Environment Center
Charles University
in Prague

Ancillary benefits of climate change mitigating policies: Are there any benefits from reducing carbon?

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(FEEM) – Econ impact modelling by WITCH model

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The Problem and Motivation

Debate over climate change mitigation $\Rightarrow$

- limited success of policymakers to agree on an international regime for controlling emissions
- only around 12 % of global emissions covered by pricing programs (carbon taxes, emissions trading) at present
- reducing GHG emissions seen as free-rider problem
- individual countries bear the costs of reducing the emissions, when the benefits largely accrue to other countries and far in the future (Ian Parry, iMF, 2014)
- much of the debate narrowed to the direct cost estimates

Air quality benefits

However, the arguments ignores the short-term air quality environmental benefits from reducing GHG emissions $\Rightarrow$

- WHO (2014) estimates that in 2012 around **7 million people died** as a result of air pollution exposure (cited in Lanzi 2014)

- OECD (2014) finds that the total economic costs of deaths from ambient air pollution amount to **1.6 trillion USD** in 2010 in OECD countries (cited in Lanzi 2014)

Background

- Strategies for GHG emission reductions (**GHG mitigating policies**) ⇒ moving away from the use of fossil fuels (e.g. energy sector)
  - **Fuel substitution** ⇒ carbon-free fuels or fuels with low carbon content (e.g. renewables, nuclear energy)
  - **Fuel efficiency improvements** ⇒ cogeneration (CHP), Integrated Gasification Combined Cycle (IGCC)
  - **Carbon capture**
- Climate mitigating policies lead to the reductions of non-GHG emissions
- Air quality improves (**ground-level air pollution:** PM, SO_2, NO_X, O_3, toxic pollutants) in the **short term**
- It brings **ancillary health and environmental benefits** („co-benefits“)
- The resulting reductions in damages to **human health, crops, ecosystems, materials** represent **real economic benefits**

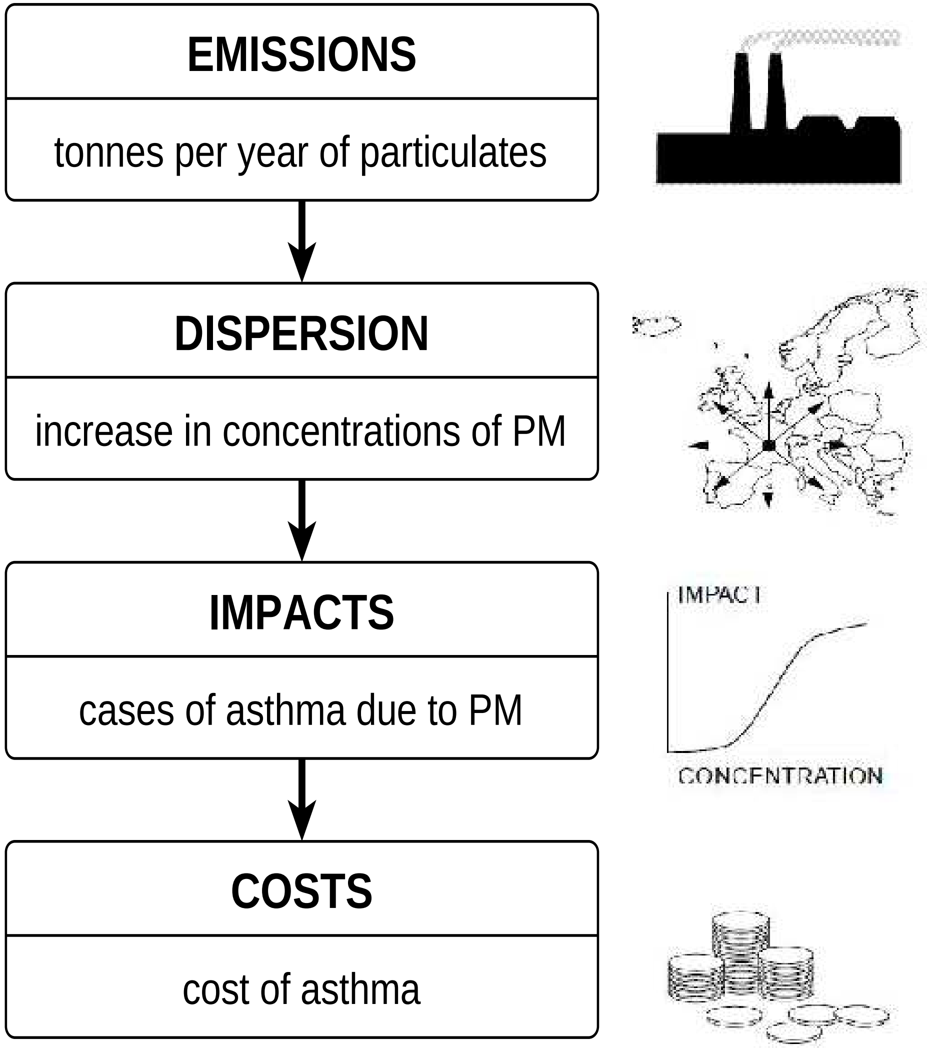
Critical Role of Co-Benefits

- Reducing GHG emissions can have significant complementarities with domestic environmental targets and can induce direct beneficial spillovers to the local economy → "**ancillary benefits**" **of climate change mitigation policies**
- Reducing the use of fossils will also result in **air quality improvements**
- If ancillary benefits can be measured in **monetary terms**, they should be **subtracted from the costs** incurred on mitigation policies in order to assess properly the social effects of such policies (Davis et al., 2000), but not if AQ pollutants are already optimally regulated (Kolstad, 2014)
- Account for these complementarities in global and local policies, in **policy discussions** and **climate change negotiations**

Review on Ancillary Benefit

Study	Country	Scenario (tax €/tC)	Side Effect (€ per tCO2)	Key Pollutants	Major Endpoints
Aunan, Aaheim, Seip, 2000	Hungary	Energy Conservation Program	**160**	TSP, SO2, NOx, CO, VOC, CO2, CH4, N2O, VOC	Health effects; materials damage; vegetation damage
Abt, 1999	US	€35-77	**0.5-0.8**	Criteria pollutants	Health – mortality and illness; Visibility and material soiling
Barker and Rosendahl, 2000	Western Europe	€ 185	**48**	SO2, NOx, PM10	Human and animal health and welfare, materials, buildings and other physical capital, vegetation
Boyd, Krutilla, Viscusi, 1995	US	€ 10	**13**	Pb, PM, SOx, SO4, O3	Health, visibility
Brendemoen & Vennemo, 1994	Norway	€ 967	**77**	SO2, NOx, CO, VOC, CO2, CH4, N2O, PM	Direct: Traffic noise, road maintenance, congestion, accidents Indirect: Health; recreation; corrosion
Burtraw et al., 1999	US	€12-29-58	**0.4-0.6-0.9**	SO2, NOx	Health
Holland et al. 2010	EU	2°C stabilisation scenario at the EU	**24** (€43 bln a year)	PM2.5,PMcoarse, SO2, Nox	ExternE (morbidity, mortality, crop, building, ecosystems)
Kiulia, Markandya, Ščasný, Tsuchimoto, 2013	Czech Rep	full internalisation of external costs	**32 to 72** (€2005)	PM, SO2, NOx	ExternE (morbidity, mortality, crop, building, ecosystems)
Melichar & Ščasný 2014	EU (EU15, EU12)	Full adaptation	**17 to 33 (EU)** 15 to 27 (Old EU) 20 to 44 (New EU)	PM2.5,PMcoarse, SO2, Nox, NMVOC, heavy metals	ExternE (morbidity, mortality, crop, building, ecosystems)
Nemeth et al. 2010	review	NA	**$44** (dev-ed) **$81** (dev-ing)		Health
Parry, Veung, Heine 2014	20 top emitters	NA	**$50** (coal, 8#) **$100** (diesel, 14#)	PM2.5, SO2, NOx	Health (intake fractions extrapolated from the average plant in China)
Scheraga and Leary, 1993	US	€ 166	**13**	TSP, PM10, SOx, NOx, CO, VOC, CO2, Pb	Health – morbidity and mortality
Ščasný & Rečka, 2014	Slovakia	€17, -20%, -25%	**11**	PM2.5,PMcoarse, SO2, NOx	ExternE (morbidity, mortality, crop, building, ecosystems)
West et al. 2013	14 world regions	NA	**$50-380** ($2005)		Health (AQ model)

ExternE –European methodological framework for damage cost assessment



Source: European Commission, 1995

ExternE „Externalities of Energy“ ⇒ developed over 20 years within the EU research projects on monetary valuation of external costs arising from electricity and heat production (www.externe.info)

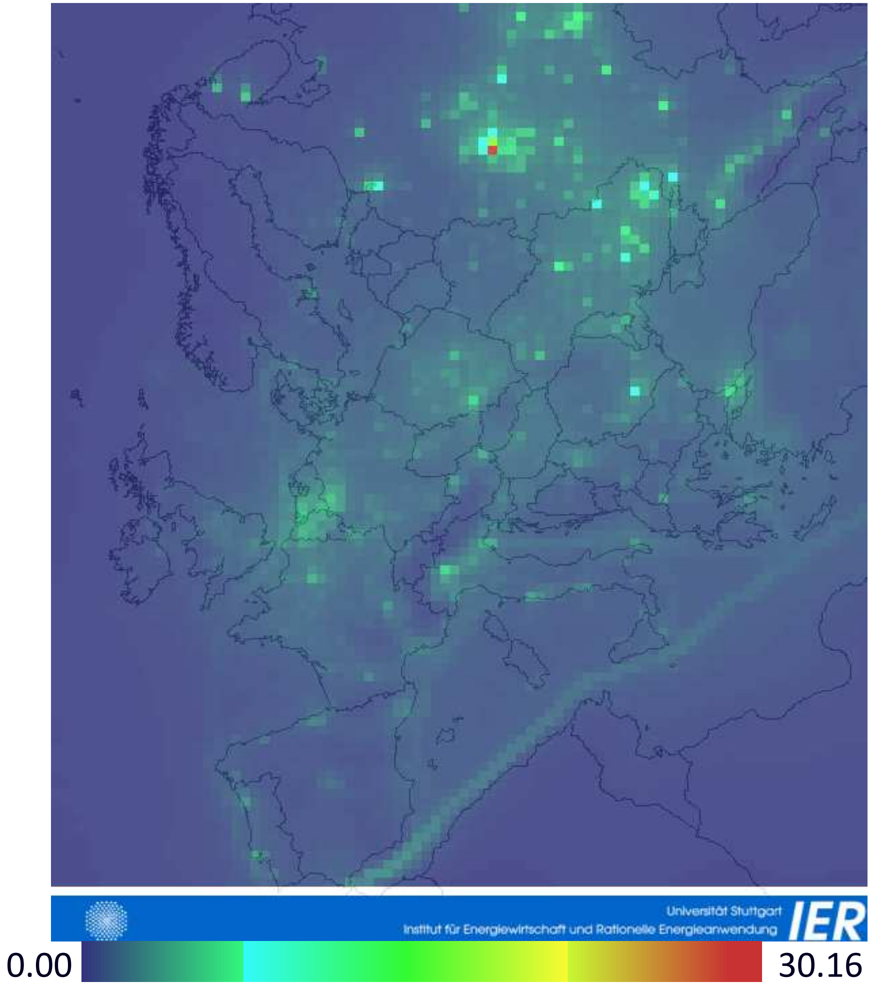
Impact Pathway Analysis ⇒ bottom up approach and it consists of **four steps**:

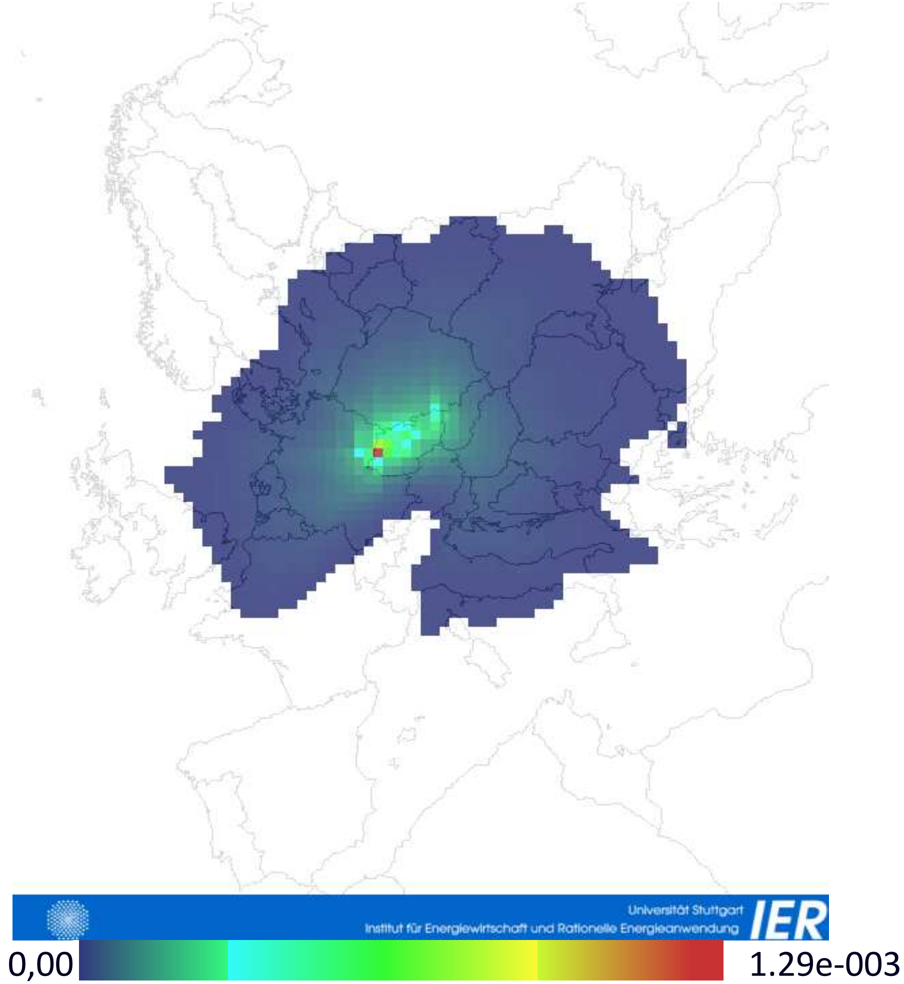
1. **source of pollution**, technological and emission parameters determined
2. calculation of changes in pollutant concentration for all affected regions using an **atmospheric dispersion models**
3. estimation of physical impacts caused by being exposed to a certain pollutant using **dose-response functions**
4. **economic valuation** of impacts following the WTP approach

Atmospheric dispersion of pollutants and calculation ⇒ **EcoSenseWeb 1.3** (local, regional and North-hemispheric module)

Atmospheric modelling in ExternE, an example

Background concentrations (left) and model dispersion (right) of particulate matters PM_{10} in EcoSenseWeb V1.3 (in µg/m³)



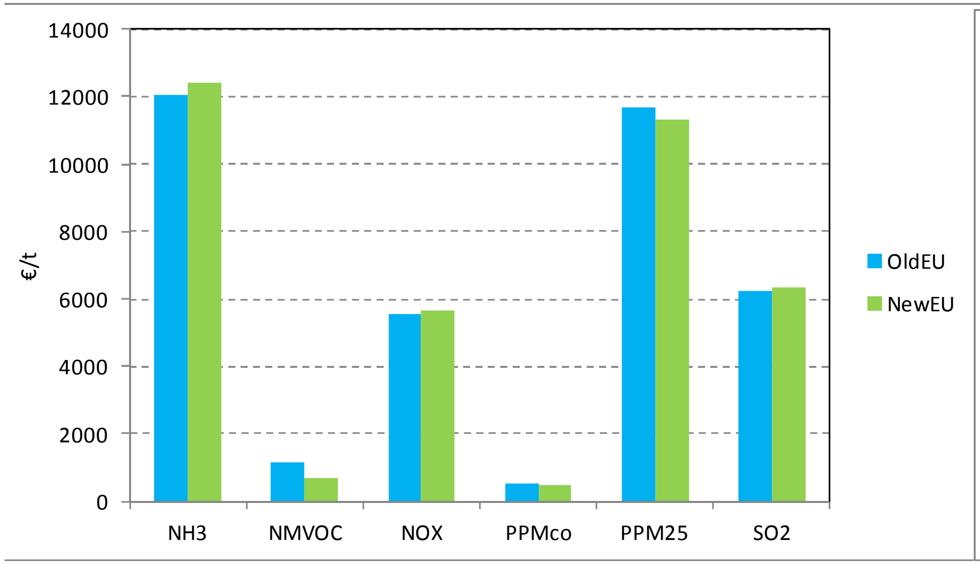


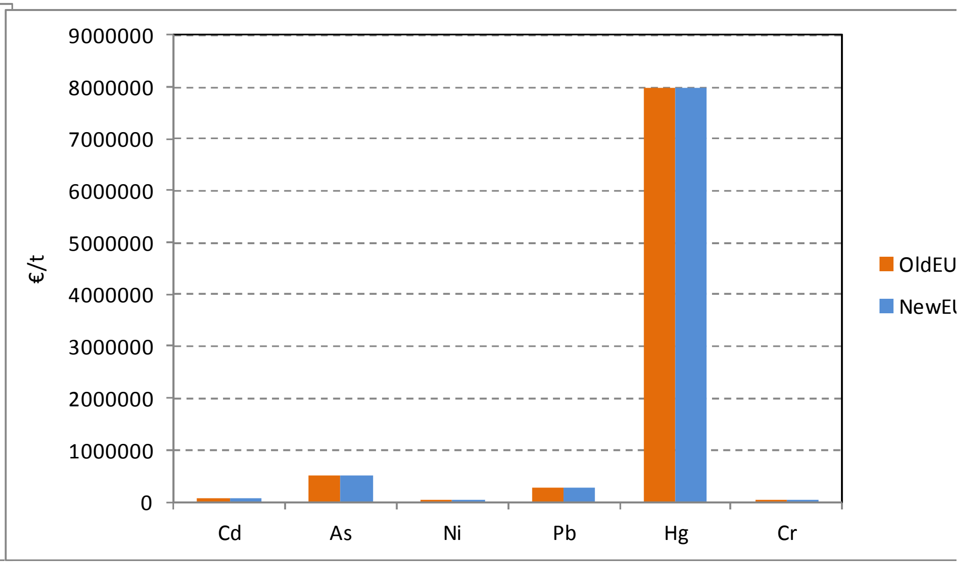
Source: output from the model EcoSenseWeb V1.3 (IER 2012)

External costs for non-GHG emissions
(€2005 per tone of pollutant)

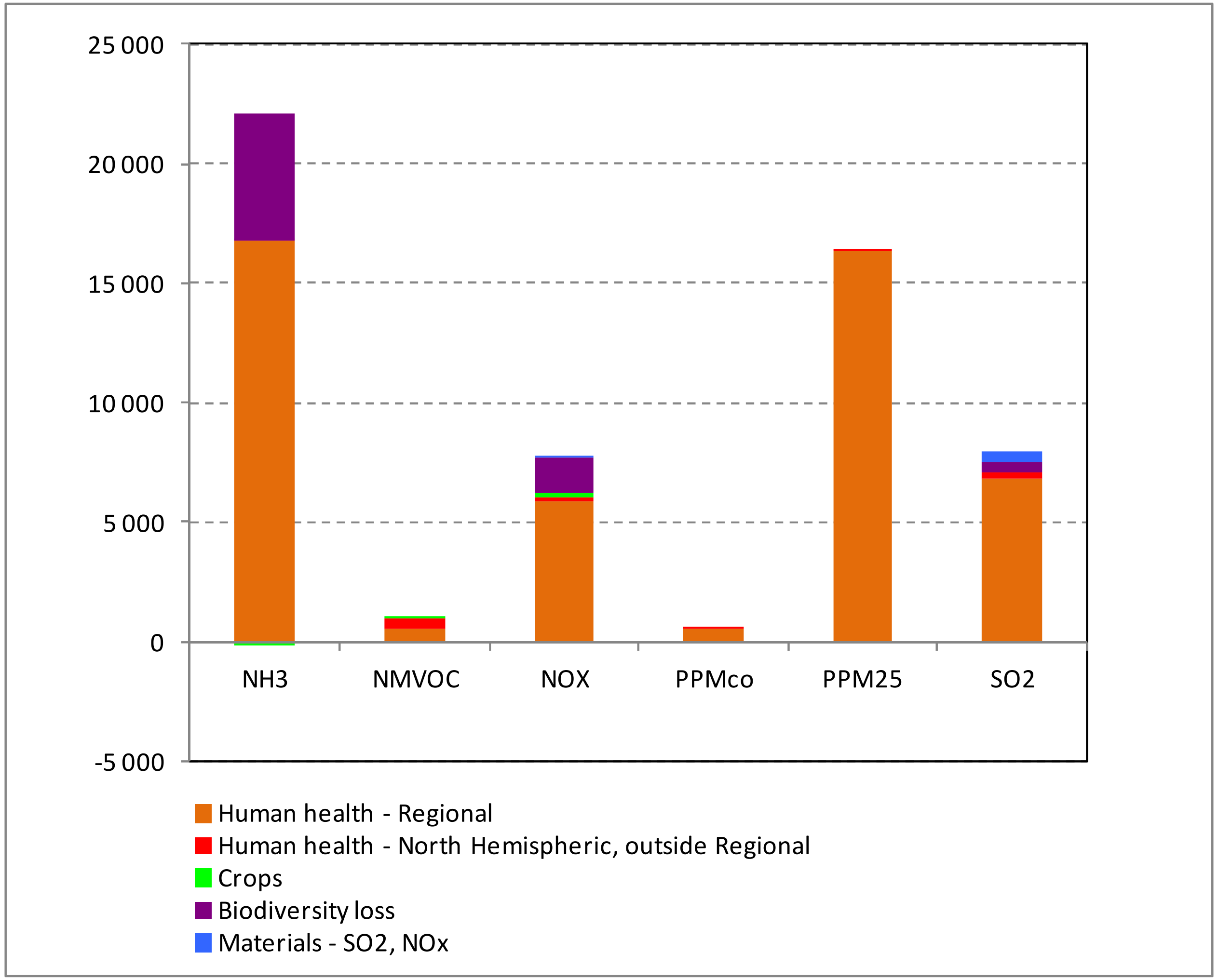
External costs per non-GHG AQ pollutant

- the country-specific estimates generated in the NEEDS projects (http://www.needs-project.org/)
- the damage factors for “old EU” and “new EU” Member States derived as an averages from country-specific damage values





Covered impacts in the external cost estimates
(EU average, €2005 /t)



The external cost estimates covers mainly the following impacts:

- on **human health** (increased morbidity, reduction in life expectancy)
- on **agricultural production**
- damage to building **materials**
- loss of **biodiversity**
- effect of **heavy metals** on human health

Modelling framework:
Soft-linking of externality assessment and macro modeling

- Soft-linkage procedure based on estimated damage factors per pollutant considered
  - **primary energy production** as an endogenous output in a macro model (WITCH - World Induced Technical Change Hybrid model)
  - **emission-fuel factors** for each fossil fuel derived from the EMEP/EEA air pollutant emission inventory guidebook EMEP/EEA (2013)
  - **emissions** of air quality pollutants (SO_X, NO_X, PM_{10}, $PM_{2.5}$, NMVOC) and heavy metals (Pb, Cd, Hg, As, Cr, Ni) calculated from fuel use and the EF coefficients
  - **damage costs per pollutant** $\Rightarrow$ damage factors per pollutant from the ExternE project NEEDS
- Ancillary benefit measures for each selected Global-IQ scenario computed as **avoided external costs** from the baseline scenario SSP-2.0
- Assumptions in **discount rate** $\Rightarrow$ we suppose that the pure rate of time preference and elasticity of the marginal utility of consumption take value about 1 and the growth rate takes 2%

Two different ancillary benefit measures

- We computed two ancillary benefit measures, **reduced total damage cost** and **reduced damage cost per reduced tone of CO_2**

Ancillary benefit measure	Definition	Description
Reduced total damage cost	ΔADC	Annual reduced damage costs (Euro)
Reduced damage cost per reduced CO_2	$\Delta ADC/\Delta CO_2$	Reduced annual damage costs per reduced tone of CO_2 emissions (Euro/tone reduced CO_2)

Note: All damage costs refer to changes in the emissions from non-GHGs, and do thus not incorporate the economic effects of GHG emissions.
Source: Riekkola et al. (2011)

Reduced total (discounted) damage costs:

$$\Delta DC = \sum_{t}^{n} \sum_{p}^{P} \frac{\Delta E_{pt} \times EC_p \times \left(1 + g_t \bullet e_{wtp}\right)^t}{\left(1 + sdr_t\right)^t}$$

ΔDC is change in total discounted damage costs (in Euro) from the baseline scenario,

$\boldsymbol{\Delta E_p}$ is net change in the emissions of pollutant *p* (*p* = 1,…,*P*) in time t *(t = 1, …,n*)

$\mathbf{EC_p}$ represents external costs per tone of pollutant (Euro per tone of pollutant p)

sdr is a social discount rate expressed as $sdr = \rho + g \cdot \mu$ where ρ is pure rate of time preference (1%), g is growth rate and μ is elasticity of the marginal utility of consumption, e_{wtp} is income elasticity of WTP values. Assuming ρ=1%, g=2%, μ=1.0, implying sdr=3%, and e_{wtp} =1.

WITCH Model and GLOBAL-IQ scenarios

- **WITCH model** ⇒ top-down integrated assessment model (www.witchmodel.org)
  - **W**orld **I**nduced **T**echnical **C**hange **H**ybrid model) developed by FEEM
  - inter-temporal optimal growth model and bottom-up like description of the energy sector (8 technologies – coal, oil, gas, biomass, nuclear, hydro, solar, wind)
  - world countries grouped in 12 regions, inlc. **EU OLD** (EU15+EEA) and **EU NEW** (EU12)
  - climate module and a damage function provide the feedback from GHGs to the economy
- **Baseline scenario** (SSP2) ⇒ a middle-of-the-road scenario
  - **Shared Socio-economic Pathway central scenario** built on the assumption of continuation of all major trends that we observe today
  - projects current trends into the future, without major changes in economic growth, use and availability of resources, technological trends, population growth, economic and envi policies
- **Climate change mitigation policy scenarios** ⇒ represent the challenges of reaching three long term radiative forcing target corresponding to 3 different representative concentration pathways (RCPs):
  - **RCP2.6** – radiative forcing is declining to 2.6 W/m^2 by 2100, correspond to ***490 ppm CO_2-eq***
  - **RCP4.5** - radiative forcing is 4.5 W/m^2 post 2100 (***650 ppm CO_2-eq***)
  - **RCP6.0** - radiative forcing is 6 W/m^2 post 2100 (***850 ppm CO_2-eq***)
- Results presented here are for **electricity generation from fossil fuels in Europe** for SSP-2.0 and **climate change mitigation scenarios with full adaptation** as simulated by WITCH model for **2005-2100**.

Economic impacts – mitigation scenarios with full adaptation, based on WITCH model
(any details in the GLOBAL-IQ reports)

	2020	2030	2040	2050	2060	2070	2080	2090	2100
Price of CO2, US$2005									
CM-RCP-6.0	3	4	5	6	7	8	10	12	14
CM-RCP-4.5	16	24	35	53	77	113	164	236	335
CM-RCP-2.6	153	232	347	519	780	1170	1738	2534	3513
GDP EU, (wrt RCP-6.0)									
CM-RCP-4.5	-0.05%	-0.10%	-0.14%	-0.22%	-0.41%	-0.62%	-0.49%	-0.62%	-0.89%
CM-RCP-2.6	-1.26%	-1.92%	-2.63%	-3.19%	-3.72%	-4.24%	-4.88%	-5.88%	-7.13%

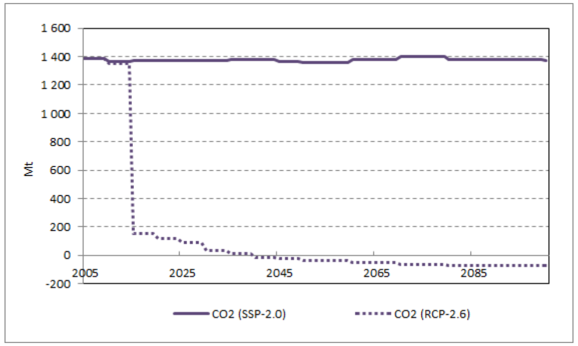
Total volume of emissions based on WITCH simulations,
Europe, SSP-2.0 and RCPs scenarios, (2005-2100)

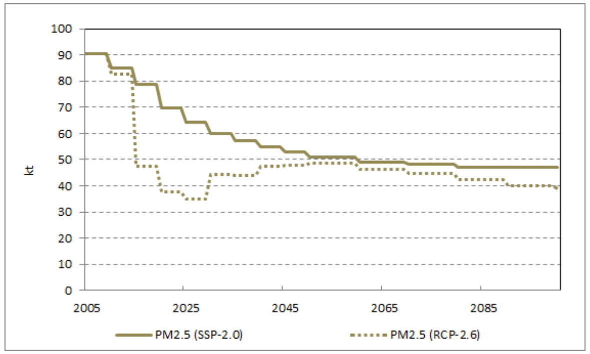
	NOx	SOx	PM2.5	CO2	Δ NOx	Δ SOx	Δ PM2.5	Δ CO2
	Mt	*Mt*	*kt*	*Mt*	*Mt*	*Mt*	*kt*	*Mt*
Reference scenario								
SSP2	270	836	5 535	132 147				
Climate mitigation scenario								
RCP-2.6	95	257	4 645	12 537	-175	-579	-890	-119 611
RCP-4.5	181	545	5 055	58 170	-89	-291	-480	-73 978
RCP-6.0	236	738	5 386	115 512	-34	-98	-149	-16 635

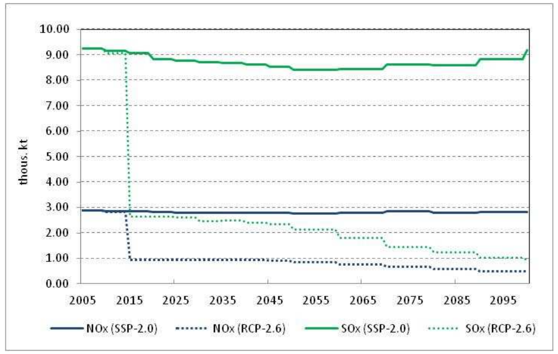
The last column gives the amount of avoided CO2 emissions if RCP-scenario was implemented.

	CO_2	$PM_{2.5}$	SO_2 & NOx

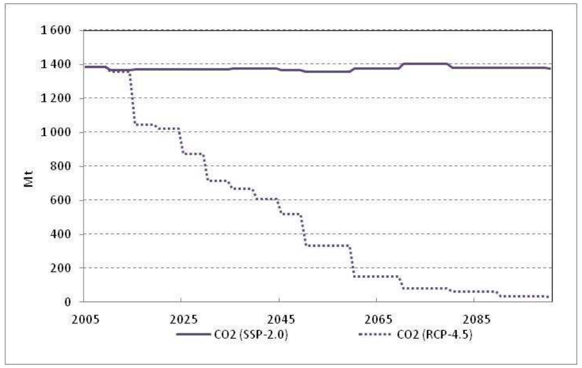
RCP-2.6
(490ppm)

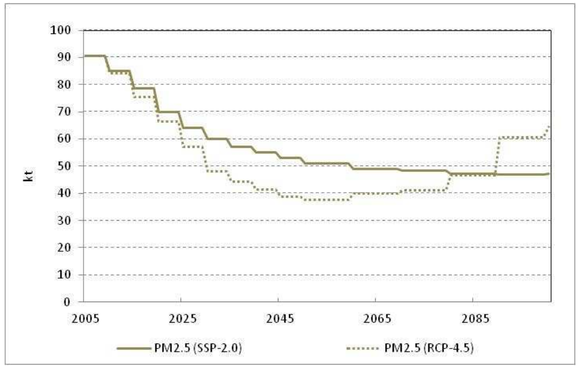


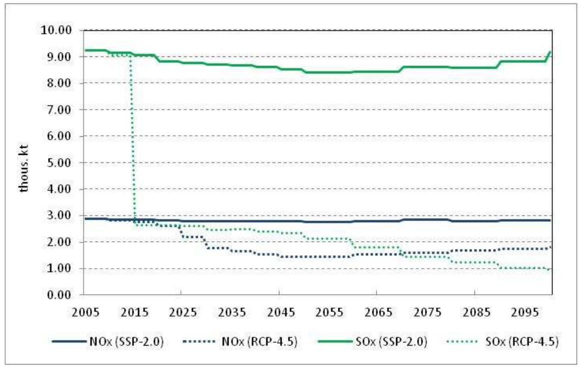




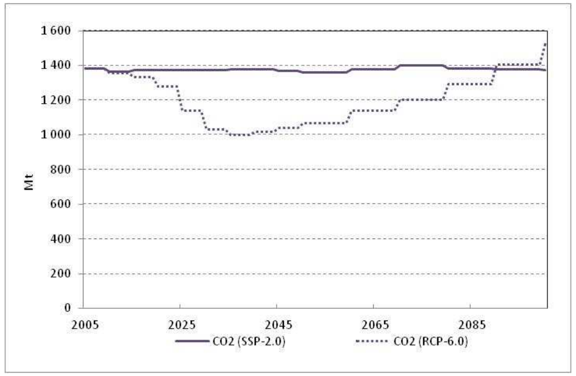
RCP-4.5
(650ppm)

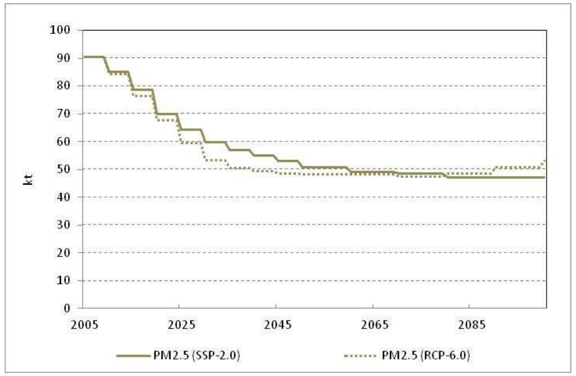


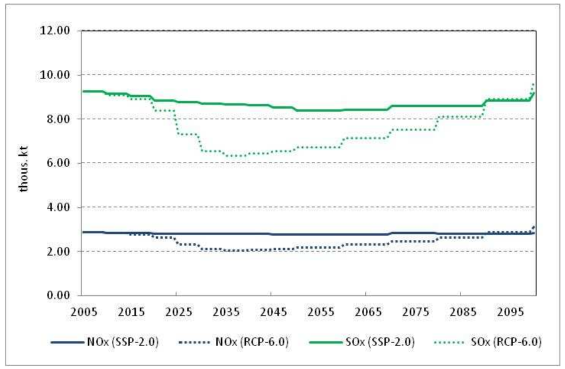




RCP-6.0
(850ppm)







Note: based on WITCH simulations for Europe (2005-2100)

Cumulative damage costs, bln. Euro, fuel type

(WITCH simulations for Europe for 2005-2100, SSP-2.0 and Global-IQ RCP)

bln. €	**Coal**	**Gas**	**Oil**	**Biomass**	**Total**	**% change**
Reference scenario						
SSP2-EU	4 141	213	193	104	**4 650**	
Climate mitigation scenario						
RCP-2.6-EU	1 088	110	128	411	**1 736**	*-63%*
RCP-4.5-EU	2 682	155	243	163	**3 243**	*-30%*
RCP-6.0-EU	3 576	178	242	104	**4 100**	*-12%*

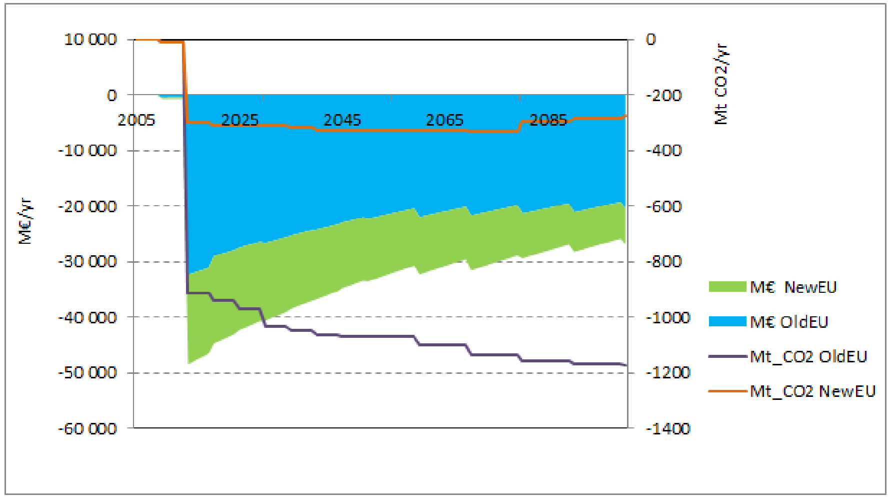
Note: all values are presented for the year of 2005.

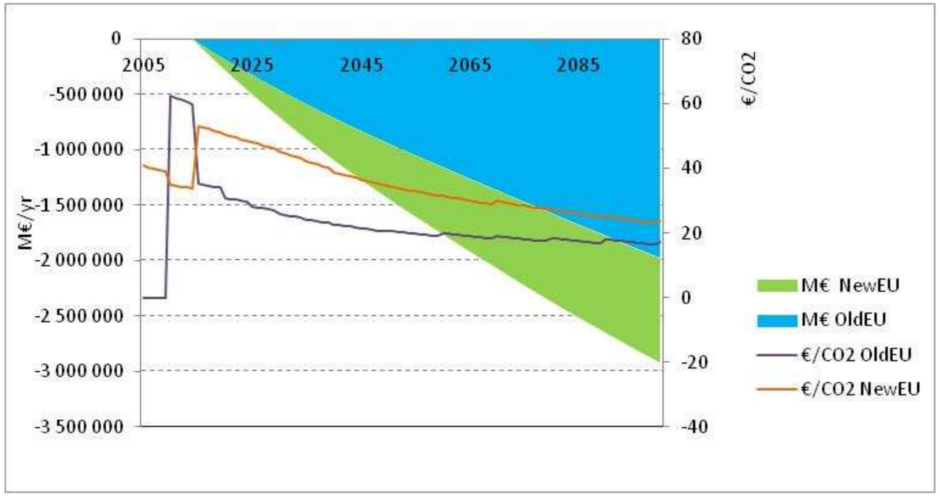
annual ancillary benefits (M€/yr)
annual CO_2 reductions (Mt CO_2/yr)

cumulative ancillary benefits (M€/yr)
benefits per CO_2 abated (€/tCO_2)

RCP-2.6

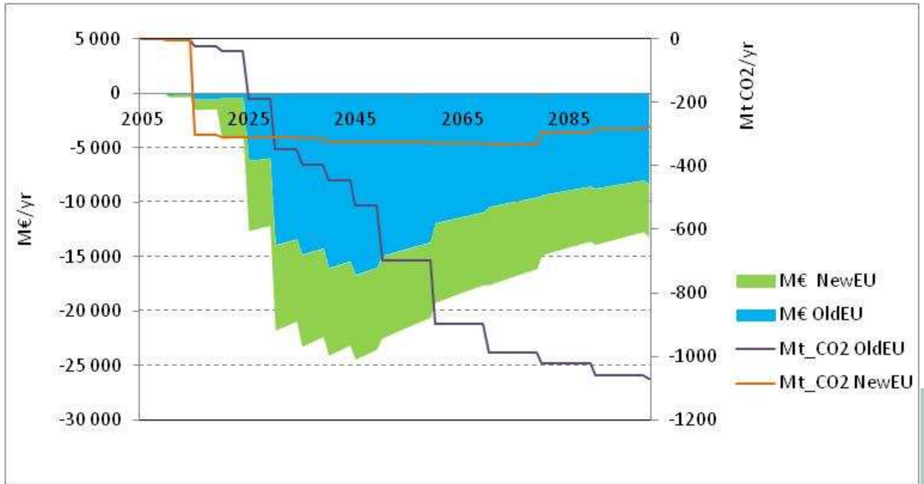
(490ppm)

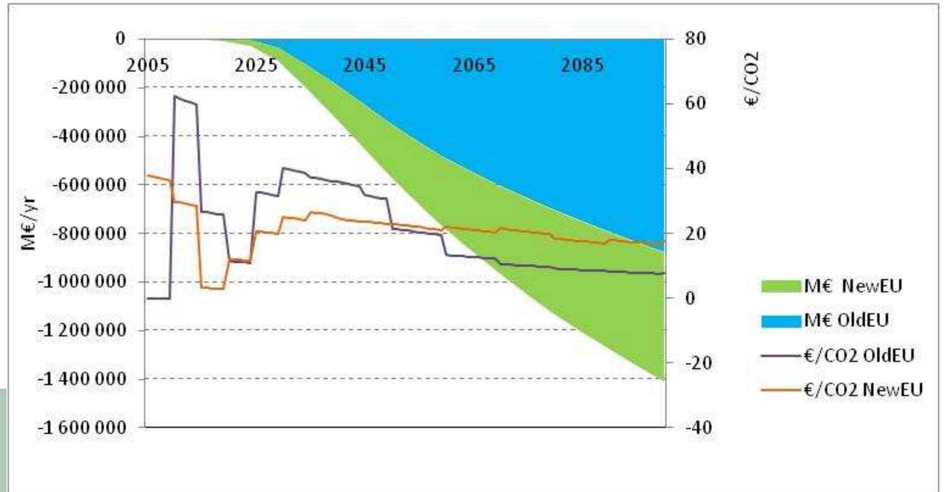




RCP-4.5

(650ppm)





Ancillary benefits, Euro per t CO_2 avoided

(WITCH simulations for Europe for 2005-2100, SSP-2.0 and RCP GIQ scenarios)

	RCP-2.6	RCP-4.5	RCP-6.0
EU Old	21.3	15.3	27.3
EU New	34.8	19.6	44.1
EU	24.4	16.6	33.1

for EU	RCP-2.6	RCP-4.5	RCP-6.0
2011-2030	35	17	41
2031-2050	27	30	37
2050-2100	21	13	27

Conclusions

- There is a compelling evidence that **ancillary health and environmental benefits from improved air quality are substantial**
- A broader extent of the impacts can be included by using **a bottom-up impact pathway approach**, as developed within the ExternE project series $\Rightarrow$ besides health benefits, also other environmental effects (crops, ecosystems, materials and toxic pollutants) are quantified
- Significant ancillary benefits accompany climate change mitigating policies - there are at least **20€ per t CO_2 abated**. Their magnitude depends on current fuel- and technology mix, receptor (population) density, and stringency of mitigation policy
- The estimates of ancillary benefits likely **underestimate the benefits** due to yet not quantified benefits $\Rightarrow$ only a subset of the health and environmental consequences from air pollution have been quantified or monetized so far

Thank for your attention and comments

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CECILIA 2050
OPTIMAL EU CLIMATE POLICY

EUROPEAN COMMISSION
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SEVENTH FRAMEWORK PROGRAMME