Thermodynamics lecture 13.

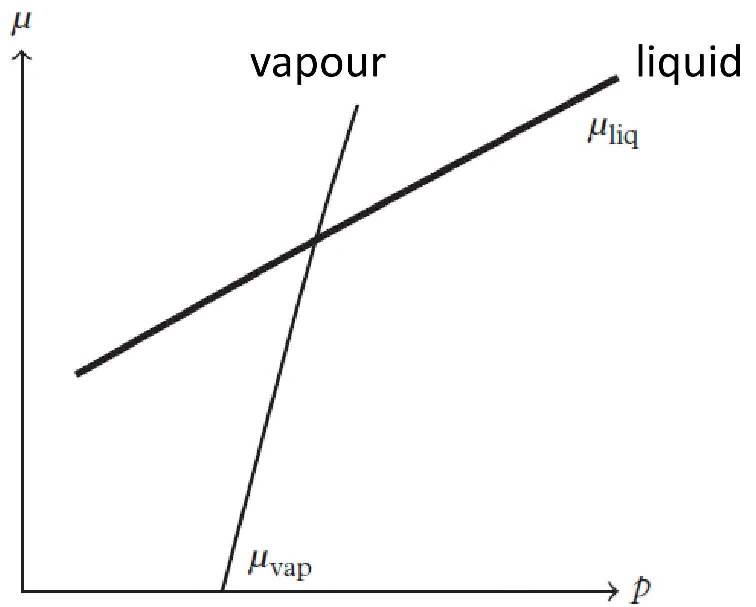
1. Some observations on chemical potential
2. Nucleation (example for supercooled vapour)
3. Radiative heat transport
4. The greenhouse effect

Gibbs Duhem relation:

$$d\mu = -s dT + v dp$$

$$s = \frac{S}{N}, \quad v = \frac{V}{N}$$

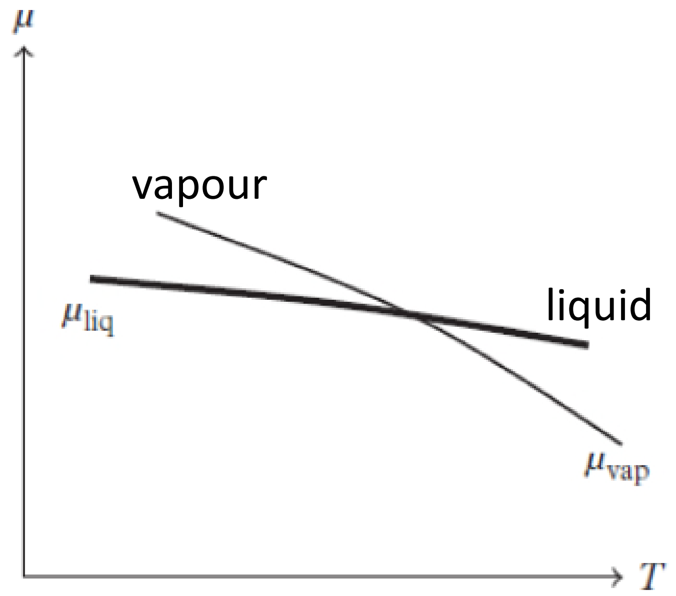
Chemical potential verses p at fixed T



$$\left.\frac{\partial \mu}{\partial p}\right|_T = v = \frac{1}{n}$$

Slope = volume per particle

Chemical potential verses T at fixed p



$$\left.\frac{\partial \mu}{\partial T}\right|_p = -s$$

Slope = −(entropy per particle)

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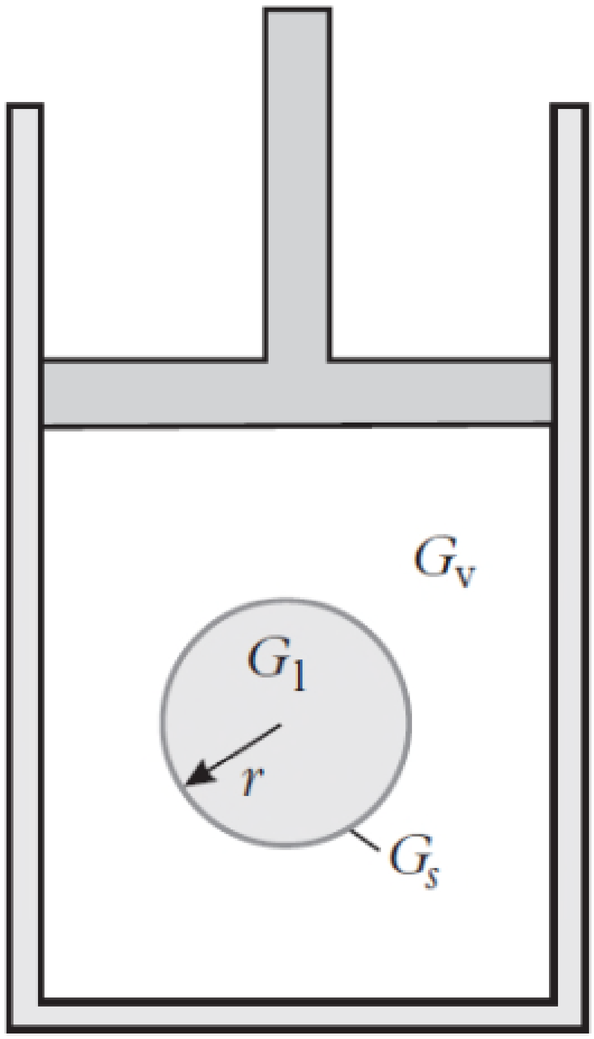
The bubbles form
on the glass at
particular places



A spherical drop of liquid forming inside a vapour

Three subsystems:
vapour,
bulk liquid,
surface.

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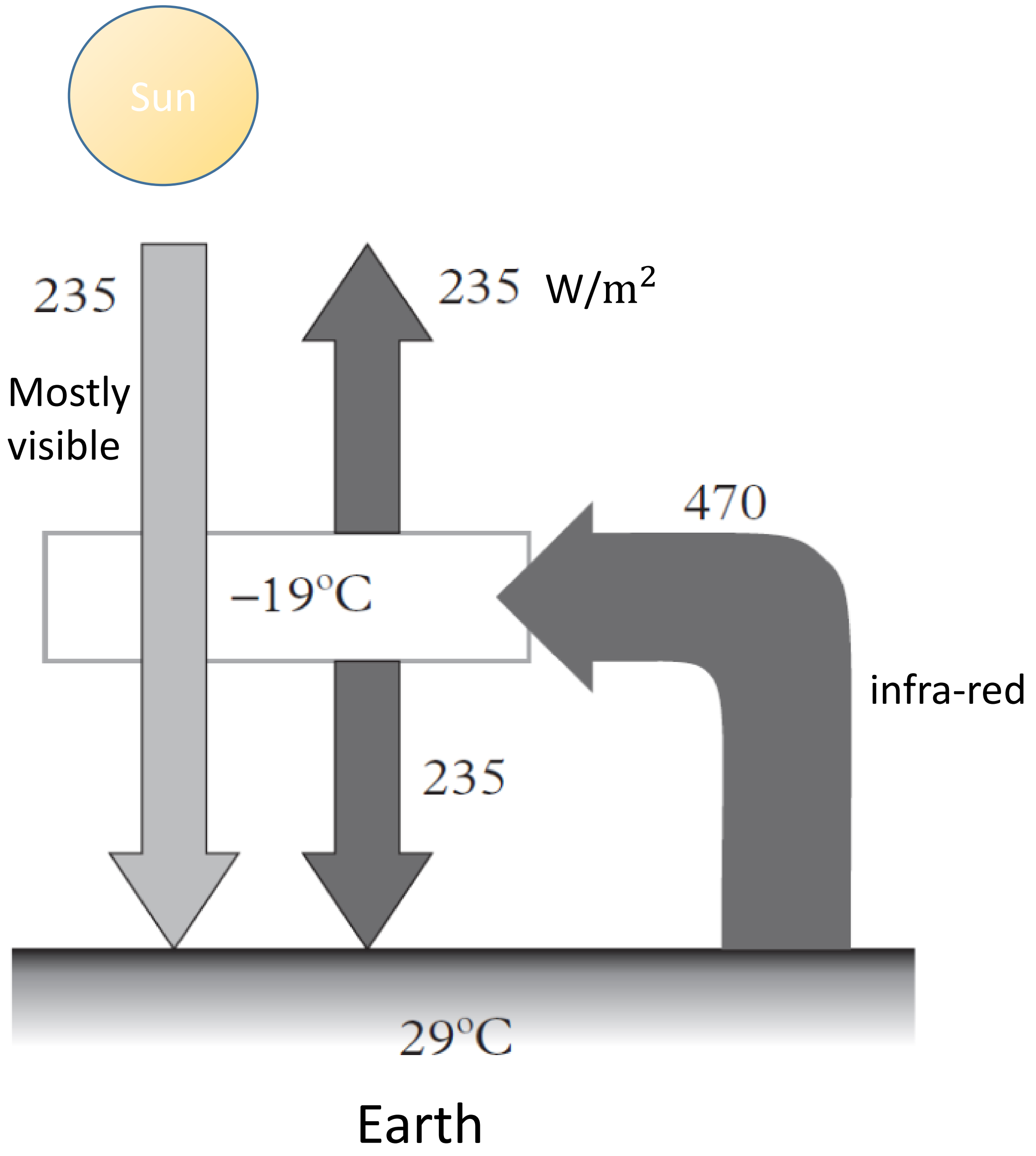
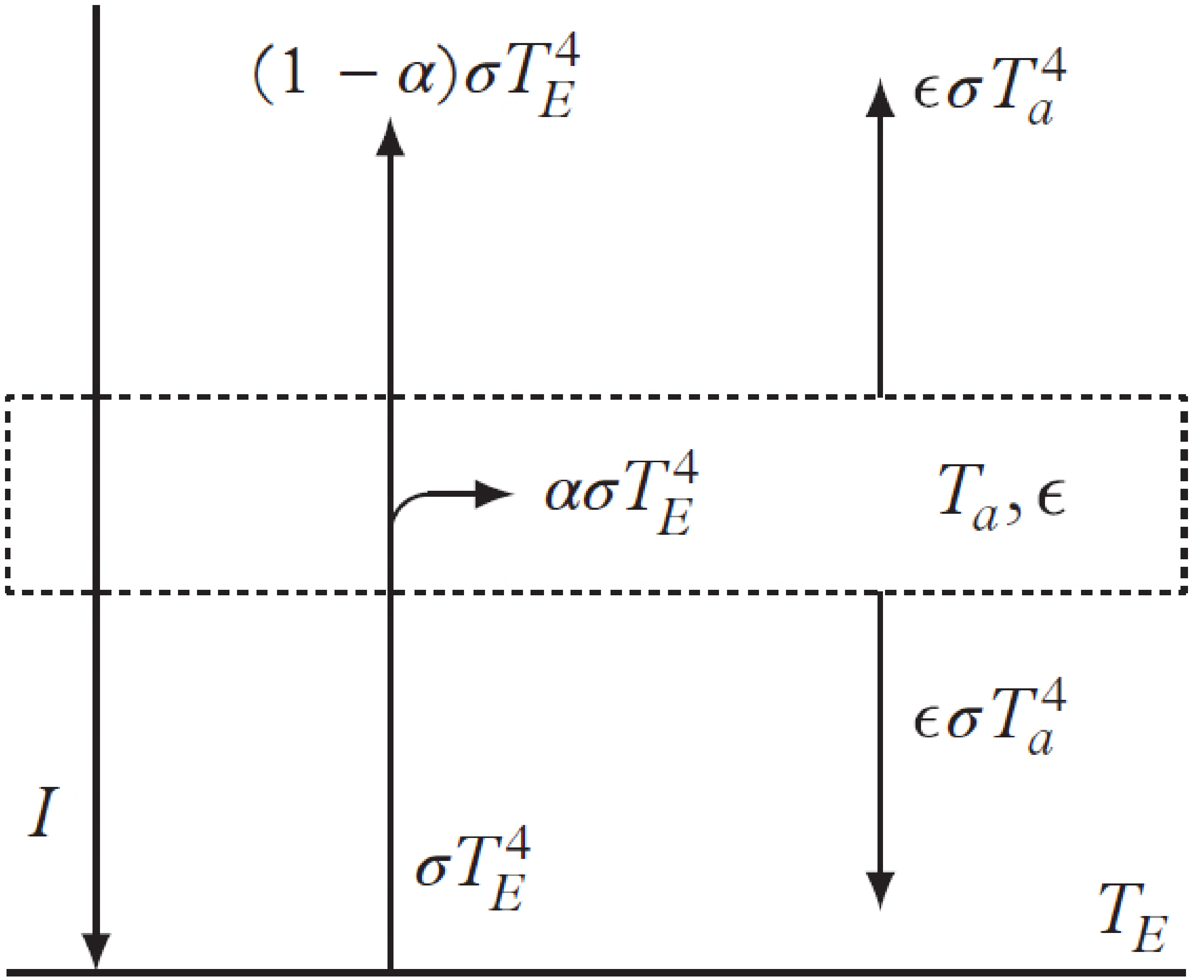
A simple model of the greenhouse effect



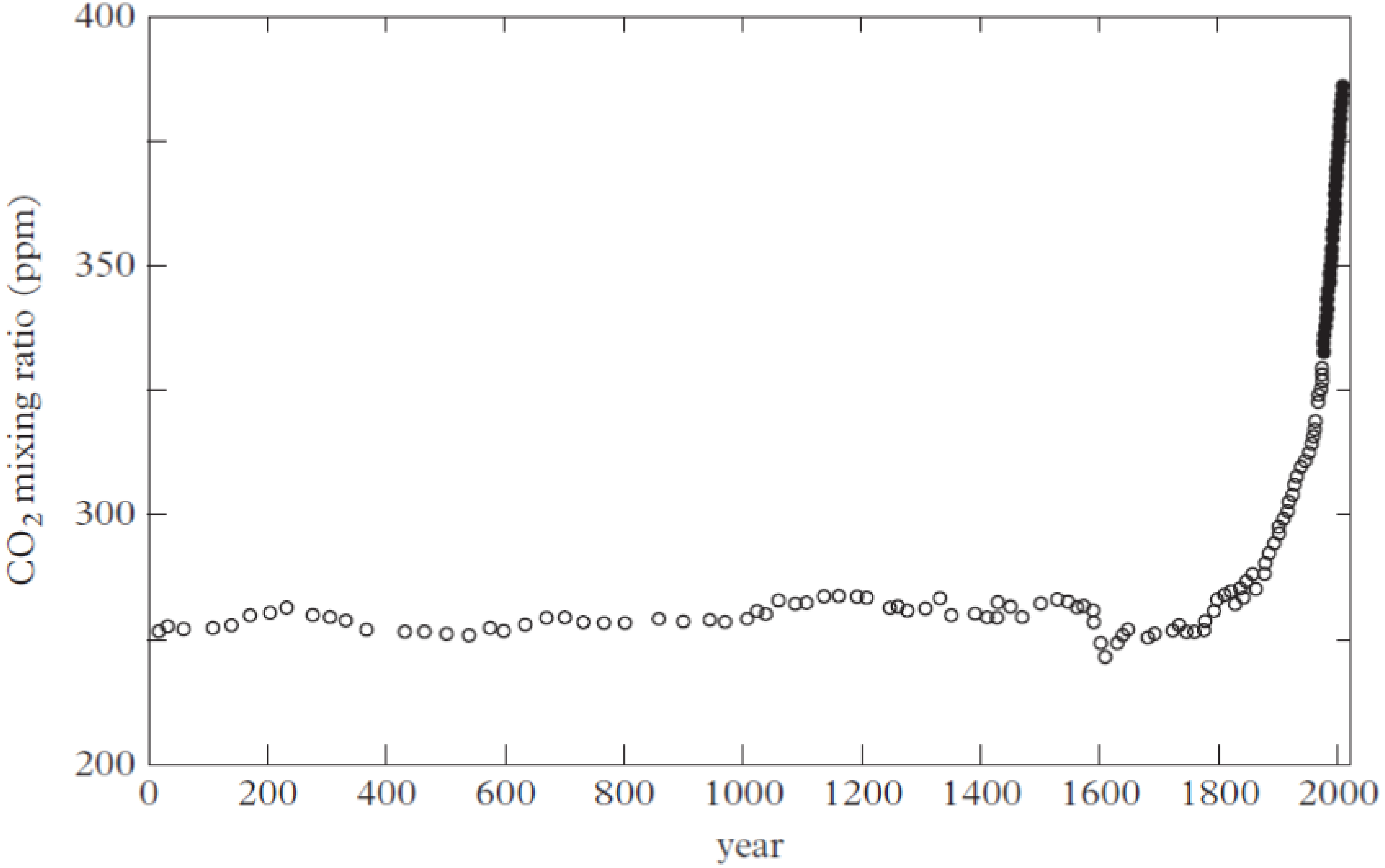


Slightly more complete model

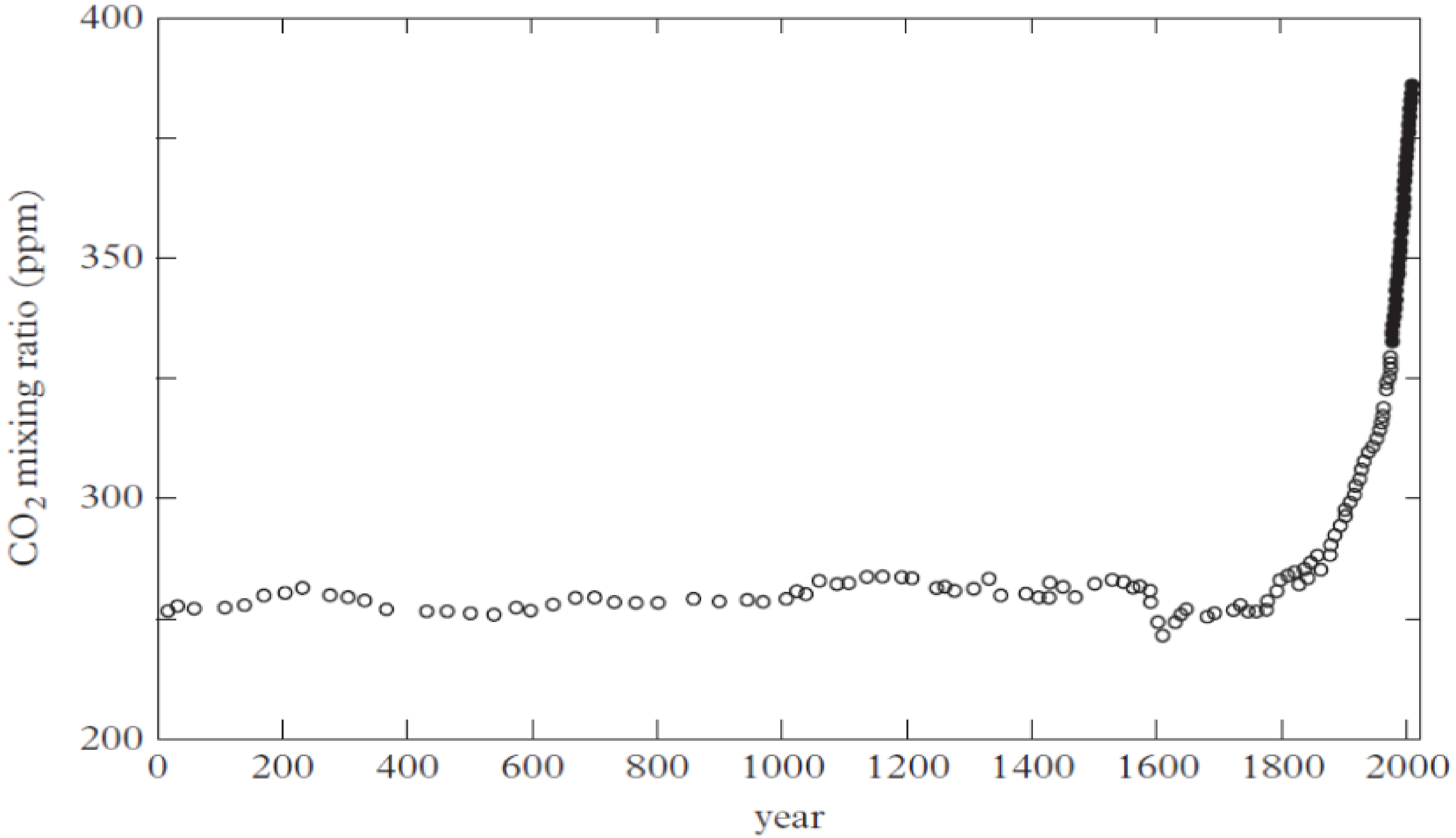
→ T_E = 15 ^{o}C

at ε = 0.78

Carbon dioxide concentration in atmosphere vs time



Carbon dioxide concentration in atmosphere vs time



Main emitters: China, USA (13billion, 6 billion) tons/yr (so 10, 18 per person)

Case study 1:

Chinese coal-fired power station policy

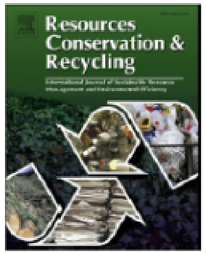
(China burns more coal than the rest of the world combined.)

Resources, Conservation & Recycling 177 (2022) 105964

Contents lists available at ScienceDirect

Resources, Conservation & Recycling

journal homepage: www.elsevier.com/locate/resconrec



Full length article

Tracking the carbon footprint of China's coal-fired power system

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ARTICLE INFO

Keywords:
Carbon footprint
Power plants
Embodied emissions
Regional imbalance

ABSTRACT

Mitigating carbon emissions from the coal-fired power system is at the core of China's carbon neutrality target. In this paper, we tracked the carbon footprint of coal-fired power plants from 2000 to 2020 in China, considering both construction and various operating processes. We linked an inventory of three types of plants (350MW, 660MW, and 1000MW) to an input–output database. The spatial distribution of the carbon footprint, carbon emissions per capita, and carbon emissions per unit economic output was used to show provincial gaps and regional imbalances. The results showed that the annual carbon emissions from China's coal-fired power plants increased by 2360.04 Mt from 2000 to 2020. Annual carbon emissions from the construction of coal-fired power plants peaked at 142.35 Mt in 2006 and decreased gradually after that. The carbon footprint gaps that existed between western and eastern provinces have narrowed with rapid growth of the annual carbon emissions per unit economic output and per capita in Xinjiang, Inner Mongolia and Ningxia over the past 20 years. The variation in the carbon footprint highlights the need for tailored, spatially balanced measures for continued decarbonization of the coal-fired power system in each province beyond 2020.

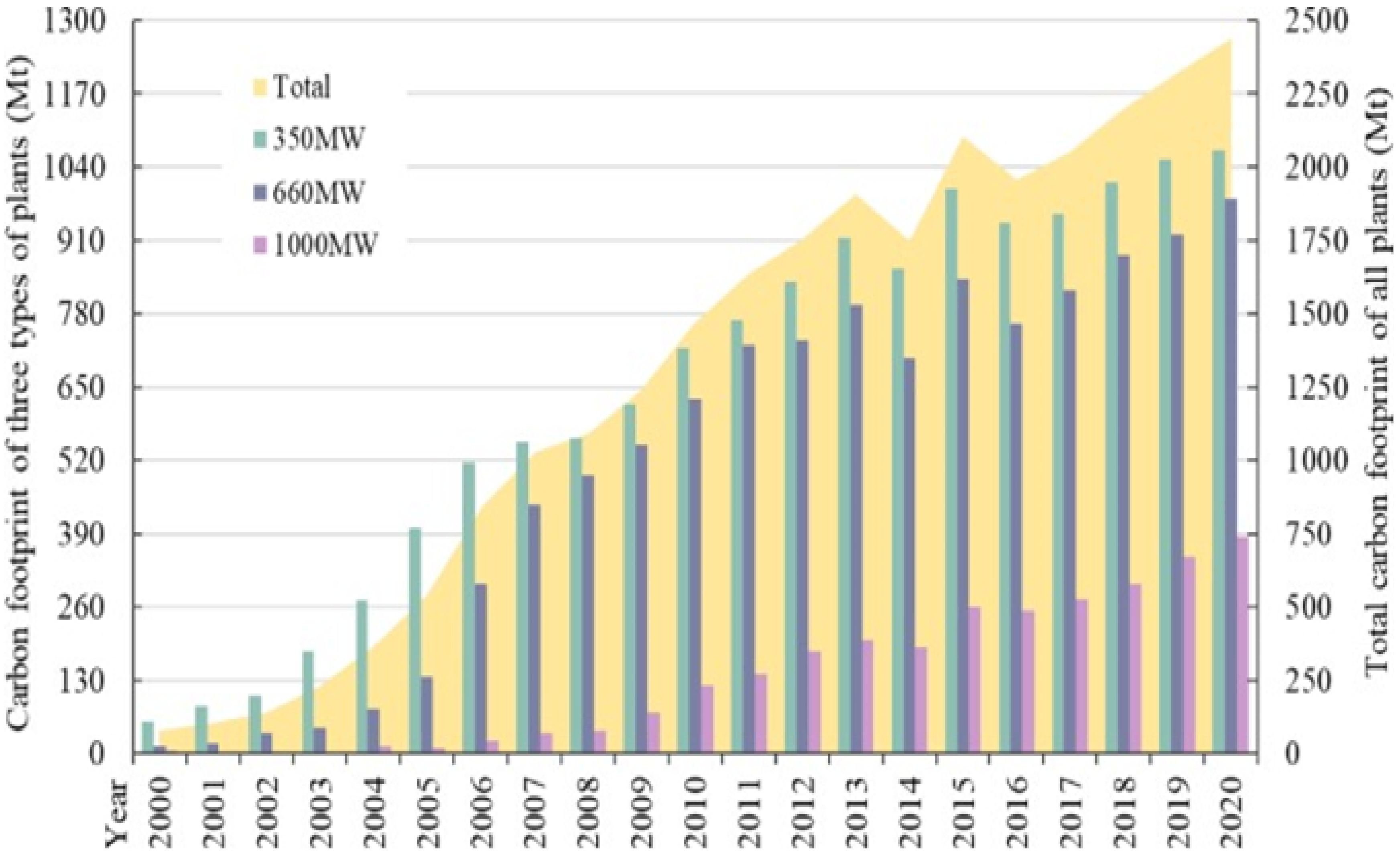
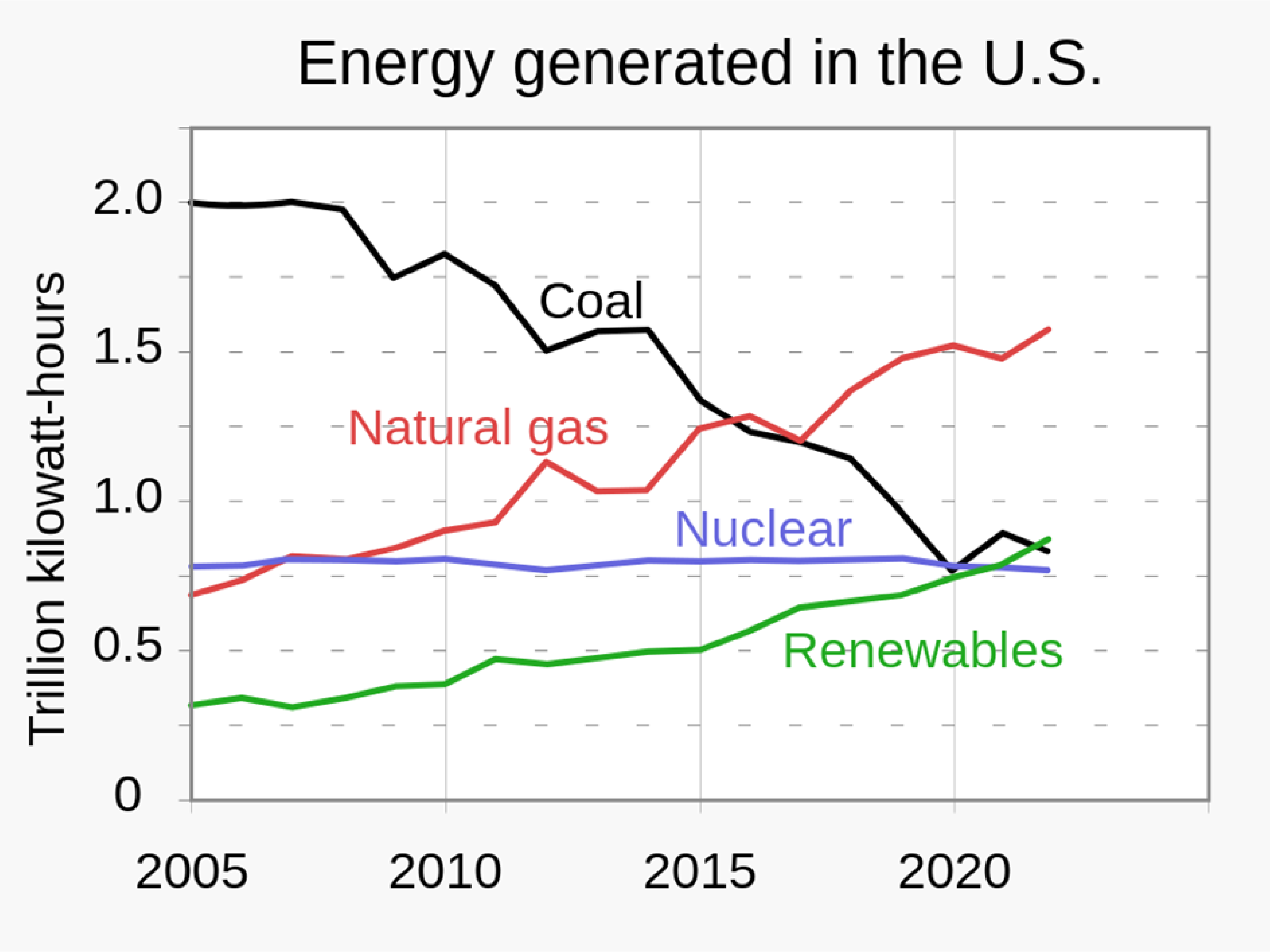


Figure 1 from Gao et al:
“Carbon footprint of China’s coal-fired power stations during 2000-2020”



Source: Alfredo Rivera, Ben King, John Larsen, and Kate Larsen (Rhodium Group), "Preliminary US Greenhouse Gas Emissions Estimates for 2022" https://rhg.com/research/us-greenhouse-gas-emissions-2022/#_ftnref1

The United States has not built a new coal plant **since 2013**.

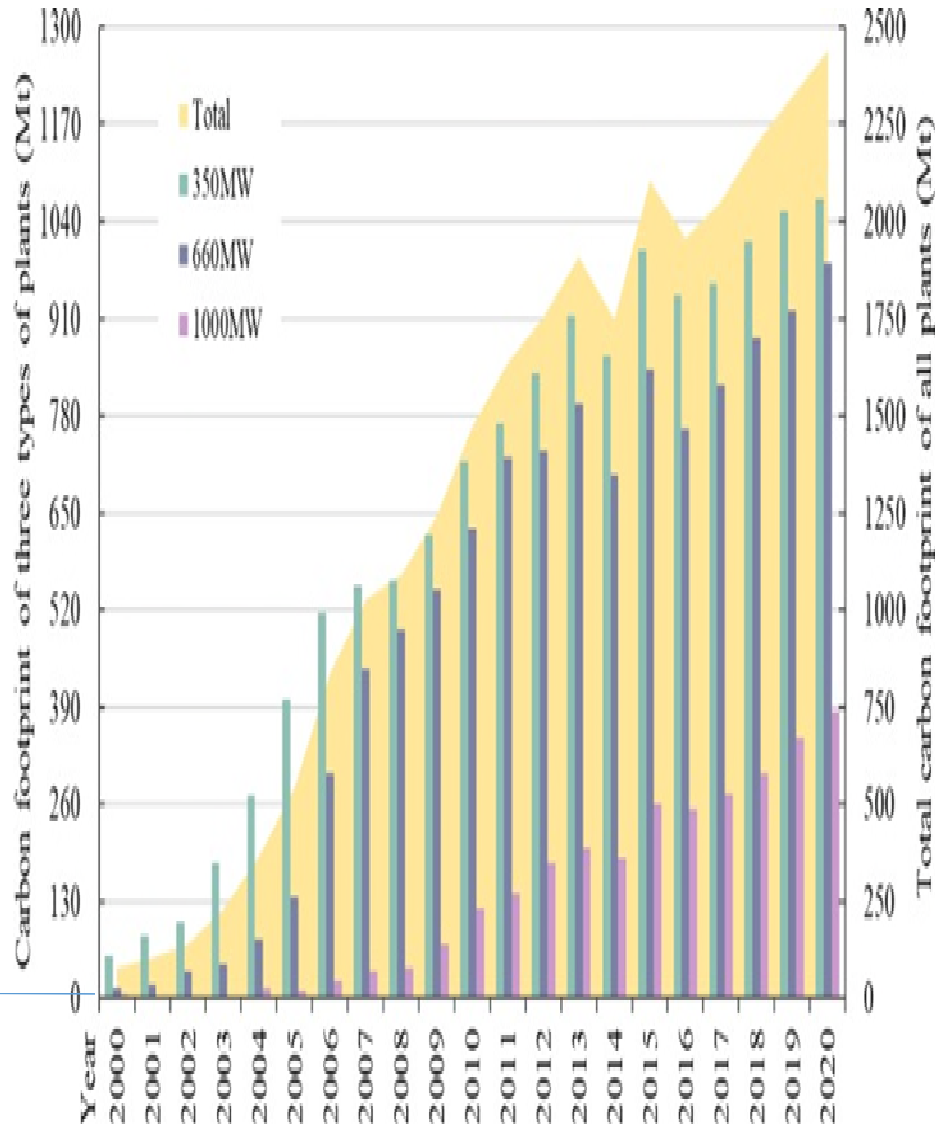
https://www.nytimes.com/2023/07/19/climate/us-china-climate-issues.html#:~:text=China%2C%20the%20world's%20biggest%20emitter,about%205.9%20billion%20tons%20annually.

(These quotes are from Wikipedia, “History of climate change science”)

“In the 1960s, the evidence for the warming effect of carbon dioxide gas became increasingly convincing”

“By the 1990s, as the result of improving the accuracy … a consensus position formed. It became clear that greenhouse gases were deeply involved in most climate changes and human-caused emissions were bringing discernible global warming”

1960 1970 1980 1990



Gao et al: “annual carbon emissions from China’s coal-fired power plants increased by 2360.04 Mt from 2000 to 2020”

Case study 2:

Aviation

5% of global emissions CO2 and other greenhouse gases.

X% of emissions unrelated to basic necessities (food, healthcare, etc.)

with X > 5

The social cost of C02 emission: about $185 per ton

Nature | Vol 610 | 27 October 2022

Article

Comprehensive evidence implies a higher social cost of CO_2

https://doi.org/10.1038/s41586-022-05224-9

Received: 23 December 2021

Accepted: 11 August 2022

Published online: 1 September 2022

Open access

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The social cost of carbon dioxide (SC-CO_2) measures the monetized value of the damages to society caused by an incremental metric tonne of CO_2 emissions and is a key metric informing climate policy. Used by governments and other decision-makers in benefit–cost analysis for over a decade, SC-CO_2 estimates draw on climate science, economics, demography and other disciplines. However, a 2017 report by the US National Academies of Sciences, Engineering, and Medicine[1] (NASEM) highlighted that current SC-CO_2 estimates no longer reflect the latest research. The report provided a series of recommendations for improving the scientific basis, transparency and uncertainty characterization of SC-CO_2 estimates. Here we show that improved probabilistic socioeconomic projections, climate models, damage functions, and discounting methods that collectively reflect theoretically consistent valuation of risk, substantially increase estimates of the SC-CO_2. Our preferred mean SC-CO_2 estimate is $185 per tonne of CO_2 ($44–$413 per tCO_2: 5%–95% range, 2020 US dollars) at a near-term risk-free discount rate of 2%, a value 3.6 times higher than the US government's current value of $51 per t$CO_2$. Our estimates incorporate updated

$185 per tonne of $C0_2$

(US govt currently estimates $51)

Case study 2: Aviation

The social cost of C02 emission: about $185 per ton

A typical flight produces 60 to 250 kg CO_2 per passenger per hour

[Hence one flight London-San Francisco = drive a car for a year

= (1/4) total per person (UK) footprint]

10 hour flight → 1500 kg → (1.5 x 185) = $280 social cost of emissions

Ticket price around $380.

(1/3) of this is for fuel, hence passenger pays around $120 for fuel.

So others bear the remaining $160 social cost.

Who is bearing the remaining $100 to $200 cost ?

The economic impact of current decisions about emissions falls mainly on the next generation.

The social and economic impact of climate change falls mainly on poorer communities.

And now the good news!

Any individual can choose to cover these hidden costs by their own contributions. We just need to set aside the money and use it to pay those poorer communities for the work they and their children are doing for us.

(In the example I gave, this is only a 25% to 50% increase in cost to the person flying, hence affordable and easily preferable to the alternative.)