The Role of Black Carbon and Methane Emissions Reductions: A Development Perspective

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(presented and commented by
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Three GHG pollutants..

- CO_2
  - Long lifetime
  - Regarded as non-reactive in the atmosphere
  - At existing and projected concentrations, the only effect is via climate change
- Black carbon
  - Contributes to climate forcing
  - Causes cardiovascular and respiratory problems
- Methane
  - Higher GWP, shorter life
  - Tropospheric ozone precursor
  - Effects via
    - Climate change
    - Ozone
      - Mortality and morbidity
      - Effects on crops and forests (which in turn affect CO_2 uptake)

Figuring out the damages from climate change

- Make a list of **the physical effects** (rising sea level, coastline erosion or loss, impact on agricultural production, health effects, etc.)
  - These physical effects are numerous and diverse
  - In most case adverse, in some cases favorable
- Attach **a $ value** to them to ease comparison and assess their seriousness

What is the value of something?

- In general, the money I am prepared to give up to get it
  - Can be inferred from the price of the good
  - Many goods (health risks, natural resources, amenities) are not bought and sold on regular markets, and we must figure out other ways to infer their values

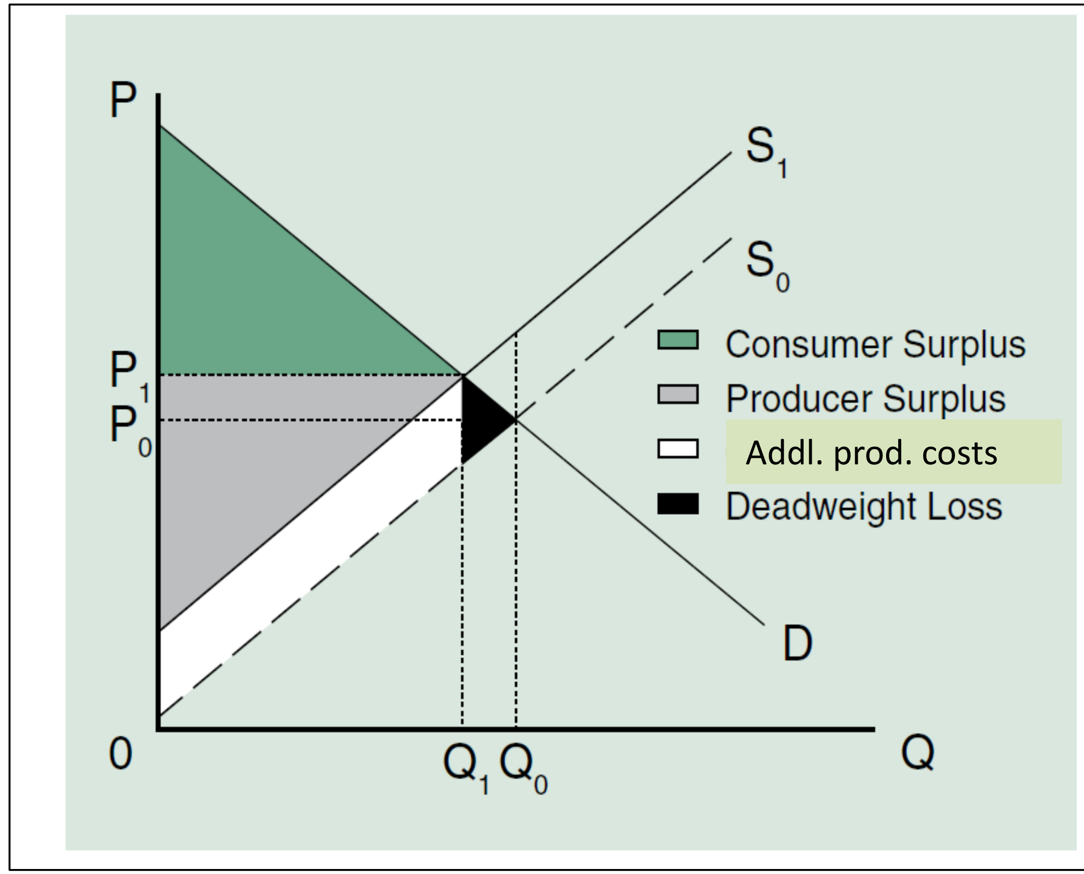
Valuation

- Market methods
  - Applied when the affected things are bought and sold in regular markets (e.g., agricultural commodities, food)
  - Based on **market data** and **observed transactions**

- Non-market methods
  - Used for things or effects not traded in regular markets, such as
    - air quality
    - other types of pollution
    - amenities (pretty views) or disamenities (proximity to a landfill, crime)
    - health risks
    - endangered species, habitat
    - natural resources

Market methods

- Assume climate change impairs ag production (drought, loss of coastal land, etc.)
- When effect is limited to one or two markets (partial equilibrium analysis)
- The damage (loss) is $\Delta CS + \Delta PS$



“Externalities” of restricted food supply

- Malnutrition
  - Stunted development in children
  - Poor school attendance, labor market and personal outcomes (China famine, Meng and Nancy Qian, 2006)
- Lower worker productivity
- Lower resistance to infections and disease
- Civil unrest, migrations

Types of non-market valuation methods

- Non-market methods
  - Types:
    - Revealed preferences methods
      - Look at actual behaviors and/or transactions of goods that contain or reflect the non-market goods (e.g., homes, cars, bike helmets, jobs, other products)
      - Hedonic pricing, the travel cost method, other methods based on household production function
    - Stated preferences
      - No actual transaction takes place.
      - Survey-based
      - People say what they would do under hypothetical but well-specified circumstances

Non-market methods

- When the effects of climate change are on…
  - Natural resources
  - Habitat
  - Certain amenities
- …we recognize the following types of values
  - Use values (whether or not consumptive; e.g., birdwatching is not consumptive)
  - Non-use values (a.k.a. passive use values)
    - Option value
    - Bequest value
    - Existence value
- These types of value are irrelevant when dealing with health risks, air quality, etc.

Applying non-market methods to valuing climate change…Maddison and Bigano (2003)

- Net value of climate change = $\frac{\partial \text{HomePrice}}{\partial C} - \frac{\partial \text{wages}}{\partial C}$
- Annual data for 1991-1995 from 95 Italian Provinces (Province in Italy ~ US county)
- Climate is represented as
  - Jan avg temp, precipitation, share of sunny days
  - July avg temp, precipitation, share of sunny days
- An increase of 1° C in avg. July temp = loss of 350 euro per household per year
- An increase of 1 mm in Jan precipitation = loss of 15 euro per household per year

Use caution…

- Difficult to do the above in developing countries where…
  - ***housing markets*** are different/sticky or prices are not recorded in a reliable manner
  - or ***labor markets*** are informal and/or based on pooling labor with neighbors and family members

Valuing effects on human health

- Methane a source of ozone, black carbon hazardous to health on its own or part of PM
- Types of effects
  - Morbidity
  - Mortality
- Description of effects
  - Duration or frequency (acute v. chronic)
  - Severity (bed disability day, work loss day, restricted activity day)
  - Affected parties (children, elderly, sensitive individuals)

A Simple Model for Morbidity

- Individual or household utility depends on consumption, leisure time, and sick days: **U(X,L,D)**
- Dose-response function: **D=D(P,A)**, where P is pollution/exposure
- Choose consumption and leisure time to maximize utility, subject to budget constraint
- Budget constraint states that…
  - we spend what we earn
  - sick days reduce work time (and hence income) *and* create medical expenditures
  - plus we spend money on averting activities (self-protection), A

What is the WTP to reduce pollution?

$$WTP = \frac{dD}{dP} \times \left[w\frac{dW}{dD} + p_M \frac{dM}{dD} + p_A \frac{dA^*}{dD} - \frac{U_D}{\lambda} \right]$$

Slope of the dose response function

Work income lost to illness

Averting expenditures

Value of the disutility and discomfort of illness

Cost of illness

WTP to pay to avoid a sick day

Assumptions

- Pollution or climate change enters in the utility function only via its effect on sick days
  - Pollution does not otherwise influence **productivity and the wage rate**
- Work time is flexible
- The specific nature of the environmental or climate effect is not important. All that matters is that they result in sick days.

Note: This model does not apply to…

- …pollutants that cause lasting **effects on human capital**, such as neurotoxics (lead, mercury, other heavy metals, certain chemicals contained in the emissions from power plants)

Pollutants with neurological and developmental effects

- Lead, mercury, heavy metals
- Effects on babies, infants, children
- Exposures to high levels → physical and neurological effects → cognitive difficulties, reduced school attendance → lower educational attendance → lower wages

- Damage from chemical = (**Lifetime wage differential** + **additional costs**) × attributable cases
- Landrigan et al. (2002), Grosse et al. (2002), Drake (2016), Trasande (2016)
- Misses **the disutility and suffering** of individual and parents → WTP study
- ***A lower bound*** to true damage

Landrigan's figures

- Average lead level in blood in 5-year-olds: 2.7 μg/dL, which is predicted to reduce IQ by 0.675 points
- 1 IQ point lost → ***2.39% loss in lifetime earnings***
- So 0.675 IQ points lost = 1.61% loss in lifetime earnings
- …or USD 21,014 for boys and USD 12,394 for girls
- Nationwide USD 27.8 billion (boys) and USD 15.6 billion (girls)

Can this method be applied to developing countries?

- **Completing schooling** extremely important for short and long-term outcomes, and there is a growing body of research on outcomes from extending mandatory instruction, facilitating school attendance, etc.
- …but difficult to infer values from **informal labor market** and **intra-family labor exchanges** and caregiving
- Large gains from reducing exposure to high level of toxics

Mortality effects

- Ozone and PM2.5 increase mortality risks (effects on cardiovascular system, lung cancer, etc.)
- Climate change may result in loss of lives due to extreme weather events (heat waves, coastal storms, floods, etc.) or illness
- Damages of emissions:
  - Expected lives lost × Value of a Statistical Life (VSL), or
  - Expected life-years lost × Value of a Statistical Life year (VOLY)

Annual premature mortality from O_3

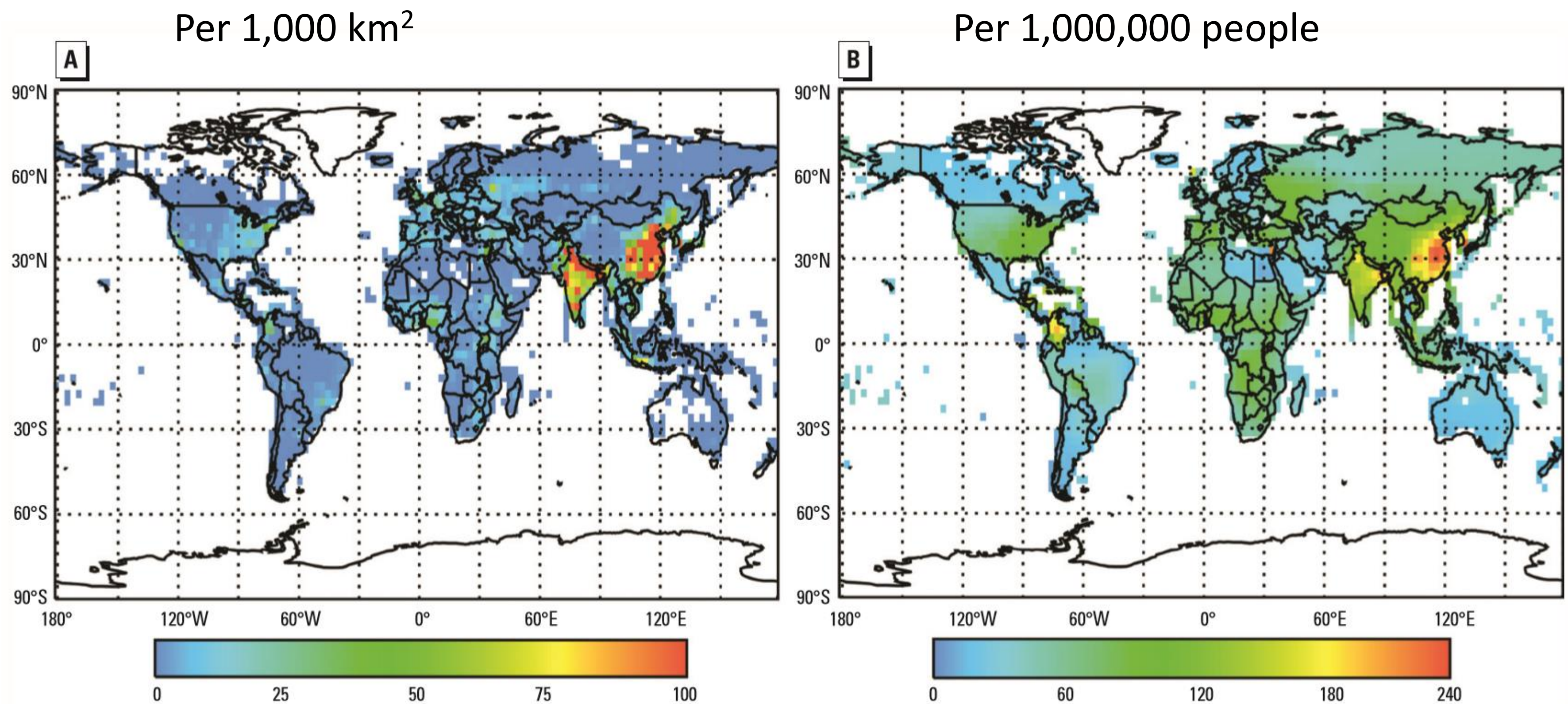


Figure 2. Estimated annual premature mortalities attributed to anthropogenic O_3 when no upper or lower concentration threshold is assumed, for respiratory mortalities per 1,000 km^2 (*A*) and rate of respiratory mortalities per 10^6 people (*B*).

Source: Anenberg et al. (2010)

Premature mortality attributed to PM2.5 (Anenberg et al., 2010)

per 1,000 km² *per 1,000,000 people*

Cardiopulmonary mortalities

Lung cancer

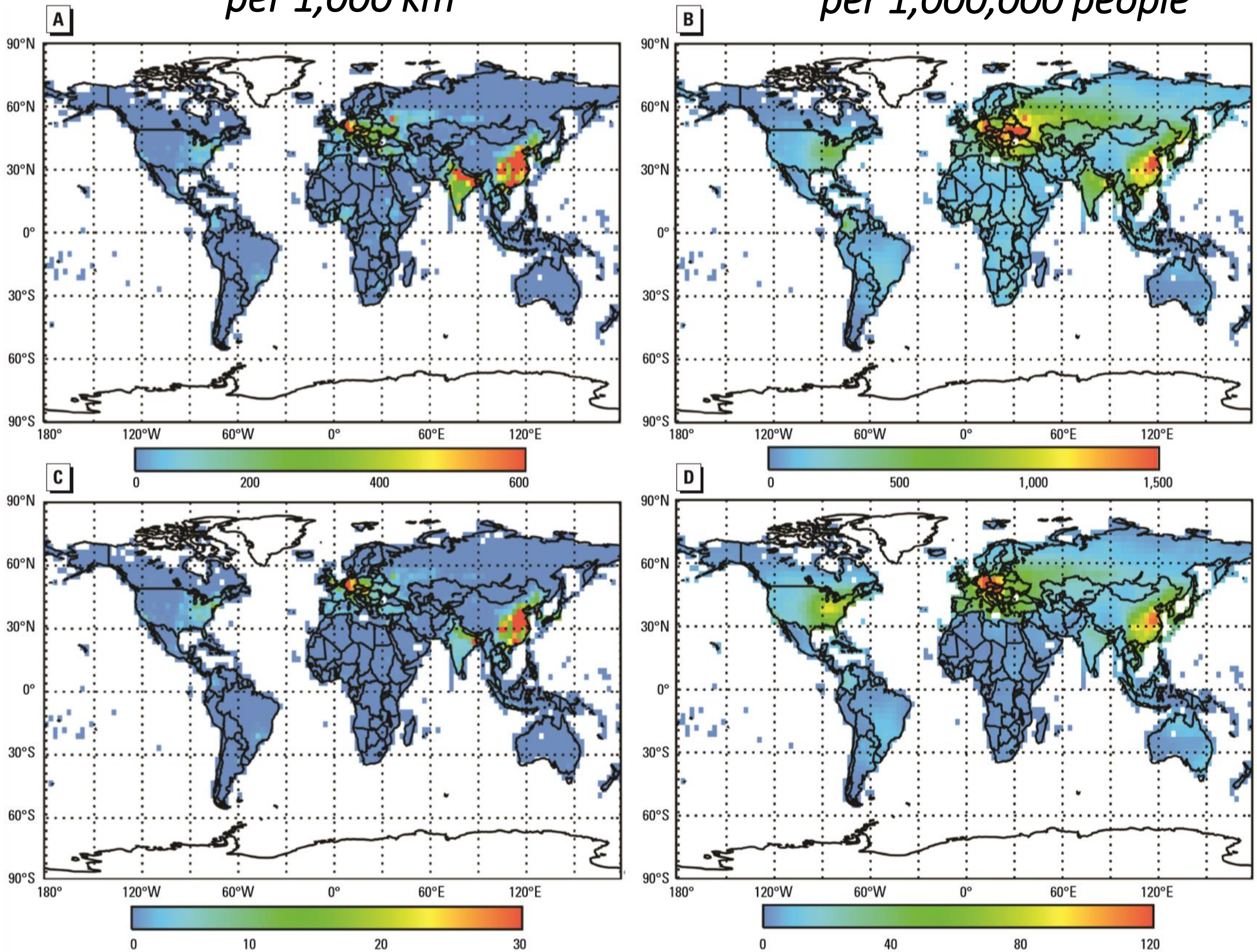


Figure 3. Estimated annual premature mortalities attributed to anthropogenic $PM_{2.5}$ when no upper or lower concentration threshold is assumed, for cardiopulmonary mortalities per 1,000 km^2 (*A*), rate of cardiopulmonary mortalities per 10^6 people (*B*), lung cancer mortalities per 1,000 km^2 (*C*), and rate of lung cancer mortalities per 10^6 people (*D*).

What is the Value of a Statistical Life?

- A summary measure of how much someone is prepared to pay to reduce his risk of dying by a small amount
- If I am willing to pay 500 euro to reduce risk by 1/10,000 (=0.0001), the VSL is $500 \times 10{,}000$ = 5,000,000 euro
- Values used by agencies in policy analyses:
  - US EPA USD 7.4 million (2006 dollars)
  - DG-Environment central value EUR 1.5 million
  - OECD recommends a base value USD 3.6 million for EU-27

Value of a Statistical Life

- Well-grounded in economic theory
- In a static model expected utility model,

$$VSL = \frac{\partial WTP}{\partial R} = \frac{U(y) - V(y)}{(1-R)\cdot U'(y) + R \cdot V'(y)}$$

How is the VSL estimated?

Compensating wage studies

$$w_i = \beta_0 + \mathbf{x}_i \boldsymbol{\beta}_1 + p_i \beta_2 + q_i \beta_3 + (q_i \times WC_i)\beta_4 + \varepsilon_i$$

- VSL inferred from the coefficient on fatal risks
- Econometric difficulties, measurement of risks, assumption that workers actually know their risks, heterogeneity and self-protection

Hedonic regressions for other goods

- Car prices depend on car characteristics, including safety
- Home prices change when environmental risks are discovered

Consumer expenditures on safety equipment

Stated preference studies

- Discrete choice experiments
- A program described by ***risk reduction***, ***risk characteristics*** (cause, latency (when), beneficiary (who), private vs. public (how), QoL impacts, etc.), and ***cost***
- VSL derived for <u>all</u> beneficiaries (retired, unemployed, adult as a child)
- VSL controlled for risk *attitudes*, *exposure*, *perception*, *socio-demo* characteristics of an individual

VSL issues

- What VSL figures do we use for developing countries?
- Some original estimation work in Taiwan, India, China, etc.
- Else, we must rely on benefit transfer
- Benefit transfer also implicitly used in IAMs
  - FUND assumes that VSL is 200×GDP per capita
  - DICE uses VOLY: one VOLY = 2 × annual income

Benefit transfer

- Have estimates of desired metric V at location A
- Wish to get an estimate of V in another location

$$V_B = V_A \cdot \left(\frac{\text{income}_B}{\text{income}_A} \right)^{\theta}$$

- θ can be 1 or less than one

Conclusions

- Valuation of the impacts using market prices (to derive variations) for market goods and WTP for non-market goods
- Need for a stated preference study to derive WTP for most of non-marketed goods (health risks)
- Benefit transfer to get WTP from other studies applied in other sites

My comments

Ancillary benefits

(*Ščasný, Massetti, Melichar, Carrara 2015*)

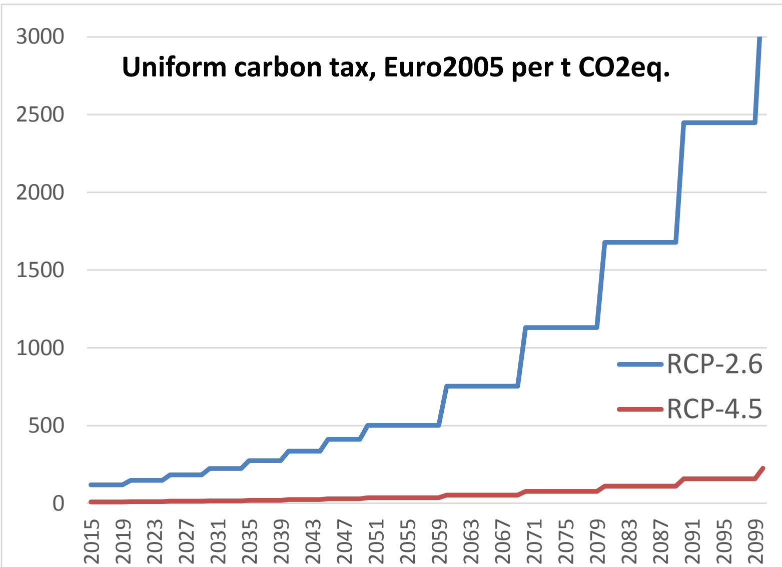
- Impacts of SSP2 and two **climate change mitigation scenarios with full adaptation** RCP2.6, and RCP4.5 simulated by WITCH model for **2005-2100**
  - **W**orld **I**nduced **T**echnical **C**hange **H**ybrid top-down IAM model developed by FEEM (see, www.witchmodel.org, Bosetti et al., 2006; 2007; 2009; 2013)

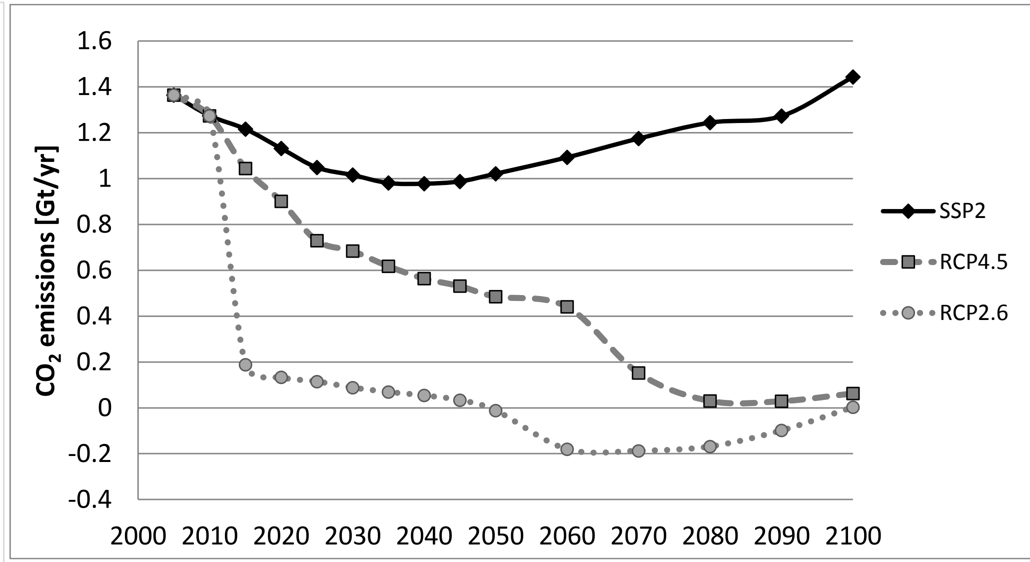
- **Baseline scenario** ⇒ *"A Middle-of-the-road Scenario" (**SSP2**)*
  - **Shared Socio-economic Pathway** built on the assumption of continuation of all major trends that we observe today (Ebi et al. 2014; Van Vuuren et al. 2014)
  - current trends, without major changes in economic growth, use and availability of resources, technological trends, population growth, economic and envi policies

- **Climate change mitigation policy scenarios** ⇒ represent the challenges of reaching two long term radiative forcing targets corresponding to **Representative Concentration Pathways (RCPs)**
  - **RCP2.6** – radiative forcing is declining to 2.6 W/m^2 by 2100, ≈ ***490 ppm CO_2-eq***
  - **RCP4.5** - radiative forcing is declining to 4.5 W/m^2 by 2100, ≈ ***650 ppm CO_2-eq***
  - **RCP6.0** - radiative forcing is 6.0 W/m^2 in 2100 ≈ ***850 ppm CO_2-eq***; is very similar to SSP2 (Ščasný et al. 2015 FEEM Working Paper)

Scasny et al 2015:

Carbon Tax, CO_2 emissions, and T increase





	RCP2.6	**RCP4.5**
Carbon tax	€120 → €3393	€8.8 → €225
Temp increase	+1.7˚C	+2.7˚C

Scasny et al 2015:

Impacts of RCP on air quality pollutant

Table 2 Cumulative difference in emission volumes and percentage change in Europe for each climate mitigation scenario compared to the corresponding Reference scenario (SSP2) for the period 2015–2100

Scenario	NMVOC (kt)	NOx (Mt)	PM2.5 (kt)	SOx (Mt)	Cd (t)	As (t)	Ni (t)	Pb (t)	Hg (t)	Cr (t)	CO_2 (Gt)
Reference (SSP2)	3088	195	25,150	563	938	6413	20,397	8321	1214	4523	96
RCP2.6	−509	−153	12,013	−551	−434	−3705	−13, 318	−2552	−769	−1983	−99
RCP4.5	−702	−93	−2240	−329	−374	−2908	−3483	−3037	−576	−1852	−60
Percentage change with respect to SSP2											
RCP2.6	−16 %	−78 %	48 %	−98 %	−46 %	−58 %	−65 %	−31 %	−63 %	−44 %	−103 %
RCP4.5	−23 %	−48 %	−9 %	−59 %	−40 %	−45 %	−17 %	−37 %	−47 %	−41 %	−62 %

Scasny et al 2015:

Impacts of RCP on air quality pollutant

Table 4 Ancillary benefits of RCP2.6 and RCP4.5 and carbon tax for various periods in present (discounted) and real values of € per tonne CO_2

	(1) AB discounted €B		(2) AB real €B		(3) ΔCO_2 Mt		(4) = (1)/(3) PV(AB)/ΔCO_2 € per ton		(5) = (2)/(3) Real AB/ΔCO_2 € per to
	RCP-2.6	RCP-4.5	RCP-2.6	RCP-4.5	RCP-2.6	RCP-4.5	RCP-2.6	RCP-4.5	RCP-2.6	RCP-4.5
2015–2019	265	62	327	76	5140	858	51.5	72.3	63.6	88.1
2020–2024	219	67	314	93	4995	1153	43.8	58.0	62.8	80.9
2025–2029	176	77	281	119	4669	1597	37.7	48.0	60.2	74.5
2030–2034	147	68	260	116	4637	1659	31.7	40.9	56.1	70.0
2035–2039	122	64	242	121	4559	1816	26.8	35.3	53.0	66.8
2040–2044	105	65	238	140	4620	2070	22.7	31.2	51.5	67.5
2045–2049	92	61	238	151	4772	2285	19.2	26.6	49.8	66.1
2050–2059	164	122	489	349	10,330	5359	15.8	22.8	47.3	65.2
2060–2069	117	108	452	401	12,734	6520	9.2	16.6	35.5	61.5
2070–2079	97	83	498	424	13,622	10,230	7.1	8.2	36.6	41.5
2080–2089	91	77	557	468	14,132	12,142	6.4	6.4	39.4	38.5
2090–2099	91	69	718	552	15,157	13,817	6.0	5.0	47.3	39.9
2015–2100	1685	923	4613	3010	99,368	59,506	17.0	15.5	46.4	50.6

AB: ancillary benefit; PV(AB) is a present value of ancillary benefits that are discounted using the endogenous interest rate from the WITCH mod emission are presented as a sum over the given period. CO_2 tax is the arithmetic average for given period

Scasny et al 2015:

Ancillary benefits by pollutant

Table 6 Present value in billion Euros of pollution cost (SSP2) and ancillary benefits (RCP) per pollutant and region

	NMVOC	NOx	PM2.5	SOx	Cd	As	Ni	Pb	Hg	Cr	Total
Reference scenario											
EU15+EFTA	0.65	402	128	1242	0.02	1.01	0.02	0.72	2.76	0.02	1779
EASTEU	0.03	47	5	169	0.00	0.10	0.00	0.06	0.31	0.00	222
RCP4.5											
EU15+EFTA	0.12	175	7	663	0.01	0.38	0.00	0.20	1.10	0.01	847
EASTEU	0.01	15	0.76	59	0.00	0.03	0.00	0.02	0.11	0.00	76
RCP2.6											
EU15+EFTA	0.11	310	−41	1208	0.01	0.53	0.01	0.19	1.58	0.01	1479
EASTEU	0.02	42	1	162	0.00	0.09	0.00	0.05	0.27	0.00	205

Values 0.00 indicates smaller value than 0.01 and is not shown due to rounding. The negative number −41 for PM2.5 in RCP2.6 in EU15+EFTA indicates the increase in emissions and hence ancillary damage

Scasny et al 2015:

Ancillary benefits by impact category

Table 7 Present value in B€ of pollution cost (SSP2) and ancillary benefits (RCP) per impact category and region

	Loss of biodiversity	Agricultural production	Building materials	Human health	Effects of heavy metals on human health	Total
Reference scenario						
EU15+EFTA	101.80	3.15	37.99	1631.56	4.57	1779
EASTEU	12.79	0.36	6.69	201.27	0.48	222
RCP4.5						
EU15+EFTA	48.63	–0.03	20.17	776.95	1.70	847
EASTEU	4.43	0.09	2.36	68.73	0.16	76
RCP2.6						
EU15+EFTA	87.07	–0.31	36.46	1353.89	2.33	1479
EASTEU	11.96	0.25	6.39	186.28	0.42	205

Scasny et al 2015:

Ancillary benefits – generated vs. received - by country

Table 8 Country's contribution to generation of ancillary benefits and where these benefits appear, present (discounted) value cumulated over 2015–2100 for RCP4.5

	AB enjoyed in the country (in the row) in that emission reduction was also made	AB due to emission in a country (in the row) whose benefits appear elsewhere	AB enjoyed in the country (in the row) due to emission abated elsewhere	Pollution costs generated (*share on total in Europe*)	Pollution costs born (*share on total in Europe*)	Ratio on AB generated and AB born	AB exported (from a country in the row)	AB imported (to a country in the row)
	[1] (€ *mil*)	[2] (€ *mil*)	[3] (€ *mil*)	[4] = ([1] + [2])/ (∑[1] + ∑[2]) (%)	[5] = ([1] + [3])/ (∑[1] + ∑[3]) (%)	[6] = [4]/[5]	[7] = [2]/ ([1] + [2]) (%)	[8] = [3]/ ([1] + [3]) (%)
AUT	4555	4062	8756	0.9	1.4	0.65	47	66
BEL	3090	8667	13,776	1.3	1.8	0.70	74	82
BGR	445	4218	149	0.5	0.1	7.85	90	25
CYP	–235	–251	0	–0.1	0.0	2.07	52	0
CZE	7714	13,500	9725	2.3	1.9	1.22	64	56
DEU	370 610	52,840	73,069	45.9	48.1	0.95	12	16
DNK	10,614	10,772	4296	2.3	1.6	1.43	50	29
ESP	16,963	2341	1524	2.1	2.0	1.04	12	8
EST	345	3486	227	0.4	0.1	6.70	91	40
FIN	7854	6252	730	1.5	0.9	1.64	44	8
FRA	24,907	20,260	16,448	4.9	4.5	1.09	45	40
GBR	129,835	34,728	14,579	17.8	15.6	1.14	21	10
GRC	11,043	7007	634	2.0	1.3	1.55	39	5
HUN	854	1300	2047	0.2	0.3	0.74	60	71
CHE	44	41	5132	0.0	0.6	0.02	48	99
IRL	1750	7589	270	1.0	0.2	4.62	81	13
ITA	51,128	6380	3066	6.2	5.9	1.06	11	6

Scasny et al 2015:

Ancillary benefits – generated vs. received - by country

Table 8 continued

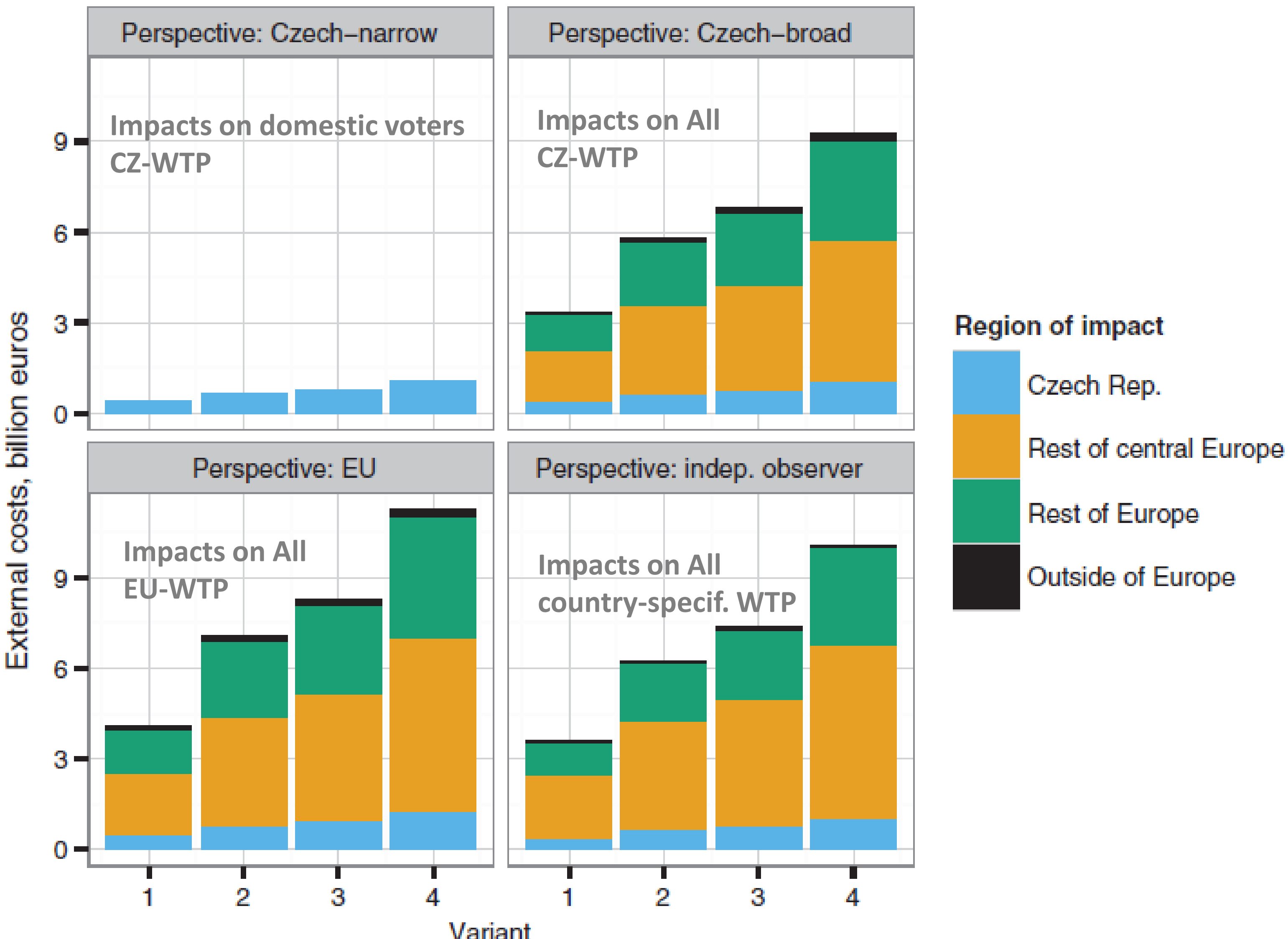
	AB enjoyed in the country (in the row) in that emission reduction was also made	AB due to emission in a country (in the row) whose benefits appear elsewhere	AB enjoyed in the country (in the row) due to emission abated elsewhere	Pollution costs generated *(share on total in Europe)*	Pollution costs born (*share on total in Europe*)	Ratio on AB generated and AB born	AB exported (from a country in the row)	AB imported (to a country in the row)
	[1] (€ *mil*)	[2] (€ *mil*)	[3] (€ *mil*)	[4] = ([1] + [2])/ (∑[1] + ∑[2]) (%)	[5] = ([1] + [3])/ (∑[1] + ∑[3]) (%)	[6] = [4]/[5]	[7] = [2]/ ([1] + [2]) (%)	[8] = [3]/ ([1] + [3]) (%)
LTU	−6	−28	386	0.0	0.0	-0.09	82	102
LUX	7	65	1274	0.0	0.1	0.06	90	99
LVA	4	36	231	0.0	0.0	0.17	89	98
NLD	16,156	31,764	27,654	5.2	4.7	1.09	66	63
NOR	75	81	790	0.0	0.1	0.18	52	91
POL	18,189	18,809	12,590	4.0	3.3	1.20	51	41
PRT	1468	1545	209	0.3	0.2	1.80	51	12
ROU	1287	1893	881	0.3	0.2	1.47	60	41
SVK	239	1083	1492	0.1	0.2	0.76	82	86
SVN	502	2376	496	0.3	0.1	2.88	83	50
SWE	1886	1050	4274	0.3	0.7	0.48	36	69
RoE	na	na	37,160					
Total	681,323	241,866	241,866	100.0	100.0	1.00	26	22

Health impacts from airborne pollution and their valuation (ExternE's Impact Pathway Analysis]

Pollutant	Endpoint (unit)	CRF (per 10 µg/m³)	EU-wide monetary value (€$_{2014}$)
Air pollution: long-term exposure			
$PM_{2.5}$	Adult mortality (loss of life expectancy, per YOLL)	1.062	65,066
PM_{10}	Post-neonatal infant mortality (per case)	1.04	2,762,767
PM_{10}	Incidence of chronic bronchitis in adults (per case)	1.117	60,443
PM_{10}	Prevalence of bronchitis in children (per case)	1.08	663
Air pollution: short-term exposure			
$PM_{2.5}$	Restricted activity days (per day)	1.047	104
$PM_{2.5}$	Work days lost (per day)	1.046	147
$PM_{2.5}$	Hospital admissions, respiratory diseases (per case)	1.019	2503
$PM_{2.5}$	Hospital admissions, cardiovascular diseases (per case)	1.0091	2503
PM_{10}	Incidence of asthma symptoms in asthmatic children (per case)	1.028	47
O_3	Adult mortality (per YOLL)	1.0029	65,066
O_3	Hospital admissions (65+years), respiratory diseases (per case)	1.0044	2503
O_3	Hospital admissions (65+years), cardiovascular diseases (per case)	1.0089	2503
O_3	Minor restricted activity days (per day)	1.0154	47
Noise exposure		ERF (per dB L_{den})	
	Slightly annoyed (per year)	$0.02815 * L_{den}^2 - 1.130 * L_{den} + 11.477$	56
	Annoyed (per year)	$0.03270 * L_{den}^2 - 2.121 * L_{den} + 36.854$	112
	Highly annoyed (per year)	$0.02523 * L_{den}^2 - 1.886 * L_{den} + 36.307$	187

Source: Maca, Melichar, Scasny, Braun Kohlova (*Rev Environ Health* Vol 32, Issue 1-2 (2017): 171-6)

Magnitude of external costs by policy-making perspective [for four variants of lifting coal limits in Czech Rep.]



Source: Maca et al., 2017

Mortality

Mortality valuation for adults and children for Health Canada (Alberini and Scasny 2015)

Consider two different options, A and B, described in the table below.

Keep in mind that they reduce the chance of dying for children the same age, gender, health status and preventi
to **23** in 10,000 over 5 years.

Which intervention would you choose, option A, option B, or Neither – that is, pay nothing and obtain no reducti

Please select one response only

	OPTION A	OPTION B	NEITHER
Cause of death	Respiratory illness	Respiratory illness	
Type of initiative	National public program	National public program	
Other beneficiaries of the reduction in the chance of dying?	Other children	Other children	
Reduction in the chance of dying	3 in 10,000 in 5 years	3 in 10,000 in 5 years	
When does the reduction in the chance of dying begin?	Immediately	In 10 years	
ANNUAL cost to your household **for each of the next 5 years**	$150	$150	
Which would you choose?			

Mortality valuation for adults and children for Health Canada (Alberini and Scasny 2015)

attribute	levels in wave 1, 3 and 4	levels in wave 2
Cause	cancer road traffic respiratory illness	n/a
Context	private action or public program	private action or public program
Deltarisk	2, 3, 4, and 5 in 10,000 over 5 years	2, 3, 4 and 5 in 10,000 over 5 years
Latency	0, 2, 5, and 10 years	0, 2, 5, and 10 years
Cost	60, 150, 300 and 620 CAN$ per year for each of the next 5 years	60, 150, 300 and 620 CAN$ per year for each of the next 5 years

Mortality valuation for adults and children for Health Canada (Alberini and Scasny 2015)

	Adult	Child	Adult	Child
VSL cancer	**6.916** (0.396)	**8.316** (0.407)		
VSL road accidents	**4.526** (0.343)	**6.858** (0.358)		
VSL respiratory	**4.943** (0.327)	**7.344** (0.344)		
VSL for any cause of death			**6.469** (0.389)	**8.709** (0.471)
Add to the VSL if public	**1.869** (0.335)	**2.443** (0.331)	**1.832** (0.458)	**1.189** (0.448)
Delta (discount rate)	0.1567 (0.0153)	0.1378 (0.0101)	0.1145 (0.0142)	0.0968 (0.0105)
N observations	6000	6024	2406	2400
N respondents	1000	1004	401	400

Fertility

Fertility valuation within discrete choice experiments

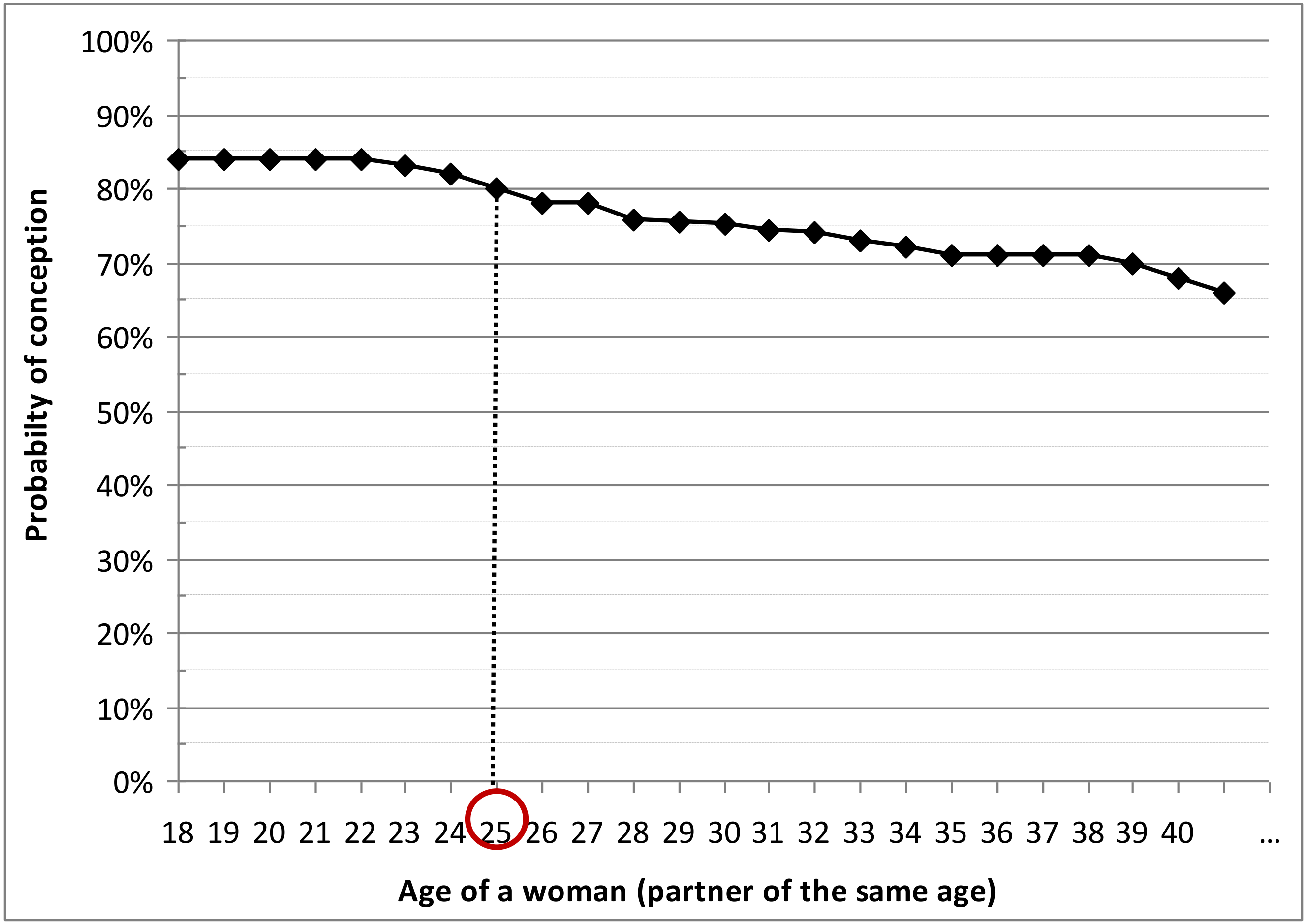
(Health Canada study by Scasny & Zverinova 2015)

Although the conception of a child seems to be a natural part of life, it is not certain and it depends on many factors.

The probability of conceiving	- decreases with **the age** - increases with **the time a couple is trying to conceive** - increases with **frequency** of sexual intercourse, - is also determined by **lifestyle** and other factors
Infertility	- failure to conceive **after 12 months or more** of regular unprotected intercourse
Treatment of infertility	- drug treatments that alter levels of reproductive hormones in tablets or injections - medical procedures involving the manipulation of sperm, eggs and embryos, such as in vitro fertilization, sometimes referred to as a "IVF conceived baby"
Quality of life impact of infertility	- difference in the sexual life of the couple, such as the planning of the intercourse - sexual dysfunction, depression, anxiety

The Problem: Probability of conceiving

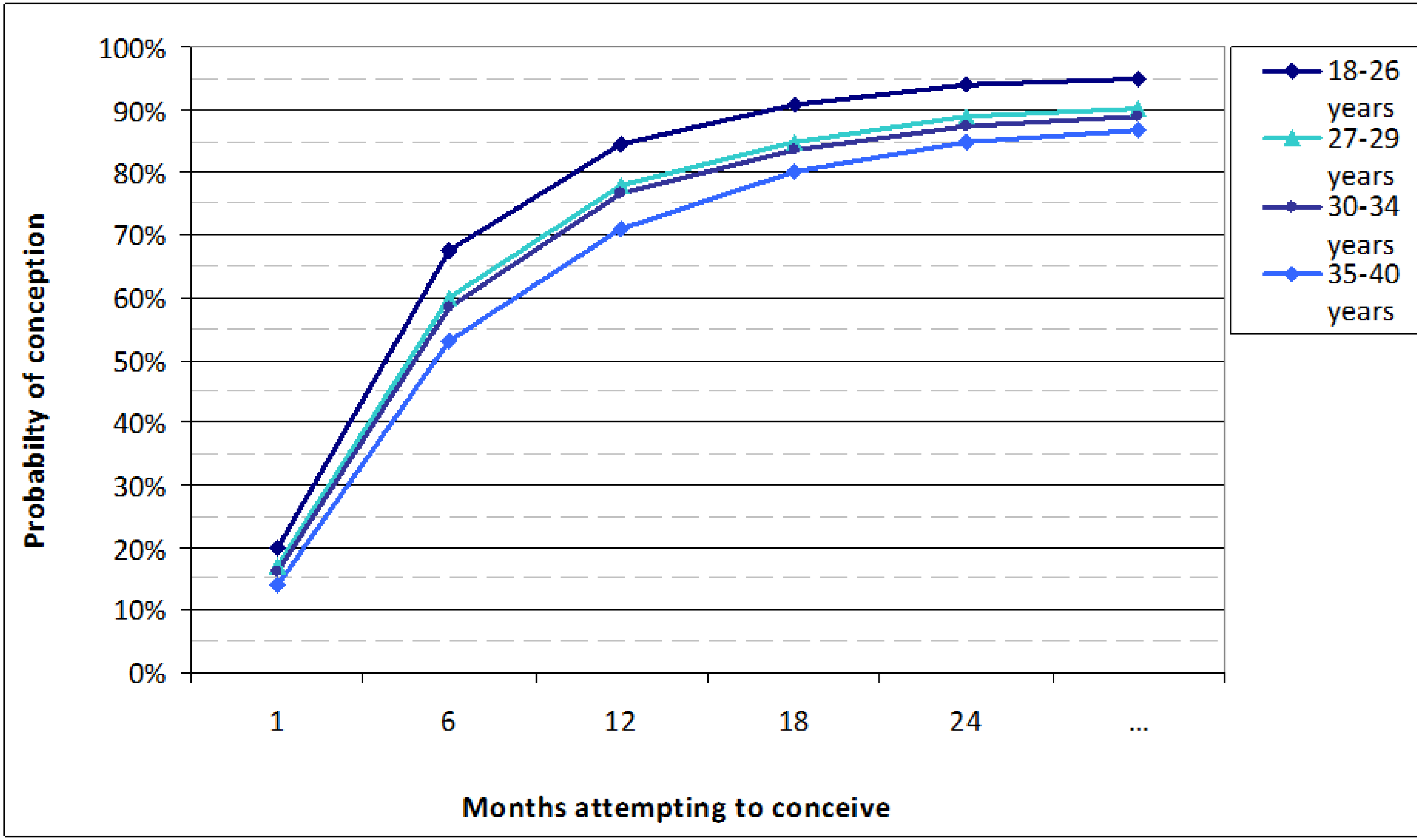
(Health Canada study by Scasny & Zverinova 2015)



Source: Medical study conducted in Europe (*Dunson D.B., Baird D.D., Colombo B. (2004): Increased infertility with age in men and women. OBSTETRICS AND GYNECOLOGY, Volume: 103, Issue: 1, 51-56)*

Time a couple is trying to conceive

(Health Canada study by Scasny & Zverinova 2015)



Note: **Infertility** = failure to conceive **after 12 months or more** of regular unprotected intercourse

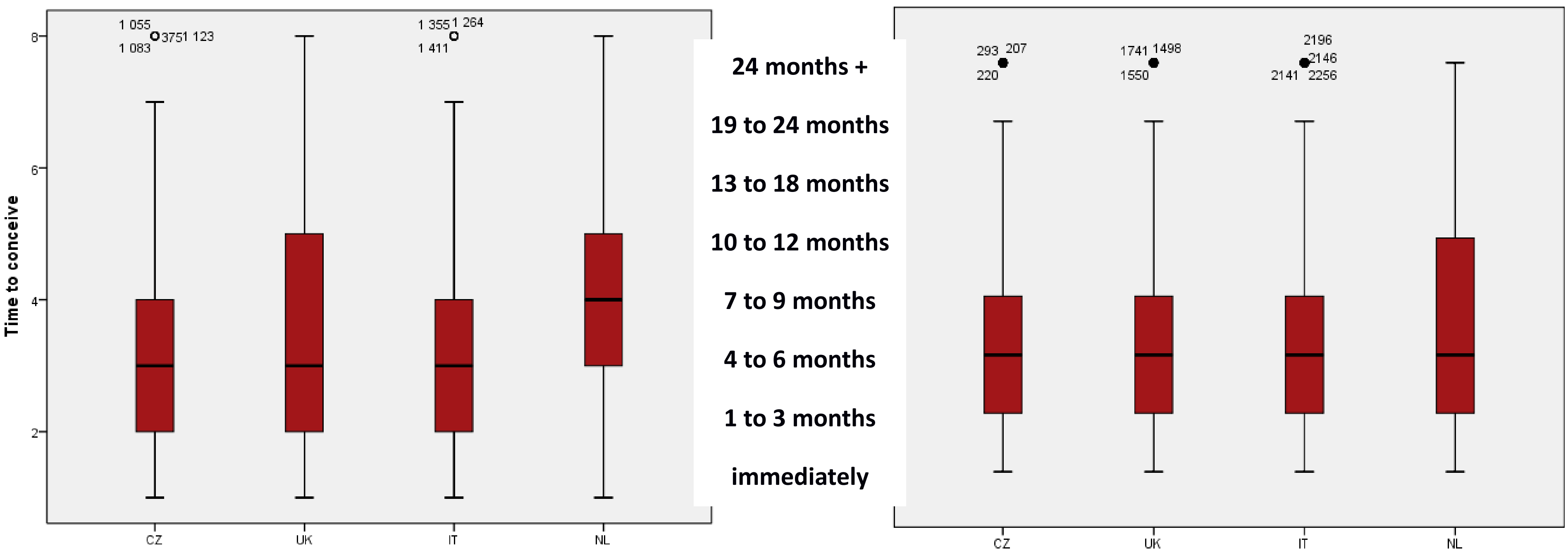
Source: Medical study conducted in Europe (*Dunson D.B., Baird D.D., Colombo B. (2004): Increased infertility with age in men and women. OBSTETRICS AND GYNECOLOGY, Volume: 103, Issue: 1, 51-56)*

How long do you think will it take you and your (future) partner to conceive?

(Health Canada study by Scasny & Zverinova 2015)

General population

People who want children



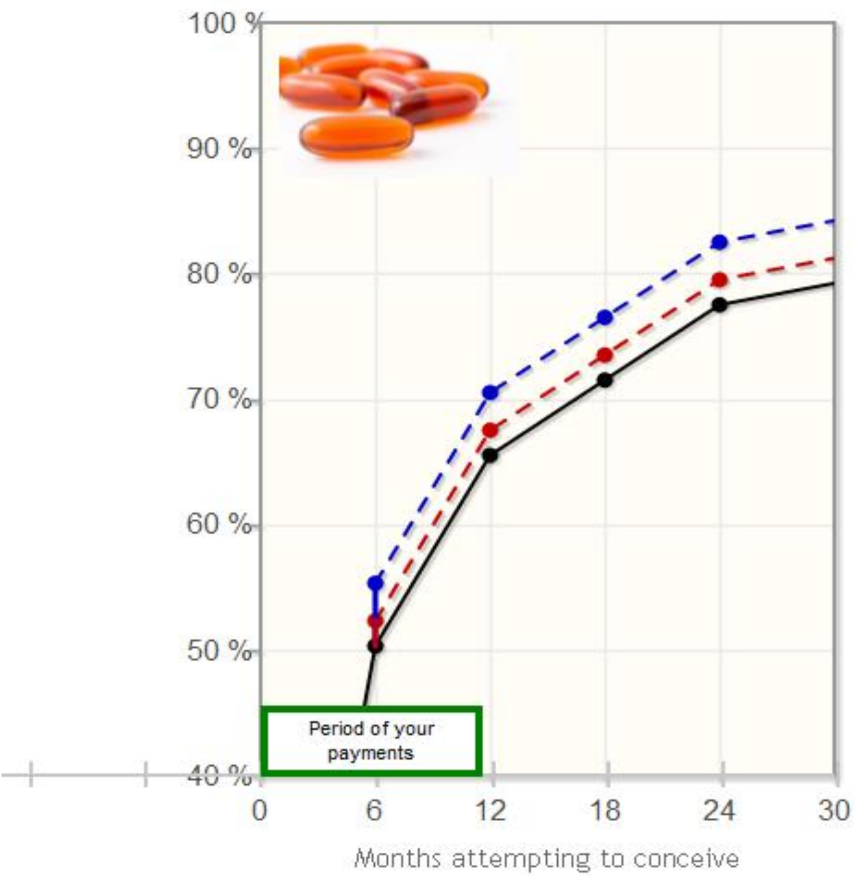
Note: black line in the red bar indicates **median***; the red bar highlights* **the first and the third quartile***, the bands in black show* ***min-max****.* Source: ECHA survey (Ščasný and Zvěřinová, 2014)

Discrete Choice Experiment: Example of choice card

(Health Canada study by Scasny & Zverinova 2015)

First choice

Would you choose Vitamins A, Vitamins B, or neither?



Attribute	**Complex of vitamins A**	**Complex vitamins B**	**Current state**
Beneficiary	You and your partner	You and your partner	You and your partner
Percentage of increase of the probability of conceiving as shown in the graph	+ 1%	+ 5%	0% no increase
Number of months of trying to conceive after which the probability will increase	after 6 months	after 6 months	
Costs	£ 120	£ 2400	£ 0
(Monthly payment over 1 year period)	(£ 10 per month for 1 year)	(£ 200 per month for 1 year)	
Which option would you prefer?	**Vitamins A**	**Vitamins B**	**Current State**

Fertility valuation for Health Canada

based on WTP for increasing probability to conceive

(Scasny and Zverinova 2015)

	WANT			General population
	DCE1 FERT-vit	IVF	DCE2 FERT-reg	DCE2 FERT-reg
CANADA				
protesters + SQ4 excluded	$54 075	$41 894	$81 000	$16 898
protester no true zero + SQ4	$30 179	$23 205	$64 496	
want a child within 3 yrs	$57 287	$48 770	$85 989	$106 393
want a child within 2 yrs	$63 463	$51 837	$91 540	$127 389
no zika	$47 035	$37 260	$76 714	$13 113
no side effects	$18 549	NA	$56 576	-$10 828
design as in the ECHA	$58 076	$56 520	NA	NA
Turnbull	NA	$15 766	NA	NA
Turnbull (ECHA design)	NA	$19 591	NA	NA
ECHA				
protesters + SQ4 excluded	$54 316	$40 526	$63 798	$54 315
want a child within 3 yrs	$61 247	$60 590		
no side effects	$33 836	NA	$32 642	$17 921
Turnbull	NA	$22 736	NA	NA

Developmental toxicity Health Canada study

based on WTP for reducing risk of…

(Scasny and Zverinova 2015)

	DCE3 vitamin WANT		
	minor	internal	external
CANADA			
protesters + SQ4 excluded	$24 007	$350 254	$208 002
want a child within 3 yrs	$23 573	$346 305	$194 387
want a child within 2 yrs	$25 365	$368 797	$214 394
no zika	$23 190	$337 684	$194 084
no side effect	$13 903	$281 880	$102 827
ECHA			
protesters SQ4 excluded	$18 978	$278 755	$169 711
want a child within 3 yrs	$20 263	$300 846	$181 462

	WANT			
	CVM1 VLBW vit	CVM2 VLBW regul	CVM3 LOW vit	CVM4 LOW regul
Central value estimate no Zika	€ 201 858	€ 875 380	€ 136 032	€ 702 401
protesters excluded (basic)	€ 238 212	€ 881 130	€ 163 305	€ 848 258
protesters excluded if no true zero	€ 153 608	€ 610 411	€ 90 297	€ 427 870
DB-DC, median	€ 235 664	€ 512 324	€ 257 059	€ 637 502
Turnbull (protesters excl)	€ 119 267	€ 437 586	€ 107 953	€ 407 651
ECHA pooled data 4countries	€ 134 206	€ 402 293	NA	NA

Black carbon

- The review was carried out by a number of experts selected by the WHO. After reviewing the available time-series studies, as well as information from panel studies, it was concluded that these provided sufficient evidence of an association of short-term (daily) variations in BC concentrations with short-term changes in health (all-cause and cardiovascular mortality, and cardiopulmonary hospital admissions). Furthermore that cohort studies provided sufficient evidence of associations of all-cause and cardiopulmonary mortality with long-term average BC exposure.
- **Studies of short-term** health effects showed that the associations with BC are more robust than those with $PM_{2.5}$ or PM_{10}, suggesting that BC is a better indicator of harmful particulate substances from combustion sources (especially traffic) than undifferentiated PM mass. The evidence from long-term studies was however inconclusive – in one of the two available cohort studies using multi-pollutant models in the analysis, the effect estimates for BC were stronger than those for sulphates, while an opposite order in the strength of relationship was suggested in the other study.
- According to the report, there are not enough clinical or toxicological studies to allow an evaluation of the qualitative differences between the health effects of exposure to BC or to PM mass (for example, different health outcomes), or to allow quantitative comparison of the strength of the associations or identification of any distinctive mechanism of BC effects.
- The review of the results of all available toxicological studies suggested that BC (measured as EC) may not be a major directly toxic component of fine PM, but it may operate in particular, as a universal carrier of a wide variety of combustion-derived chemical constituents of varying toxicity to sensitive targets in the human body such as the lungs, the body's major defence cells and possibly the systemic blood circulation.
- Based on these findings, the Task Force on Health agreed that a reduction in exposure to $PM_{2.5}$ containing BC and other combustion-related PM material for which BC is an indirect indicator should lead to a reduction in the health effects associated with PM. The Task Force therefore recommended that $PM_{2.5}$ should continue to be used as the primary metric in quantifying human exposure to PM and the health effects of such exposure, and for predicting the benefits of exposure reduction measures. It also recommended that the use of BC as an additional indicator may be useful in evaluating local action aimed at reducing the population's exposure to combustion PM.

Table 2. Estimated annual mortalities ± 1 SD due to anthropogenic O_3 and $PM_{2.5}$, assuming natural background only or LCTs (33.3 ppb for O_3 and 5.8 μg/m^3 for $PM_{2.5}$) (× 1,000).

	O_3 respiratory		$PM_{2.5}$ cardiopulmonary		$PM_{2.5}$ lung cancer	
	Background	Threshold	Background	Threshold	Background	Threshold
Africa	63 ± 34	45 ± 30	154 ± 44	52 ± 33	3 ± 1	1 ± 1
North America	35 ± 17	25 ± 15	124 ± 37	65 ± 30	17 ± 7	10 ± 5
Europe	41 ± 21	23 ± 17	586 ± 149	383 ± 143	47 ± 17	31 ± 14
Asia	543 ± 253	370 ± 220	2,584 ± 618	1,991 ± 603	152 ± 53	122 ± 47
South America	18 ± 9	8 ± 6	48 ± 15	16 ± 9	2 ± 1	1 ± 1
Oceania	1 ± 1	0 ± 0	2 ± 1	0 ± 0	0 ± 0	0 ± 0
World	700 ± 335	470 ± 288	3,499 ± 864	2,506 ± 816	222 ± 80	164 ± 68

SDs reflect uncertainty in the CRF and simulated present-day concentrations (SD = 25% of simulated concentration).

Table 3. Estimated annual YLL ± 1 SD due to anthropogenic O_3 and $PM_{2.5}$, assuming the natural background or LCTs (33.3 ppb for O_3 and 5.8 μg/m^3 for $PM_{2.5}$) (× 1,000).

	O_3 respiratory		$PM_{2.5}$ cardiopulmonary		$PM_{2.5}$ lung cancer	
	Background	Threshold	Background	Threshold	Background	Threshold
Africa	901 ± 486	644 ± 429	1,694 ± 484	572 ± 363	40 ± 13	13 ± 13
North America	285 ± 138	203 ± 122	804 ± 240	421 ± 194	152 ± 62	89 ± 45
Europe	243 ± 125	136 ± 101	4,336 ± 1,103	2,834 ± 1,058	472 ± 171	311 ± 141
Asia	4,322 ± 2,014	2,945 ± 1,751	20,620 ± 4,932	15,888 ± 4,812	1,594 ± 556	1,280 ± 493
South America	137 ± 68	61 ± 46	365 ± 114	122 ± 68	19 ± 10	10 ± 10
Oceania	7 ± 7	0 ± 0	11 ± 6	0 ± 0	0 ± 0	0 ± 0
World	6,251 ± 2,992	4,197 ± 2,572	27,607 ± 6,817	19,772 ± 6,438	2,169 ± 782	1,602 ± 664

SDs reflect uncertainty in the CRF and simulated present-day concentrations (SD = 25% of simulated concentration).

Change in O_3 and PM2.5 since pre-industrial times

From Anenberg et al. (2010)

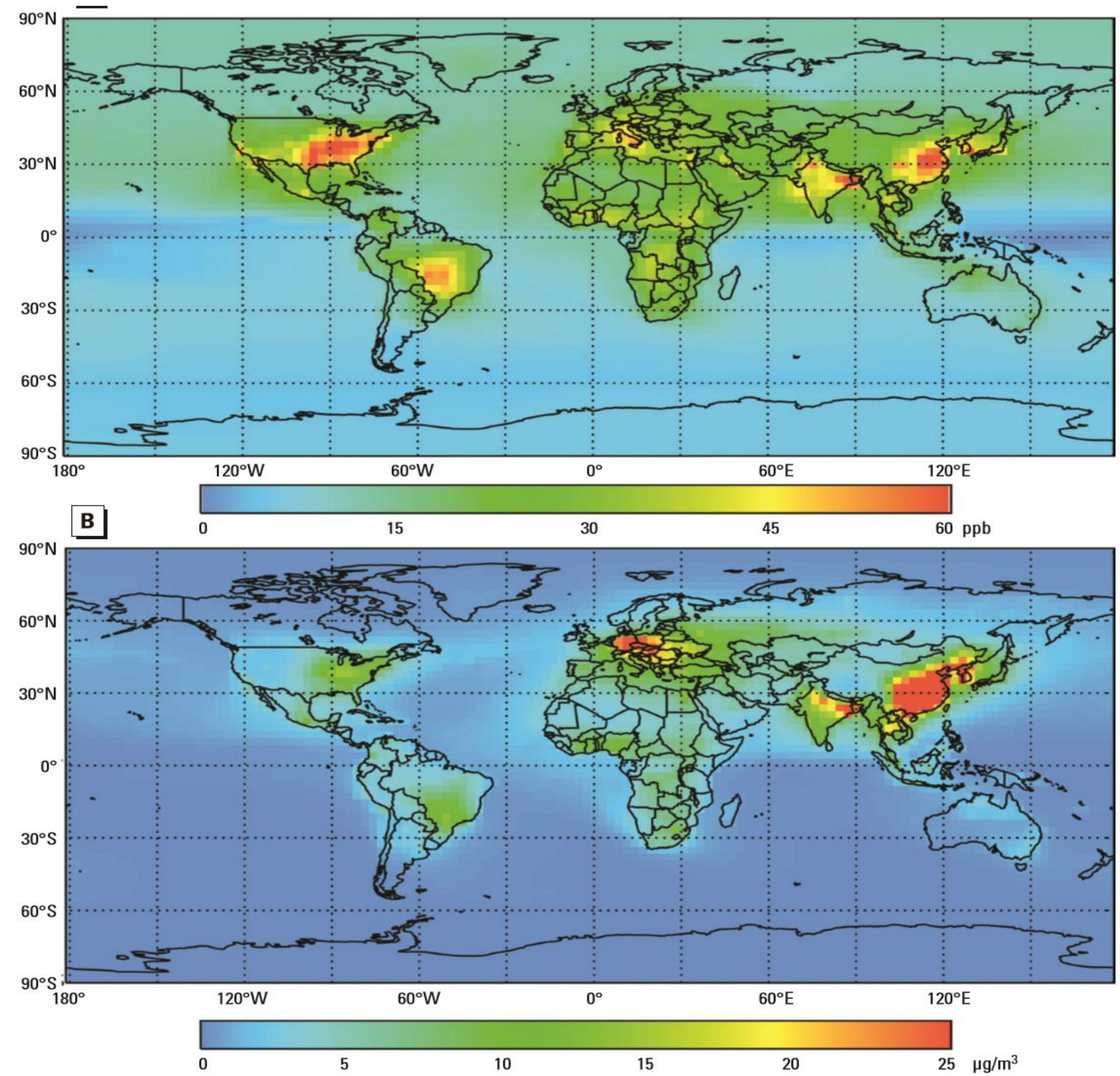


Figure 1. Estimated change (present minus preindustrial) in seasonal average (6-month) 1-hr daily maximum O_3 concentrations (ppb; *A*) and annual average $PM_{2.5}$ (µg/m^3; *B*) from Horowitz (2006) simulations.