Lecture 5: A New Economics of the Planet

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April 25 2016
1. The climate crisis reinvented  
Klein, chapters 1 & 2 | Optional: Dove & Kammen, chapter 1

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

3. We don’t tenure Mother Teresa  
Klein, chapter 9 | Optional: Dove & Kammen, chapter 2

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

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

6. Pasteur’s Quadrant  
Klein, chapter 7, 11 | Optional: Dove & Kammen, chapter 4
Resources:

Website: http://rael.berkeley.edu

Twitter: @dan_kammen
How much warming by 2100?

Global Emissions of Greenhouse Gases

Estimated temperature in 2100:

- 4.5°C Business as usual
- 3.5°C Current national commitments with no change after the pledge period, ending 2025-2030
- 2°C Path

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.
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.

VIEWPOINT

Silence, Miss Carson


_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."
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 $\rightarrow$ discount rate reasoning..

  – The higher the discount rate, depending on consumption and opportunity costs factors, the less future benefits and costs are valued...

  – $r = $ pure time myopic preference + consumption growth; otherwise equals the market opportunity 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$, N$_2$O, O$_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

- **Opportunity Space for Improvement**
- **Optimal tax** $T^*$
- **Constrained tax** $T^C$

Graph showing the relationship between price and quantity with different tax and cost lines, indicating the gap between social and private cost.
Mind the (Economic) Gap: Social and Private Cost

There is no reason to believe that bureaucrats and politicians, no matter how well meaning, are better at solving problems than the people on the spot, who have the strongest incentive to get the solution right.

— Elinor Ostrom —

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 $I = \text{dep}$, 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: $\text{Investment} \geq \text{depreciation}$
• 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.
SD is linked to Total capital or natural capital?

• Total capital = manmade + human capital + natural capital

• Each capital stock is defined by a rate of growth, I – Deprec.

• 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.

• 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. Arab countries management of non renewable resources
  - UK oil exploitation
  - In any case, rents from natural resource use should be re-invested... right?
Four Actions to Reduce Emissions

1. Efficiency

2. Electrification

Summary

"Low-Carb" Fuels + Electricity

2050 Target Emissions (80 MtCO₂e)

Efficiency

2050 BAU Emissions (830 MtCO₂e)
The Challenge is Big...

2013: 20%
2020: 33%
2030: 50%
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 >$400/ton CO$_2$e
- 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

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# How Do You Price Carbon?

## Carbon Pricing Elements

<table>
<thead>
<tr>
<th>Pricing Mechanism</th>
<th>Emissions Included</th>
<th>Revenue Use</th>
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# How Do You Price Carbon?

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<tr>
<td>Carbon Tax or Fee</td>
<td>CO₂</td>
<td></td>
</tr>
<tr>
<td>Cap and Trade</td>
<td>What about:</td>
<td></td>
</tr>
<tr>
<td>Cap and Dividend</td>
<td>Biodiversity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cultural Survival</td>
<td></td>
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</table>
Both mechanisms have been tried; both can be effective.
Offsets

Projects which sequester carbon can offset some emissions/permits
Emissions from Different Sectors

2012 U.S. CO$_2$e Emissions

- Commercial: 197 Tg CO$_2$ Eq.
- Residential: 289 Tg CO$_2$ Eq.
- Industrial: 774 Tg CO$_2$ Eq.
- Transportation: 1,740 Tg CO$_2$ Eq.
- Electricity Generation: 2,023 Tg CO$_2$ Eq.

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Carbon Markets in Place Today

- European Union
- RGGI
- New Zealand
- California
- Quebec
- China (pilot)
- Kazakhstan (pilot)
- S. Korea (planned)

Price on 11/1/14
- CA: $11.85
- EU: $7.20
- RGGI: $2.67
- China: $4-20

Adapted from Newell et al. Science, 343:1316-1317 (2014)
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<td>Electricity generation</td>
<td>Government Programs</td>
</tr>
<tr>
<td>Cap and Trade</td>
<td>Transportation</td>
<td>Mitigate/adapt</td>
</tr>
<tr>
<td></td>
<td>Industrial</td>
<td>Reduce deficit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Infrastructure, etc</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Revenue Neutral</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Return to people</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduce other taxes</td>
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California

- Reduce deficit
- Infrastructure, etc
- Revenue Neutral
- Return to people
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How Do You Price Carbon?

Carbon Pricing Elements

Pricing Mechanism
- Carbon Tax or Fee
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Revenue Use
- Government Programs
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How Do You Price Carbon?

Carbon Pricing Elements

**Pricing Mechanism**
- Carbon Tax or Fee
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**Revenue Use**
- Government Programs
  - Mitigate/adapt
  - Reduce deficit
- Infrastructure, etc
- Revenue Neutral
- Return to people
- Reduce other taxes

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## Climate Accounting ...New Math!

<table>
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<tr>
<th>Emissions Category</th>
<th>Industrialized</th>
<th>Developing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative CO$_2$, energy</td>
<td>86</td>
<td>14</td>
</tr>
<tr>
<td>Cumulative CO$_2$, energy, biota</td>
<td>68 – 80</td>
<td>32 – 20</td>
</tr>
<tr>
<td>CO$_2$, energy (current)</td>
<td>72</td>
<td>28</td>
</tr>
<tr>
<td>Partial CO$_2$, CH$_4$ (current)</td>
<td>57</td>
<td>43</td>
</tr>
<tr>
<td>Comprehensive (current)</td>
<td>52 - 57</td>
<td>48 - 43</td>
</tr>
</tbody>
</table>
Global carbon intensity fell by an average of 0.9% a year from 2000 to 2013. In the last year, global carbon intensity fell by 1.2%.

At current rates of decarbonisation of 0.9%, we would be heading towards the worst projected scenario of the IPCC, leading to a significant chance of exceeding 4°C of warming.

To meet the global carbon budget necessary to limit warming to 2°C, the global economy needs to increase decarbonisation to 6.2% a year, every year to 2100.

The global energy system will have to be virtually zero-carbon by the end of the century.
Past Emissions

Billion of Tons of Carbon Emitted per Year

Historical emissions

Year
What does it mean to ‘solve the carbon and climate problem’ over the next 50 years?
The Stabilization Triangle

- Billion of Tons of Carbon Emitted per Year
- Currently projected path
- Stabilization Triangle
- Flat path
- Historical emissions
- Interim Goal
- Easier CO₂ target ~850 ppm
- Tougher CO₂ target 500 ppm

Emissions history from 1955 to 2005, with projections for 2055 and beyond.
Billion of Tons of Carbon Emitted per Year

Historical emissions

Currently projected path

Flat path

2.0 →

14 GtC/y

7 GtC/y

Seven “wedges”
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)

<table>
<thead>
<tr>
<th>Energy Efficiency and Conservation</th>
<th>Option</th>
<th>Effort by 2054 for one wedge, relative to 14 GtC/year BAU</th>
<th>Comments, issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Efficient vehicles</td>
<td>Increase fuel economy for 2 billion cars from 30 to 60 mpg</td>
<td>Car size, power</td>
<td></td>
</tr>
<tr>
<td>2. Reduced use of vehicles</td>
<td>Decrease car travel for 2 billion 30-mpg cars from 10,000 to 5,000 miles per year</td>
<td>Urban design, mass transit, telecommuting</td>
<td></td>
</tr>
<tr>
<td>3. Efficient buildings</td>
<td>Cut carbon emissions by one-fourth in buildings and appliances projected for 2054</td>
<td>Weak incentives</td>
<td></td>
</tr>
<tr>
<td>4. Efficient baseload coal plants</td>
<td>Produce twice today’s coal power output at 60% instead of 40% efficiency (compared with 32% today)</td>
<td>Advanced high-temperature materials</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fuel shift</th>
<th>Option</th>
<th>Effort by 2054 for one wedge, relative to 14 GtC/year BAU</th>
<th>Comments, issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>5. Gas baseload power for coal baseload power</td>
<td>Replace 1400 GW 50%-efficient coal plants with gas plants (4 times the current production of gas-based power)</td>
<td>Competing demands for natural gas</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CO₂ Capture and Storage (CCS)</th>
<th>Option</th>
<th>Effort by 2054 for one wedge, relative to 14 GtC/year BAU</th>
<th>Comments, issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Capture CO₂ at baseload power plant</td>
<td>Introduce CCS at 800 GW coal or 1600 GW natural gas (compared with 1060 GW coal in 1999)</td>
<td>Technology already in use for H₂ production</td>
<td></td>
</tr>
<tr>
<td>7. Capture CO₂ at H₂ plant</td>
<td>Introduce CCS at plants producing 250 MTH₂/year from coal or 500 MTH₂/year from natural gas (compared with 40 MTH₂/year today from all sources)</td>
<td>H₂ safety, infrastructure</td>
<td></td>
</tr>
<tr>
<td>8. Capture CO₂ at coal-to-synfuels plant</td>
<td>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</td>
<td>Increased CO₂ emissions, if synfuels are produced without CCS</td>
<td></td>
</tr>
</tbody>
</table>

| Geological storage                | Create 3500 Sleipners | Durable storage, successful permitting |
# Wedges #9 - #15 (out of 15)

<table>
<thead>
<tr>
<th>Option</th>
<th>Effort by 2054 for one wedge, relative to 14 GtC/year BAU</th>
<th>Comments, issues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear Fission</td>
<td>9. Nuclear power for coal power</td>
<td>Add 700 GW (twice the current capacity)</td>
</tr>
<tr>
<td>Renewable Electricity and Fuels</td>
<td>10. Wind power for coal power</td>
<td>Add 2 million 1-MW-peak windmills (50 times the current capacity) “occupying” 30x10^6 ha, on land or off shore</td>
</tr>
<tr>
<td></td>
<td>11. PV power for coal power</td>
<td>Add 2000 GW-peak PV (700 times the current capacity) on 2x10^6 ha</td>
</tr>
<tr>
<td></td>
<td>12. Wind H₂ in fuel-cell car for gasoline in hybrid car</td>
<td>Add 4 million 1-MW-peak windmills (100 times the current capacity)</td>
</tr>
<tr>
<td></td>
<td>13. Biomass fuel for fossil fuel</td>
<td>Add 100 times the current Brazil or U.S. ethanol production, with the use of 250x10^6 ha (1/6 of world cropland)</td>
</tr>
<tr>
<td>Forests and Agricultural Soils</td>
<td>14. Reduced deforestation, plus reforestation, afforestation and new plantations.</td>
<td>Decrease tropical deforestation to zero instead of 0.5 GtC/year, and establish 300 Mha of new tree plantations (twice the current rate)</td>
</tr>
<tr>
<td></td>
<td>15. Conservation tillage</td>
<td>Apply to all cropland (10 times the current usage)</td>
</tr>
</tbody>
</table>
Global cost curve of GHG abatement opportunities beyond business as usual

- ~27 Gton CO$_2$e below 40 EUR/ton (-46% vs. BAU)
- ~7 Gton of negative and zero cost opportunities
- Fragmentation of opportunities

Cost of abatement
EUR/tCO$_2$e

Abatement
GtCO$_2$e/year

- Smart transit
- Small hydro
- Industrial non-CO$_2$
- Airplane efficiency
- Stand-by losses
- Nuclear
- Livestock/soils
- CCS EOR; New coal
- Industrial feedstock substitution
- Wind; low pen.
- Forestation
- CCS; coal retrofit
- Coal-to-gas shift
- Avoid deforestation
- Asia
- Industrial CCS
- Industrial motor systems
- Avoided deforestation America
- Water heating
- Fuel efficient vehicles
- Sugarcane biofuel
- Air Conditioning
- Lighting systems
- Fuel efficient commercial vehicles
- Insulation improvements

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Marginal Abatement Costs for Cooling Scenarios

**Marginal cost:**
(EUR/tCO₂e)

- 25–35
- 35–40
- 40 – 50

Cost of abatement
EUR/tCO₂e

Abatement potential
GtCO₂e/year

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†Energy and Resources Group, ‡Goldman School of Public Policy, and §Department of Nuclear Engineering, University of California, Berkeley, California 94720, United States

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

What do they do first?
They check their own community ...
& compare to neighbors