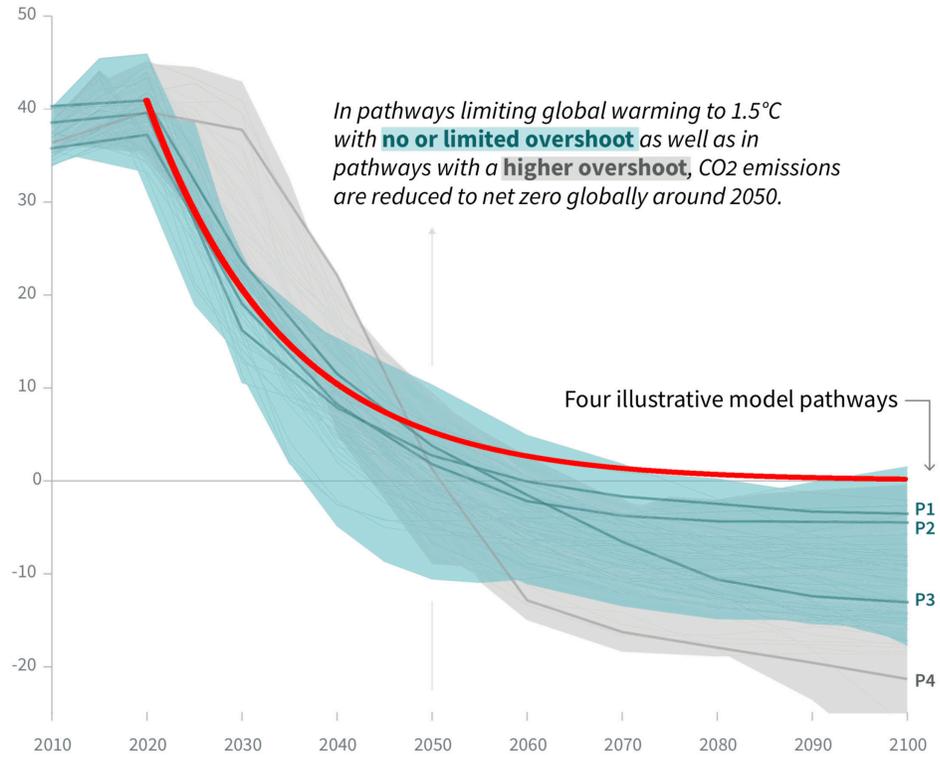
Required annual reduction in carbon intensity to limit CO<sub>2</sub> levels to 450 ppm starting in year  $x$



# Rapid Reductions are necessary

## Global total net CO<sub>2</sub> emissions

Billion tonnes of CO<sub>2</sub>/yr



In pathways limiting global warming to 1.5°C with **no or limited overshoot** as well as in pathways with a **higher overshoot**, CO<sub>2</sub> emissions are reduced to net zero globally around 2050.

Four illustrative model pathways

P1  
P2  
P3  
P4

### Timing of net zero CO<sub>2</sub>

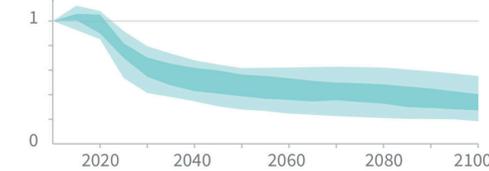
Line widths depict the 5-95th percentile and the 25-75th percentile of scenarios



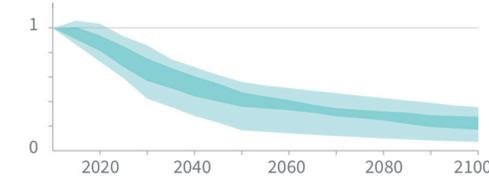
## Non-CO<sub>2</sub> emissions relative to 2010

Emissions of non-CO<sub>2</sub> forcers are also reduced or limited in pathways limiting global warming to 1.5°C with **no or limited overshoot**, but they do not reach zero globally.

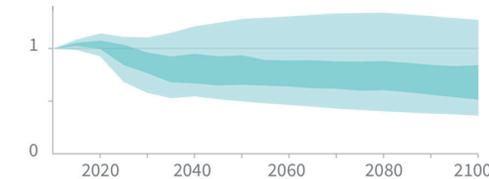
### Methane emissions



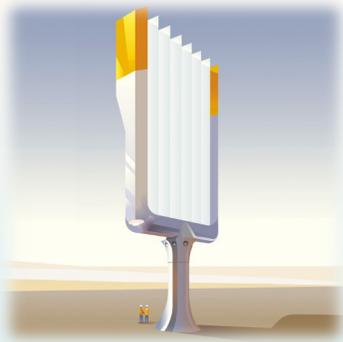
### Black carbon emissions



### Nitrous oxide emissions



IPCC, 2018: Summary for Policymakers. In: *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. *World Meteorological Organization, Geneva, Switzerland, 32 pp.*



# A new perspective: Carbon as waste management problem

KLAUS S. LACKNER  
CHRISTOPHE JOSPE

## Climate Change is a Waste Management Problem

**T**he physical problem underlying climate change is very simple: dumping carbon dioxide and other greenhouse gases into the air raises their concentrations in the atmosphere and causes gradual warming. In the several decades since climate change has been an important international political issue, the necessary solution to this simple problem has been viewed as equally simple: the world must radically reduce its emissions of carbon-carrying gases.

Here we explore a different perspective, and a different type of solution. Carbon dioxide is a waste product; dumping it into the open air is a form of littering. Dumping can be avoided or cleaned up with technological fixes to our current infrastructure. These fixes do not require drastic reductions in energy use, changes in lifestyle, or transformations in energy technologies. Keeping carbon dioxide out of the atmosphere is a waste management problem. The rapid mixing of carbon dioxide in the atmosphere simplifies this waste management problem compared with others, such as sewage or municipal garbage, where local buildup of waste is deleterious and therefore requires the disposal of the specific waste material as it is generated. By contrast, carbon dioxide does not create local damage, and it does not matter where carbon dioxide molecules are removed from the atmosphere as long as the amount removed equals the amount added.

- **CO<sub>2</sub> like garbage or sewage must not be dumped into the environment**
- **Regulation must forbid dumping of CO<sub>2</sub>**
  - Fast mixing in the atmosphere makes it acceptable to balance inputs and outputs
  - DAC combined with sequestration (DACCS) remedies dumping
- **Waste management becomes a lucrative business**

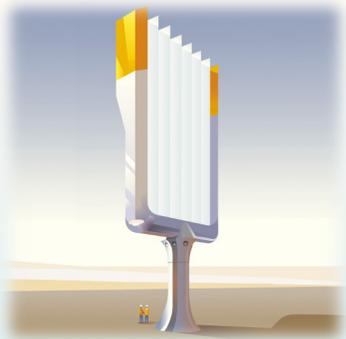
Dumping can be avoided or cleaned up with technological fixes to our current infrastructure. These fixes do not require drastic reductions in energy use, changes in lifestyle, or transformation in energy technologies. Keeping carbon dioxide out of the atmosphere is a waste management problem.

Lackner, Klaus S., and Christophe Jospe.

"Climate Change is a Waste Management Problem.

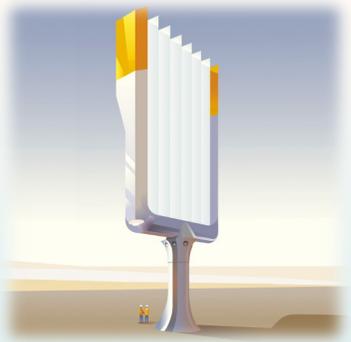
*"Issues in Science and Technology* 33, no. 3 (2017): 83-88.

Reframing our understanding of carbon dioxide emissions can help clear the path for practical approaches to reducing carbon in the atmosphere.



# Certificates of Sequestration

- **Measurable and verifiable**
  - Option 1: Permanence is assured scientifically
    - *Mineralization, deep underground injection can give 100,000 year assurance through scientific analysis*
  - Option 2: Operator accepts responsibility for storage
    - *Continued monitoring at the expense of the storage operator*
    - *Needs financial risk management*
      - insurance, bonding, transfer to trusted operators etc.

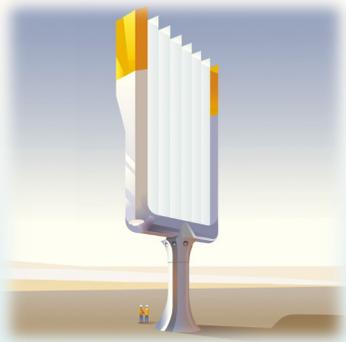


# Balancing the Carbon Books

**Extraction + Losses from Storage = Carbon Removal**

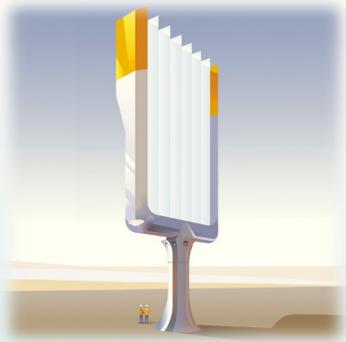
- **Certificates of Sequestration should be required for**
  - extraction of carbon from the ground
    - *Oil, coal, gas, fossil CO<sub>2</sub>*
  - release of carbon in the calcination of carbonate minerals
    - *cement and steel production*
  - loss of carbon from temporary sequestration
    - *Monitoring and verification*
  - Import of raw fossil carbon into a local jurisdiction
    - *Allows for starting nation by nation*

**A carbon takeback obligation requires a regulatory framework**



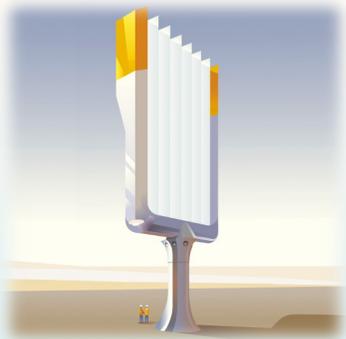
# No need for Life Cycle Accounting

- Carbon accounting through supply chains is notoriously difficult
- Balancing the books at the top of the supply chain makes it unnecessary
- Far easier than carbon tracking
- Far easier than closing the carbon cycle at the end consumers

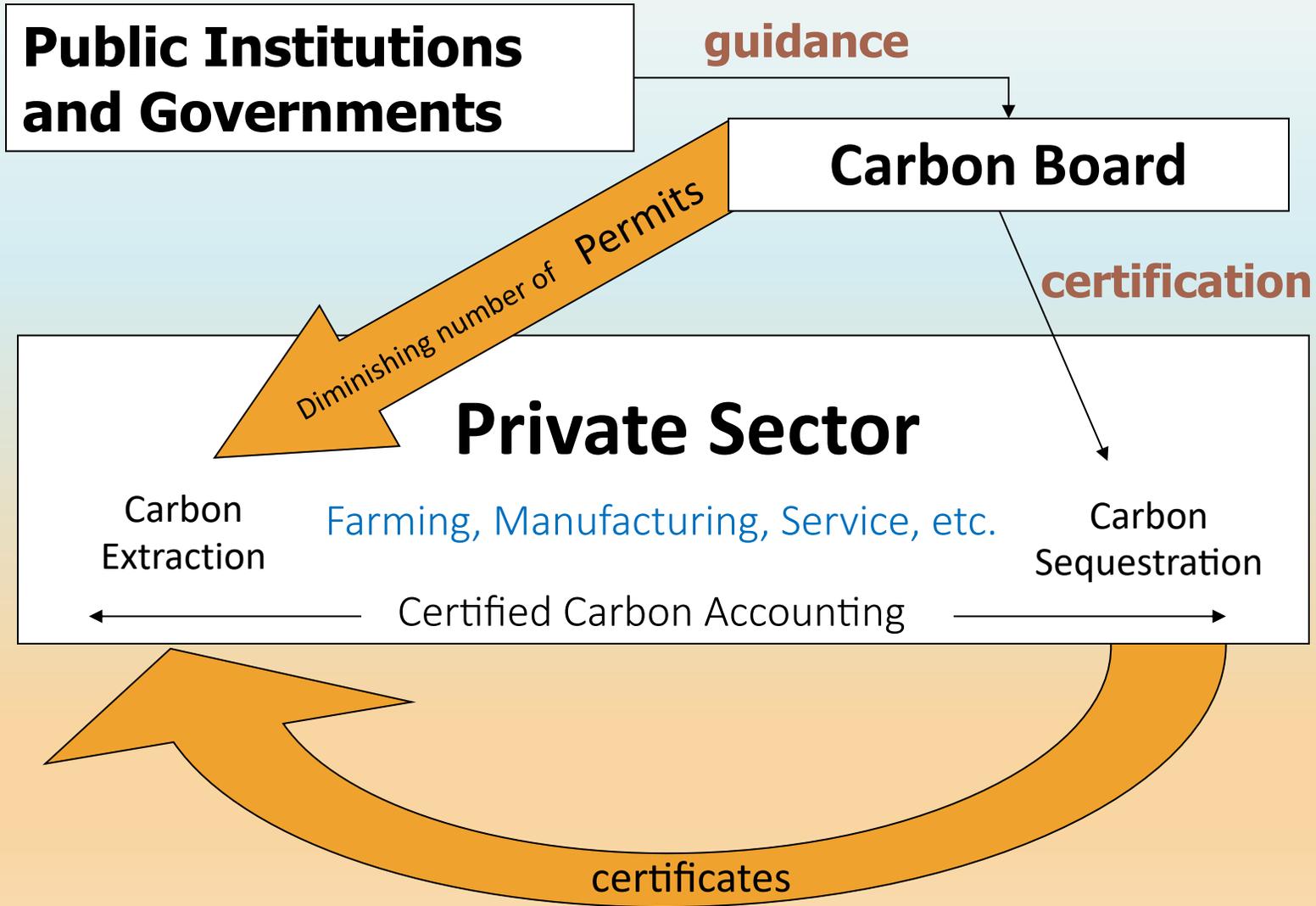


# Carbon Accountability

- **Carbon accountability is the major challenge in solving climate change**
  - Requires policy and regulations
  - International cooperation
- **Going all the way upstream makes the problem as simple as possible**
  - Minimizes rules
  - Quantifying and certifying storage is still a big task



# Pricing carbon: Toward net zero



Increased carbon cost favors non-fossil alternatives



## Intergenerational equity and responsibility: a call to internalize impermanence into certifying carbon sequestration

Stephanie H. Arcusa<sup>1\*</sup>, Klaus S. Lackner<sup>2</sup>

<sup>1</sup>Center for Negative Carbon Emissions, Global Futures Laboratory, Arizona University, Tempe, Arizona, USA

<sup>2</sup>Center for Negative Carbon Emissions, School of Sustainable Engineering & the Built Environment, Arizona State University, Tempe, Arizona, USA

**\* Correspondence:**

Stephanie Arcusa  
sarcusa@asu.edu

**Keywords:** Carbon Dioxide Removal, carbon sequestration, certificates of carbon sequestration, Negative Emission Technology, certification, intergenerational equity, responsibility, permanence

**Abstract**

Carbon Dioxide Removal that limits or reduces cumulative emissions for the goal of climate action requires sequestration. The assurance that carbon remains sequestered is colloquially known as

# CNCE Report

## Working Paper Series

Nov. 2022  
Issue #1



### Carbon Removal Accounting Methodologies:

*How to rethink the system for negative carbon emissions*



Center for  
Negative  
Carbon  
Emissions  
Arizona State  
University