Renewable & Appropriate Energy Laboratory

RAEL

Lecture 5:
A New Economics of the Planet

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University of California, Berkeley

April 25 2016

1. The climate crisis reinvented **(3.28.2016)**
Klein, chapters 1 & 2 | Optional: Dove & Kammen, chapter 1

2. Our mistrust of the future makes it hard to give up the past **(4.4.16)**
Klein, chapters 3 | Optional: Dove & Kammen, chapter 5

3. We don't tenure Mother Teresa **(4.11.2016)**
Klein, chapter 9 | Optional: Dove & Kammen, chapter 2

4. What are the barriers to action? **(4.18.2016)**
Klein, chapter 6 - 8 |

5. A new economics of the planet **(4.25.2016)**
Klein, chapter 4 | Optional: Dove & Kammen, chapter 3; Klein 12

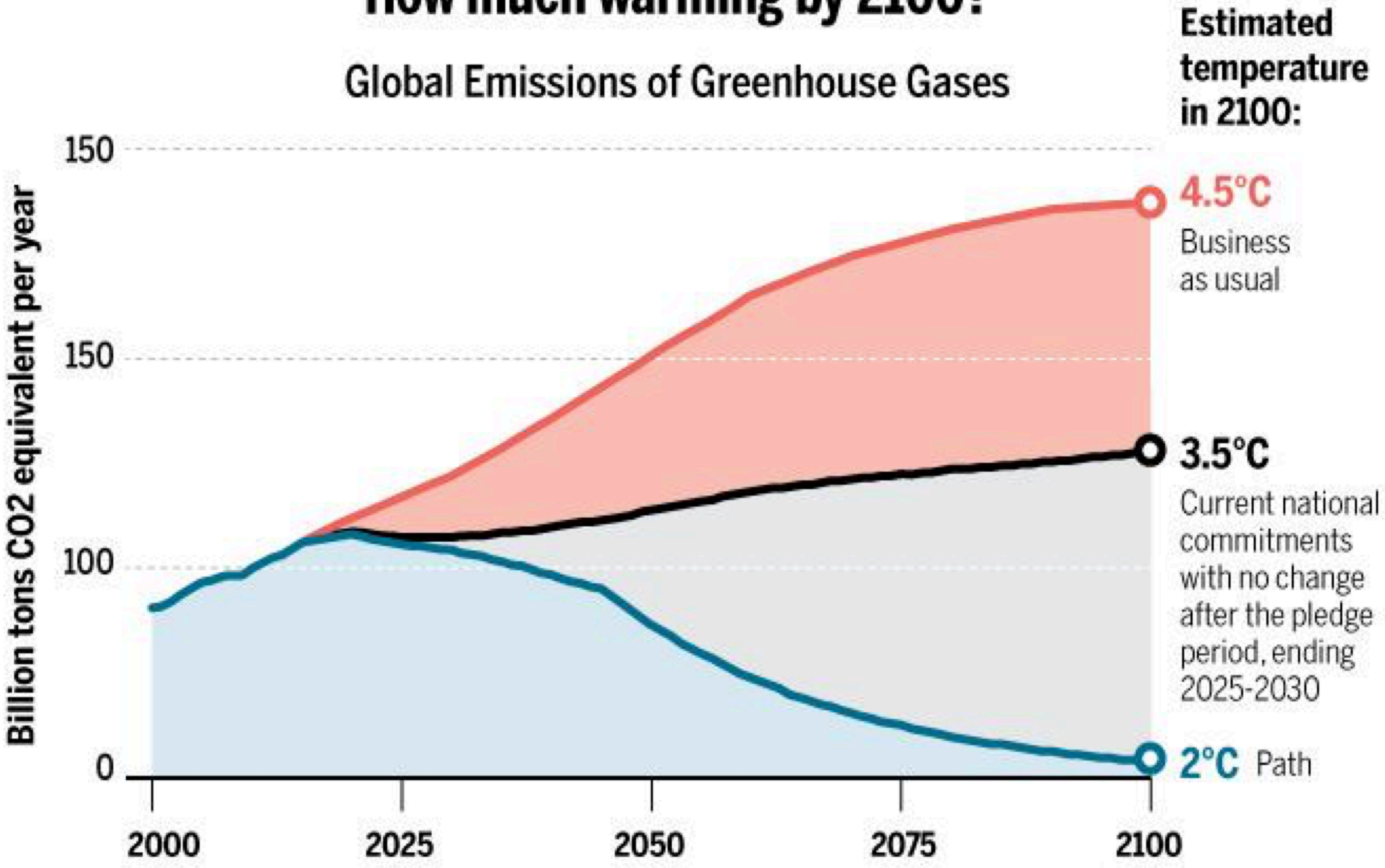
6. Pasteur's Quadrant **(5.2.2016)**
Klein, chapter 7, 11 | Optional: Dove & Kammen, chapter 4

Resources:

Website: http://rael.berkeley.edu

Twitter: @dan_kammen

How much warming by 2100?



Source: 27-Sep-2015 Climate Scoreboard ©Climate Interactive www.ClimateScoreboard.org


CLIMATE
SUMMIT
WHAT IF IT'S A BIG HOAX AND WE CREATE A BETTER WORLD FOR NOTHING?
• ENERGY INDEPENDENCE
• PRESERVE RAINFORESTS
• SUSTAINABILITY
• GREEN JOBS
• LIVABLE CITIES
• RENEWABLES
• CLEAN WATER, AIR
• HEALTHY CHILDREN
• ETC. ETC.
12/19 USATODAY
JOEL PETT


Always keen to see youthful enthusiasm
but before we start 'making the world a better place'
could we have a look at how you fill out
forms AC56/F5 through to BF675/ND.
FRAN

Rachel Carson

Scientist

Author

Campaigner

Cancer victim

Darby, William J. 1962. "Silence, Miss Carson." *Chemical & Engineering News* (Oct. 1): 62-63.

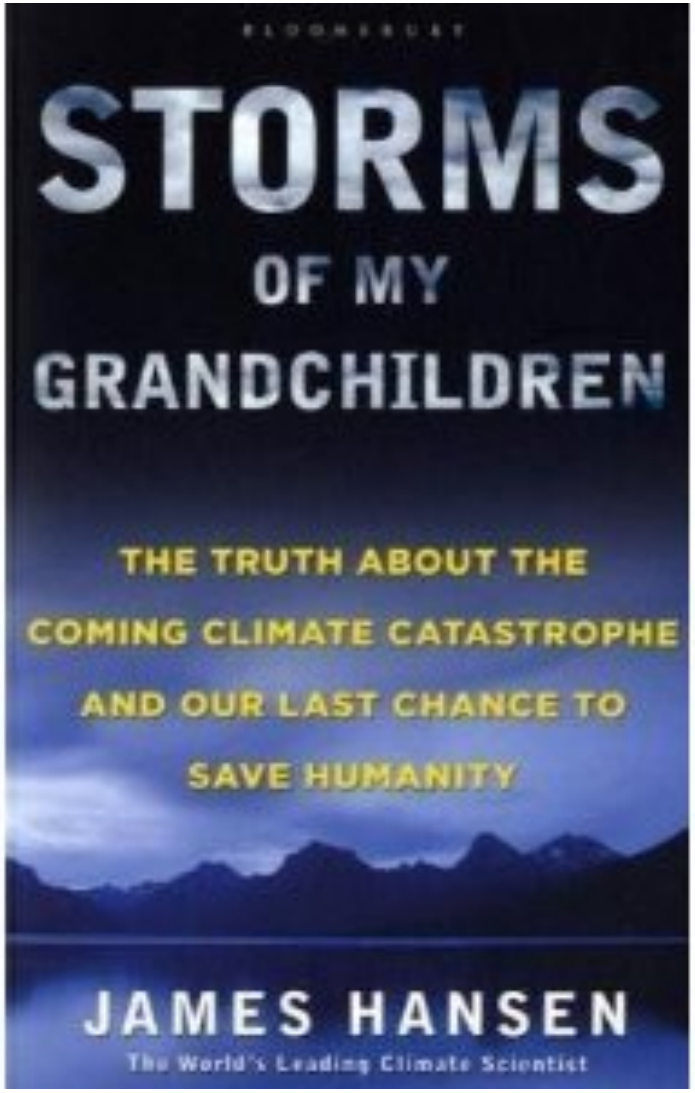
VIEWPOINT

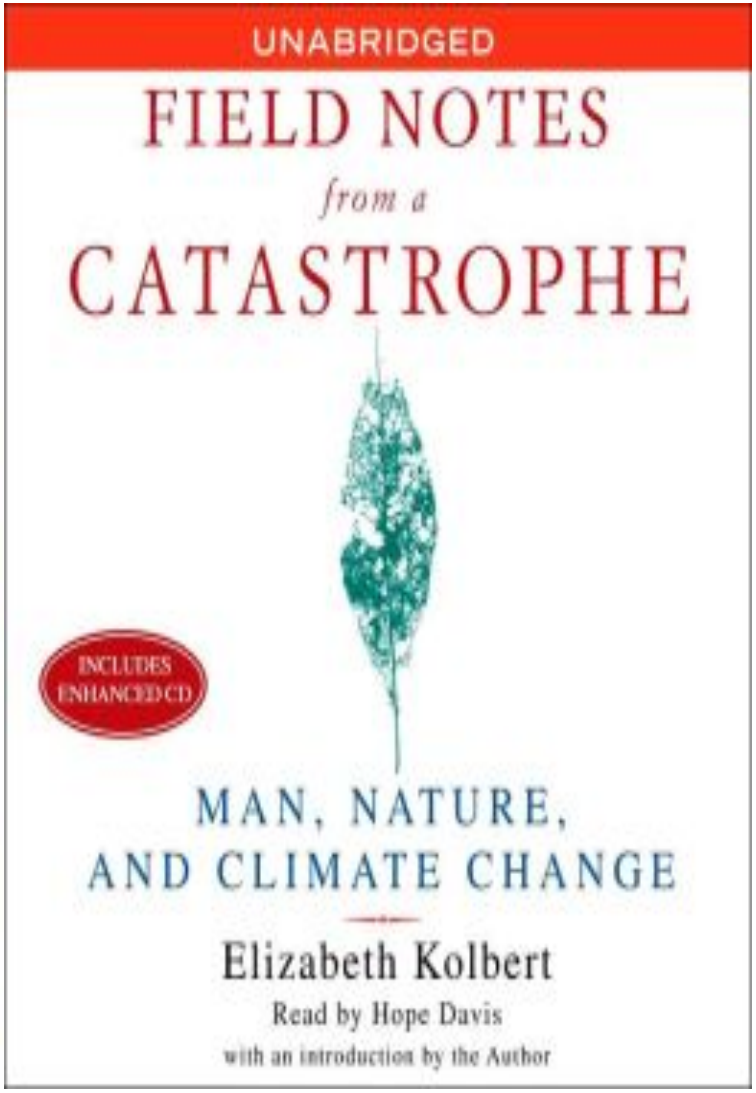
Silence, Miss Carson

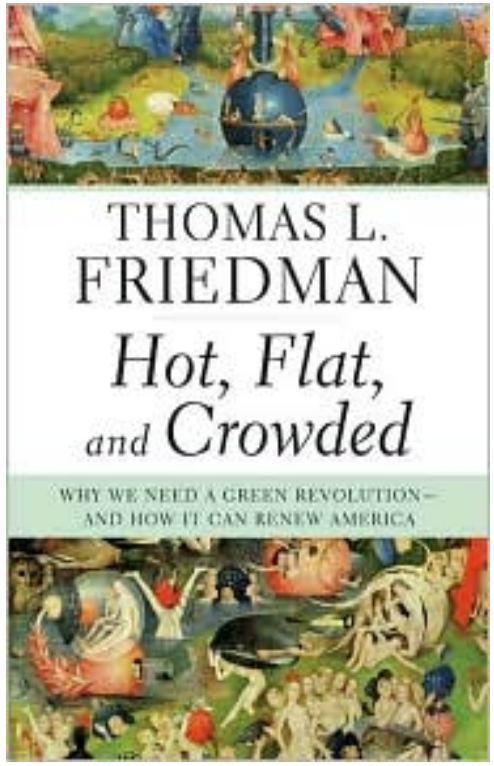
Silent Spring. Rachel Carson. 368 pages. Houghton Mifflin Co., 2 Park St., Boston, Mass. 1962. $5.00. Reviewed by Dr. William J. Darby.

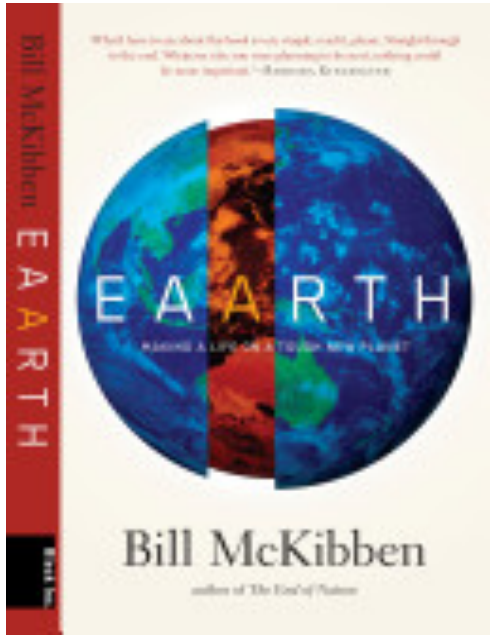
Dr. Darby is professor and chairman of the department of biochemistry and director, division of nutrition, at Vanderbilt University school of medicine; member and past chairman of the Food Protection Committee, National Academy of Sciences-National Research Council' and a member of the NAS-NRC Food and Nutrition Board.

"Silent Spring" starts with a bit of dramatic description which the author then acknowledges does not actually exist. It then orients the reader to its subject matter by stating that "only within. . .the present century has man. . .acquired significant power to alter the nature of his world." It identifies as irrevocable and "for the most part irreversible" the effects of "this now universal contamination of the environment [in which] chemicals are the sinister and little recognized partners of radiation in changing the very nature of the world, the very nature of life itself."


BLOOMSBURY
STORMS
OF MY
GRANDCHILDREN
THE TRUTH ABOUT THE
COMING CLIMATE CATASTROPHE
AND OUR LAST CHANCE TO
SAVE HUMANITY
JAMES HANSEN
The World's Leading Climate Scientist


UNABRIDGED
FIELD NOTES
from a
CATASTROPHE
INCLUDES
ENHANCED CD
MAN, NATURE,
AND CLIMATE CHANGE
Elizabeth Kolbert
Read by Hope Davis
with an introduction by the Author


THOMAS L.
FRIEDMAN
Hot, Flat,
and Crowded
WHY WE NEED A GREEN REVOLUTION—
AND HOW IT CAN RENEW AMERICA


Bill McKibben EARTH
EARTH
Bill McKibben

What is sustainable development?

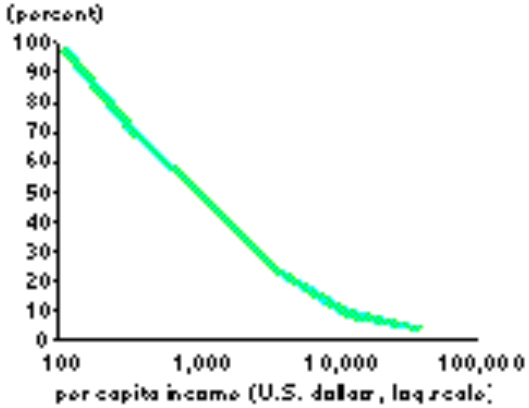
- SD is the achievement of a sustained path of economic growth which does not undermine future generation possibilities of consumption

- Different definitions of what "future generations" are
  - An orthodox economist would claim that this depends on our time preference → discount rate reasoning..
  - The higher the discount rate, depending on consumption and oportunity costs factors, the less future benefits and costs are valued…
  - r = pure time myopic preference + consumption growth; otherwise equals tha market oppotunity cost, the foregone benefit of an investment

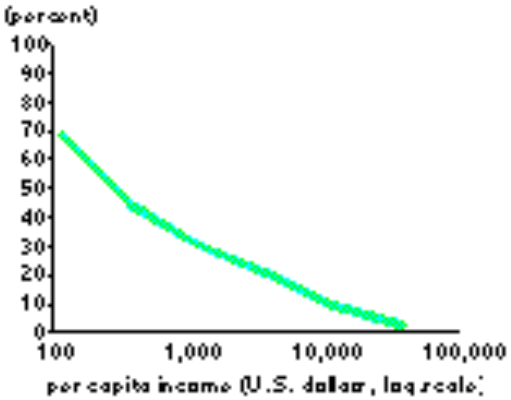
Caution and a Method: Know the Trend: Environmental Indicators vs. Income

"Kuznets Curves"

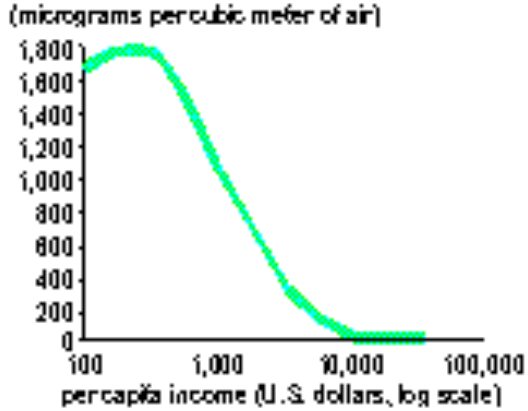
A. Population without Safe Water



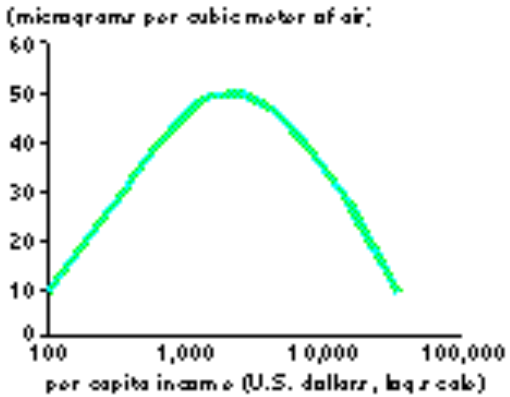
B. Urban Population without Adequate Sanitation



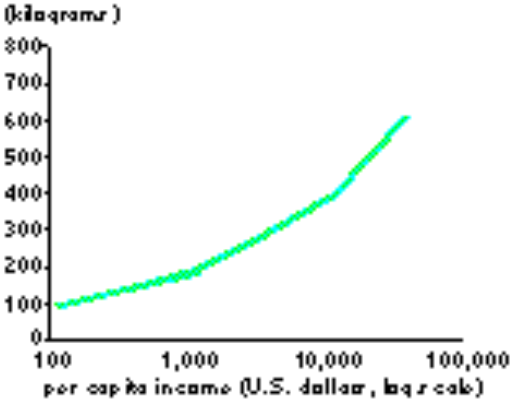
C. Urban Concentrations of Particulate Matter



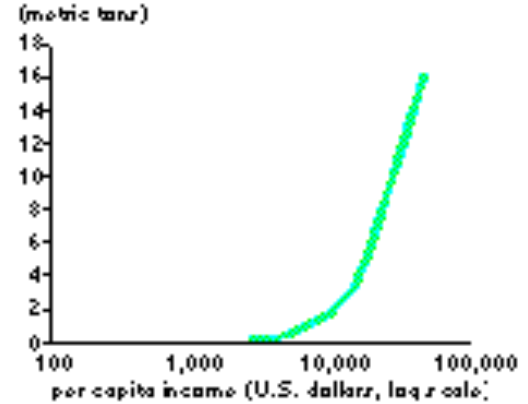
D. Urban Concentrations of Sulfur Dioxide



E. Municipal Wastes per Capita

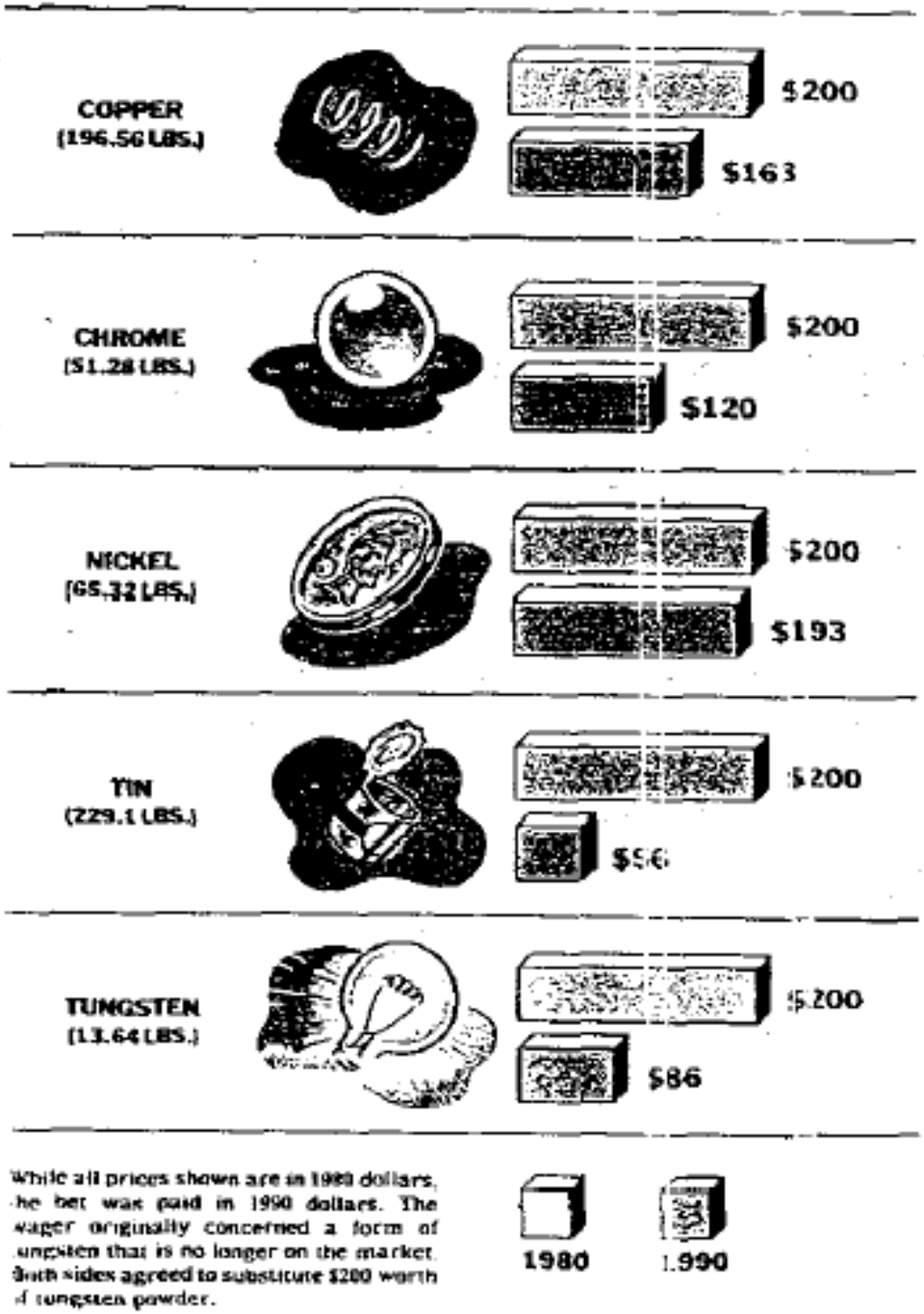


F. Carbon Dioxide Emissions per Capita



Two Views

- Pessimists (“Mathusian” or “Cassandra”)
  - Economies of Developed Nations are unsustainable; developing nations cannot follow in their path; technology is not keeping pace with resource depletion, environmental impact
- Optimists (“Cornucopian” or “Dr. Pangloss”)
  - No barriers to growth; substitutes will be developed for scarce resources; economic development and technology produce net improvement in environmental quality



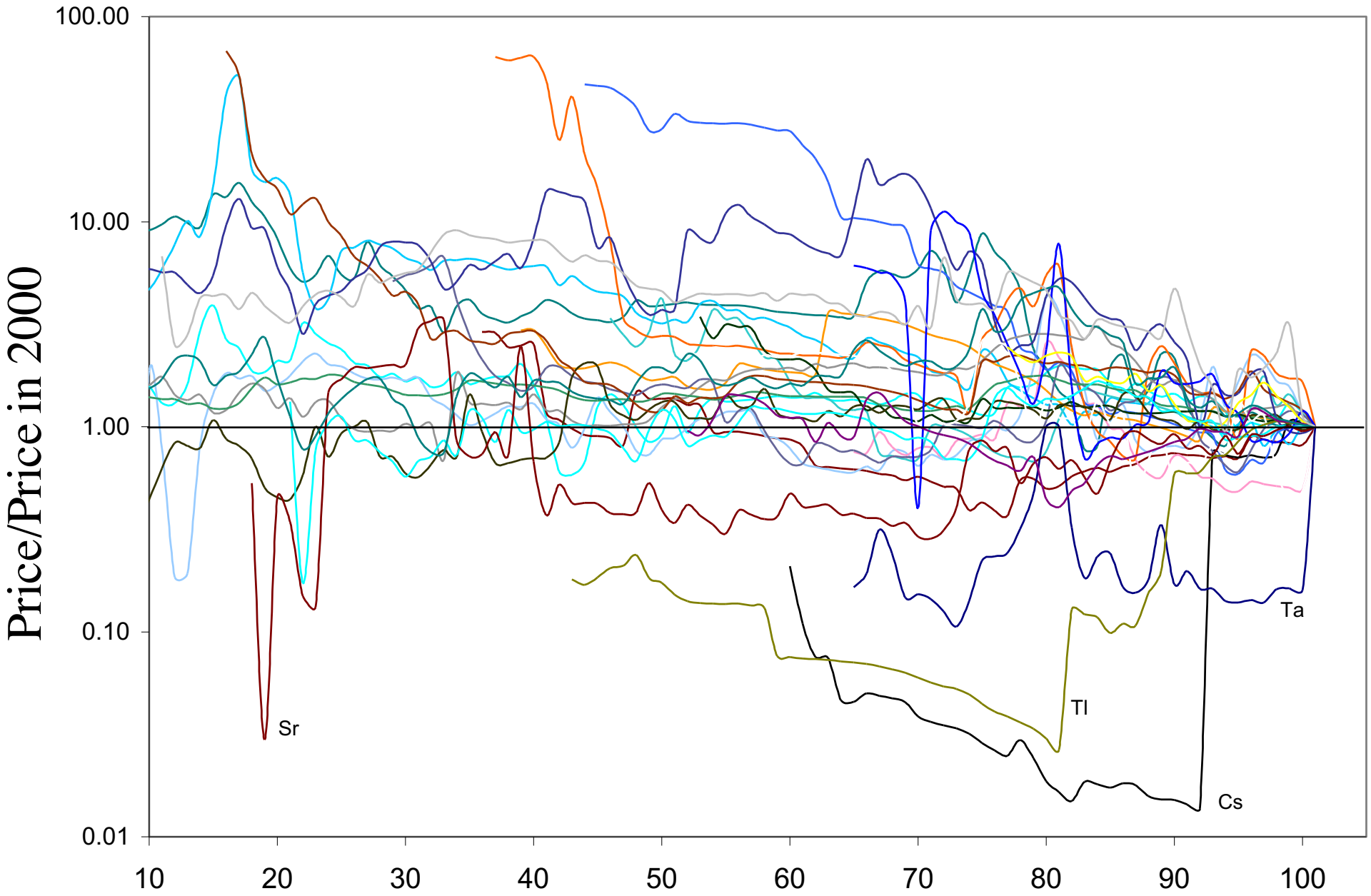
The ER100 Bet:

Simon offered to bet $1000 that the price of any five commodities would decrease from 1980 to 1990. Ehrlich et al. selected Cu, Cr, Ni, Sn, W. Simon won.

Simon subsequently offered to bet that any set of environmental measures relating to human welfare would get improve. Ehrlich et al. selected CO_2, N_2O, O_3, temperature, SO_2 in Asia, tropical forest, per-capita grain and fish, species, AIDS, sperm counts, rich-poor gap.

Simon declined.

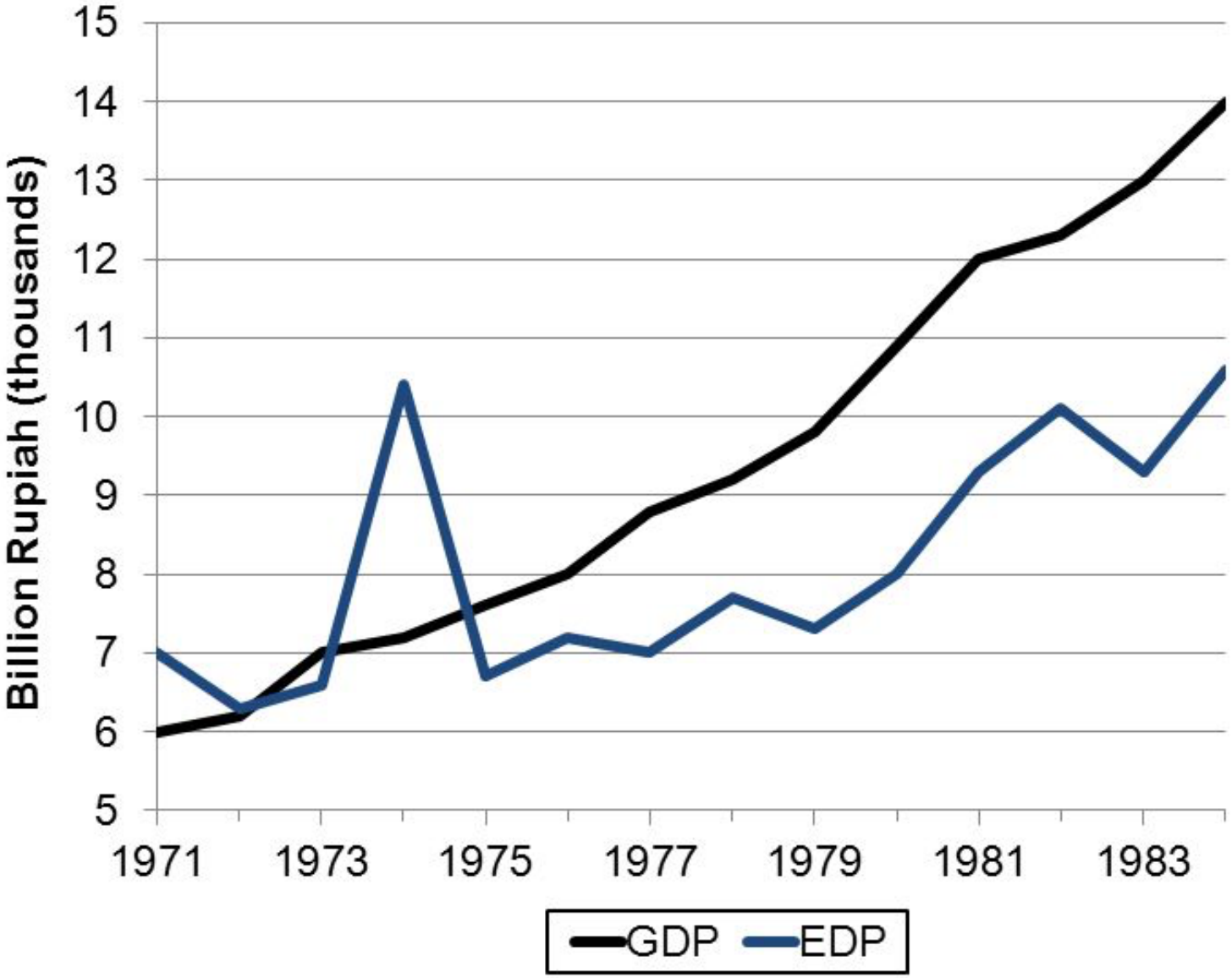
Only 4 of 47 elements increased in price over the last century



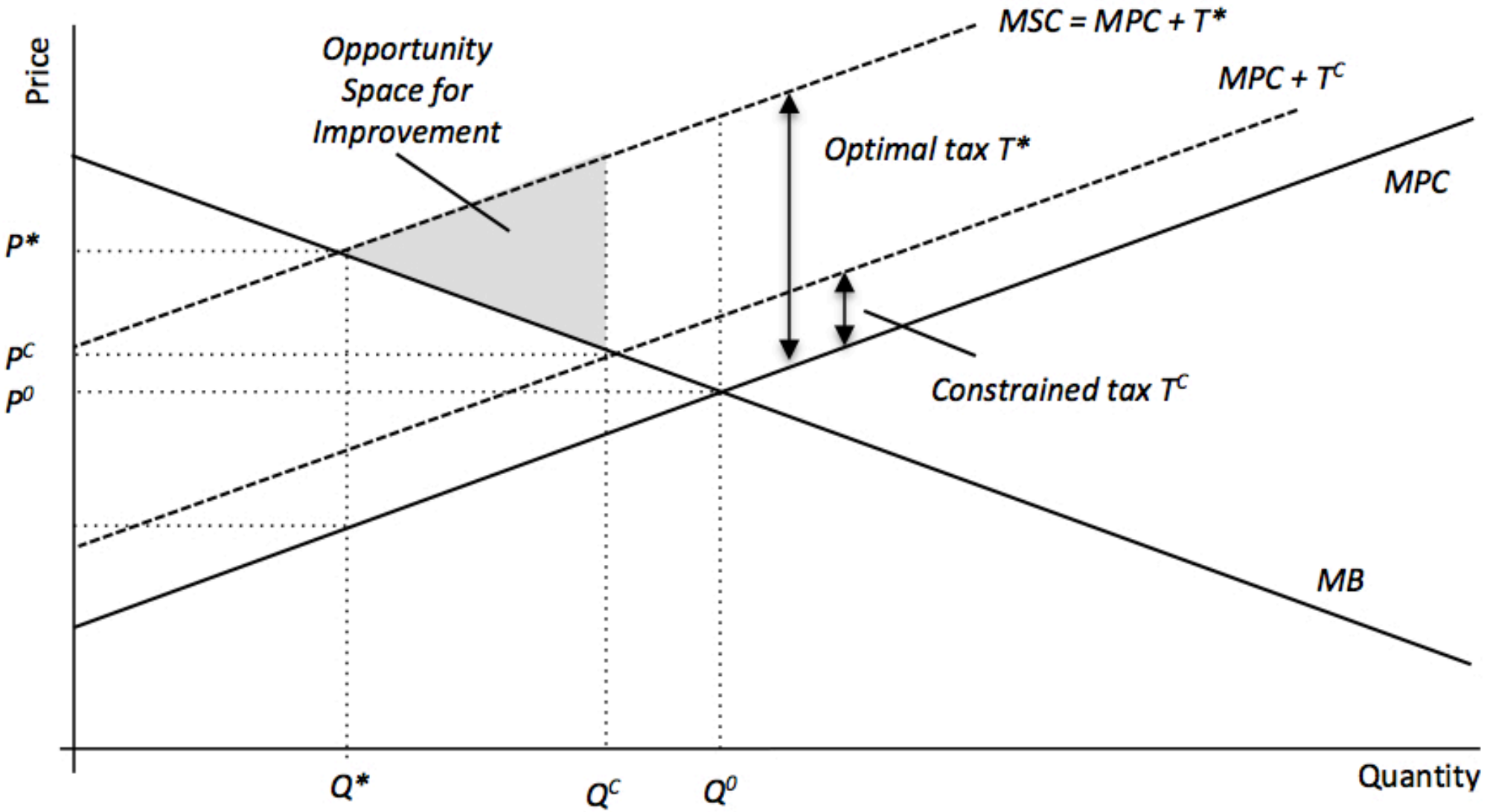
Really Simple Math, right ….?

- Recall that GNP=C+I
- Recall that Net NP= GNP – depreciation of capital
- Capital stock dynamics depends on accumulation and depreciation

Figure 6.6 Indonesian GDP Adjusted for Resource Depreciation



Mind the (Economic) Gap: Social and Private Cost



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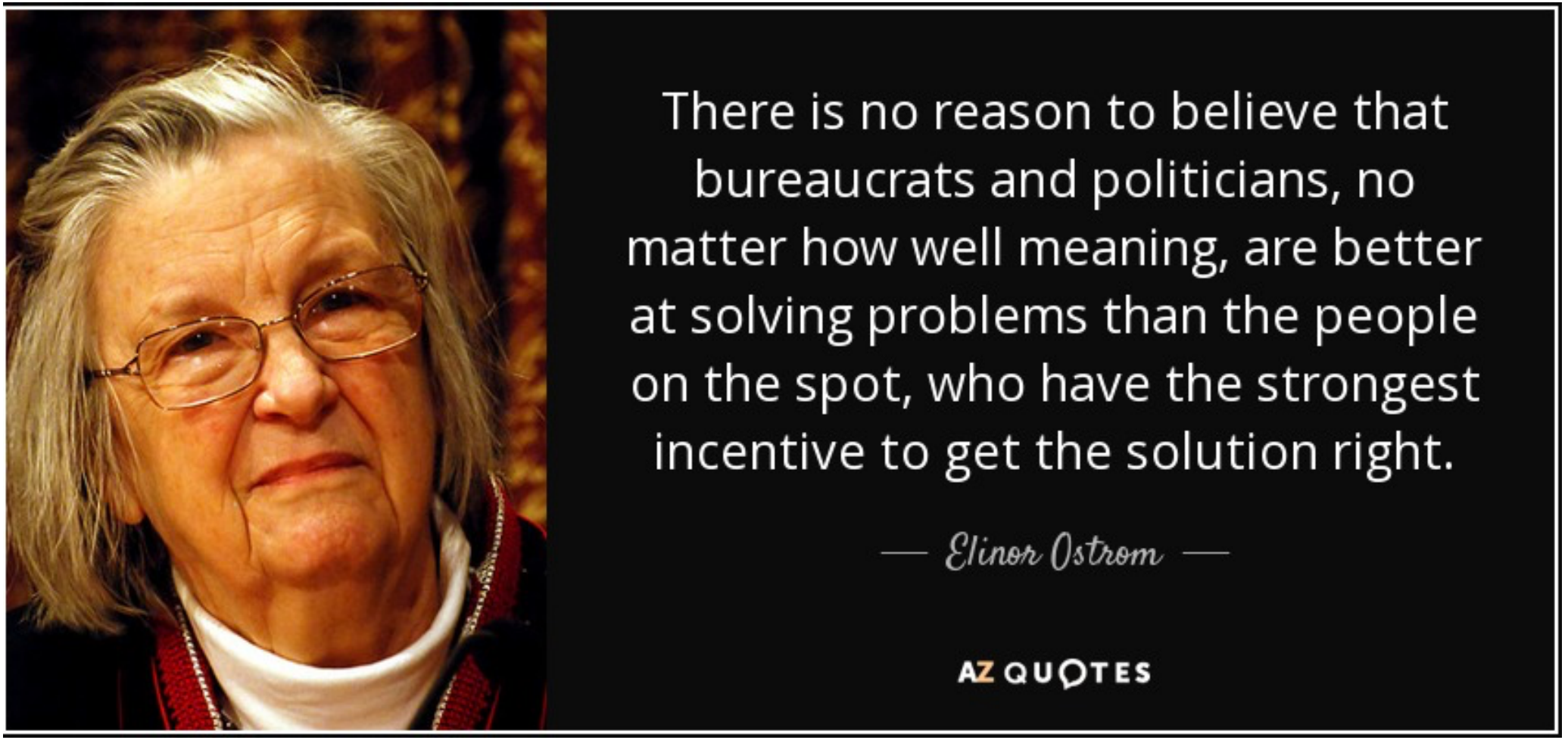

200 9 Nobel Prize in Economics

SD is linked to Total capital or natural capital?

- Total capital = human capital + natural capital
- Each capital stock is defined by a rate of growth, I, less any Depreciation
- If I=dep, then capital is steady
- Thus, a first intuitive golden rule for SD is that total K should be at least constant, Inv should at least match depreciation. (And that assumes no new demands on resources)
- Genuine saving rule: ***Investment >= depreciation***

..but..

- This may imply a decreasing natural capital stock, if natK is substituted by other forms
  - This is the western country history
  - i.e. OPEC countries management of non renewable resources
  - UK oil exploitation
  - In any case, rents from natural resource use should be re-invested..

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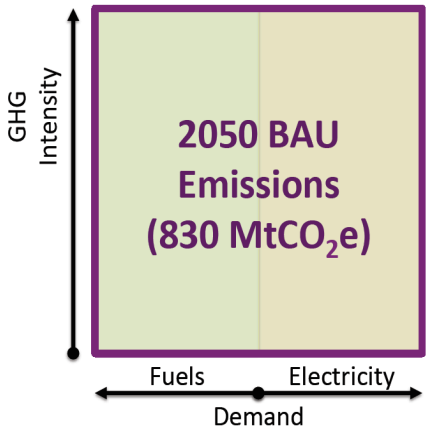
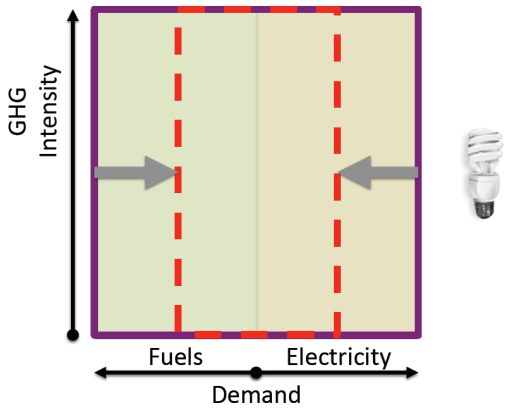
  - UK oil exploitation
  - In any case, rents from natural resource use should be re-invested… right?

Four Actions to Reduce Emissions

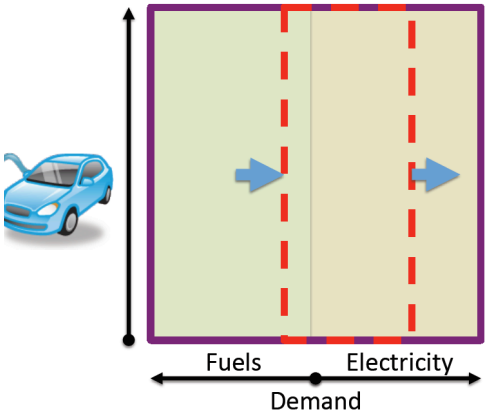
GHG Intensity-Demand Diagram



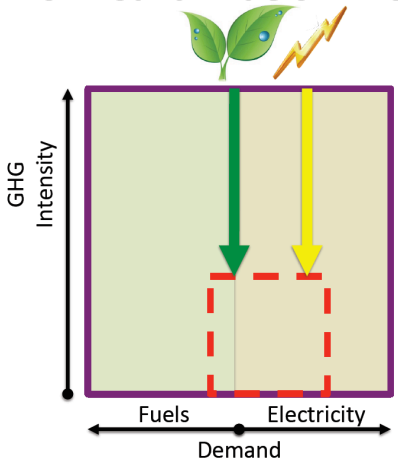
1. Efficiency



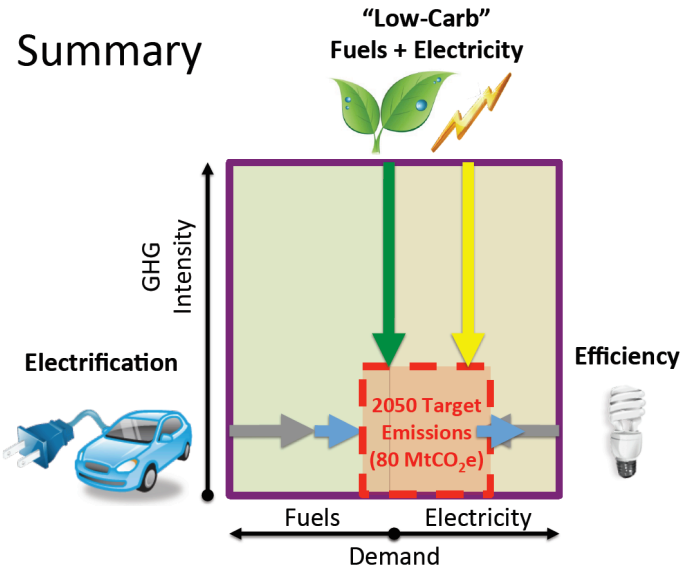
2. Electrification



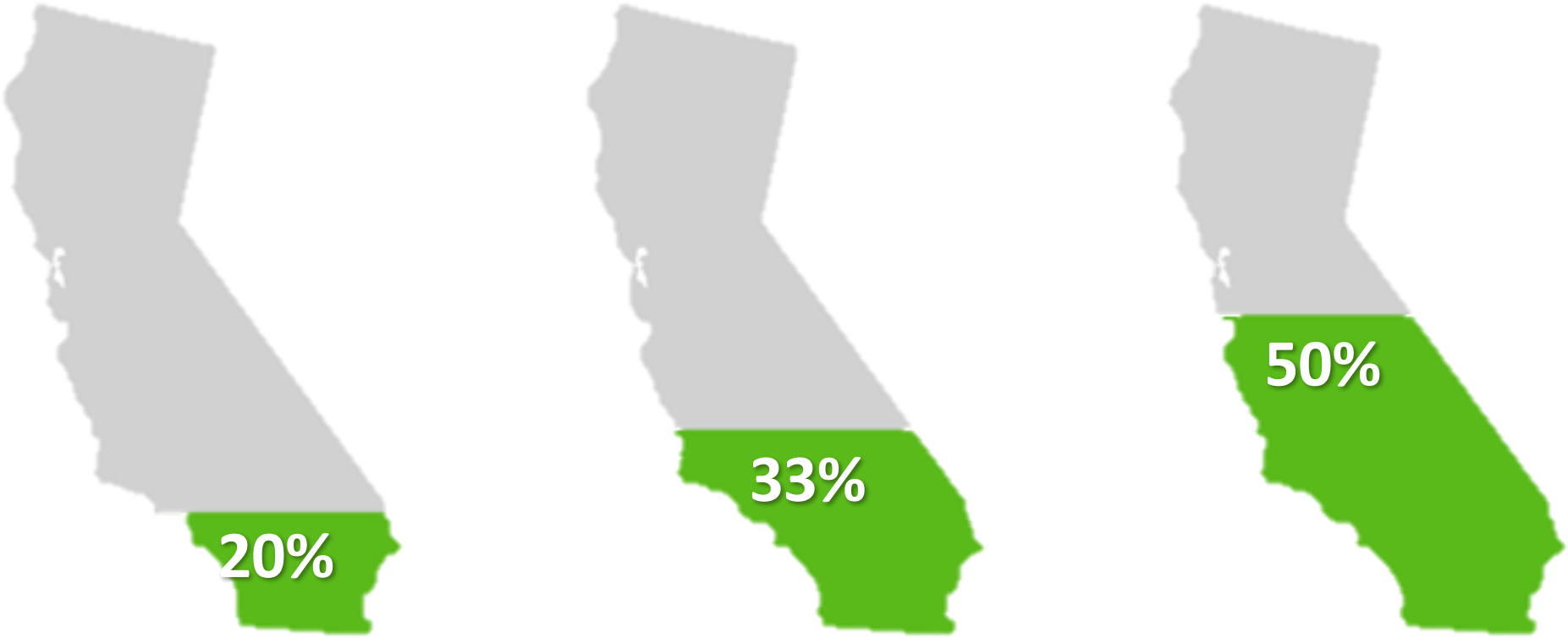
1. "Low-Carb" Fuels + Electric



Summary



The Challenge is Big…



2013 2020 2030

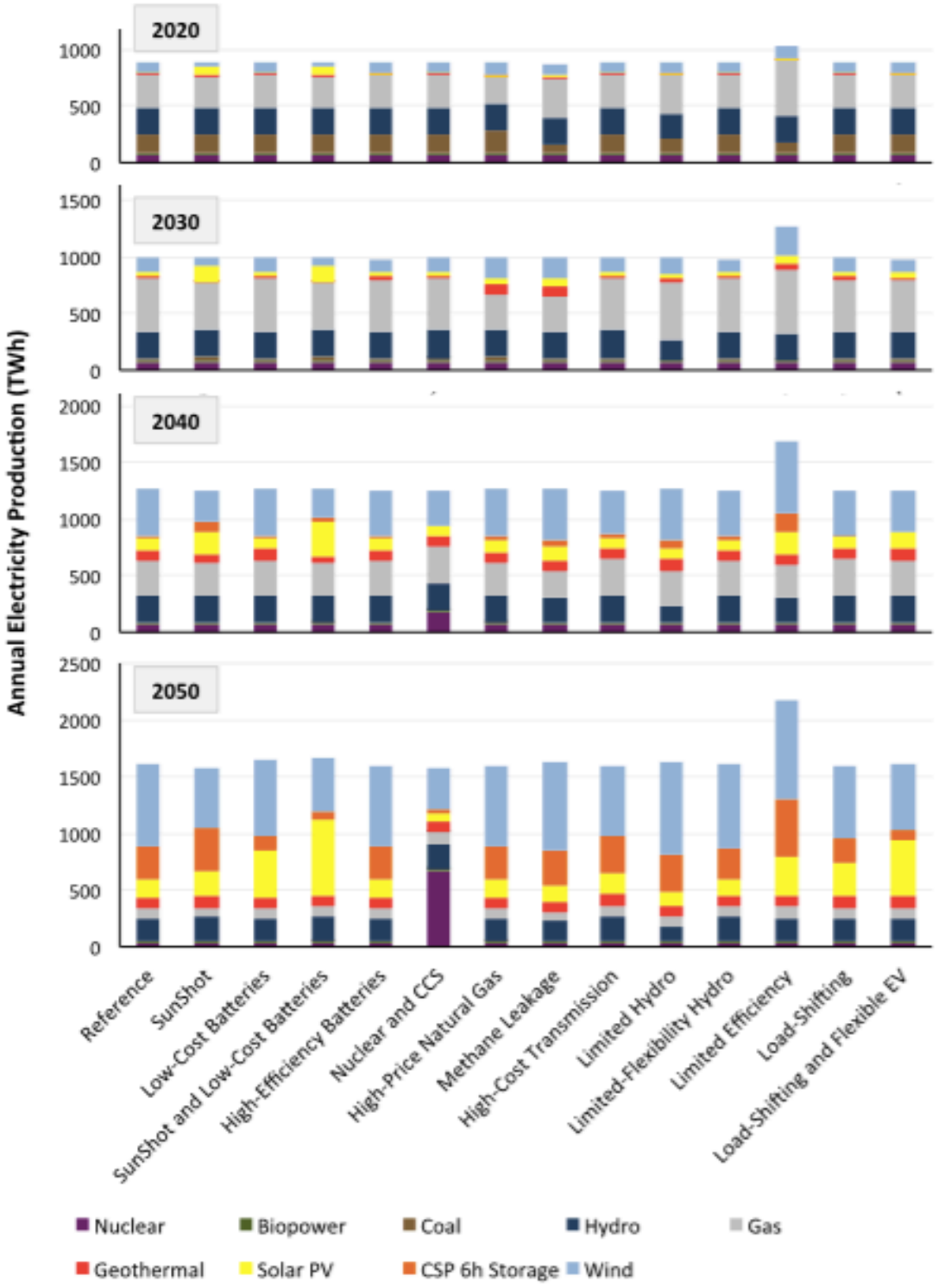
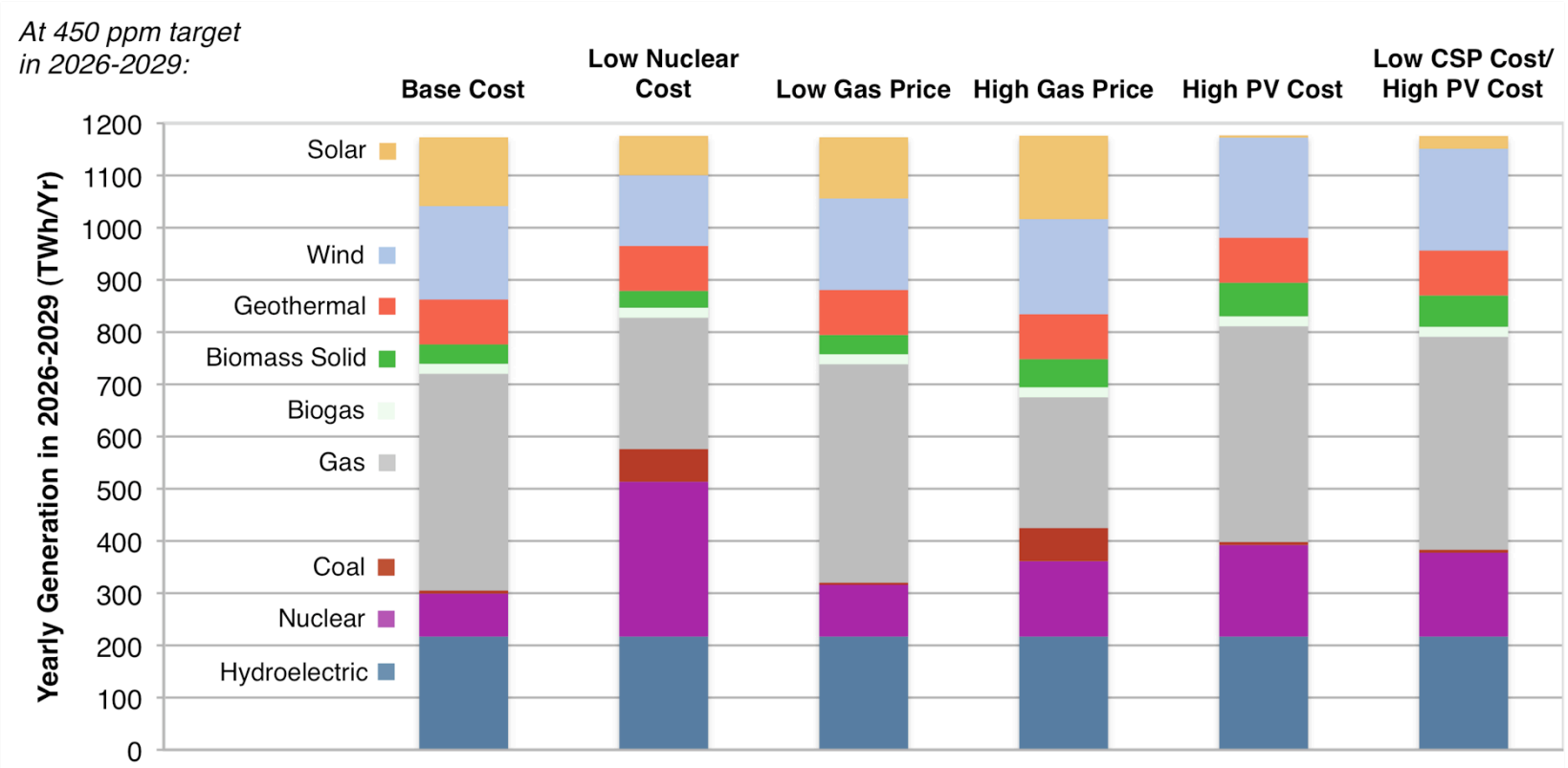

2020
2030
2040
2050
Annual Electricity Production (TWh)
Reference
SunShot
Low-Cost Batteries
SunShot and Low-Cost Batteries
High-Efficiency Batteries
Nuclear and CCS
High-Price Natural Gas
Methane Leakage
High-Cost Transmission
Limited Hydro
Limited-Flexibility Hydro
Limited Efficiency
Load-Shifting
Load-Shifting and Flexible EV
Nuclear
Biopower
Coal
Hydro
Gas
Geothermal
Solar PV
CSP 6h Storage
Wind

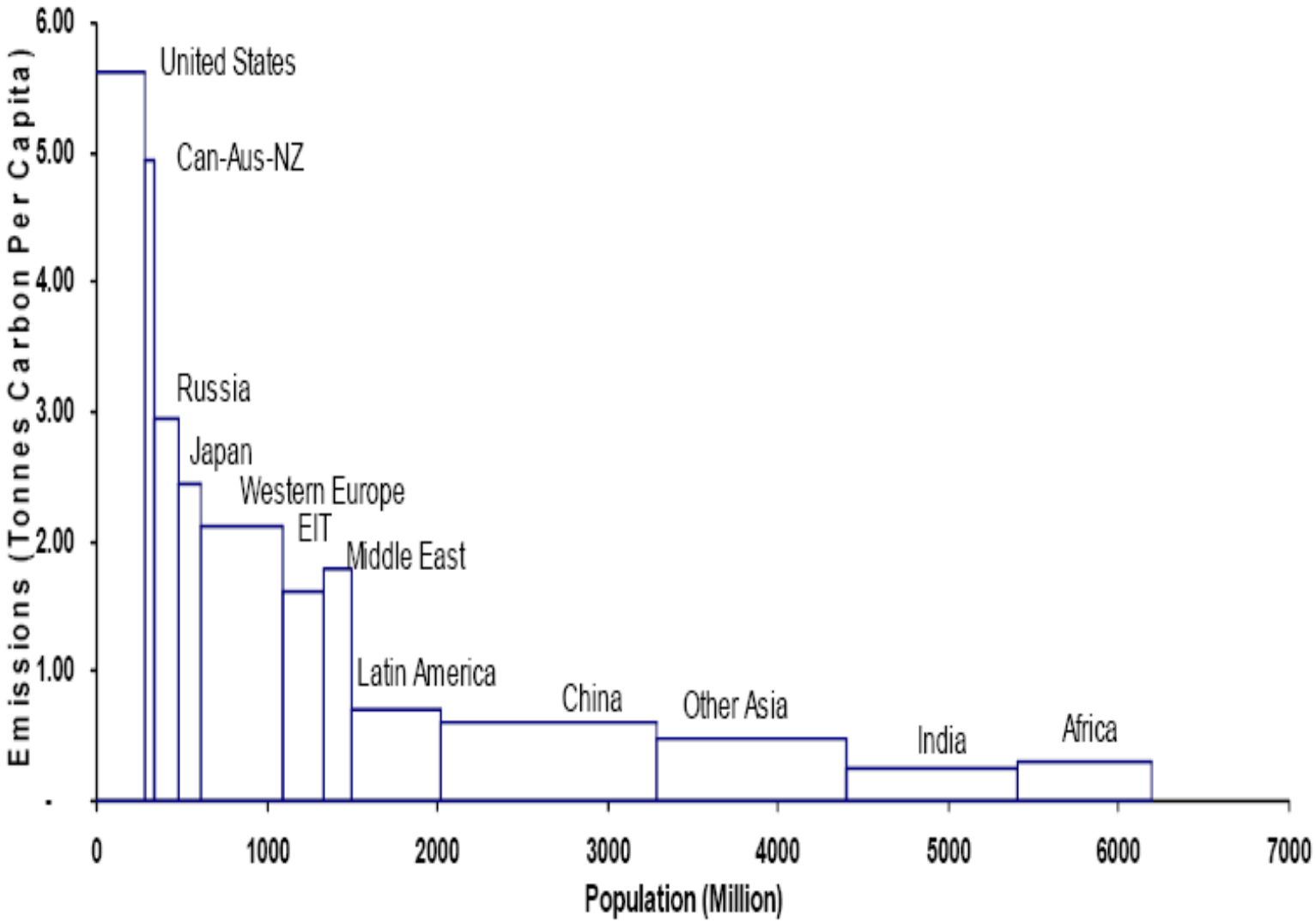
Figure 8



	Base Cost	Low Nuclear Cost	Low Gas Price	High Gas Price	High PV Cost	Low CSP Cost/ High PV Cost
Carbon price adder ($2007/tCO$_2$)	70	59	87	66	84	86
Power cost ($2007/MWh)	113	110	110	114	114	114
Cumulative new transmission built by 2030 (10^3 GW-km)	9.8	6.0	9.0	11.7	12.0	12.3

Figure 8. *Yearly generation by fuel in 2026-2029 for all scenarios discussed in this paper at an emission level consistent with the 450 ppm climate stabilization target (54% of 1990 carbon emission levels by 2030). The carbon price adder, cost of power, and cumulative new transmission built at the 450 ppm climate stabilization target are also tabulated for each scenario in 2026-2029. Results in this figure are obtained by varying the carbon price adder for each scenario until the target emission level is reached.*

Two dimensions of carbon emissions



Carbon Pricing 101

Costs of fossil fuel use are not included in the current price

- Hurricanes *(Sandy $65b),* drought, health costs, sea level rise
- Social Cost of Carbon estimates from $37 to >$400/ton CO_2e
- Fossil fuels are artificially inexpensive

Put a price on carbon emissions so users pay the fair price

- Fossil fuel use will decrease; CO_2 emissions will decrease
- Alternatives become more affordable and grow
- The economy can also grow

Pricing Carbon is not a new idea

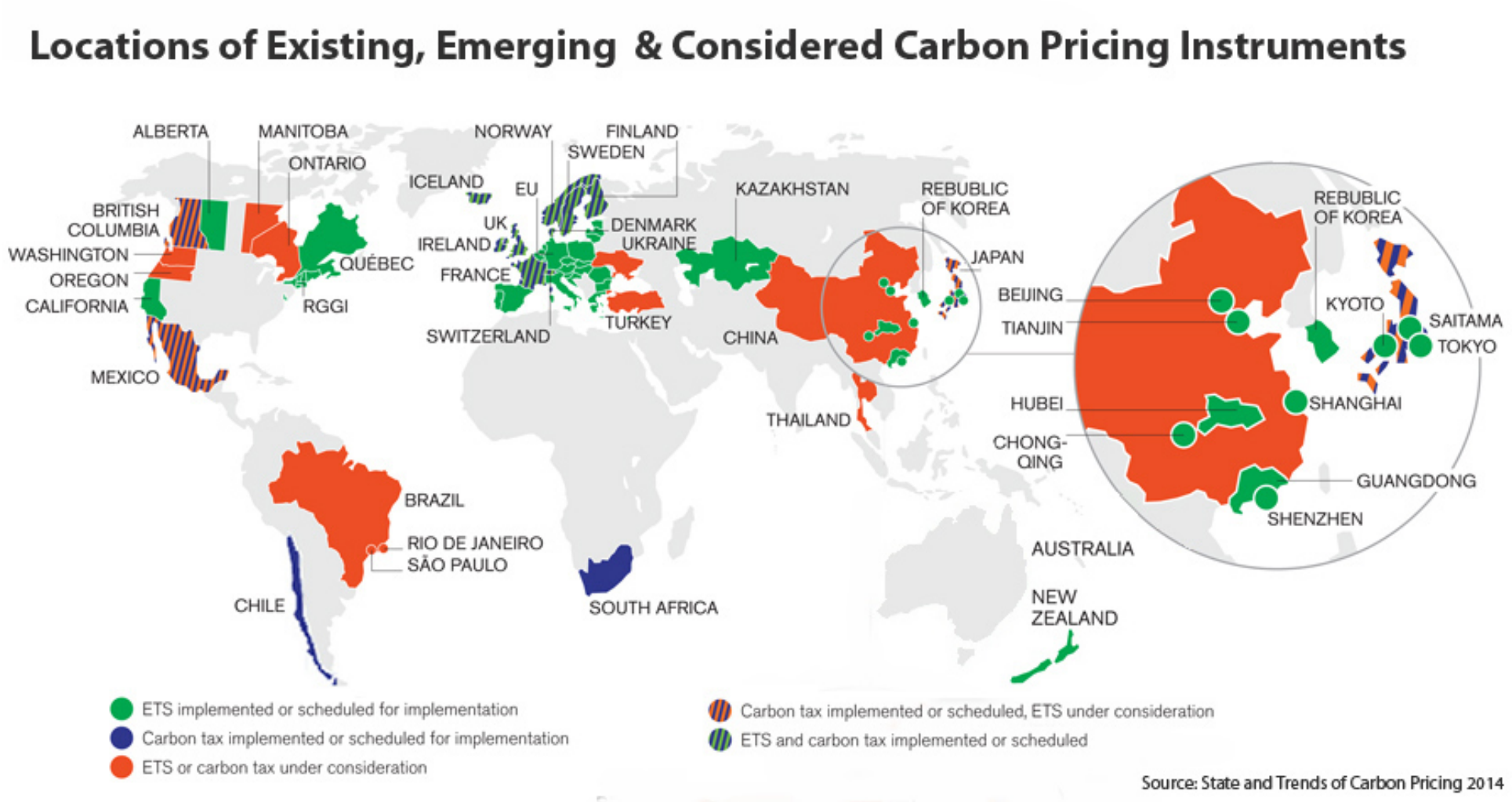


Figure from World Bank report, 2014

How Do You Price Carbon?

Carbon Pricing Elements

Pricing Mechanism	Emissions Included	Revenue Use

How Do You Price Carbon?

Carbon Pricing Elements

Pricing Mechanism	Emissions Included	Revenue Use
Carbon Tax or Fee	CO_2	
Cap and Trade	What about:	
Cap and Dividend	Biodiversity	
	Cultural Survival	

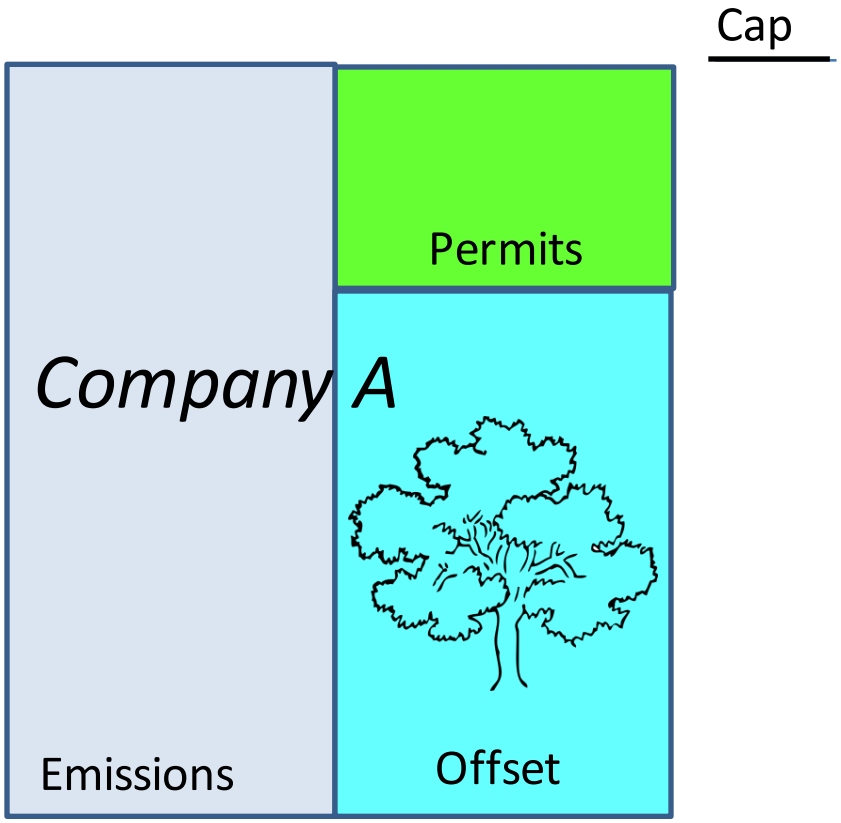
Pricing Mechanism

	Cap and Trade	Carbon Tax
Emissions	Declining emissions cap set by government	Emissions volume based on market
Price	Price based on market	Rising price set by government

Both mechanisms have been tried;
both can be effective.

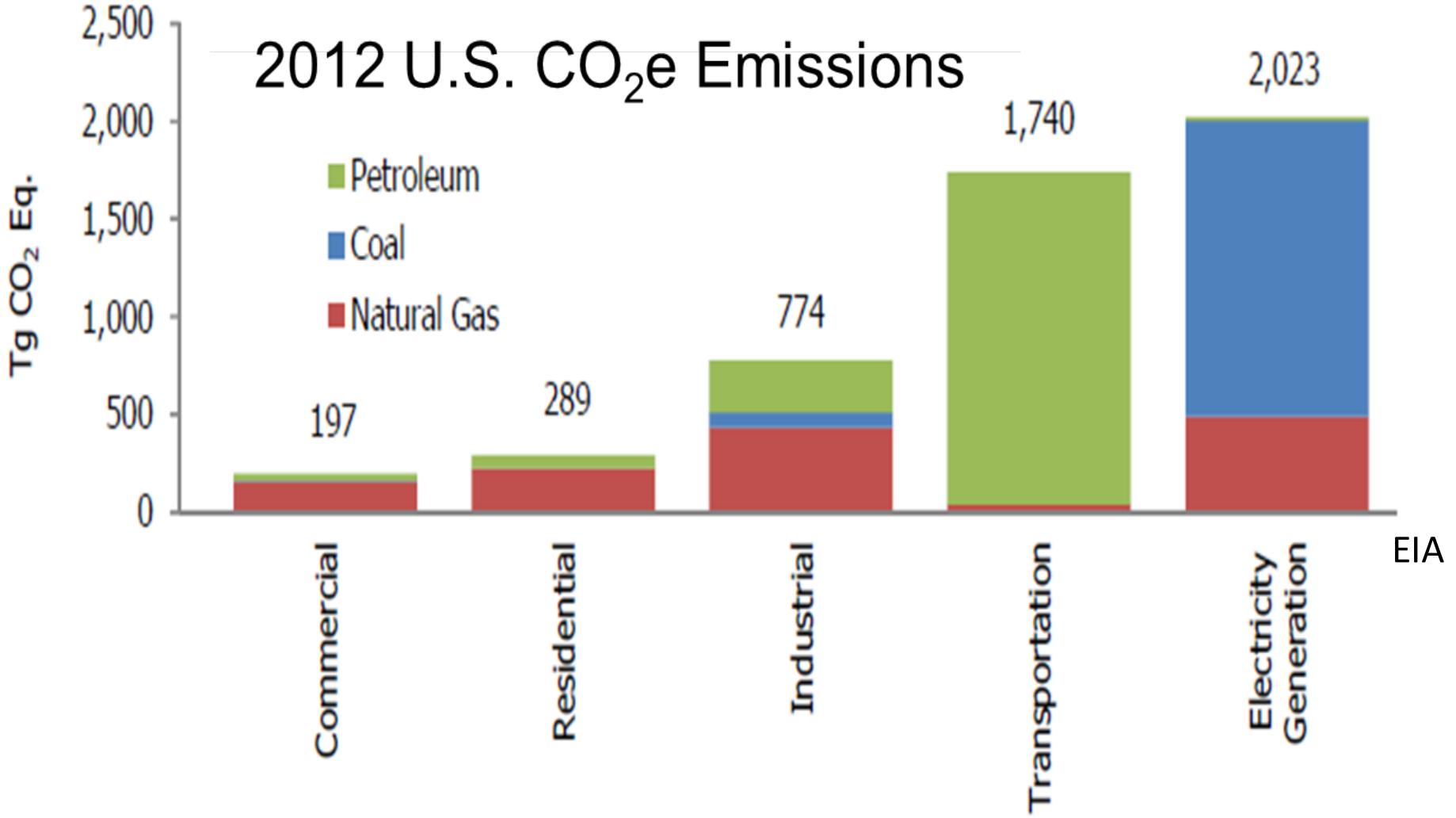
Complications

Offsets

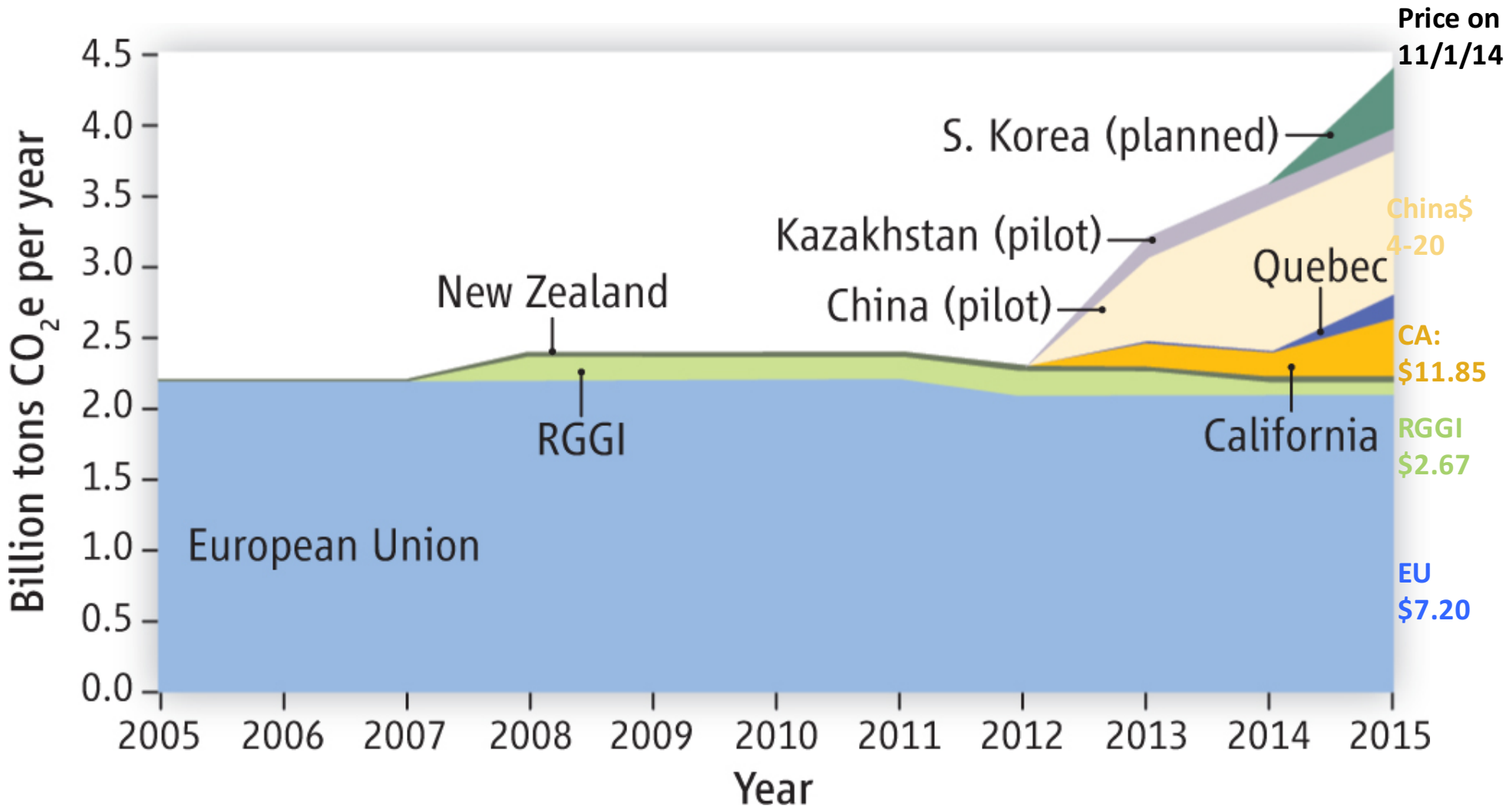


Projects which sequester carbon can offset some emissions/permits

Emissions from Different Sectors



Carbon Markets in Place Today



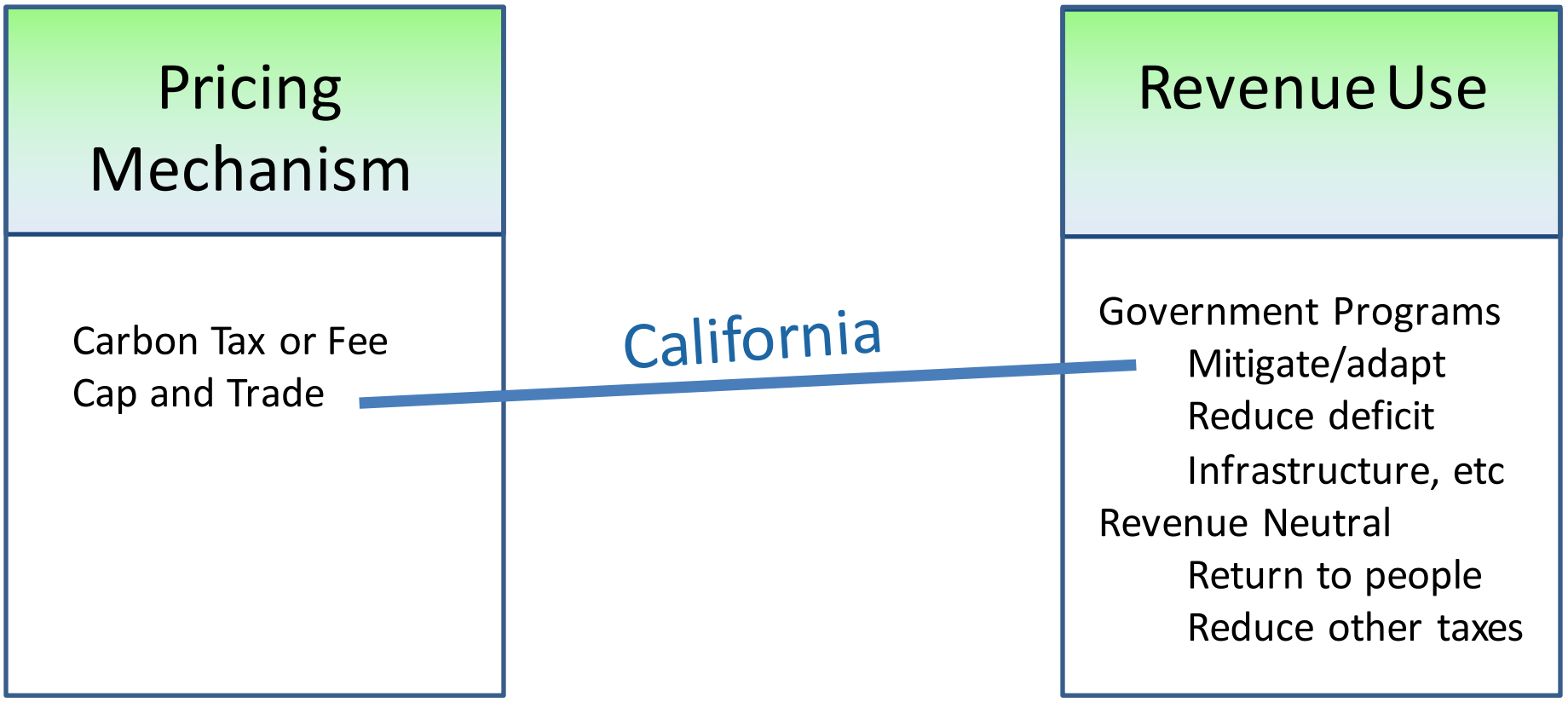
How Do You Price Carbon?

Carbon Pricing Elements

Pricing Mechanism	Emissions Included	Revenue Use
Carbon Tax or Fee Cap and Trade	Electricity generation Transportation Industrial	Government Programs Mitigate/adapt Reduce deficit Infrastructure, etc Revenue Neutral Return to people Reduce other taxes

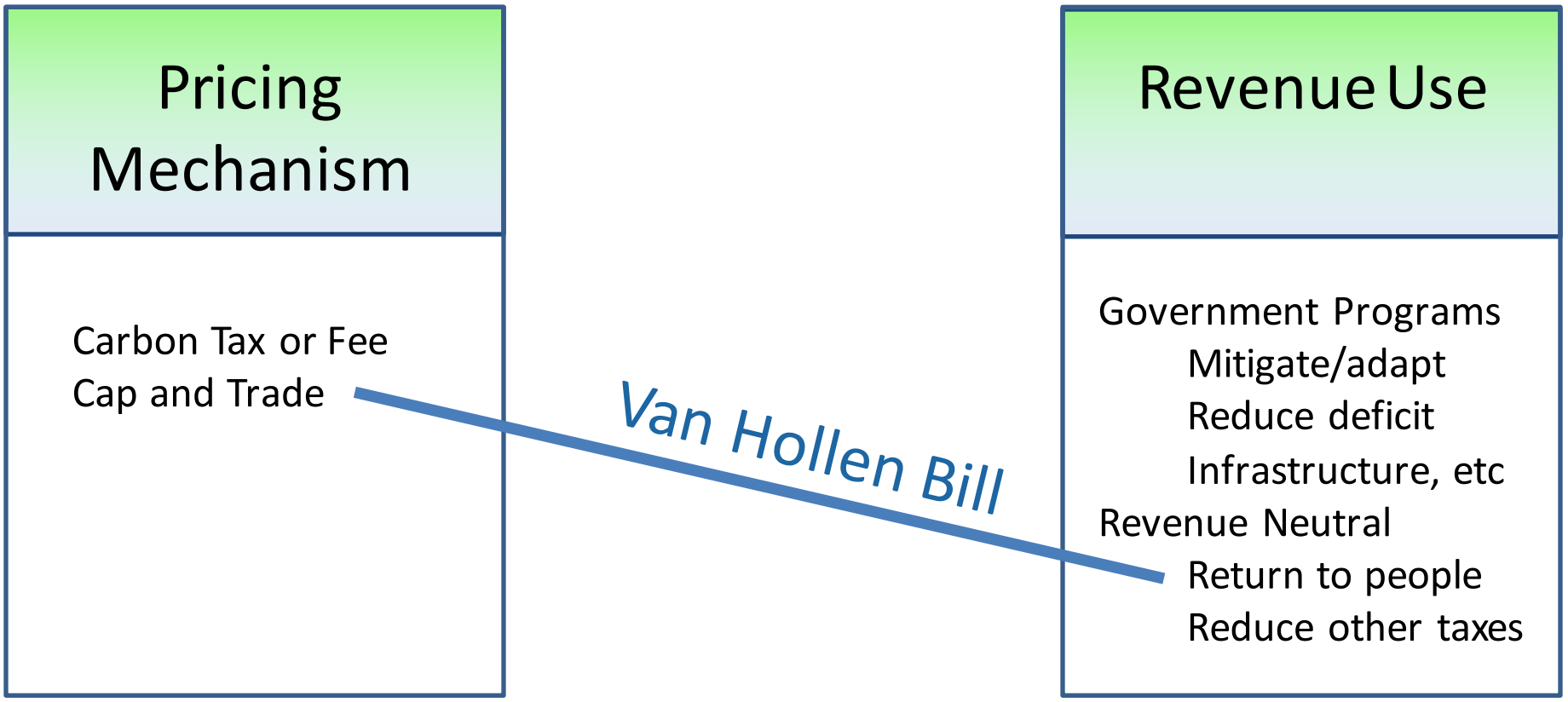
How Do You Price Carbon?

Carbon Pricing Elements



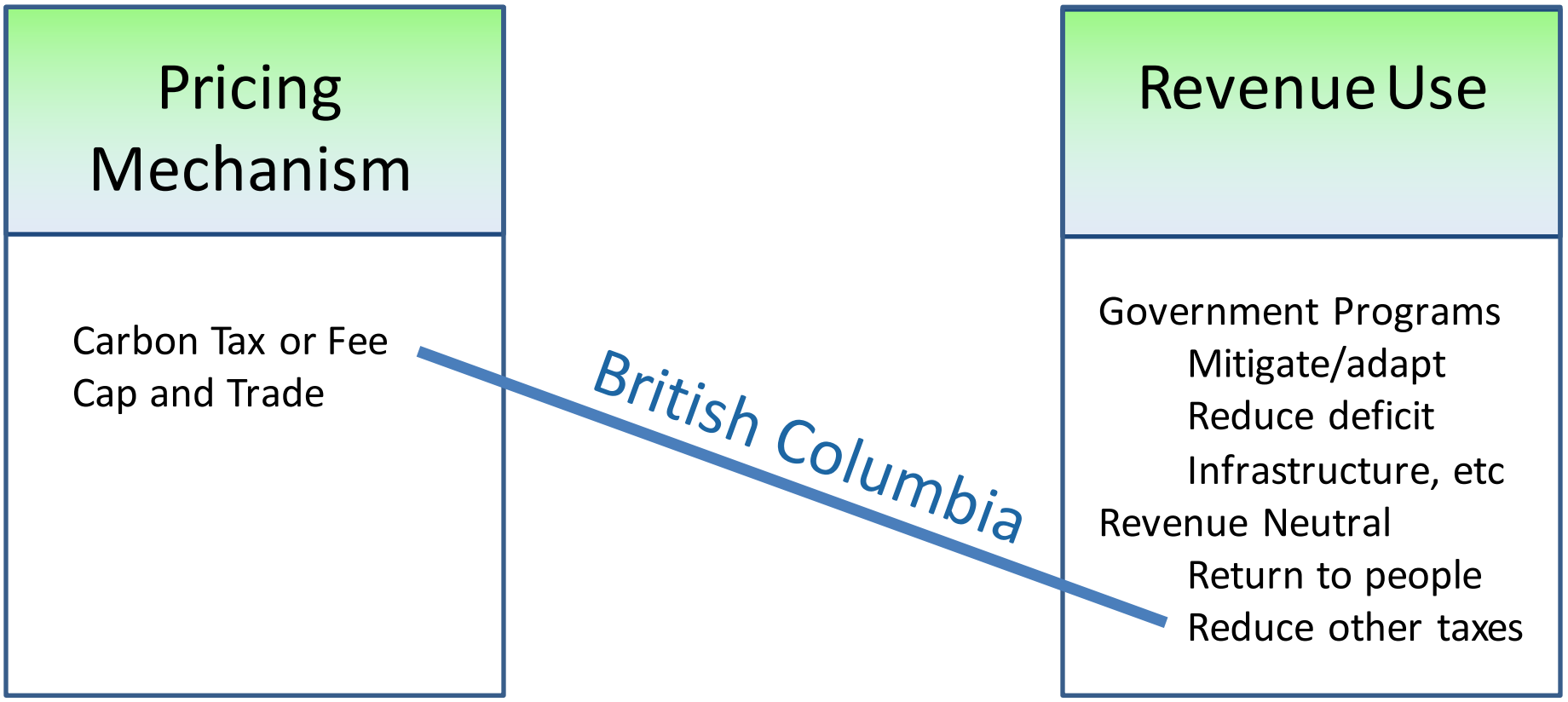
How Do You Price Carbon?

Carbon Pricing Elements



How Do You Price Carbon?

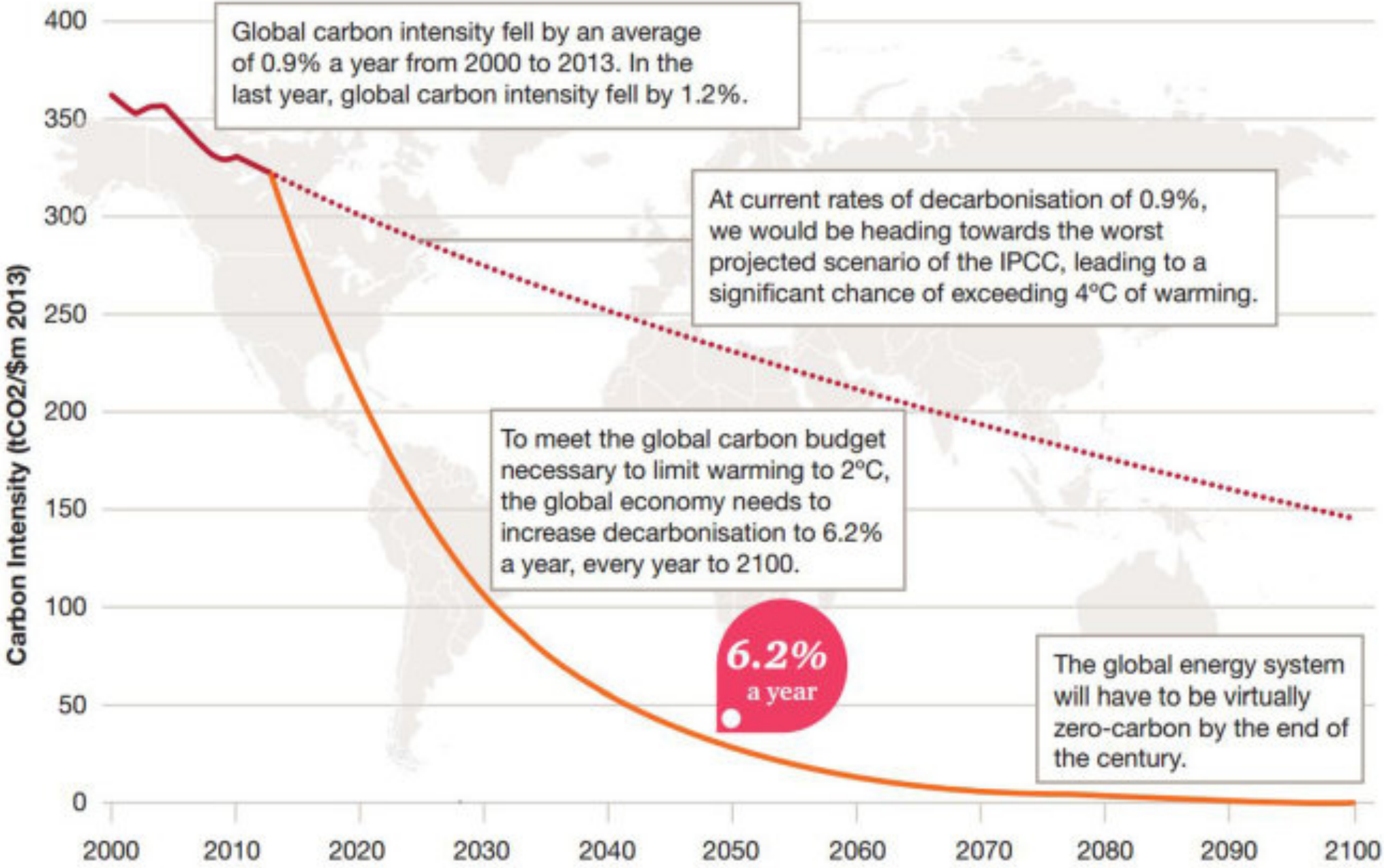
Carbon Pricing Elements



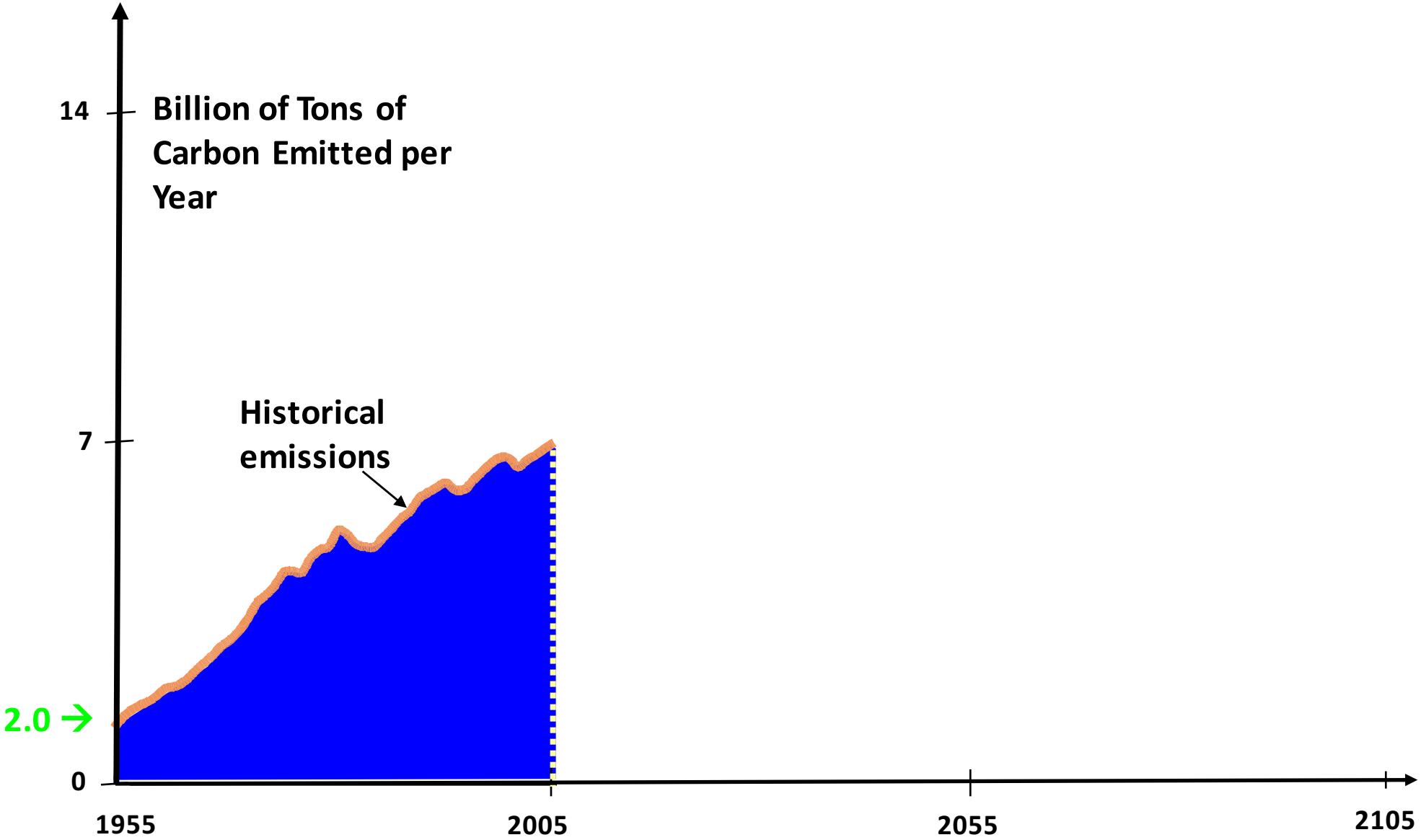
Climate Accounting ...New Math!

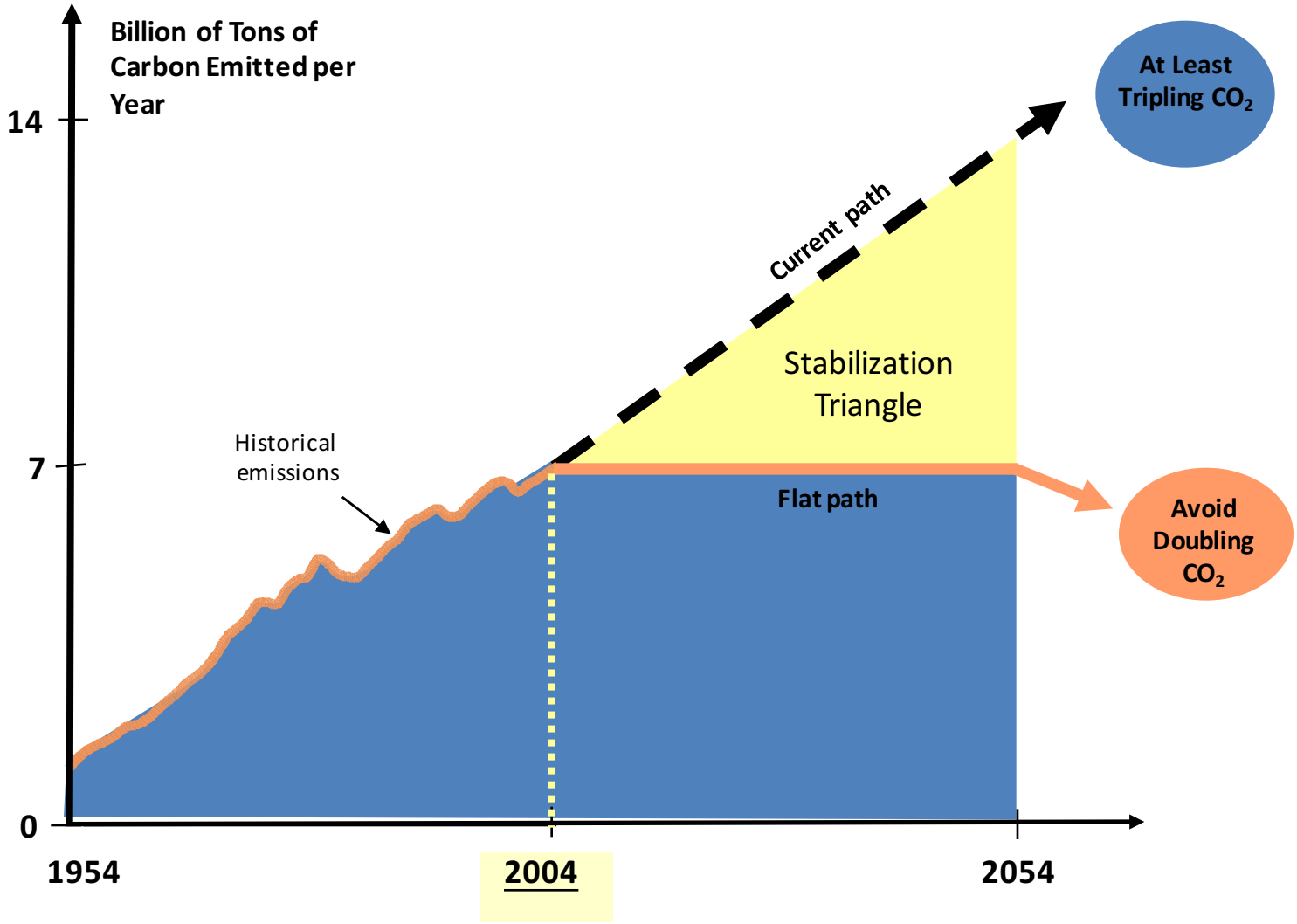
Emissions Category	Industrialized	Developing
Cumulative CO_2, energy	86	14
Cumulative CO_2, energy, biota	68 – 80	32 – 20
CO_2, energy (current)	72	28
Partial CO_2, CH_4 (current)	57	43
Comprehensive (current)	52 - 57	48 - 43

Pathway to two degrees



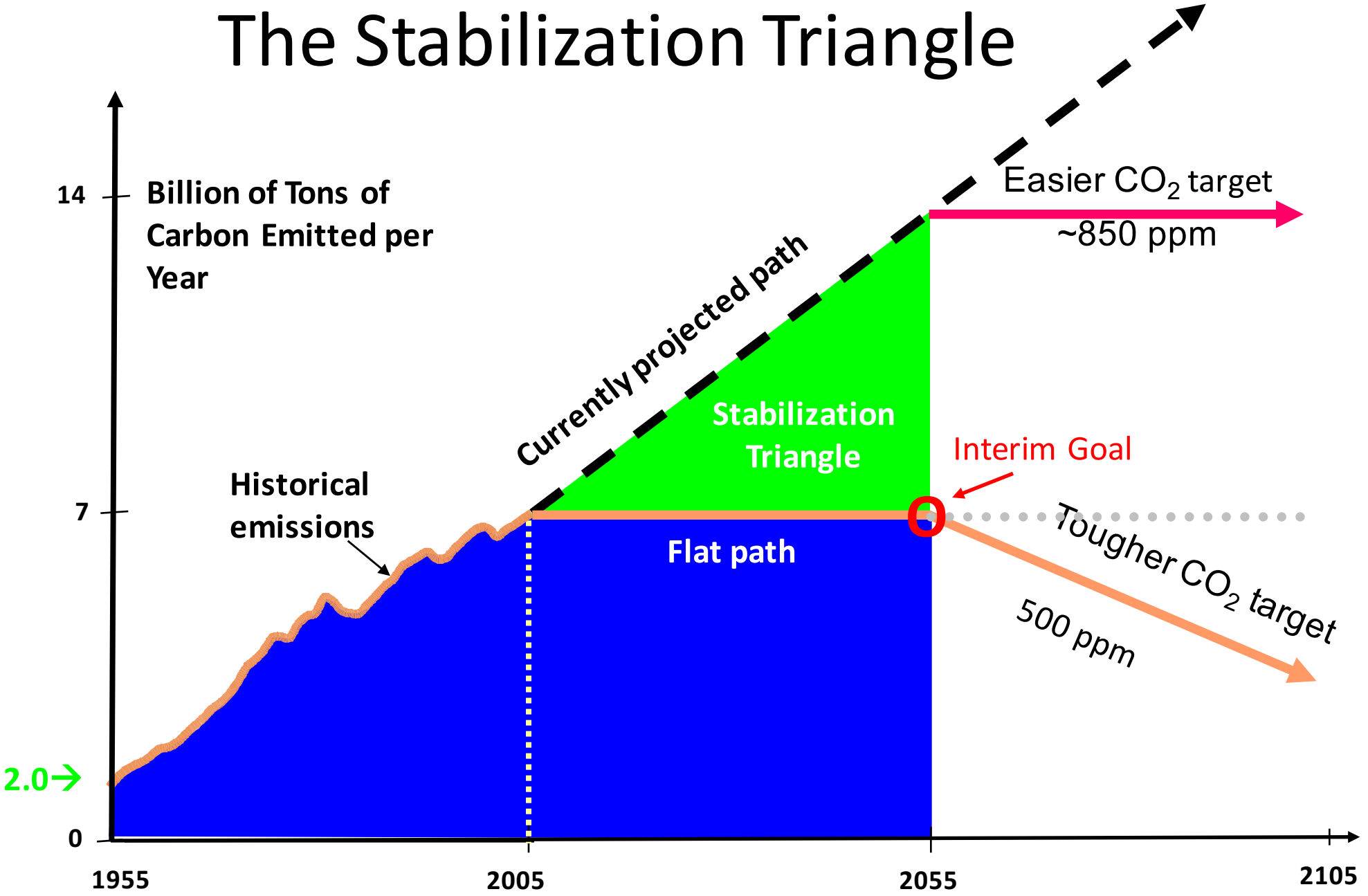
Past Emissions



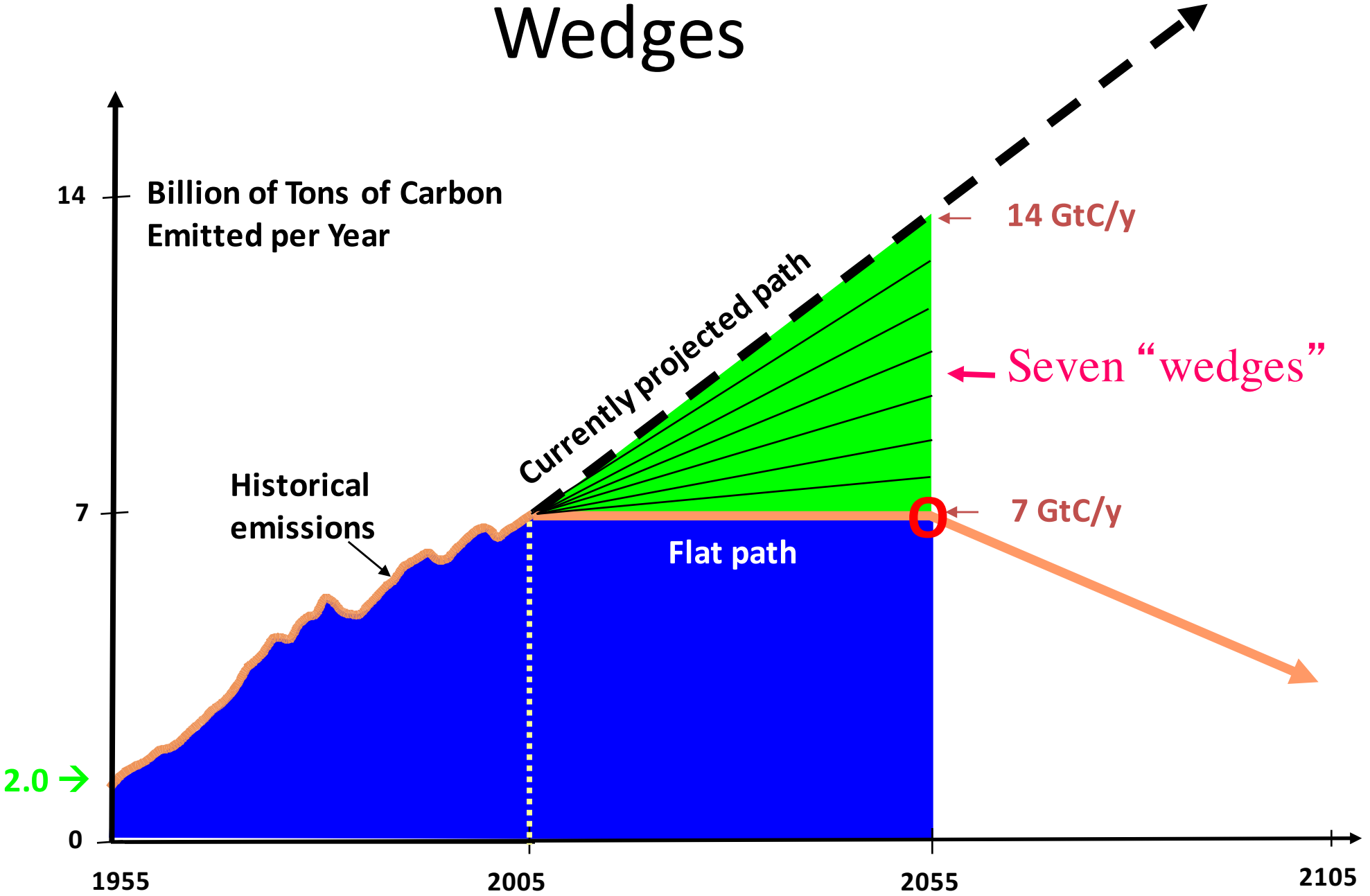


What does it mean to 'solve the carbon and climate problem' over the next 50 years?

The Stabilization Triangle

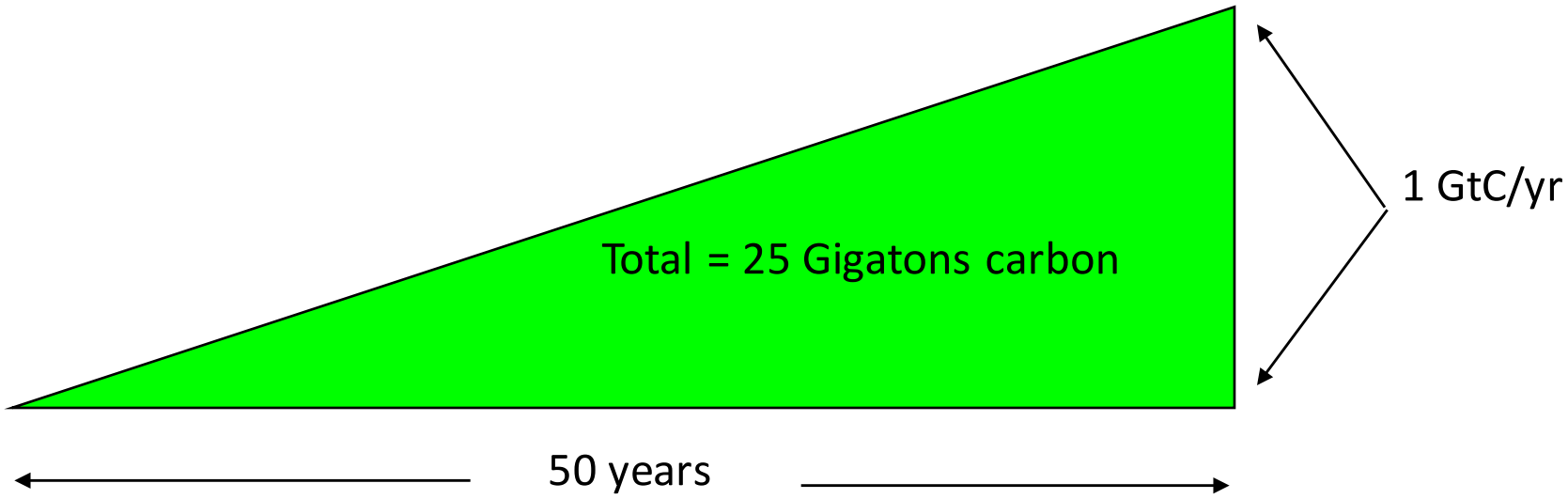


Wedges


14
Billion of Tons of Carbon
Emitted per Year
7
2.0
0
1955
2005
2055
2105
Historical
emissions
Currently projected path
14 GtC/y
Seven "wedges"
7 GtC/y
Flat path

What is a "Wedge"?

A "wedge" is a strategy to reduce carbon emissions that grows in 50 years from zero to 1.0 GtC/yr. The strategy has already been commercialized at scale somewhere.



Cumulatively, a wedge redirects the flow of 25 GtC in its first 50 years. This is 2.5 trillion dollars at $100/tC.

A "solution" to the CO_2 problem should provide at least one wedge.

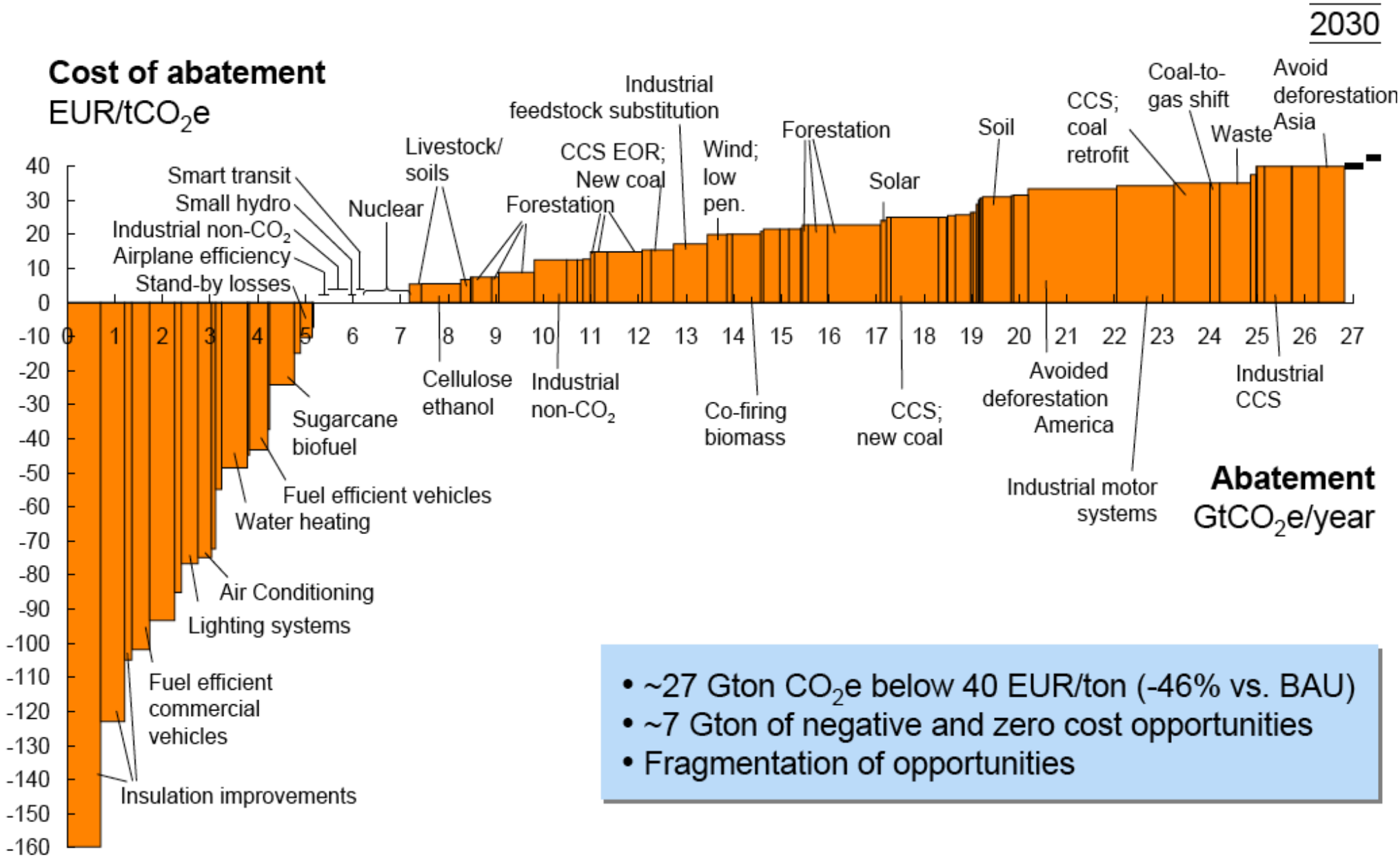
Wedges #1 - #8 (out of 15)

	Option	Effort by 2054 for one wedge, relative to 14 GtC/year BAU	Comments, issues
Energy Efficiency and Conservation	Economy-wide carbon-intensity reduction (emissions/$GDP)	Increase reduction by additional 0.15% per year (e.g., increase U.S. goal of reduction of 1.96% per year to 2.11% per year)	Can be tuned by carbon policy
	1. Efficient vehicles	Increase fuel economy for 2 billion cars from 30 to 60 mpg	Car size, power
	2. Reduced use of vehicles	Decrease car travel for 2 billion 30-mpg cars from 10,000 to 5,000 miles per year	Urban design, mass transit, telecommuting
	3. Efficient buildings	Cut carbon emissions by one-fourth in buildings and appliances projected for 2054	Weak incentives
	4. Efficient baseload coal plants	Produce twice today's coal power output at 60% instead of 40% efficiency (compared with 32% today)	Advanced high-temperature materials
Fuel shift	**5.** Gas baseload power for coal baseload power	Replace 1400 GW 50%-efficient coal plants with gas plants (4 times the current production of gas-based power)	Competing demands for natural gas
CO_2 Capture and Storage (CCS)	**6.** Capture CO_2 at baseload power plant	Introduce CCS at 800 GW coal or 1600 GW natural gas (compared with 1060 GW coal in 1999)	Technology already in use for H_2 production
	7. Capture CO_2 at H_2 plant	Introduce CCS at plants producing 250 MtH_2/year from coal or 500 MtH_2/year from natural gas (compared with 40 MtH_2/year today from all sources)	H_2 safety, infrastructure
	8. Capture CO_2 at coal-to-synfuels plant	Introduce CCS at synfuels plants producing 30 million barrels per day from coal (200 times Sasol), if half of feedstock carbon is available for capture	Increased CO_2 emissions, if synfuels are produced *without* CCS
	Geological storage	Create 3500 Sleipners	Durable storage, successful permitting

Wedges #9 - #15 (out of 15)

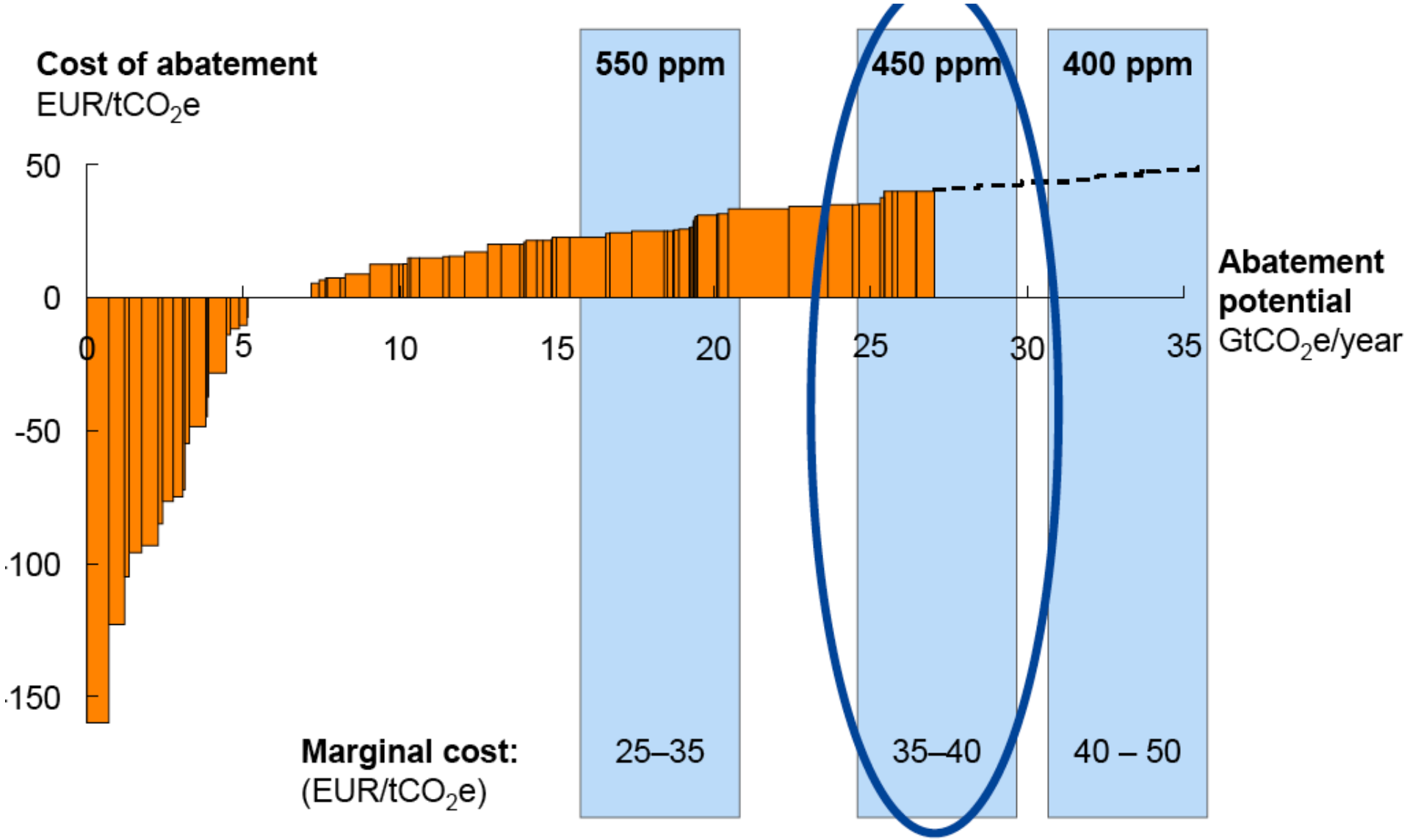
	Option	Effort by 2054 for one wedge, relative to 14 GtC/year BAU	Comments, issues
Nuclear Fission	**9.** Nuclear power for coal power	Add 700 GW (twice the current capacity)	Nuclear proliferation, terrorism, waste
Renewable Electricity and Fuels	**10.** Wind power for coal power	Add 2 million 1-MW-peak windmills (50 times the current capacity) "occupying" 30×10^6 ha, on land or off shore	Multiple uses of land because windmills are widely spaced
	11. PV power for coal power	Add 2000 GW-peak PV (700 times the current capacity) on 2×10^6 ha	PV production cost
	12. Wind H_2 in fuel-cell car for gasoline in hybrid car	Add 4 million 1-MW-peak windmills (100 times the current capacity)	H_2 safety, infrastructure
	13. Biomass fuel for fossil fuel	Add 100 times the current Brazil or U.S. ethanol production, with the use of 250×10^6 ha (1/6 of world cropland)	Biodiversity, competing land use
Forests and Agricultural Soils	**14.** Reduced deforestation, plus reforestation, afforestation and new plantations.	Decrease tropical deforestation to zero instead of 0.5 GtC/year, and establish 300 Mha of new tree plantations (twice the current rate)	Land demands of agriculture, benefits to biodiversity from reduced deforestation
	15. Conservation tillage	Apply to all cropland (10 times the current usage)	Reversibility, verification

Global cost curve of GHG abatement opportunities beyond business as usual



- ~27 Gton CO_2e below 40 EUR/ton (-46% vs. BAU)
- ~7 Gton of negative and zero cost opportunities
- Fragmentation of opportunities

Marginal Abatement Costs for Cooling Scenarios



www.vattenfall.com/climatemap

Environmental Science & Technology

coolclimate.berkeley.edu/maps

Policy Analysis

pubs.acs.org/est

Spatial Distribution of U.S. Household Carbon Footprints Reveals Suburbanization Undermines Greenhouse Gas Benefits of Urban Population Density

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http://coolclimate.berkeley.edu/maps

We have seen access rate up to 100,000/day

What do they do first?

They check their own community …

& compare to neighbors