Accounting for Carbon:
A Review of Leading Models and Implications for Efficiency

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OVERVIEW

- **Carbon mitigation is necessary to limit damages**
- **Response will involve political decisions in jurisdictions ranging from individuals to nations**
- **Models are useful - and imperfect - representations of reality**

Alpha and Omega, by S Ashmarin, Russia

Monetize carbon (method 1): Quantify cost of damages

- **Estimate the value of damages caused by greenhouse gas (GHG) emissions to the atmosphere**
  - **Global problem over long time scale**
  - **Difficult to account for all effects**
  - **Uncertainty in projecting magnitude and timing of damages**
  - **Mostly by carbon dioxide from combustion of fossil fuels**

- **EXAMPLE: IPCC (www.ipcc.ch)**
  - **Average social cost of carbon, $43 per ton carbon, will increase with global temperature. (IPCC, AR4)**
  - **Range $-10/tC to $350/tC or $-3/tCO2 to $95/tCO2**
  - **The range in costing is large due to differences in assumptions regarding climate sensitivity, response lags, the treatment of risk and equity, economic and non-economic impacts, the inclusion of potentially catastrophic losses, discount rates, and technological change.**

Monetize carbon (method 2): Quantify cost to mitigate emissions

- Depends on timing and magnitude
- Many approaches possible, e.g.
  - —Improve or replace power production technologies
  - —Energy efficiency
  - —Carbon capture and sequestration
  - —Behavioral change

Policy approaches to GHG mitigation

- R&D
- Voluntary trading
  - —EXAMPLE: Chicago Climate Exchange
- Regulatory limits on emissions
  - —EXAMPLE: CAFÉ standards
- Carbon tax
  - —EXAMPLES: Sweden, Finland, Netherlands, Norway

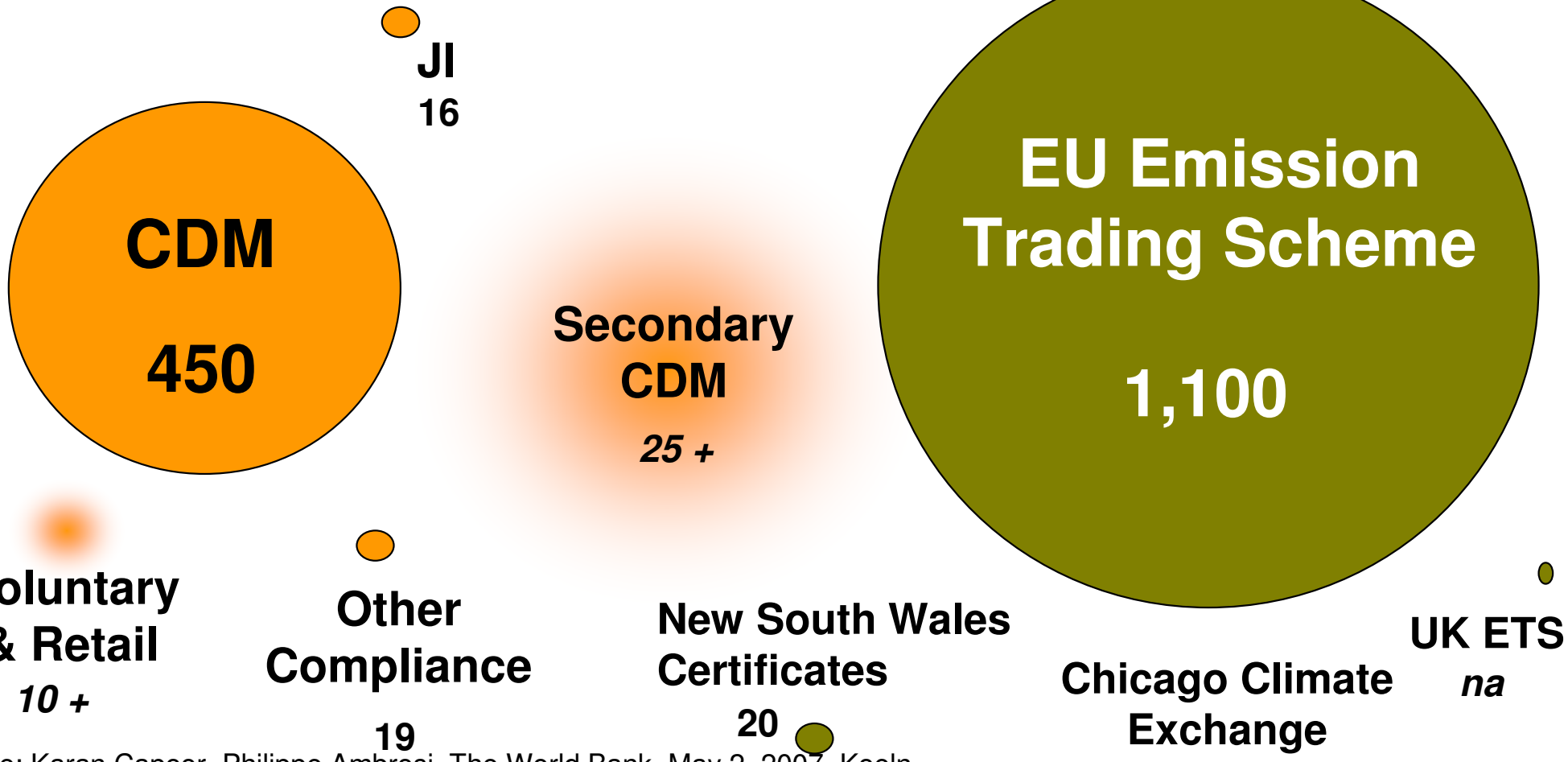
- ***Cap and trade*** (EU, RGGI, CA)
  - —Allocate maximum limits on emissions
    - All(?) relevant emissions from all(?) sectors
    - Global, no leakage, verifiable?
  - —Market determines prices of trades
    - Unless safety valve constrains maximum price

Global Carbon Market: *$59 Billion in 2007*: $30 Billion in 2006; $11 B in 2005

Volumes transacted in 2006 (in $MtCO_2e$)

Project-Based Transactions

Allowance Markets



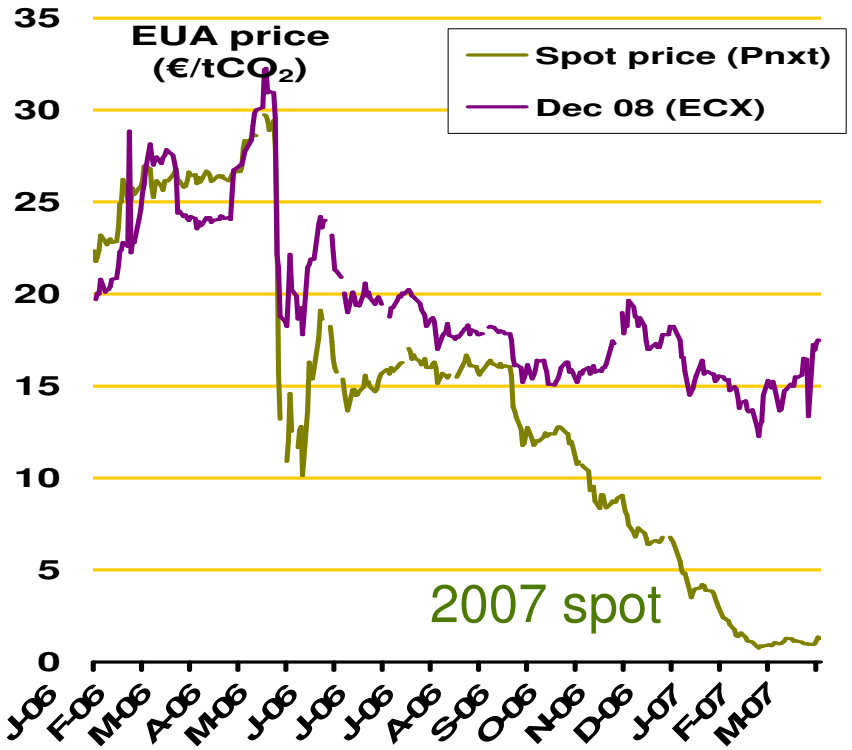
Source: Karan Capoor, Philippe Ambrosi, The World Bank, May 2, 2007, Koeln

EU ETS markets have adjusted
(European Union Emissions Trading Scheme)

Phase I was long pushing EUA prices < € 2

— **Overall generous allocation, weather, energy price & no EUA banking**

HISTORY, 2005-2007



Phase II (2008-2012) expected to be short

- **Tightened allocation by about 7% for 11 countries**
- **EU Directive allows EUAs banking**

CURRENT, 2008

22.7€/tCO$_2$

Dec 08 (ECX)

As of 09 Oct 2008

30-day history:
Sep-Oct, 2008

Source: PointCarbon.com 9 Oct 2008

Based on: Karan Capoor, Philippe Ambrosi, The World Bank, May 2, 2007, Koeln

Regional approaches in the US

- **Jan 01, 2009 – Implement RGGI (10 states)**
  - **—CO2 Cap-and-trade (to 1990 levels by 2014)**
  - **—Power generators: 25MW & 50% fossil**
  - ***—Issues: short enough, liquid enough?***

Quarterly auctions: Sep 25, '08 price $3/t CO2
Allocation is higher than actual emissions
Next auction: Dec,'08 (New York, others)

www.rggi.org

www.arb.ca.gov

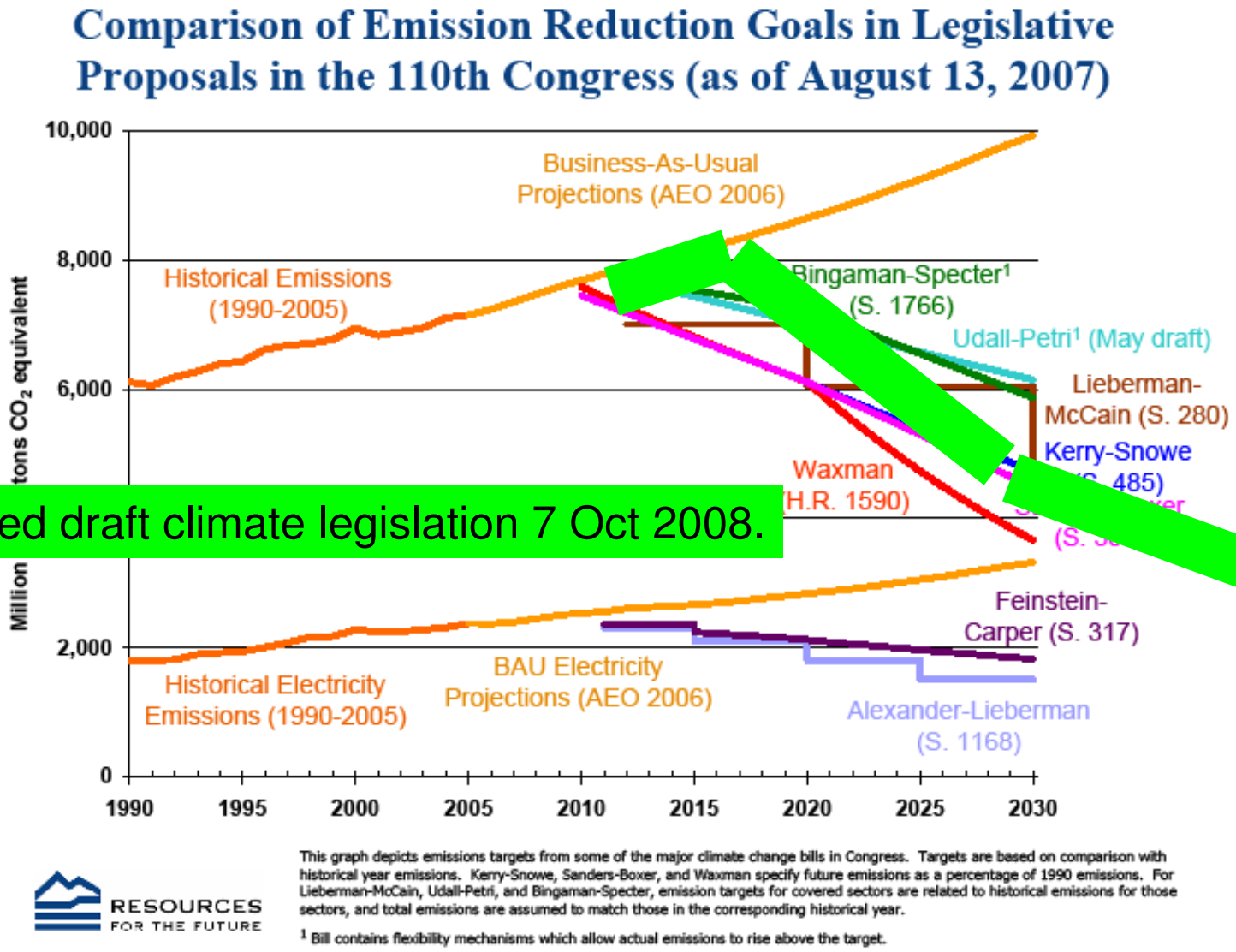
- **Jan 01, 2012 – California implements**
  - **—GHG (1990 levels by 2020, -80% by 2050)**
  - **—Entire state economy**
  - ***—Market-based mechanisms***
    - ***And regulations and utility programs***
  - ***—Possible links to RGGI, EU, others?***

+$10-100/ton carbon means…

- **$10 per ton of carbon would be an *increase* of about ($2.70/tCO2)**
  - —2.7 cents per gallon of gasoline
  - —0.27 cents per kilowatt-hour for coal-fired electricity, and 0.13 cent per kilowatt-hour for gas-fired electricity.

- **$100 per ton of carbon would be an *increase* of about ($27/tCO2)**
  - —27 cents per gallon of gasoline
  - —*2.7 cents per kilowatt-hour for coal-fired electricity, and 1.3 cent per kilowatt-hour for gas-fired electricity*.

Congress has drafted U.S. legislation



2050 target from 2005

House released draft climate legislation 7 Oct 2008.

McCain

-80%

2008 Oct 7. House Energy and Commerce Committee released draft climate legislation

- Target -6% 2020, -44% 2030, -80% 2050 from 2005
  - —First, transportation and power sectors (start 2012)
    - Requires CCS for coal plants by set date
  - —Other sectors later
  - —EPA to set industry-specific standards for < 25kt/a
- Cap and trade (FERC). Options to preempt:
  - —EPA, California fuel economy standards (must be DOT)
  - —Regional markets, like RGGI
- Allocation: 4 options. Auction:
  - —Money from partial auction to fund energy efficiency and clean technologies (CCS, RE deploy, smart grid, Clean Vehicles, Clean Fuel)
  - —In 2026, all permits would be sold, with proceeds going to taxpayers (unless Congress reauthorizes the bill)
- Allows banking, borrowing, offsets (2012 <5%, 2024 <35%)
- Authors: House Energy and Commerce Committee
  - — Chairman John Dingell, D-Mich
  - — Rich Boucher, D-Va (chairman, energy and air quality subcommittee)

Summary of Market-Based Climate Change Bills Introduced in the 110th Congress

Draft as of August 13, 2007 (See companion figure for target levels.)

	Who's Regulated	Allowance Allocation	Price Stability	Offsets	Technology	Competitiveness
Bingaman-Specter (S. 1766)	Economy-wide cap: coal and process emissions at emitters; oil refiners, NG processors, and oil/NG importers; and F-gas producers and importers.	55% free to industry (with phase out); 22% auctioned to support R&D, transition assistance, adaptation; 14% set aside for CCS and sequestration; 9% to states.	$12/metric ton CO_2 safety valve, rising at 5% per year above inflation.	Unlimited domestic offsets including methane and SF_6. Limits on international offsets (10% of cap) and domestic agricultural offsets (5% of cap).	Detailed technology development programs funded from allowance auction revenues (12-26% of auction revenues).	Bulk, energy-intensive imports from countries w/o comparable policy require permits after 10 years.
Udall-Petri (May draft and staff talks)	Economy-wide cap: primarily upstream sources (e.g., producers and importers of fuels).	20% free to industry. 80% auctioned to support RD&D; developing country engagement; adaptation, dislocation aid; sequestration; debt reduction.	$12/metric ton CO_2 safety valve, rising at 2-8% per year above inflation.	Unlimited geological sequestration offsets. 5% of allowances set aside to fund biological sequestration and 1% for CCS projects.	Establishes ARPA-E to fund technology advancement and sequestration projects (30% of auction revenues).	Inaction by developing countries can justify delay in safety valve escalation.
Lieberman-McCain (S. 280)	Economy-wide cap: large downstream at emitter; transport emissions regulated at refinery.	Discretion of EPA, with guidance for some free allocation and an auction to fund R&D, transition assistance, adaptation measures.	Borrowing: up to 25% of allowances, for no more than 5 years.	Up to 30% of obligation can be met with domestic sequestration projects and international offsets.	Revenues from some auctioned allowances used for RD&D.	No provisions.
Kerry-Snowe (S. 485)	Economy-wide cap: point of regulation at discretion of EPA.	Discretion of the President.	No provisions.	USDA sets rules for domestic biological sequestration.	Vehicle emission rules; efficiency & renewable standards for electric generation; additional bill-specific mandates.	
Waxman (H.R. 1590)				No provisions.		
Sanders-Boxer (S.309)	Economy-wide cap: EPA has discretion to implement a market-based allowance program to achieve cap.					
Feinstein-Carper (S. 317)	Electricity-sector cap: power plants. (S. 1168 also covers utility SO_2, NO_X, and mercury emissions.)	85% free to industry, based on generation. Phase out by 2036.	Borrowing up to 10%, for no more than 5 years.	International offsets up to 25% of cap; extensive domestic biological offsets.	Distributes auction revenues to multitude of technology programs.	
Alexander-Lieberman (S. 1168)		75% free to industry, based on heat input.	No provisions.	Domestic offsets in five categories, including methane, SF_6, efficiency, and forest sequestration.	New NSPS for CO_2 emissions from electric generation units.	
Stark (H.R. 2069)	Economy-wide tax: fossil fuels taxed by CO_2 content at the point of production and import.	100% revenues to US Treasury.	$3/metric ton CO_2, rising $3 annually.	Tax refunds for fuel CO_2 sequestered downstream: CCS, plastics.	No provisions.	Tax applied to fossil fuel imports; fossil fuel exports are exempt.
Larson (H.R. 3416)		1/6 of revenues to R&D, 1/12 to industry transition assistance (with phase out), remainder to payroll tax rebates.	$16.5/metric ton CO_2, rising 10% plus inflation annually.	Tax refunds for domestic sequestration and HFC destruction projects.	1/6 of tax revenues up to $10 billion annually goes to clean energy technology R&D.	

RESOURCES FOR THE FUTURE

Resources for the Future • kopp@rff.org, pizer@rff.org, aldy@rff.org

Can't control what you don't measure

- **What emissions to measure**
  - **Relative to what baseline**
- **How to measure quantitatively**
- **What are the reporting requirements**

Trend is toward third parties for objectivity

Climate Registry provides methodology

THE ISSUE IS

If we measure loosely, we can't afford all the efficiency claimed.
If we measure strictly, may bottleneck massive mobilization needed.

Source: Personal communication, Holmes Hummel, October, 2008.

Projects or programs?

- Clean Development Mechanism (Kyoto Protocol) has relatively rigorous measurement, designed for individual projects
- Not well suited to widely dispersed energy efficiency
- Approval of programs, rather than individual installations, more difficult to verify
  - —Statistical sampling must be accepted as sufficient

•Would codes and standards be easier to verify and less expensive?

How to treat energy efficiency

- Measure at site or at generation source
  - —Individual home/business OR energy supplier/utility
- Is energy efficiency a primary mitigation measure OR an offset (purchased by regulated entities if primary measures are insufficient to stay under cap)
  - —How can individuals receive payment for mitigation?
  - —How to measure, enforce?
- Major issues for energy efficiency
  - —Measurement and verification
  - —Who pays whom (utilities, consumers, ESCOs)?
  - —How much energy efficiency?
    - level of carbon price, efficiency measures interact

What is the mitigation potential?

- **Bottom-up and top-down estimates**
  - **Emission reduction potentials, 2030 (IPCC WGIII AR4)**

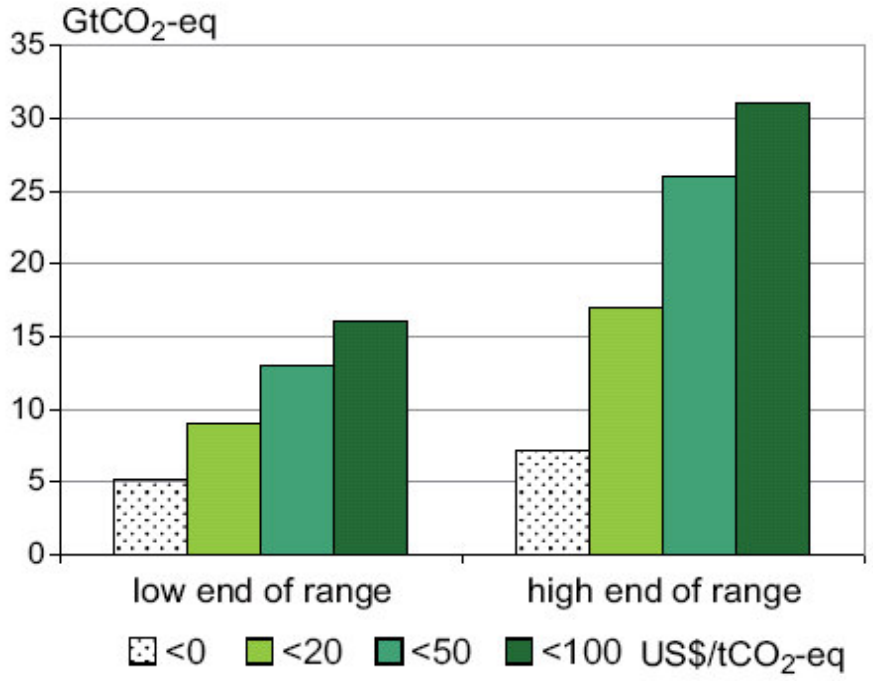


Figure SPM.5A: *Global economic mitigation potential in 2030 estimated from bottom-up studies (data from Table SPM.1)*

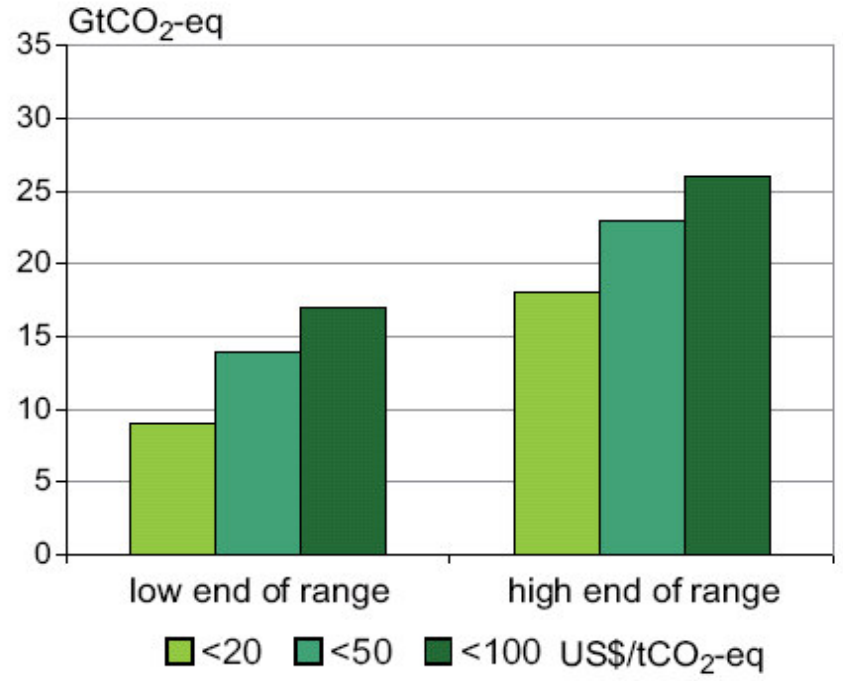


Figure SPM.5B: *Global economic mitigation potential in 2030 estimated from top-down studies (data from Table SPM.2)*

Source: www.mnp.nl. **Monique Hoogwijk, et al**: (Ecofys), 2008

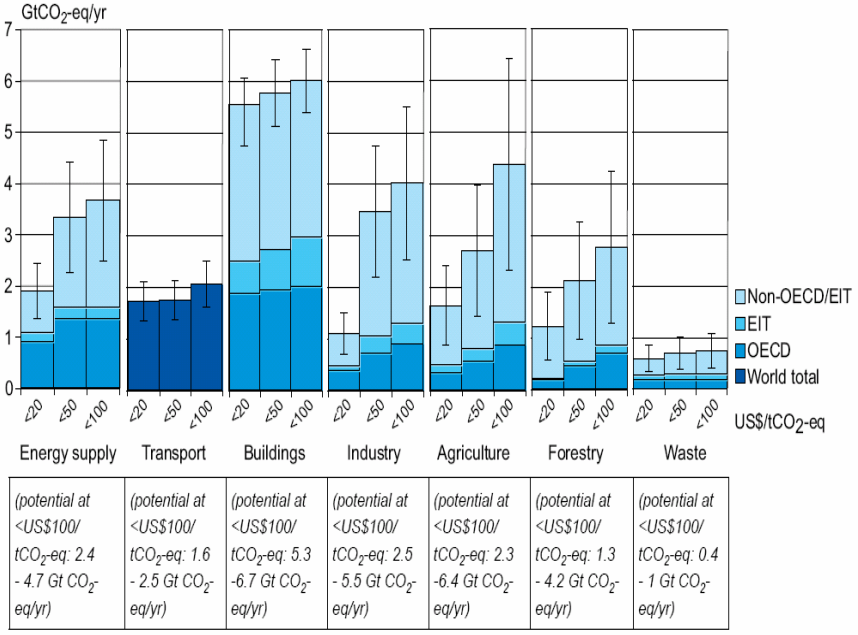
Bottom up

- Sectoral assessment per chapter
- Integrated in Chapter 11
- Different baselines
- Not all options included

Top Down

- 35 studies that reported c-tax and reductions
- Statistical analysis to derive "responses"
- Black box

At sectoral level no good comparison possible



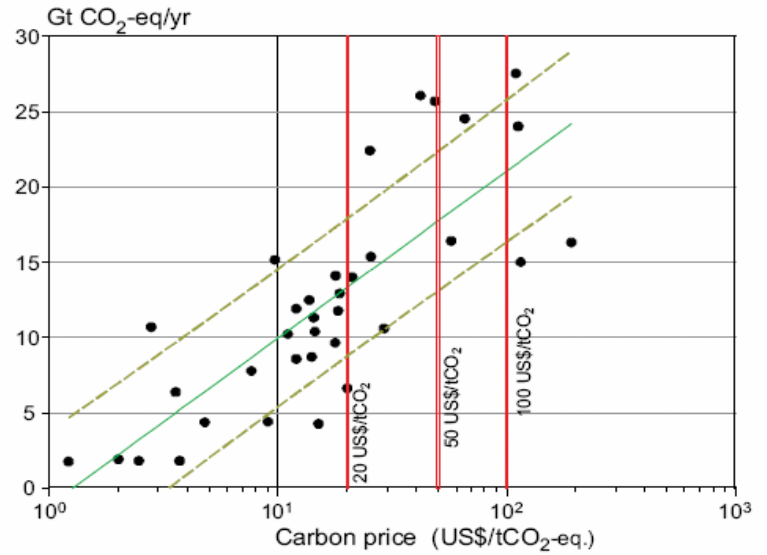


Figure 3.40: *Permit price versus level of emission reduction – total economy in 2030 (the natural logarithm of the permit price is used for the x-axis). The uncertainty range indicated is the 68% interval.*

What is the real potential for efficiency?

- Current estimates of potentials for 2050 may be low
- Current estimates of costs to achieve them may be
  - low?
  - high?
- More research needed
  - while implementing measures

How will we mitigate?

- **Less economic activity**
  - —Shut down factories
- **Supply-side efficiency**
  - —Upgrade the efficiency of power plants
- **Conservation + structural change + efficiency**
  - —Turn off lights when you leave the room
  - —Use more daylight (not lights when you are in the room)
  - —Use more efficient lights and controls

Source: Personal communication, Holmes Hummel, October 2008

PRODUCT CARBON FOOTPRINTING: Supply chain GHG emissions accounting

- **Direct emissions from an industry are, on average, only 14% and direct emissions plus industry energy inputs are, on average, only 26% of the total supply chain emissions (Tier 1 and 2 emissions).**
  - **Source: *Environ. Sci. Technol., 42* (16), 5839–5842, 2008. H. Scott Matthews, Chris T. Hendrickson, and Christopher L. Weber, Carnegie Mellon University**

- **74% of total supply chain emissions are from**
  - **supply chain (Tier 3) and**
  - **delivery, use, end-of-life (Tier 4)**

- **Life Cycle Assessment (LCA) captures total impact**
  - **(Examples: Tesco, Wal-mart, UK Carbon Trust)**
  - **Two methods: Process-based or Input-output**

Source: Personal communication, Eric Masanet, LBNL, Oct 10, 2008

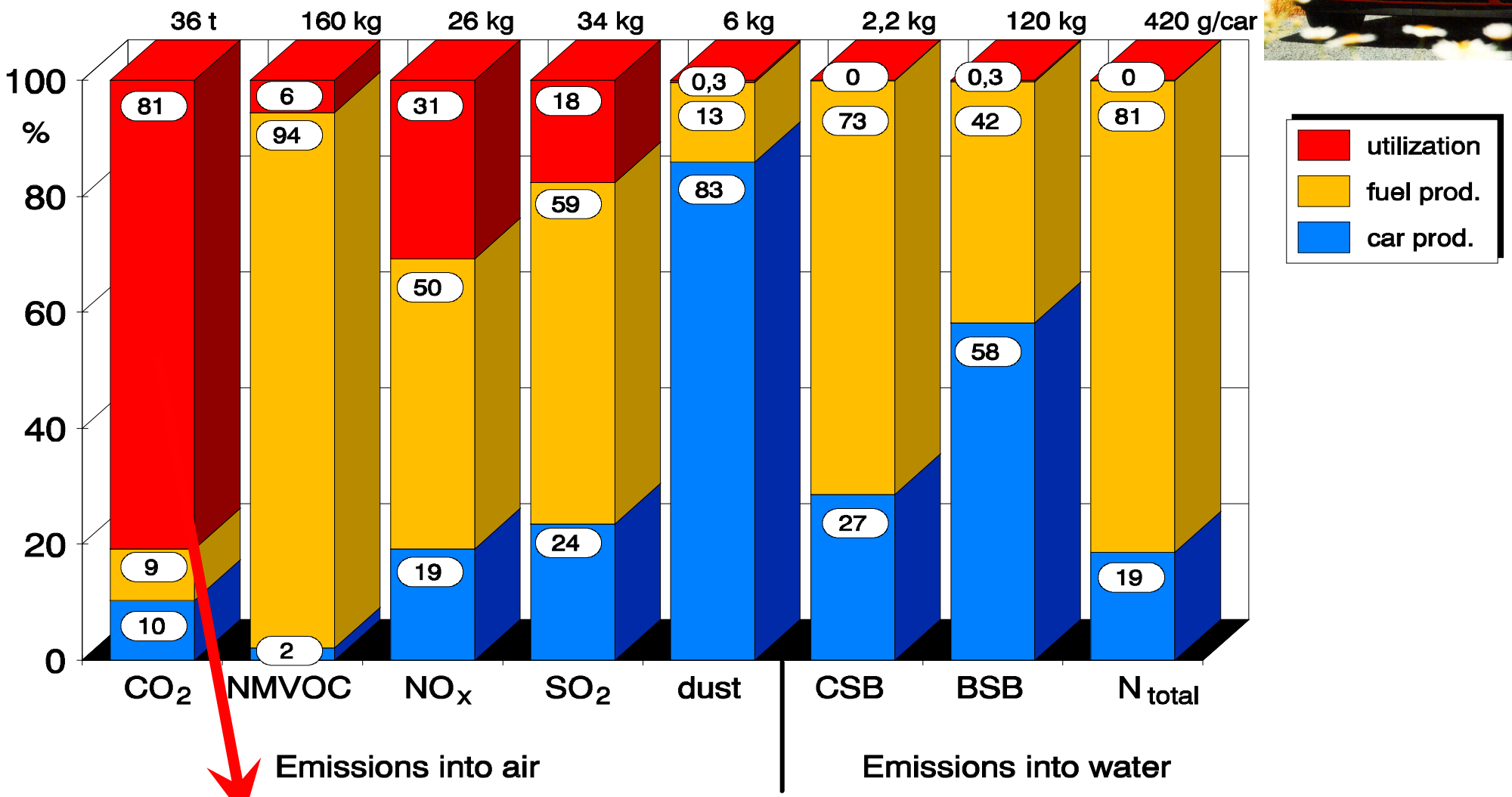
Selected results for VW Golf III LCI

	Tools, Factories	The product "car"	Service fluids Fuel/Oil	Infrastructure, Roads
Administration				
Planning				
R & D				
Raw materials		Materials	Crude oil	
Production		Suppliers VW factories	Refinery Distribution	
Use phase		Maintenance	Fuel combustion	
End of Life		Shredder	Used oil	
Disposal				

Source: Personal communication, Eric Masanet, LBNL, Oct 10, 2008

Selected results for VW Golf III LCI

Courtesy of IKP, University of Stuttgart, Germany



Most CO2 emissions are from utilization.
That does not encompass the total impact.

Source: Personal communication, Eric Masanet, LBNL, Oct 10, 2008

Some advantages and disadvantages

Process-based methods

Major advantages:
- Detailed process-specific data
- Geographic specificity
- Technological specificity
- Can facilitate scenario-playing

Major disadvantages:
- Time consuming
- Expensive
- Data availability and quality
- System boundary definition

I-O based methods

Major advantages:
- Inexpensive
- Quick
- Eliminates system boundary issues
- Comprehensive of all sectors
- Good for rough analyses

Major disadvantages:
- Old data (1997)
- National averages
- Data uncertainties
- No intra-sectoral resolution
- Impacts scale with $
- Imports

- **Hybrid methods are often a good compromise**

Conclusions

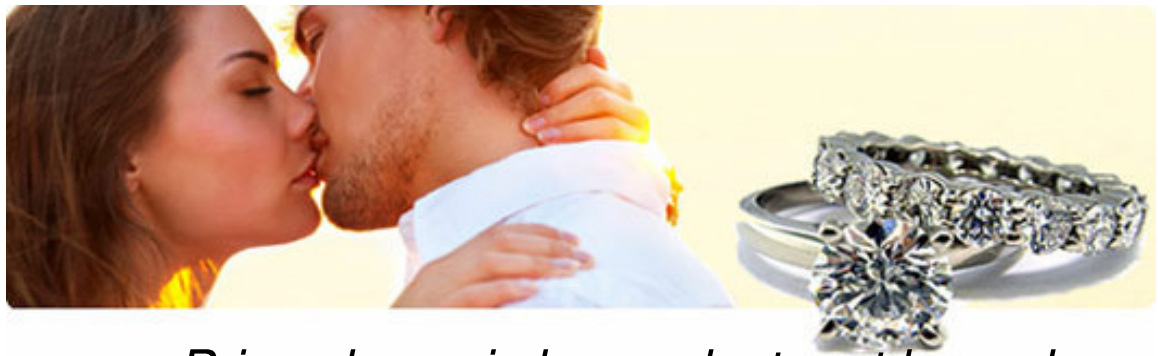
- **STATUS: More questions than answers**
- **Much activity is underway and needed prior to resolution**
  - **Resolution = setting the rules, defining functional units**
  - **>< not perfect precision**
- **Different models for different folks**
  - **We must all engage**
- **Political and technical issues interact**

Alternative carbon investments, 2007

- Coal **$30 per ton (average)**
  - **Range: $10-70 depending on region**
- Charcoal
  - **BBQ $678 per ton**

- Capsules $69,800 per ton

- Diamonds
  - **$ billions per ton (wholesale)**
  - **Priceless?**



Price shown is by product, not by carbon content.