ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

The Economics of Climate Change

Lecture 1: Introduction

Dr. Markus Ohndorf

Autumn Term 2014

Preliminary Organization

- Term: Autumn 2014
- Lecture: The Economics of Climate Change
- Time: 10-12, Wednesday
- Place: LFW E13
- Coursework: Problem Sets will be discussed in lecture
- Lecturer: Dr. Markus Ohndorf
- Address: Chair of Economics, Clausiusstrasse 35, WEH G7 (3rd floor)
- Office Hours: By appointment
- E-mail: ohndorfm@ethz.ch
- Examination: (closed book) written exam

Lecture notes and advice

Lecture slides will appear online before the respective lecture

Recommendations:

- Slides are in no way a substitute for attending lectures
- Take notes and ask questions during the lecture
- Study the cited literature

Preliminary Courses

- This course involves standard calculus and algebra manipulation (e.g.constrained optimization) and game theoretical issues. It is however more important to understand the logic than the tools applied.

Prerequisites:

- Knowledge of game theory

Aims of course:

1. To provide an up-to-date economic interpretation of climate change
2. To discuss and compare the theoretical economic solutions to combating climate change.
3. To outline possible future climate policy issues.

Main focus of the course

As there are an enormous amount of issues in climate change, this course restricts attention to:

- A game theoretical view of climate change
- The types of polices available for governments
- A discussion of optimal policies
- An outlook on future climate policy in light of institutional economics.

Lecture Outline

- Lecture 1 : Introduction
- Lecture 2 : Economics primer (of pollution)
- Lecture 3&4 : Optimal level of greenhouse gases
- Lecture 5: International environmental agreements
- Lecture 6 : Economic instruments: Carbon taxes
- Lecture 7 : Tradable pollution permit markets
- Lecture 8 : Regulation via prices vs. Quantities
- Lecture 9: Multiple policy goals and multiple instruments
- Lecture 10: Credit-based Mechanisms
- Lecture 11: Voluntary approaches to climate change
- Lecture 12: Climate Policy in Switzerland
- Lecture 13: Repetition/Results from COPs and Climate Policy

Literature

The recommended textbook is

Perman et al. (2003), Natural Resource and Environmental Economics, Pearson Addison Wesley,

which deals with most of the issues. Chapters: 5,6,7,8,10 and 16. I will supplement this with recent journal articles.

Journals:

- Journal of Environmental Economics and Management (JEEM)
- Environmental and Resource Economics (ERE)
- Ecological Economics
- Energy Policy
- Journal of Regulatory Economics (JRE)
- Journal of Public Economics
- Climate Policy

All can be found in the e-journals link (ETH)

Literature Textbooks

Other Suggested Textbooks on Environmental Economics and climate change:

- Baumol and Oates (1988), *The Theory of Environmental Policy*, Cambridge University Press. Chapters: 5, 12, 13 and 16.
- Owen and Hanley (2004), *The Economics of Climate Change*, Taylor and Francis.
- Helm, D. (ed.) (2005), *Climate change Policy*, Oxford Economic Press: Oxford.
- Helm and Hepburn (2009) *The Economics and Politics of Climate Change*. Oxford Economic Press: Oxford.
- Tietenberg (2004*), Environmental Economics and Policy*, Pearson Addison Wesley.

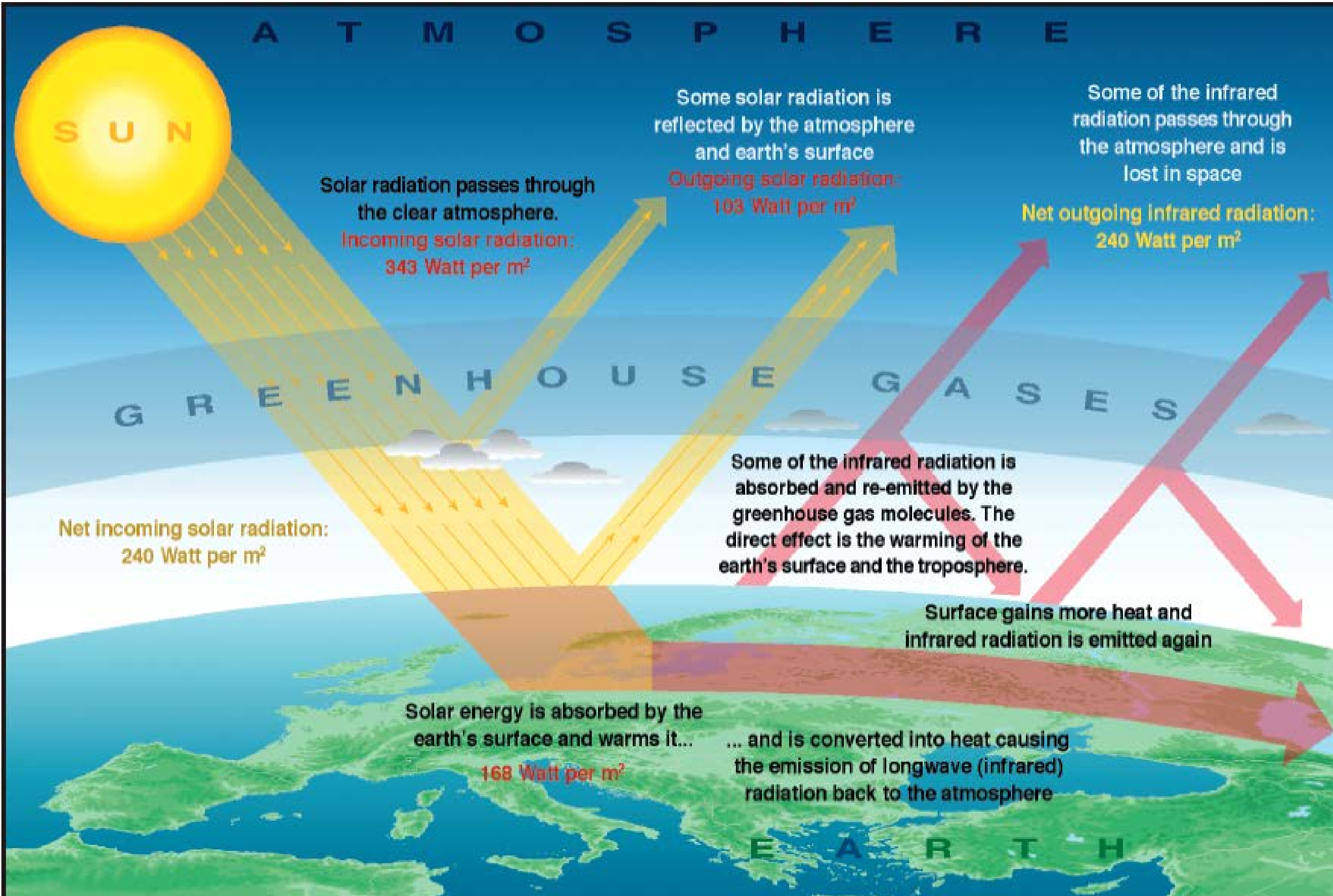
Useful Websites

- United Nations Framework Convention on Climate Change (UNFCCC)
  - http://unfccc.int/2860.php
- Tom Tietenberg's bibliography page (taxes and permits):
  - http://www.colby.edu/personal/t/thtieten/trade.html
- Stern Review:
  - http://www.hm-treasury.gov.uk/

The Basic Science behind Global Warming

The Greenhouse Effect

- CO_2,CH_4,N_2O, PFC, HFC, SF_6 and water vapour
- Pollutants allow natural process that warms earth surface 30°C above normal
- Greenhouse Effect history:
- Long establishment in history e.g.Tyndall 1800s
- Infrared radiation (heat energy) trapped in atmosphere by pollutants


ATMOSPHERE
SUN
Solar radiation passes through the clear atmosphere.
Incoming solar radiation: 343 Watt per m²
Some solar radiation is reflected by the atmosphere and earth's surface
Outgoing solar radiation: 103 Watt per m²
Some of the infrared radiation passes through the atmosphere and is lost in space
Net outgoing infrared radiation: 240 Watt per m²
GREENHOUSE GASES
Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules. The direct effect is the warming of the earth's surface and the troposphere.
Net incoming solar radiation: 240 Watt per m²
Surface gains more heat and infrared radiation is emitted again
Solar energy is absorbed by the earth's surface and warms it...
168 Watt per m²
... and is converted into heat causing the emission of longwave (infrared) radiation back to the atmosphere
EARTH

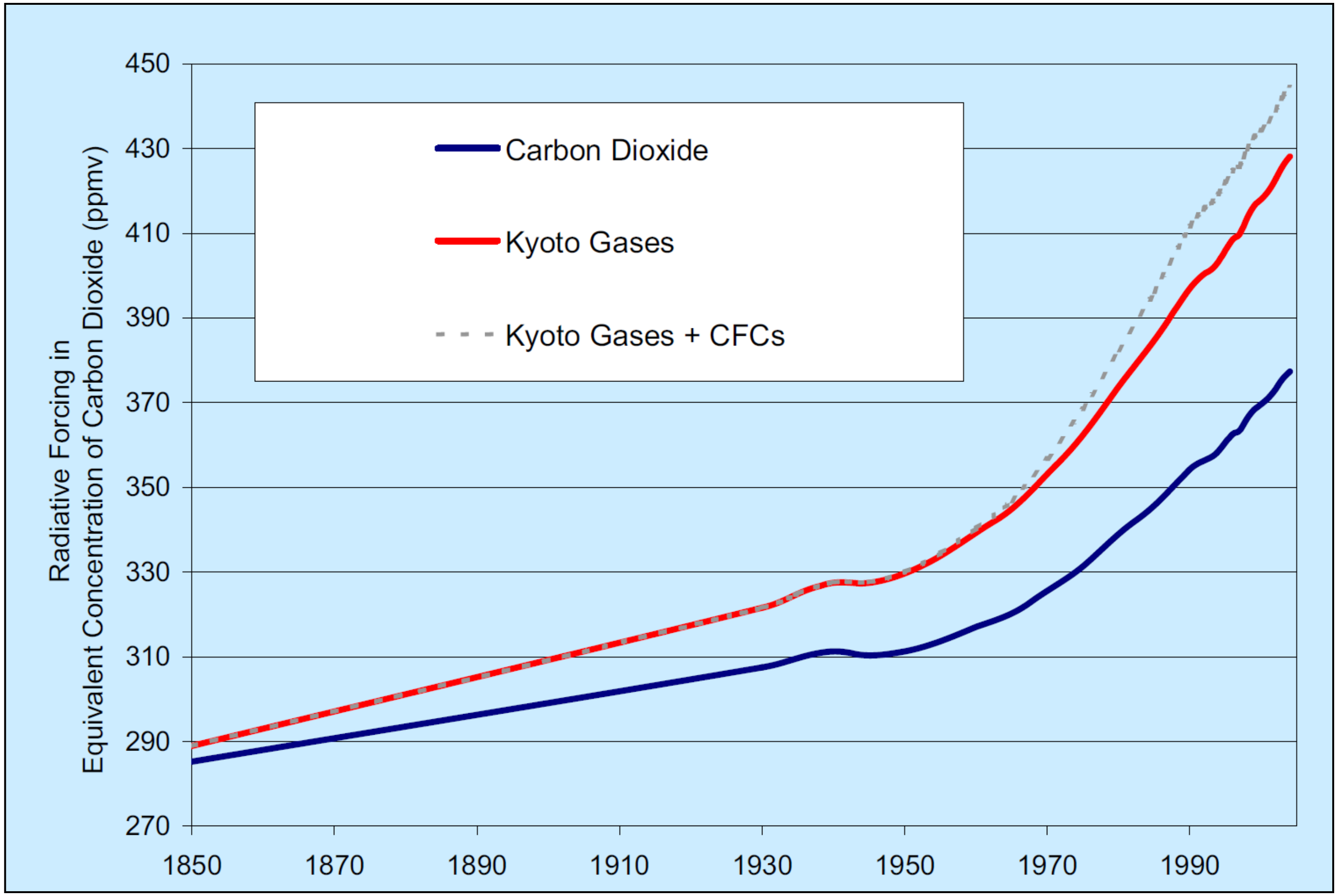
Where is the problem?

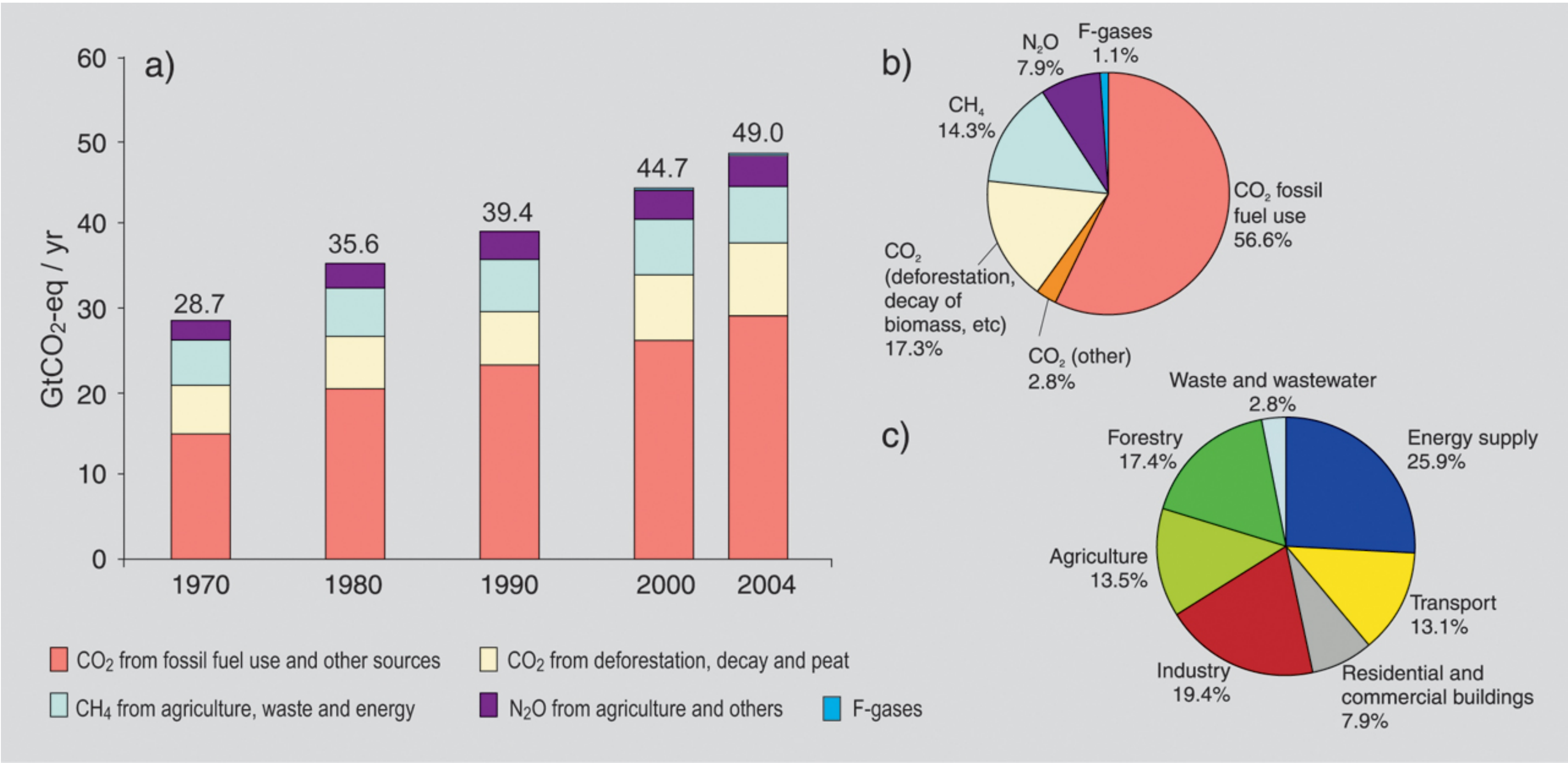
- Human activity (mostly postindustrial revolution) has changed the composition and level of GHG in atmosphere.
- 280 ppm (pre industrial) to 380 ppm today

Reasons for the increase:

  - Energy, burning fossil fuels
  - deforestation (land use)
  - Transport
  - Industry
  - Agriculture
  - Emissions are increasing at an increasing rate!
  - Methane and nitrous oxide appear to be increasing the most
  - Highest concentration of GHG for 650,000 years
  - If concentrations remained constant from now on the global temperature would still rise by 1-3C above preindustrial levels

Rising levels of greenhouse gases Source: Stern (2006)




a)
GtCO2-eq / yr
60
50
40
30
20
10
0
28.7
35.6
39.4
44.7
49.0
1970
1980
1990
2000
2004
CO2 from fossil fuel use and other sources
CO2 from deforestation, decay and peat
CH4 from agriculture, waste and energy
N2O from agriculture and others
F-gases
b)
N2O 7.9%
F-gases 1.1%
CH4 14.3%
CO2 fossil fuel use 56.6%
CO2 (deforestation, decay of biomass, etc) 17.3%
CO2 (other) 2.8%
c)
Waste and wastewater 2.8%
Forestry 17.4%
Energy supply 25.9%
Agriculture 13.5%
Transport 13.1%
Industry 19.4%
Residential and commercial buildings 7.9%

IPCC (2007)

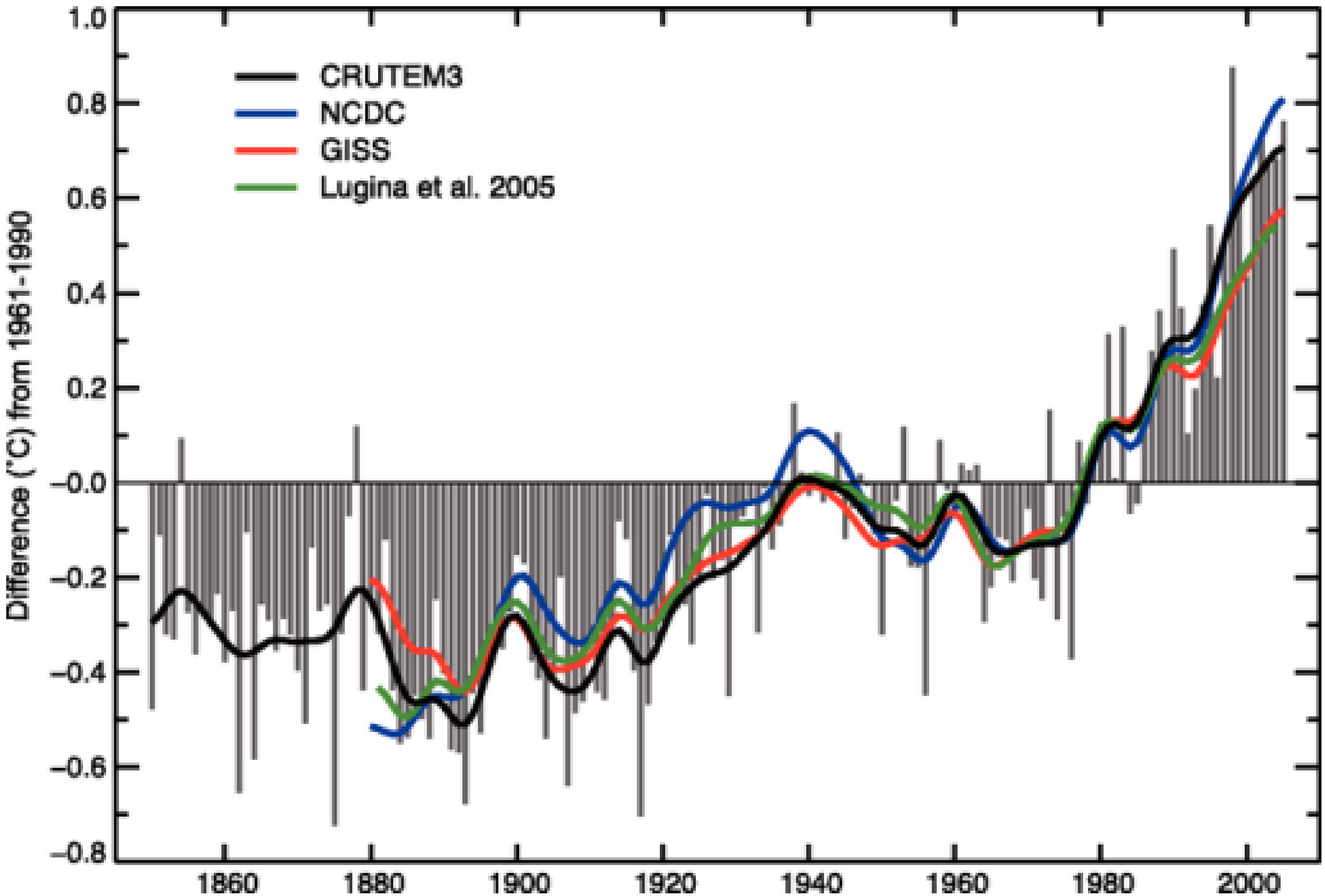


Figure 3.1. Annual anomalies of global land-surface air temperature (°C), 1850 to 2005, relative to the 1961 to 1990 m

Difficulties with increasing GHG concentrations: positive feedback

- Not only do GHG concentrations increase the temperature level, the increase in concentrations also have feedback effects:
- Land carbon sinks (initially increase absorption then decrease)
- Ocean sinks reduce (reduction of absorbing algae)
- Release of methane from wetlands, permafrost etc
- Appears positive feedback effects could add 1-2°C onto temperature by 2100

The Consequences of the temperature increase

Change in regional weather patterns/cycles will affect regions unevenly:

- Change in water supply (of which 70% is used for crop irrigation and food provision)
- increase risk of extreme events
- increase risk of more heat waves/droughts
- Declining crop yields
- spread of vector-borne diseases such as malaria
- increased risk of rising sea levels/reduction of ice sheets (feedback effects)
- extinction of flora and wildlife
- Threshold effect... irreversible changes such as complete destruction of ecosystems in long run.

Consequences for Europe

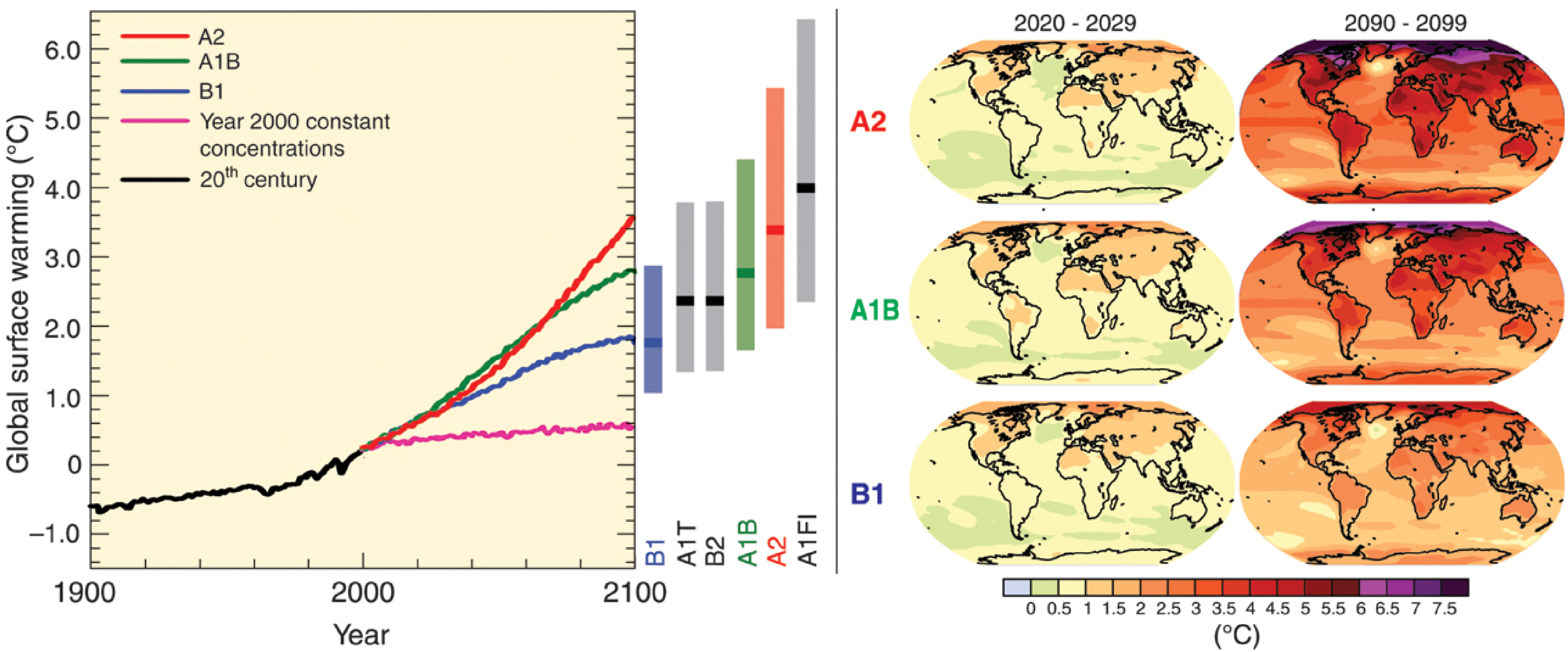
- Weakening of the Atlantic thermohaline Circulation: cooling effect
- Increased sea levels
- increased ooding, rainfall
- 20% fall in crop yield and water supply in southern Europe with a 2C
- increase in temperature
- Possible benets?
- possible higher crop yields, less winter mortality, increased tourism in some areas e.g. Scandinavia

Table 3.1 Highlights of possible climate impacts discussed in this chapter

Temp rise (°C)	Water	Food	Health	Land	Environment	Abrupt and Large-Scale Impacts
1°C	Small glaciers in the Andes disappear completely, threatening water supplies for 50 million people	Modest increases in cereal yields in temperate regions	At least 300,000 people each year die from climate-related diseases (predominantly diarrhoea, malaria, and malnutrition) Reduction in winter mortality in higher latitudes (Northern Europe, USA)	Permafrost thawing damages buildings and roads in parts of Canada and Russia	At least 10% of land species facing extinction (according to one estimate) 80% bleaching of coral reefs, including Great Barrier Reef	Atlantic Thermohaline Circulation starts to weaken
2°C	Potentially 20 - 30% decrease in water availability in some vulnerable regions, e.g. Southern Africa and Mediterranean	Sharp declines in crop yield in tropical regions (5 - 10% in Africa)	40 – 60 million more people exposed to malaria in Africa	Up to 10 million more people affected by coastal flooding each year	15 – 40% of species facing extinction (according to one estimate) High risk of extinction of Arctic species, including polar bear and caribou	Potential for Greenland ice sheet to begin melting irreversibly, accelerating sea level rise and committing world to an eventual 7 m sea level rise Rising risk of abrupt changes to atmospheric circulations, e.g. the monsoon Rising risk of collapse of West Antarctic Ice Sheet Rising risk of collapse of Atlantic Thermohaline Circulation
3°C	In Southern Europe, serious droughts occur once every 10 years 1 - 4 billion more people suffer water shortages, while 1 – 5 billion gain water, which may increase flood risk	150 - 550 additional millions at risk of hunger (if carbon fertilisation weak) Agricultural yields in higher latitudes likely to peak	1 – 3 million more people die from malnutrition (if carbon fertilisation weak)	1 – 170 million more people affected by coastal flooding each year	20 – 50% of species facing extinction (according to one estimate), including 25 – 60% mammals, 30 – 40% birds and 15 – 70% butterflies in South Africa Onset of Amazon forest collapse (some models only)	
4°C	Potentially 30 – 50% decrease in water availability in Southern Africa and Mediterranean	Agricultural yields decline by 15 – 35% in Africa, and entire regions out of production (e.g. parts of Australia)	Up to 80 million more people exposed to malaria in Africa	7 – 300 million more people affected by coastal flooding each year	Loss of around half Arctic tundra Around half of all the world's nature reserves cannot fulfill objectives	
5°C	Possible disappearance of large glaciers in Himalayas, affecting one-quarter of China's population and hundreds of millions in India	Continued increase in ocean acidity seriously disrupting marine ecosystems and possibly fish stocks		Sea level rise threatens small islands, low-lying coastal areas (Florida) and major world cities such as New York, London, and Tokyo		
More than 5°C	The latest science suggests that the Earth's average temperature will rise by even more than 5 or 6°C if emissions continue to grow and positive feedbacks amplify the warming effect of greenhouse gases (e.g. release of carbon dioxide from soils or methane from permafrost). This level of global temperature rise would be equivalent to the amount of warming that occurred between the last age and today – and is likely to lead to major disruption and large-scale movement of population. Such "socially contingent" effects could be catastrophic, but are currently very hard to capture with current models as temperatures would be so far outside human experience.					

Source: Stern Review 2006

IPCC - Projections (scenario-based)

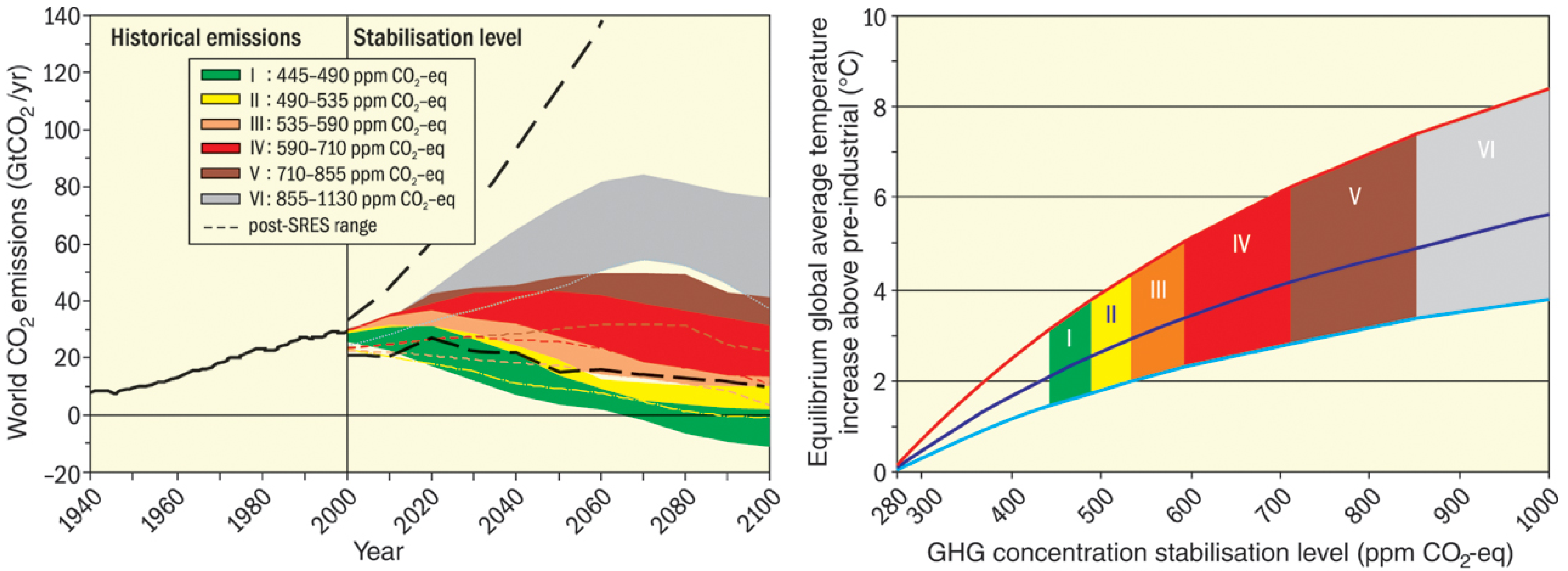


Projected Emissions

- Initial aim is to reduce or at least stabilise GHG concentrations in atmosphere
- What level of concentrations should be set?

  "Stabilising at or below 550 ppm CO2e (around 440 – 500 ppm CO2 only) would require global emissions to peak in the next 10 - 20 years, and then fall at a rate of at least 1 - 3% per year. By 2050, global emissions would need to be around 25% below current levels. These cuts will have to be made in the context of a world economy in 2050 that may be three to four times larger than today - so emissions per unit of GDP would need to be just one quarter of current levels by 2050." (Stern 2006))
- 550 ppm seen as the objective, or equivalently a 2C degree change in global temperatures.

The Reason for the 2 degree target



Expected costs in Stern Review

- Overall, the expected annual cost of achieving emissions reductions, consistent with an emissions trajectory leading to stabilisation at around 500-550ppm CO2e, is likely to be around 1% of GDP by 2050, with a range of +/- 3%, reflecting uncertainties over the scale of mitigation required, the pace of technological innovation and the degree of policy flexibility.

(Stern 2006).

These projected costs depend on:

- The timing of abatement, (later abatement will cost more)
- Assumptions used in the models about technological progress/change
- The extent to which global pollution is “flexible" (including international cooperation)
- The extent of the target: large change in costs from 550 ppm to 450 ppm.
- note that CO2 is a stock pollution i.e. stays in atmosphere for 40-50 years, so stabilisation is not a reduction in stock of CO2

The Skeptics

- Some critical of link between human activity and global warming. However, most evidence suggests human activity is playing a role
- More "noticeable" after Copenhagen: 'climate deniers'
- "The Skeptical Environmentalist" by Lomborg (2001), suggests that the data is unsupported about global warming and the problem is often overstated.
- Stern vs. Nordhaus: discounting

The `debate'

Usual debate: many skeptics have long suspected:

- Neither the rate nor magnitude of recent warming is exceptional.
- There was no significant warming from 2002-2008. According to the IPCC we should have seen a global temperature increase of at least 0.2°C per decade.
- The IPCC models may have overestimated the climate sensitivity for greenhouse gases, underestimated natural variability, or both.
- This also suggests that there is a systematic upward bias in the impacts estimates based on these models just from this factor alone.
- The logic behind attribution of current warming to well-mixed man-made greenhouse gases is faulty.
- The science is not settled, however unsettling that might be.
- There is a tendency in the IPCC reports to leave out inconvenient findings, especially in the part(s) most likely to be read by policy makers. (source: www.climate-skeptic.com)

The role of Economics in Climate Change

- This course focuses on the institutions and government policy that can mitigate climate changes. The questions we, as economists, need to ask are:
- What are the incentives for citizens, rms and governments in mitigating GHGs? once we know this we can find out:
- How can we mitigate GHG to a specific level efficiently? i.e. how can we minimise the cost of GHG abatement? Given we find technologies and policy that can reduce GHGs, we then can ask:
- What mechanisms are optimal/desirable for Climate change mitigation, and under what conditions are some mechanisms preferred to other types?
- The "Economic way of thinking" is very dierent from the "science way of thinking", e.g. ecologist, biologist.
- Example: Assume we have a country that is emitting a pollutant, say SO2 Acid rain. What is the optimal level of pollution in that country?