Economics of Climate Change
"Cost of Inaction"

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Questions

Is it possible to measure **the costs of climate change**?

If so, which are the main challenges when measuring the social costs of Climate Change?

Three ways to get a price for carbon

How to get the value ?

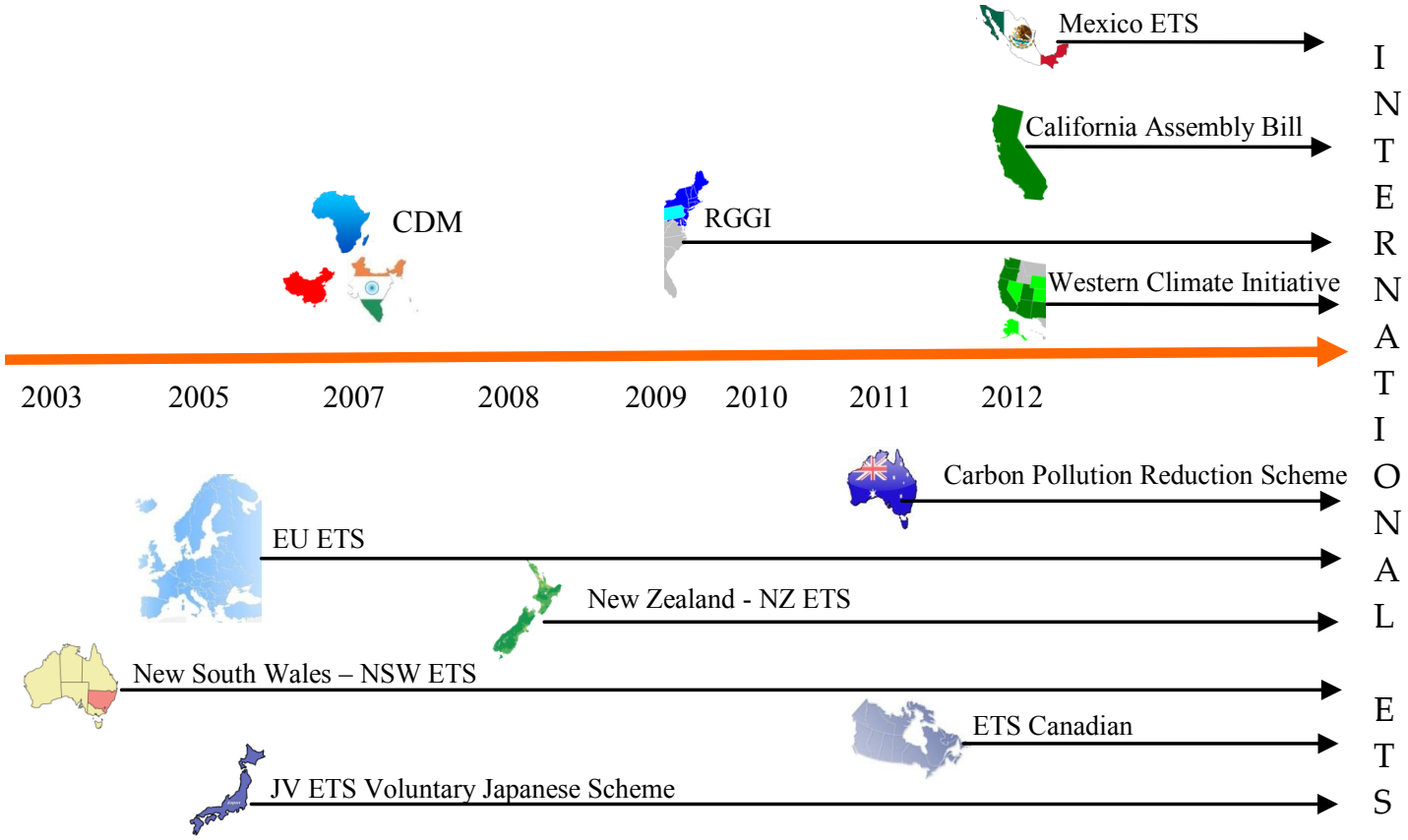
- **Market price** (e.g. EUA)
- **Marginal Abatement Costs** (MAC)
- **Social Costs of Climate Change** (SCC)
  i.e. marginal damage per ton, 'MSC of Carbon', 'Cost of Inaction')

In an ideal world they all would coincide

- large differences in reality
- nothing is perfect

1] MARKET PRICE

1] Market price from carbon market [Is there any market at all?]



Source: Taken from Carraro and Favere, 2009

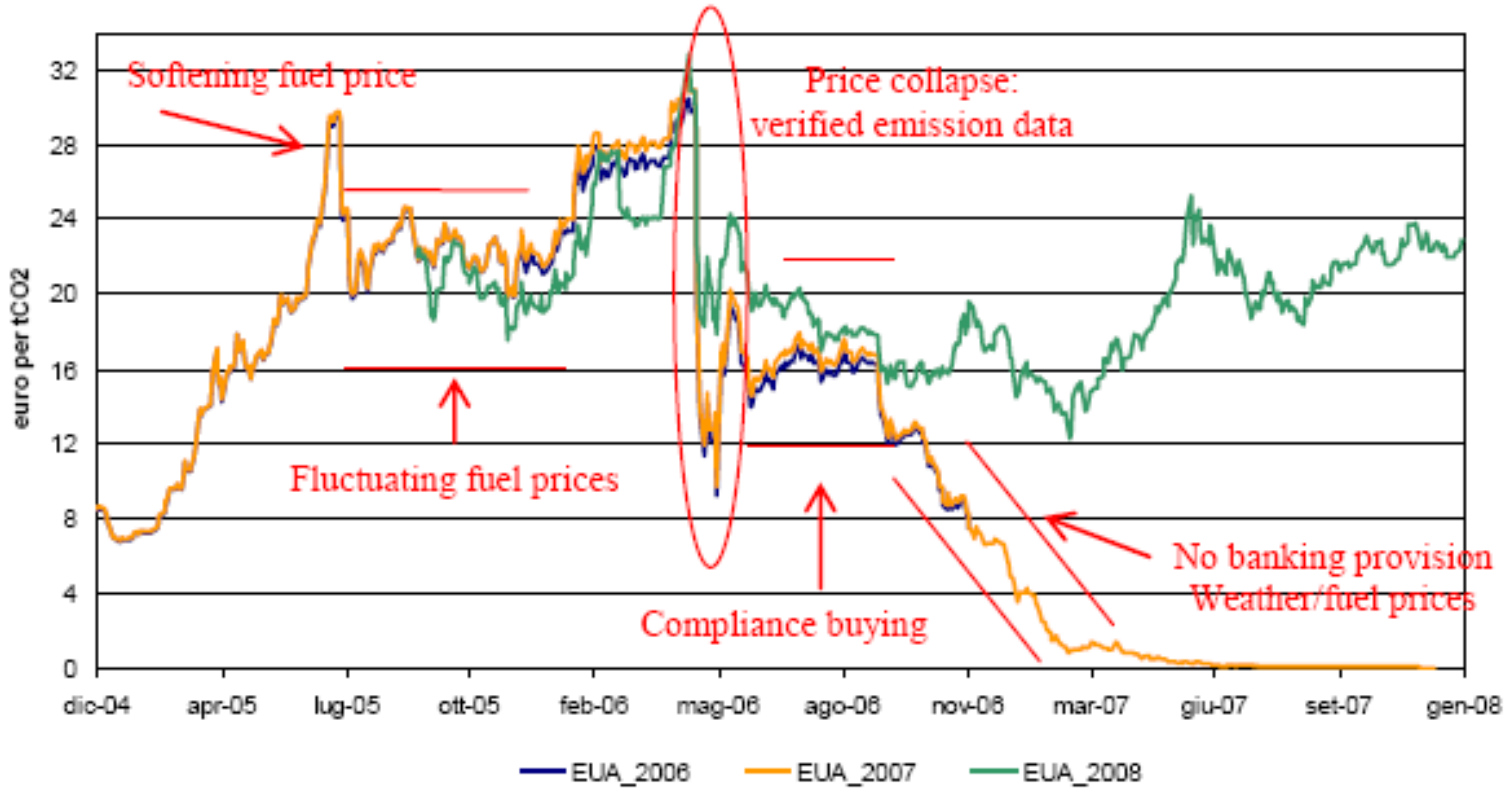
1] Market price from carbon market [What the value of carbon is there?]

Name	Average price in 2008
EUA – European emission allowances	13.5-29.4 €/tCO2
CER – Certified emission reduction	8.00-13.00 €/tCO2 (no registred projects)
	12.00-13.00 €/tCO2 (registred projects)
ERU - Emission reduction units	14.00 €/tCO2
RGGI allowances (RGAs)	3.41 $/short tCO2
NGAC – New South Wales Greenhouse Gas Abetment Credits	3.75-8.05 A$/tCO2
AEU – Australian emission unit (2011-2012)	19.00-23.00 A$/tCO2
Voluntary credits (traded OTC)	2.50-12.20 $/tCO2
CFI CCX – Chicago Climate Exchange	1.65 $/tCO2

SOURCE: PointCarbon (9th January 2009). *Carbon Market Monitor. 2008: year in review.*

Source: Taken from Carraro and Favere, 2009

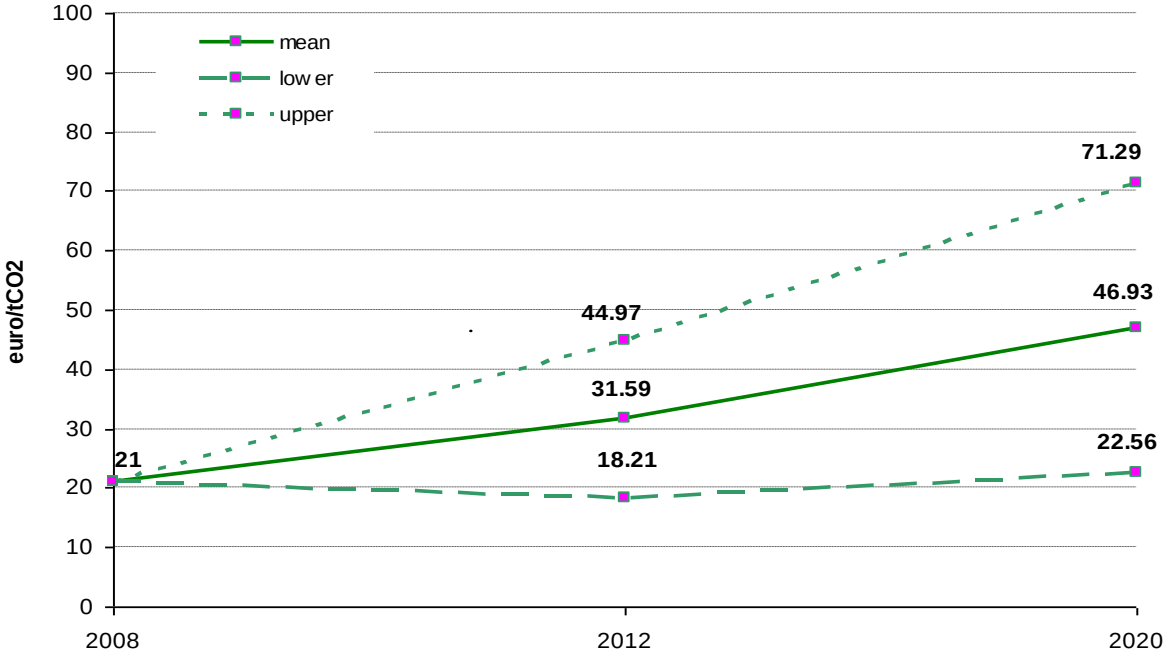
1] Market price from carbon market (EU ETS) [Any price volatility and fluctuations?]



Source: Taken from Carraro and Favere, 2009

1] Market price of EU allowance [short-term forecast of EUA price and MAC]

FIGURE 3. EUA PRICE FORECAST FOR II AND III PHASE



EUA price forecast by PRIMES model

20€/t CO_2 in 2010

22€/t CO_2 in 2020

24€/t CO_2 in 2030

Source: Taken from Carraro and Favere, 2009; see more CJEF (Finance a úvěr) 5/2009

Source: DG TREN 2008: Trends to 2030

1] Market price from carbon market [...emerging market]

Scope of the market

- Carbon markets in almost all OECD countries
- Regional schemes (e.g. EU ETS) linked by CDM
- Trading volume of 20-30 bln tCO2, assets of 7.5 bln allowances, worth $200 billion (Fankhauser 2009)
- *Leakage and competitiveness impacts*

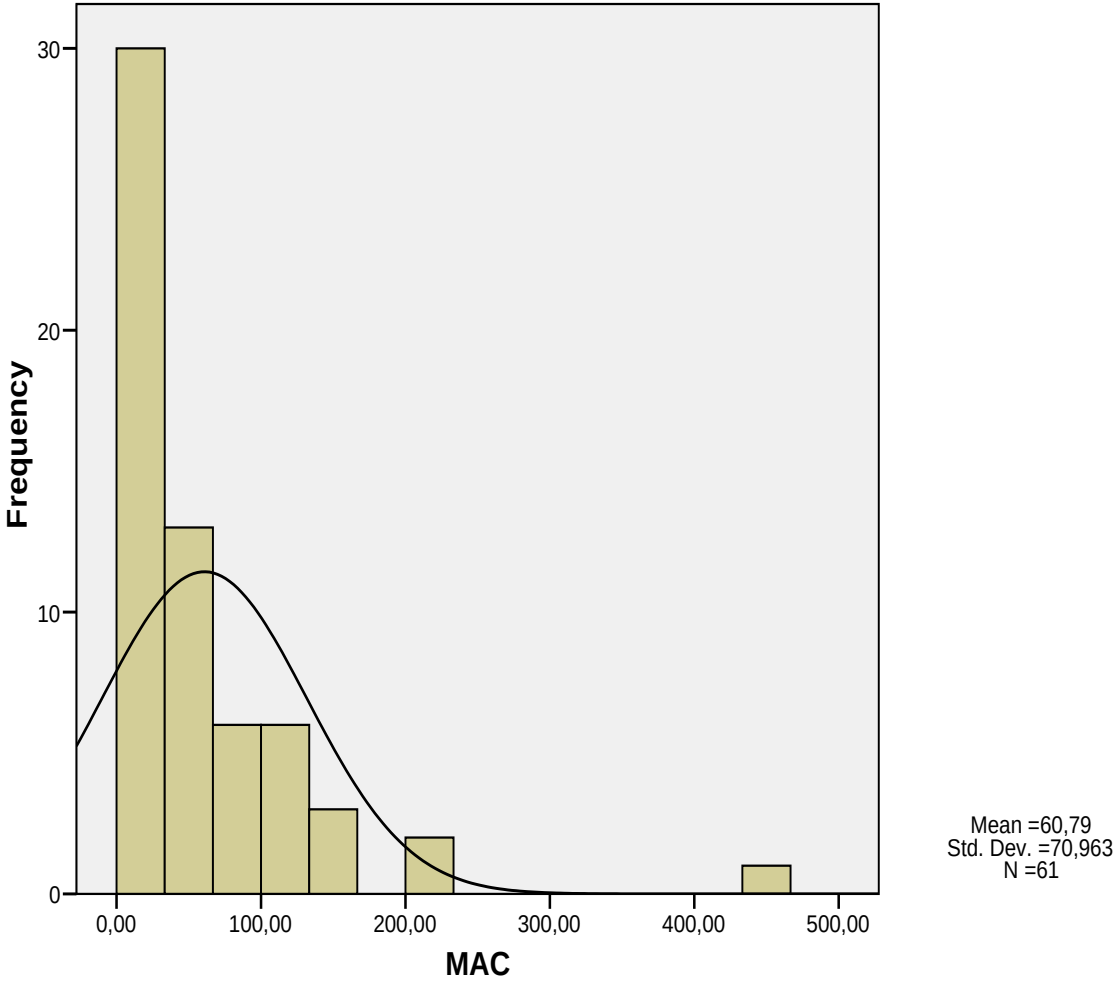
Is carbon market really a market

- Degree of price intervention *(ceilings, floors, safety valves, reserve prices)*
- Allowance allocation *(auctioning, grandfathering, benchmarking)*
- Scope of market *(agri, tran; with/wo US, China...)*

2) MAC

2] Marginal Abatement Costs

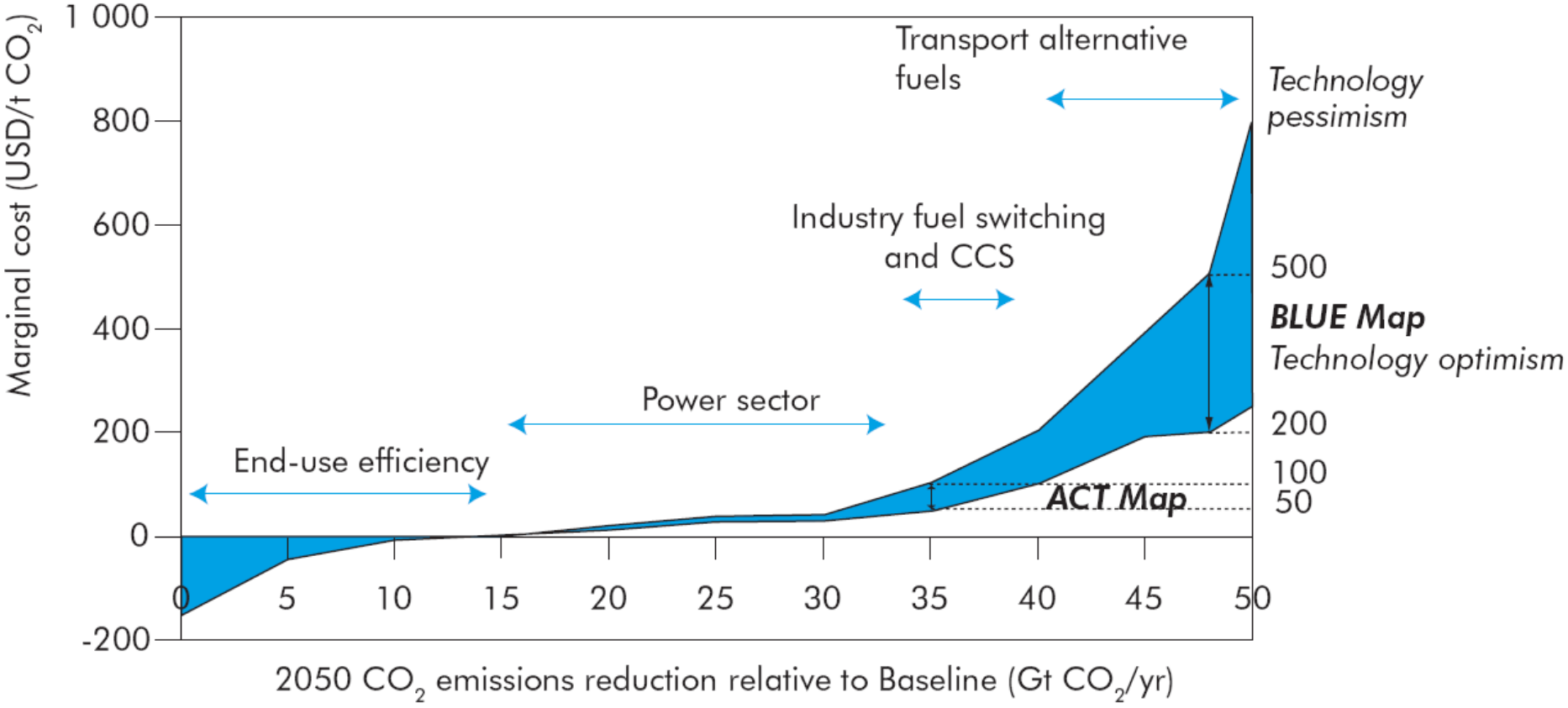
[the costs to mitigate GHG emissions: a review of studies]



Source: Kuik et al, 2008 based on a review within CASES project

2] Marginal Abatement Costs

[a variation across the sectors and measures]



Source: IEA 2008 Report

2] Marginal Abatement Costs

[the stabilization target matters]

The cost of avoiding the impacts of climate change, i.e. the costs of stabilizing GHG concentrations in the atmosphere at certain level

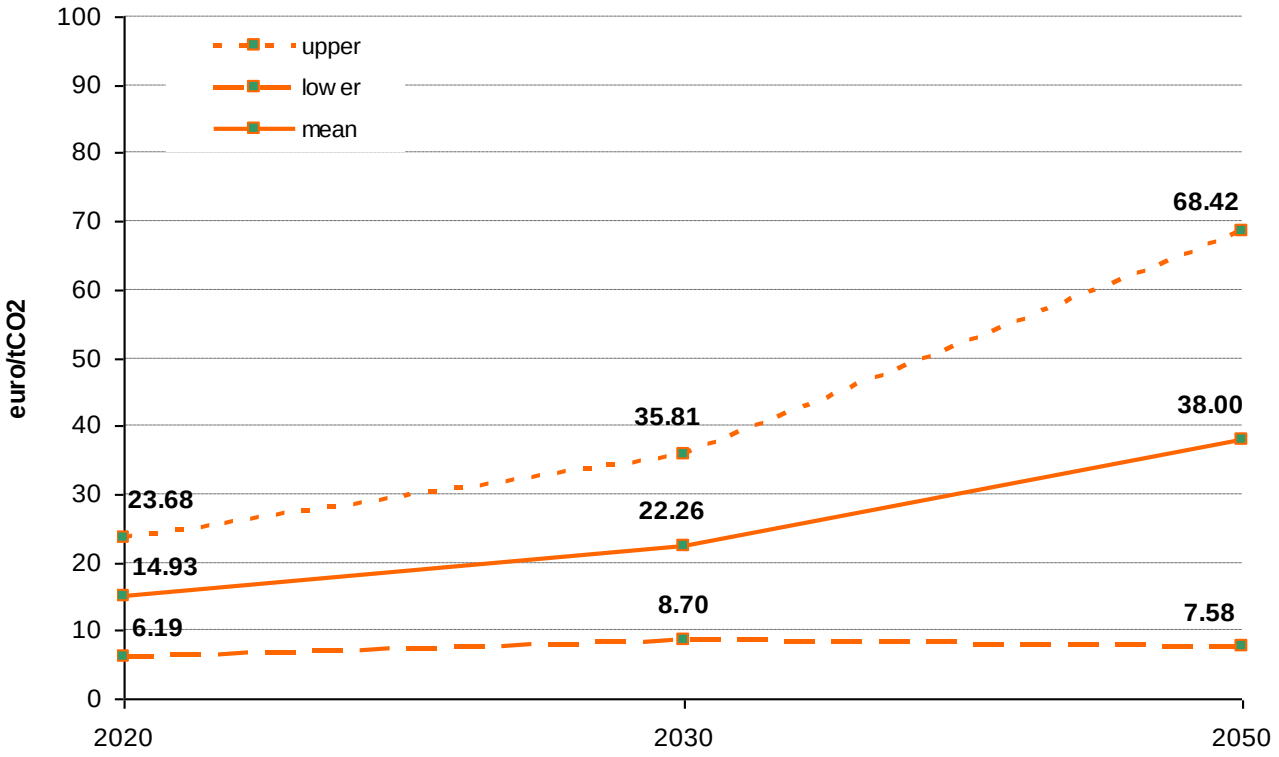
Target		Carbon dioxide
ppm	ºC	$/tCO2
500	2.2	26.0
550	2.4	13.6
650	2.9	5.5
750	3.2	2.8
-	3.7	0

Source: Tol (2004) by IAM NEEDS model

2] Marginal Abatement Costs

[long-term assessment for 550 ppm]

FIGURE 6. CO2 EMISSIONS PRICE: 550 PPM CO2 STABILIZATION



*Source: Carraro and Favere, 2009; see more in CJEF (*Finance a úvěr*) **5**/2009*

2] Marginal Abatement Costs

[long-term for 450 ppm]

FIGURE 6. CO2 EMISSIONS PRICE: 550 PPM CO2 STABILIZATION

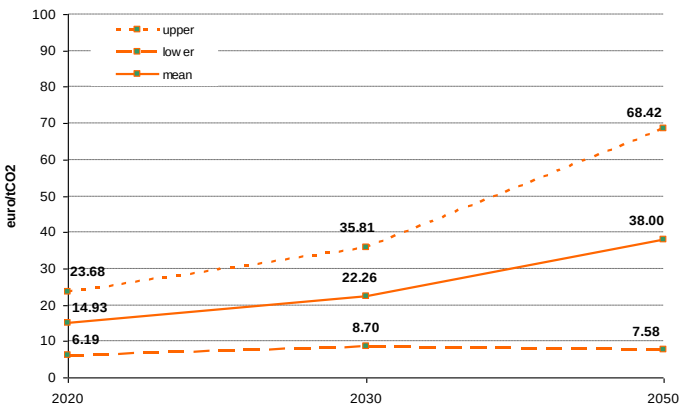
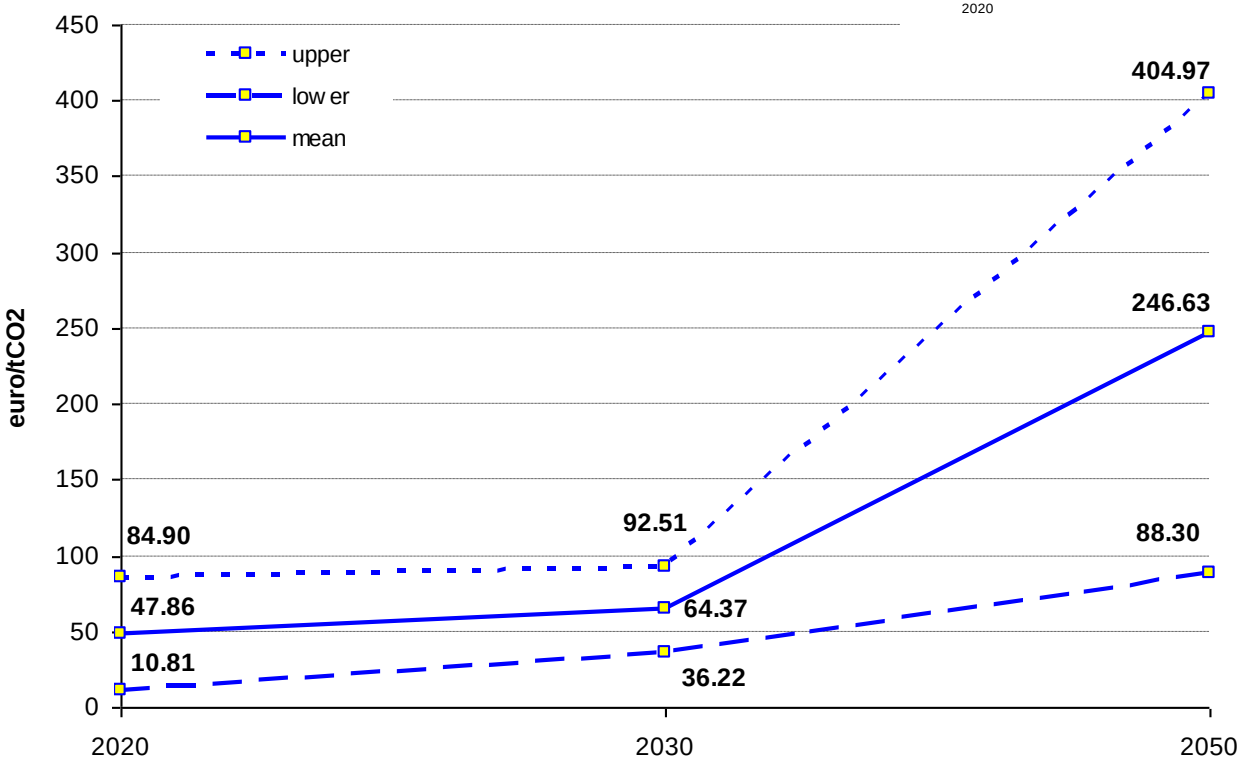


FIGURE 5. CO2 EMISSIONS PRICE: 450 PPM CO2 STABILIZATION



*Source: Carraro and Favere, 2009; see more in CJEF (*Finance a úvěr*) **5**/2009*

2] Marginal Abatement Costs: the latest news !

pricing carbon > economics models for the long-term carbon price evaluations

- A comprehensive review of IAM models: WITCH, FAIR, FUND 2009, EPPA, MERGE, IMACLIM REMIND, E3MG, REMIND-R, RICE-2009, ETSAP, GTEM, IMAGE, MESSAGE, POLES, SGM, G-CUBED, RICE-2010, DART, PACE, GEMINI-E3, ETSAP-TIAM, TIAMEC, TIMES, DEMETER
- See **"International Center for Climate Change"** (http://www.iccgov.org) & bi-monthly report **"International Climate Policy & Carbon Markets"** (http://www.cmcc.it)

€/tCO2	2020	2030	2050	2100
450 ppm				
Mean	43	68	235	1069
(s.d.)	*(29)*	*(43)*	*(169)*	*(843)*
550 ppm				
Mean	23	27	54	162
(s.d.)	*(20)*	*(15)*	*(46)*	*(215)*

Source: ICCG; http://www.iccgov.org/policy-4_economics-models-carbon-priceevaluation.htm
(downloaded September 9th, 2010)

2] Marginal Abatement Costs: Conslusions

Abatement cost estimates vary but can be derived under realistic assumptions

- 20-27 € per t CO_2 *(for the 550 ppm target !)*
- the more strict stabilization target, the higher costs
- higher costs in the long run

Abatement (avoidance) costs are not the same as **damage** or **social costs**

…no **optimum** can be derived

3] SCC

3] Marginal Social Costs of Carbon
[<Cost of Inaction>]

- If we don't act, the overall costs and risk might exceed the benefits generated by the economy
  - The European Council (2004; 2005) requested that the Commission investigate the benefits of climate change mitigation policies, recognising that *„monetised avoided impact benefits, estimated globally, but with a focus also on the European scale, will enable fully informed policy making"*.

- the economic costs of climate change effects> ***'Costs of Inaction'***
  - ***Social Costs of Carbon (SCC)*** *or 'Social Costs of Climate Change'*
    - estimates of the damages associated with emitting an extra ton of C
  - **Total economic damage**
    - estimates of the damages associated with a given level of climate change relative to preindustrial mean temperature

3] Marginal Social Costs of Carbon

[evidence and why the estimates vary?]

- reviews and studies boosted; see some
  - IPCC Reports
  - OECD (2008), Costs of Inaction of Key Environmental Challenges, Paris.
  - EC (2007): Limiting Global Climate Change to 2 degrees Celsius The way ahead for 2020 and beyond COM(2007) 2
  - EEA (2007): Climate Change: the Cost of Inaction and the Cost of Adaptation. EEA Technical report No 13/2007. EEA, Copenhagen, 2007….
- Stern Review, 2006
  - *'costs of inaction'* - loosing at least **5%** of global **GDP**, or **$2.5 trillion** p.a.
  - marginal damage for release of a unit of CO_2: **$85 per t CO_2**
- Other studies report different values of MSC of climate change.
  - RICE-2001: **4.4€** in 2010 that balance C & B (Nordhaus 2005)
  - FUND: **0.5-17$** and the values **decline** over time (Tol 2005; ExternE 2008)

3] Marginal Social Costs of Carbon [how?]

- the marginal damage cost is **the discounted** difference in the two flows of real consumption (or **cost and benefits**) **over long time period**

  → *the difference from two model runs, i.e. with and without additional release of a unit of emission*

  - Damage is **global in scope**
  - Damage can last for **a long time**
  - Damage includes market and **non-market goods and services**
  - Damage may and need not include the impacts from **extreme weather event** and **catastrophes**

3] Marginal Social Costs of Carbon

[SSC values: a review]

€/tCO2		2000	2010	2020	2030	2040	2050	2060
Social Costs of Carbon								
Existing SCC central		23.9	27.3	30.7	34.1	37.5	40.9	44.3
	Mean (1%)	37.8						
	5%	-3.4						
Lit. Rev	95%	187.5						
	Mean (1%)	22.2	25.6	29.0	32.4	33.1	44.0	
	5%	-18.1	-15.7	-15.7	-14.0	-16.0	-13.6	
FUND	95%	105.3	128.9	164.3	156.1	169.8	196.0	
	Mean	15.7	20.8	26.3	34.8	43.3	53.5	63.8
	5%	3.1	4.1	4.8	6.8	9.2	10.2	11.6
PAGE	95%	44.3	54.2	73.3	92.0	110.5	142.5	174.9
Energy White Paper MAC estimates - Year of Emission								
	central				0.0	4.4	82.5	
	Low				31.7	65.8	119.7	
MAC	High				48.8	78.1	183.4	

Source: AEAT 2006

Reasons for variations

1] Incomplete damage functions

Risk Matrix

Uncertainty in Predicting Climate Change ↓		Uncertainty in Valuation → Market	Non Market	(Socially Contingent)
	Projection (e,g, sea level Rise)	Coastal protection Loss of dryland Energy (heating/cooling)	Heat stress Loss of wetland	Regional costs Investment
	Bounded Risks (e.g. droughts, floods, storms)	Agriculture Water Variability (drought, flood, storms)	Ecosystem change Biodiversity Loss of life Secondary social effects	Comparative advantage & market structures
	System change & surprises (e.g. major events)	Above, plus Significant loss of land and resources Non- marginal effects	Higher order social effects Regional collapse Irreversible losses	Regional collapse

Zdroj: Downing and Watkiss (2003); Watkiss et al. (2007)

Reasons for variations

1] Incomplete damage functions

- Expanding coverage of cost categories increases the cost estimates (OECD 2008, p. 90)

Table 3.11. **Estimates of present value of environmental damages**

	% loss in terms of current consumption equivalents due to climate change[1]	5th percentile	95th percentile
Market Impacts	2.1	0.3	5.9
+ Risk of Catastrophe	5.0	0.6	12.3
+ Non-Market Impacts	10.9	2.2	27.4
+ Feedbacks	14.4	2.7	32.6

- Many of them cannot be adequately treated with a continuous and differentiable damage function
  - and occur suddenly and/or bring irreversible changes

Reasons for variations

2] Adaptive behaviour

Types of adaptation

- ***ecological*** *– the effect of changing climatic conditions on the location of* ecosystems and species habitats;
- ***physiological*** *– the effect of exposure to new diseases and pests on resistance* (agricultural crops, human health); or
- ***economic*** *– the effect of investments (such as dikes), output selection (such* as crops) and input choice (such as fertilizers)

Behavior

- **"pure myopic"** – agents do not adjust at all in the face of a changing climate
- **"perfect foresight"** – they anticipate all changes and adjust efficiently

Reasons for variations

3] Equity

There is a variation in the regional impacts of climate change

No weighting

- apply monetary value of the costs, damage and benefits that **concerned people would be ready to pay** (i.e. willing to pay) to get the benefits or to avoid the damage
- For instance, health effects due to climate change would be valued lower in the region with low income than the health effects that would occur in richer region.

Reasons for variations

3] Equity

with weighting

- argument
  - we enjoy additional dollar less than that one we previously spent
  - richer people has smaller utility from additional consumption than poor people

- explicit distribution weight
  - To evaluate importance of incomes/benefits those who will win or lost (OECD CBA Guide by Pearce-Atkinson-Mourato 2006)
  - Diminishing marginal utility of consumption

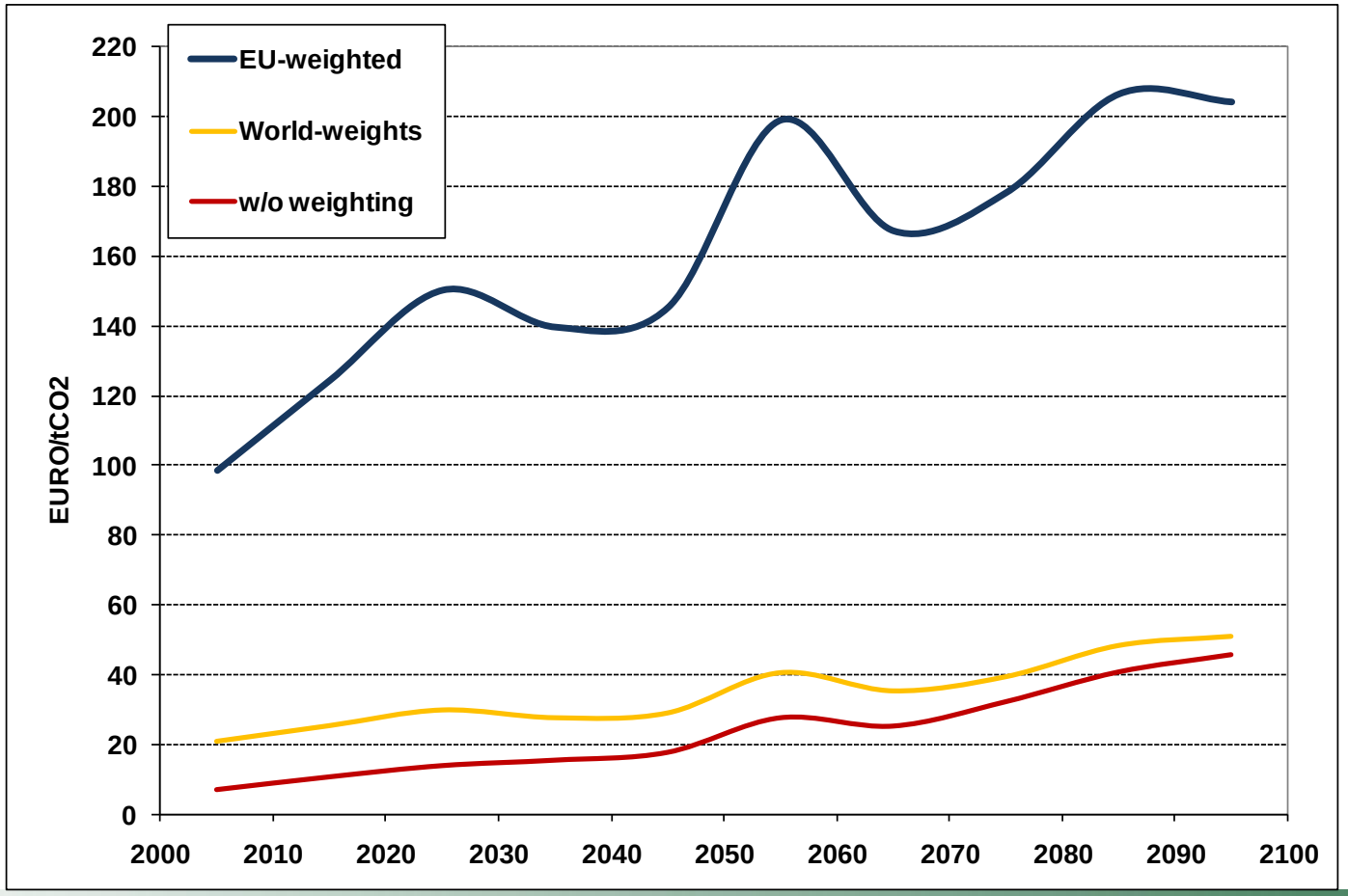
$$w = (Y_N / Y_{ch})^{\varepsilon}$$

Y_N – the reference mean income (e.g. of EU, world)

Y_{ch} – the mean income fo given country ($Y_N/Y_{ch} > 1$ for Nigeria, $Y_N/Y_{ch} < 1$ for Switzerland)

ε – the elasticity of marginal utility wrt (dollar) consumption

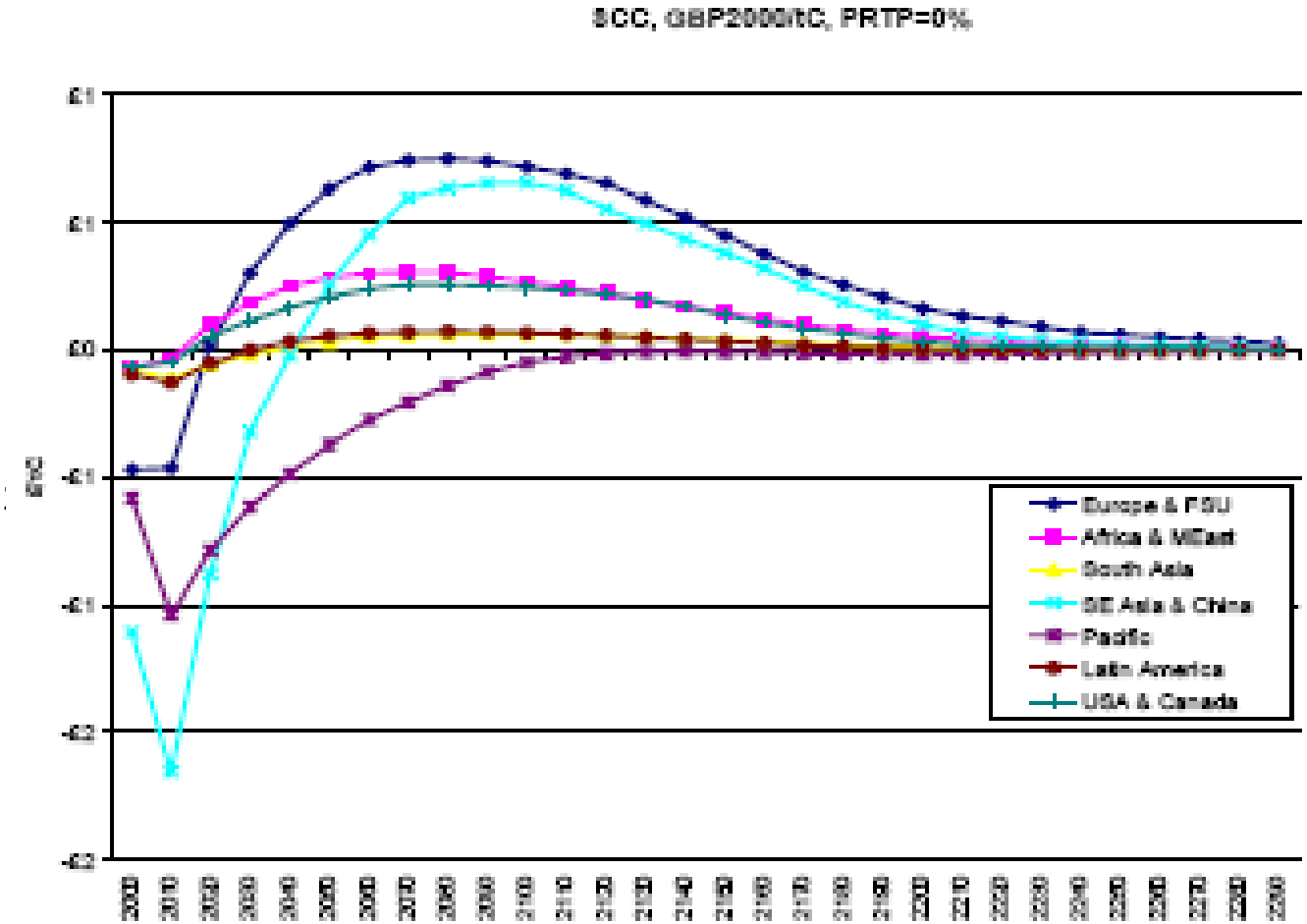
Marginal Social Costs of Carbon [equity weighting]



Source: FUND model by Tol & Anthoff, 2008 in NEEDS and CASES project

Reasons for variations

4] Discounting & intergenerational equity



[discount net damage (shaded area)]

4] Discounting

- Shall we weight values in future same as it would appear now?
- Shall we value increments in consumption going to different people differently?
  - they live at different times
  - they will have different income levels
- Discount rates

$$DR = \frac{1}{(1 + d\%)^t}$$

Discounting of consumption flows

- consumption discount rate (or social discount rate) consists of two parts
  - pure rate of time preference, δ
    - impatience
    - you value the utility future people less than of present people, just because they live in the future rather than the present
  - diminishing returns to consumption
    - the first glass of wine is always the best or I enjoy the fifth less than first
    - one dollar is less important to a rich person than to a poor person

$$sdr_t = \delta + \varepsilon_y \cdot g_t$$

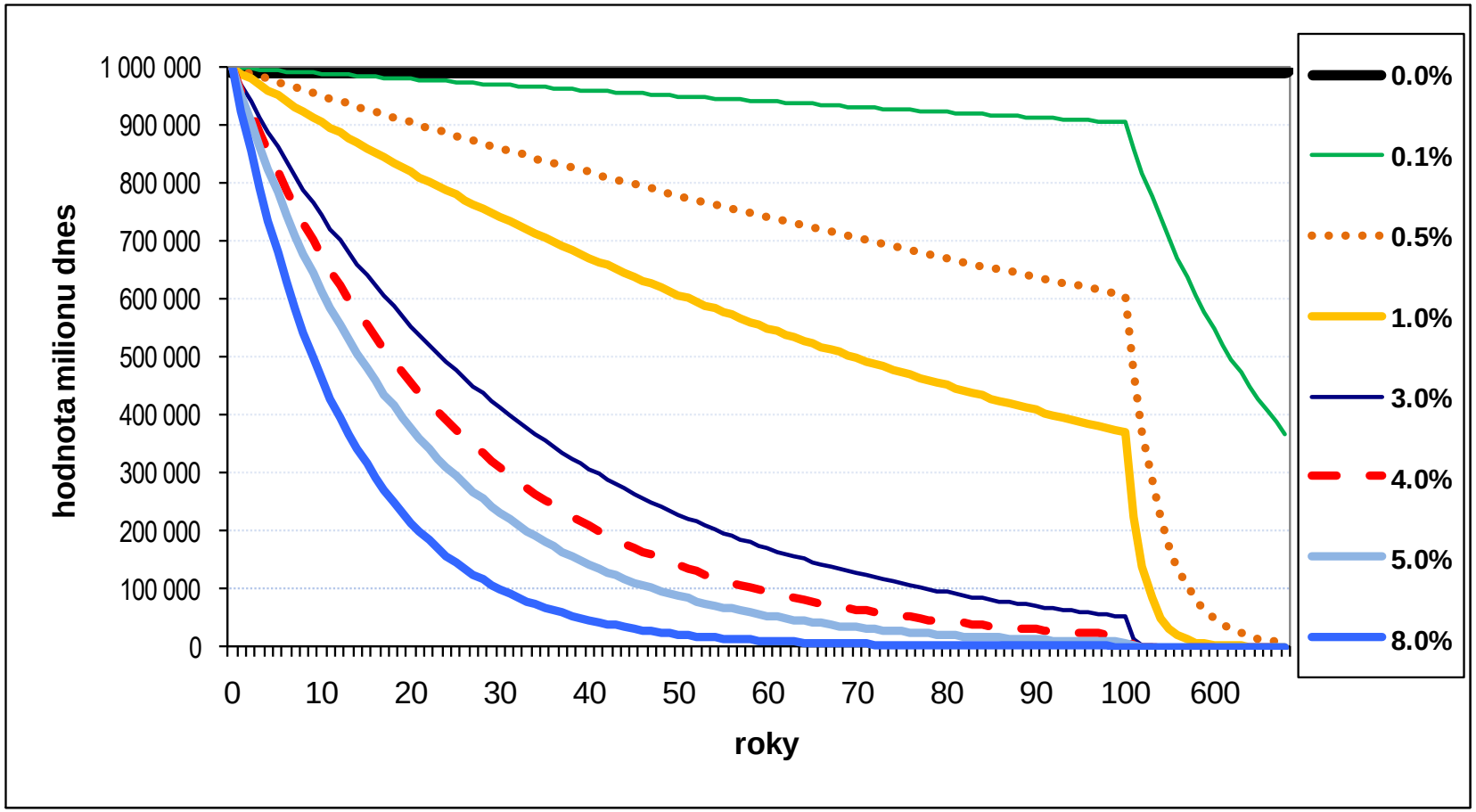
Discounting> pure rate of time preference

Two extremes

- Treat all the same
  - → discount by zero → weight equal to one for any period
  - → 'dictate' of future generations
  - → You should be indifferent between eating fruits now and leaving them for future generations. Is this realistic vision of the world?
- Don't bother about far uncertain future
  - → very large discounts → decreasing weights over time
  - → 'dictate' of current generation
  - → Do we really do not care about grand grandsons at all?

Discounting>

example for damage of 1 million



Discounting

[What is the present value of 10,000 Kč paid x years from now?]

$$weight = \frac{10{,}000}{10000} = 1.0$$

	25	50	75	100	200	300
0.0%	10 000 Kč	10 000 Kč	10 000 Kč	10 000 Kč	10 000 Kč	10 000 Kč
0.5%	8 828 Kč	7 793 Kč	6 879 Kč	6 073 Kč	3 688 Kč	2 240 Kč
1.0%	7 798 Kč	6 080 Kč	4 741 Kč	3 697 Kč	1 367 Kč	505 Kč
1.5%	6 892 Kč	4 750 Kč	3 274 Kč	2 256 Kč	509 Kč	115 Kč
2.0%	6 095 Kč	3 715 Kč	2 265 Kč	1 380 Kč	191 Kč	26 Kč
2.5%	5 394 Kč	2 909 Kč	1 569 Kč	846 Kč	72 Kč	6 Kč
3.0%	4 776 Kč	2 281 Kč	1 089 Kč	520 Kč	27 Kč	1 Kč
3.5%	4 231 Kč	1 791 Kč	758 Kč	321 Kč	10 Kč	0.33 Kč
4.0%	3 751 Kč	1 407 Kč	528 Kč	198 Kč	4 Kč	0.08 Kč
4.5%	3 327 Kč	1 107 Kč	368 Kč	123 Kč	2 Kč	0.02 Kč
5.0%	2 953 Kč	872 Kč	258 Kč	76 Kč	0.58 Kč	0.0044 Kč
6.0%	2 330 Kč	543 Kč	126 Kč	29 Kč	0.09 Kč	0.0003 Kč
7.0%	1 842 Kč	339 Kč	63 Kč	12 Kč	0.01 Kč	0.000015 Kč
8.0%	1 460 Kč	213 Kč	31 Kč	5 Kč	0.0021 Kč	0.000001 Kč
9.0%	1 160 Kč	134 Kč	16 Kč	2 Kč	0.0003 Kč	0.00000006 Kč
10.0%	923 Kč	85 Kč	8 Kč	1 Kč	0.000053 Kč	0.0000000038 Kč

$$weight = \frac{528}{10{,}000} = 0.0528 \approx 5\%$$

Marginal Social Costs of Carbon

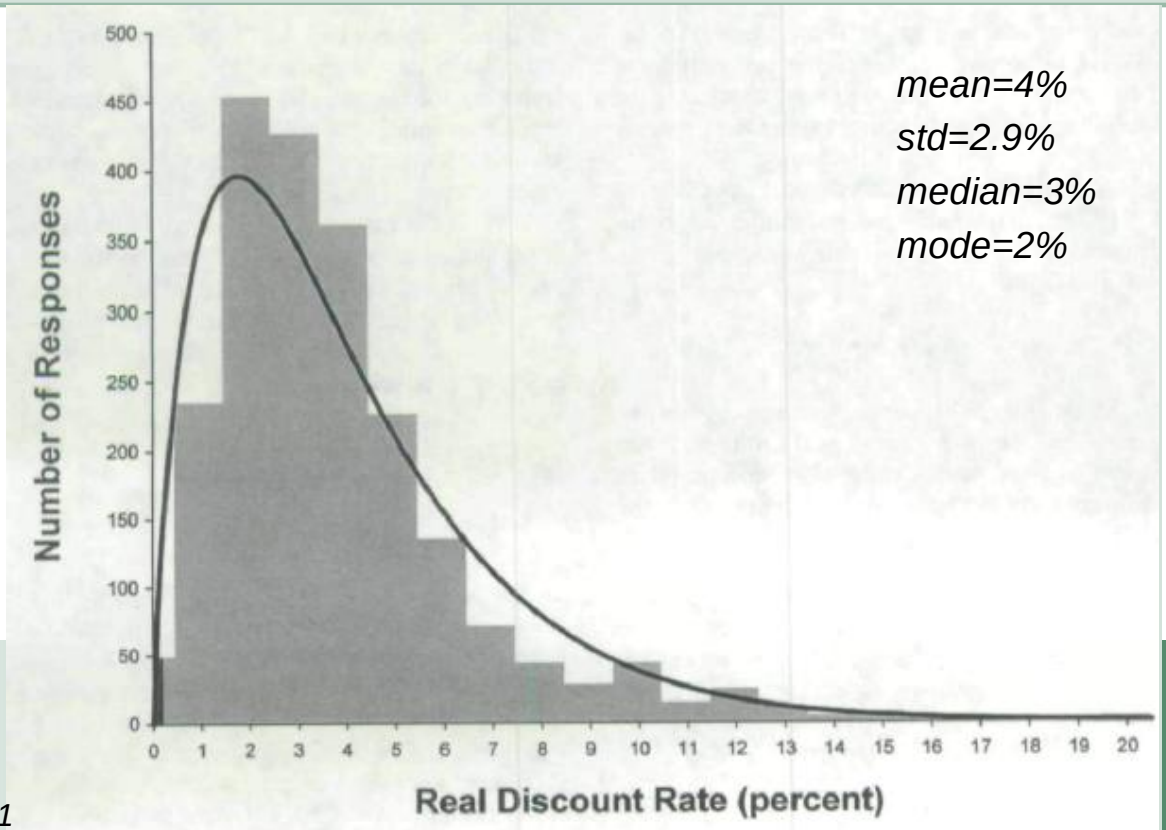
[How much our grand grandsons would need to have in the year t
You would be indifferent between this [future] amount and spending 10,000 Kc just now?]

	25	50	75	100	200	300
0.0%	10 000 Kč	10 000 Kč	10 000 Kč	10 000 Kč	10 000 Kč	10 000 Kč
0.5%	11 328 Kč	12 832 Kč	14 536 Kč	16 467 Kč	27 115 Kč	44 650 Kč
1.0%	12 824 Kč	16 446 Kč	21 091 Kč	27 048 Kč	73 160 Kč	197 885 Kč
1.5%	14 509 Kč	21 052 Kč	30 546 Kč	44 320 Kč	196 430 Kč	870 588 Kč
2.0%	16 406 Kč	26 916 Kč	44 158 Kč	72 446 Kč	524 849 Kč	3 802 345 Kč
2.5%	18 539 Kč	34 371 Kč	63 722 Kč	118 137 Kč	1 395 639 Kč	16 487 683 Kč
3.0%	20 938 Kč	43 839 Kč	91 789 Kč	192 186 Kč	3 693 558 Kč	70 985 135 Kč
3.5%	23 632 Kč	55 849 Kč	131 986 Kč	311 914 Kč	9 729 039 Kč	303 462 435 Kč
4.0%	26 658 Kč	71 067 Kč	189 453 Kč	505 049 Kč	25 507 498 Kč	1 288 254 860 Kč
4.5%	30 054 Kč	90 326 Kč	271 470 Kč	815 885 Kč	66 566 863 Kč	5 431 091 682 Kč
5.0%	33 864 Kč	114 674 Kč	388 327 Kč	1 315 013 Kč	172 925 808 Kč	22 739 961 286 Kč
6.0%	42 919 Kč	184 202 Kč	790 569 Kč	3 393 021 Kč	1 151 259 039 Kč	390 624 590 520 Kč
7.0%	54 274 Kč	294 570 Kč	1 598 760 Kč	8 677 163 Kč	7 529 316 217 Kč	6 533 310 601 448 Kč
8.0%	68 485 Kč	469 016 Kč	3 212 045 Kč	21 997 613 Kč	48 389 495 849 Kč	106 445 338 182 523 Kč
9.0%	86 231 Kč	743 575 Kč	6 411 909 Kč	55 290 408 Kč	305 702 920 777 Kč	1 690 243 919 154 970 Kč
10.0%	108 347 Kč	1 173 909 Kč	12 718 954 Kč	137 806 123 Kč	1 899 052 764 605 Kč	26 170 109 961 884 500 Kč

Discounting> alternative specifications

Martin Weitzman (*Am Econ Rev* 2001) asked 2,800 PhD-level economist (getting over 2,100 responses)

'what real interest rate do you think should be used to discount over time the expected benefits and costs of projects being proposed to mitigate the possible effects of global climate change?'



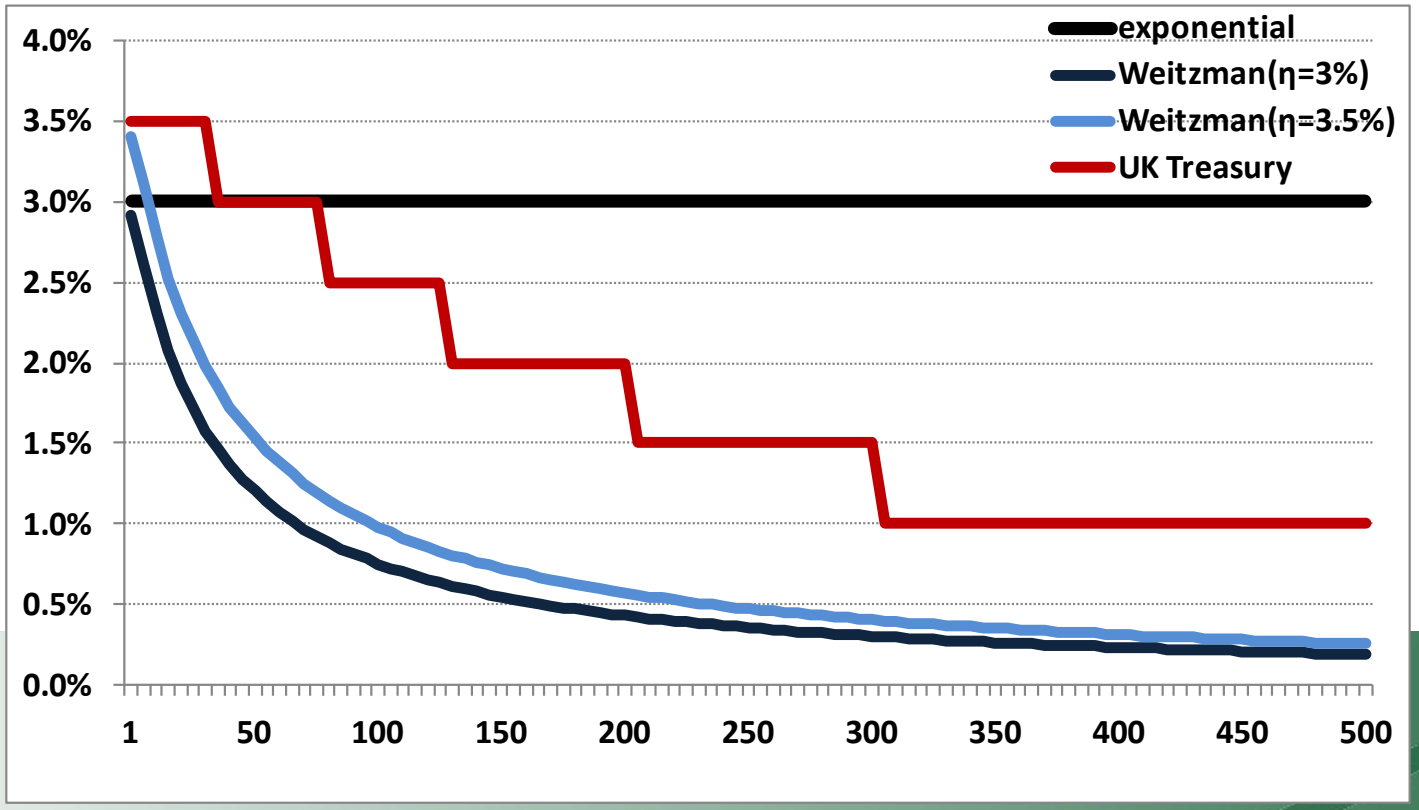
Source: Weitzman 2001

Discounting

[exponential versus hyperbolic discounting]

Exponential discounting assumes one constant discount rate, i.e. the rate is displayed by a linear line

Discounting with **a declining rate over time** *(hyperbolic, gamma, Weitzman)*



Hyperbolic discounting: Examples

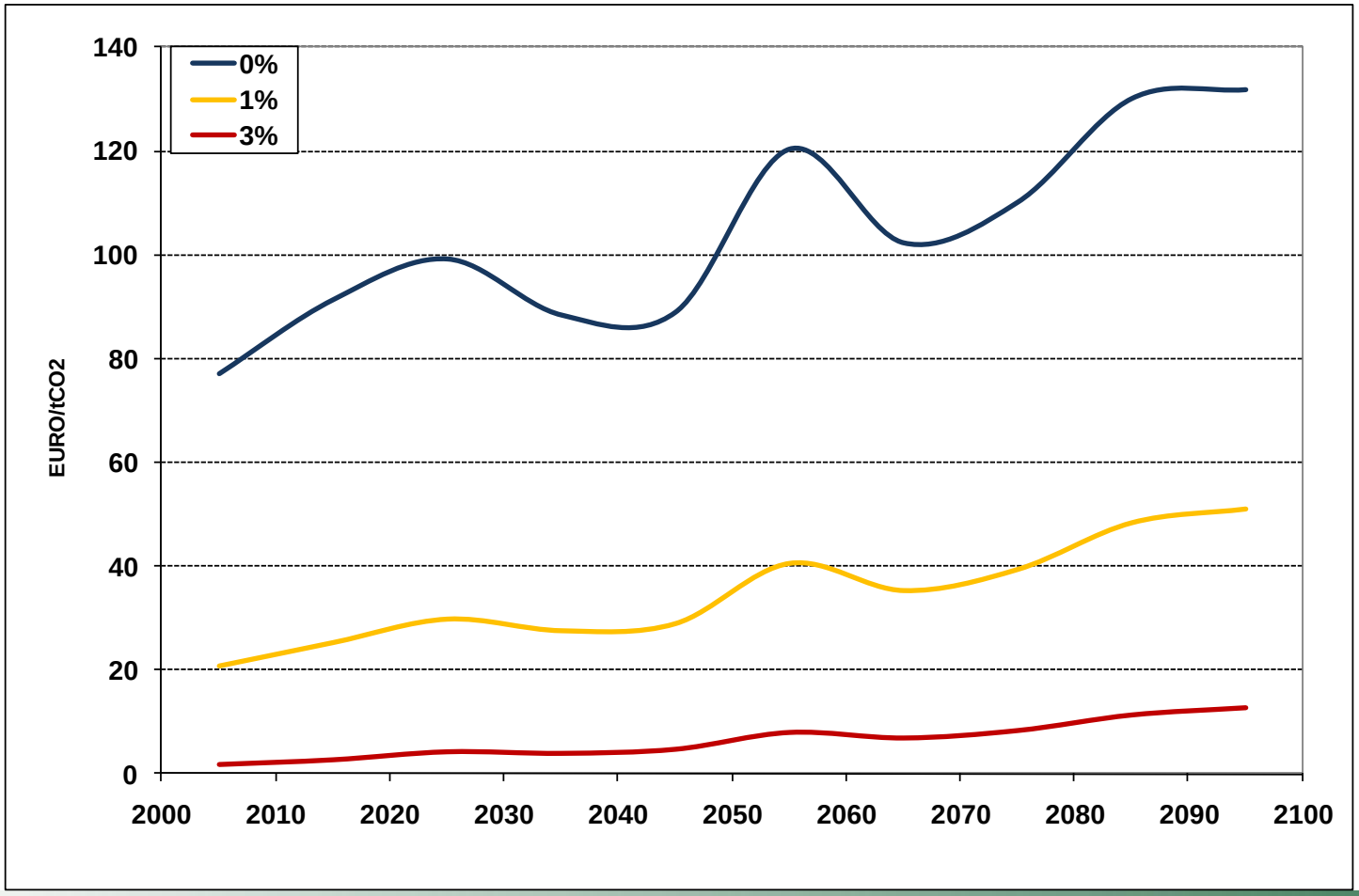
FUND model

- Starts with 3% p.a., which decreasing rates at the level of 1% after 25 years that remain at this level after

UK Greenbook (HM Treasury)

Period of years	0–30	31–75	76–125	126–200	201–300	301+
Discount rate	3.5%	3.0%	2.5%	2.0%	1.5%	1.0%

Marginal Social Costs of Carbon [after discounting with 0%, 1%, 3% p.a.]



Source: FUND model by Tol & Anthoff, 2008 in NEEDS and CASES project

Summary: Cost of Inaction

by IAM FUND model in USD_{2000} per tCO_2

[various discounts, equity weighting, decade of release]

	0%		1%		3%		Weitzman	
Decade	SS	EW	SS	EW	SS	EW	SS	EW
2005	14,8	16,9	**4,1**	5,4	0,4	0,6	5,9	7,0
2015	14,4	15,8	**4,0**	4,8	0,4	0,6	5,8	6,5
2025	13,9	14,8	**3,7**	4,2	0,4	0,5	5,5	6,0
2035	13,4	13,7	**3,3**	3,7	0,4	0,4	5,2	5,5
2045	12,7	12,7	**3,0**	3,2	0,3	0,3	4,9	5,0
2055	12,0	11,7	**2,6**	2,7	0,2	0,2	4,6	4,5
2065	11,2	10,8	**2,3**	2,3	0,2	0,2	4,2	4,1
2075	10,5	9,9	**2,0**	1,9	0,1	0,1	3,9	3,7
2085	9,8	9,1	**1,7**	1,6	0,1	0,1	3,5	3,3
2095	9,1	8,3	**1,5**	1,4	0,1	0,1	3,2	3,0

Marginal Social Costs of Carbon [a review by Tol 2005 [103 estimates]

$/tC ($1995)	Mode	**Mean**	5%	10%	**Median**	90%
Base	1.5	**93**	-10	-2	**14**	165
Author-weights	1.5	129	-11	-2	16	220
Peer-reviewed only	5.0	50	-9	-2	14	125
No equity weights	1.5	90	-8	-2	10	119
Equity weights	-0.5	101	-20	-2	54	250
PRTP=3% only	1.5	16	-6	-2	7	35
PRTP=1% only	4.7	51	-14	-2	33	125
PRTP≤ 0% only	6.9	261	-24	-2	39	755

Source: Toll 2005

Marginal Social Costs of Carbon

Magnitude of Social Costs of Carbon can be derived by Integrated Assessment Models

- positive science
- normative assumptions on key model parameters (e.g. discounting, weighting, marginal utility of consumption etc.)

Types of uncertainties

1) Uncertain outcomes with "known" probabilities

   Expected value by Monte carlo simulations

2) Uncertain outcomes with unknown probabilities

   Expected value only bounded from left by zero

3) Policy variables

   discounting and equity weighting

Readings

Heal, G. (2005), Intertemporal Welfare Economics and the Environment. In: Mäler K G and Vincent J R (ed), Handbook of Environmental Economics, 3, Elsevier B.V., 1105-1145.

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OECD (2008), *Costs of Inaction on Key Environmental Challenges.* OECD, Paris.