International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

science for global insight

GAINS model
Principles and applications

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Mitigation of Air Pollutants and Greenhouse Gases (MAG)

Air Pollution advice 1947

Our mission in 2011: *Give a better advice!*


富卓商厦
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Outline

- RAINS/GAINS integrated assessment models (IAM) – *basic ideas*
- Application examples:
  - Gothenburg Protocol
  - UNEP Black Carbon and Ozone Assessment
- GAINS is available online: http://gains.iiasa.ac.at

Economic development and air pollution

Economic development ↑

… to global
climate change

… and regional pollution …

… over urban smog …

From indoor pollution …

Scale of pollution →

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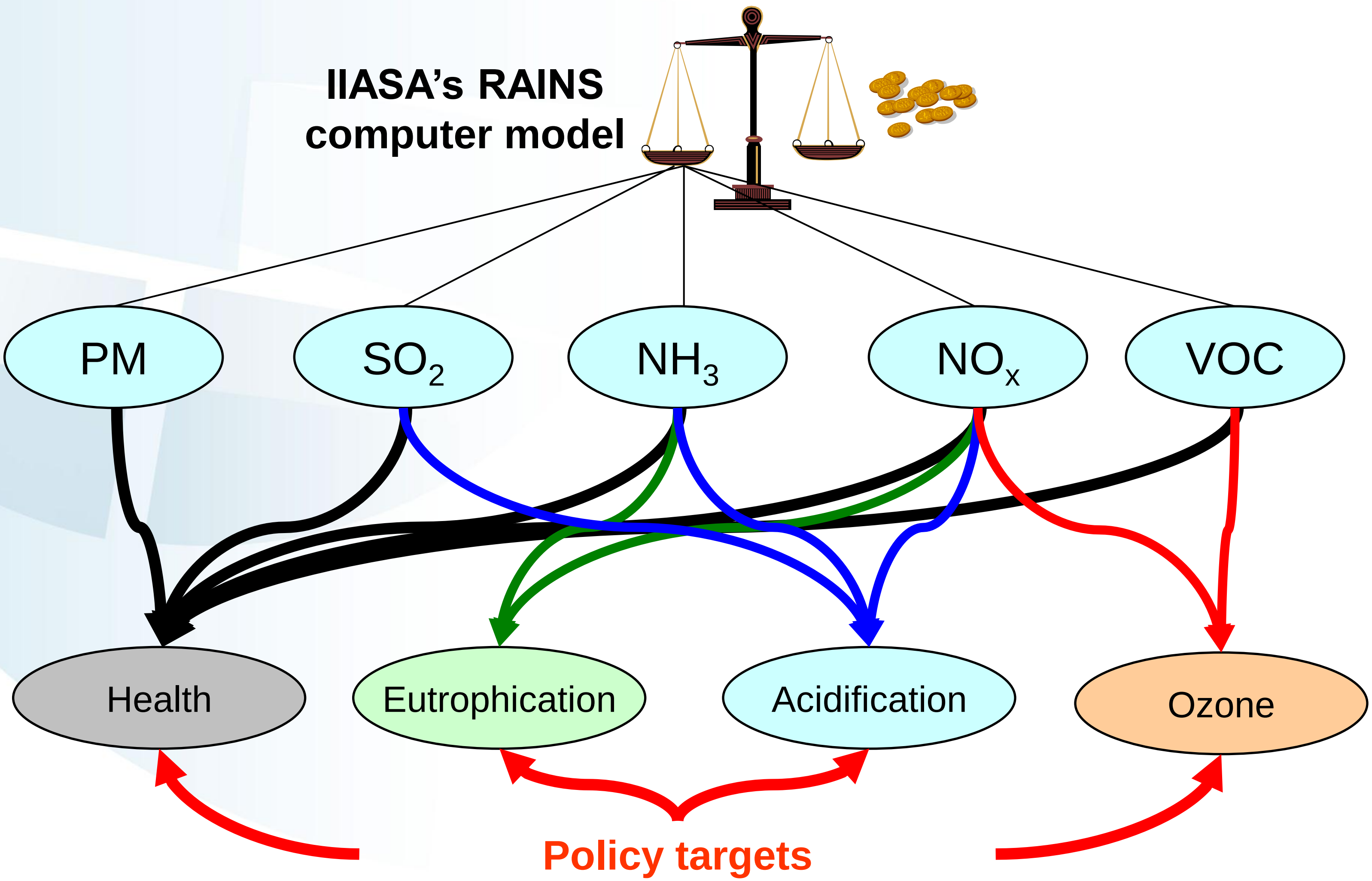
Integrated Assessment
(Jeroen P van der Sluijs, Encyclopedia of Global Environmental Change, 2002)

- *Integrated assessment (IA) can be defined as an* ***interdisciplinary*** *process of combining, interpreting and communicating knowledge from* ***diverse scientific disciplines*** *in such a way that the* ***whole cause–effect chain*** *of a problem can be evaluated from a synoptic perspective with two characteristics:*
  - *it should have* ***added value*** *compared to single disciplinary assessment; and*
  - *it should provide* ***useful information to decision makers****.*
- *Thus (IA) is an* ***iterative participatory process*** *that links knowledge (science) and action (policy) regarding complex global change issues such as acidification and climate change.*

Where did we start our *Integrated Assessment Modelling* adventure?

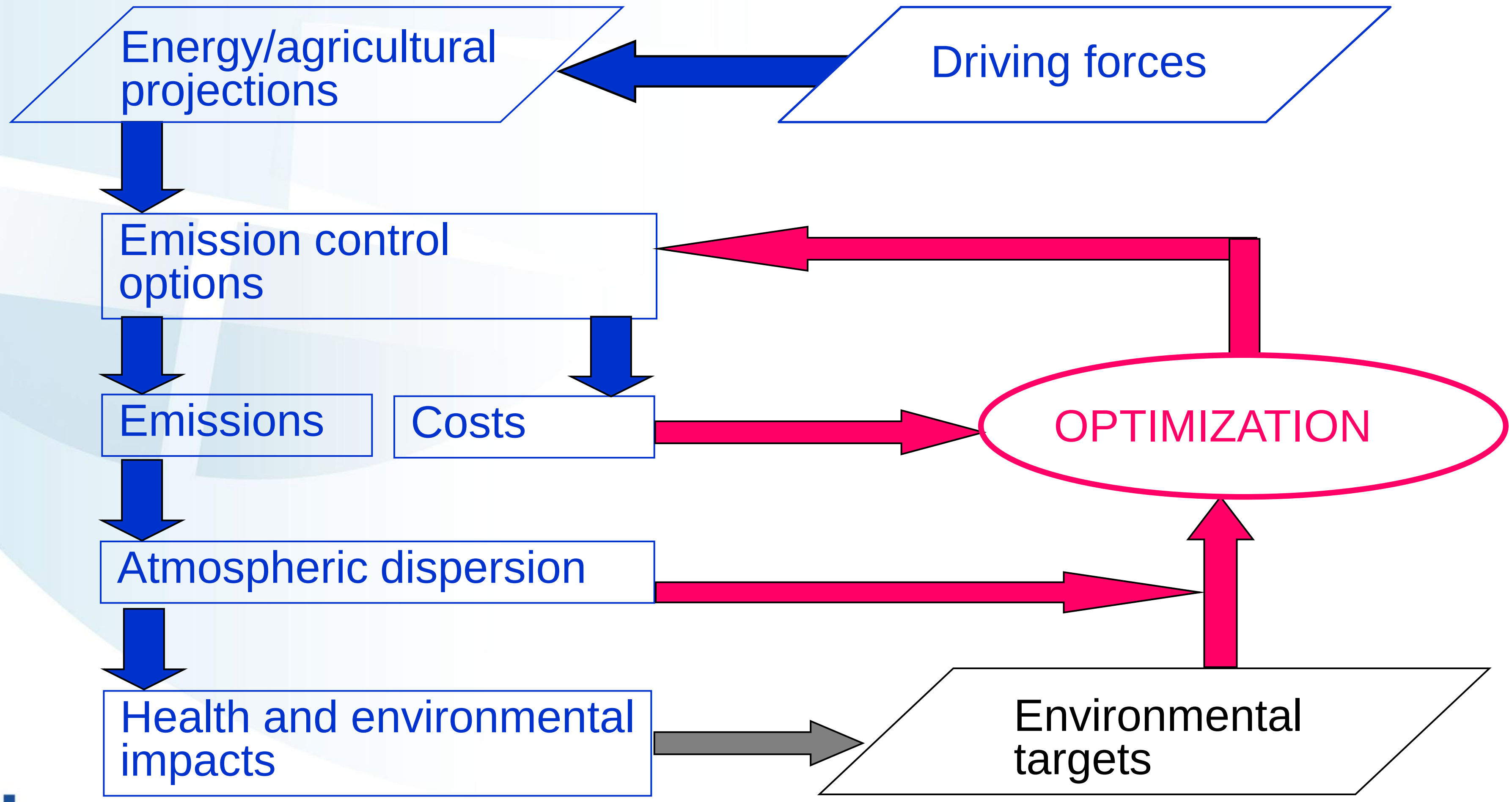
Acid rain

Multi-pollutant/multi-effect analysis
for identifying cost-effective policy scenarios



The RAINS cost-effectiveness approach

(Regional Air pollution INformation and Simulation)



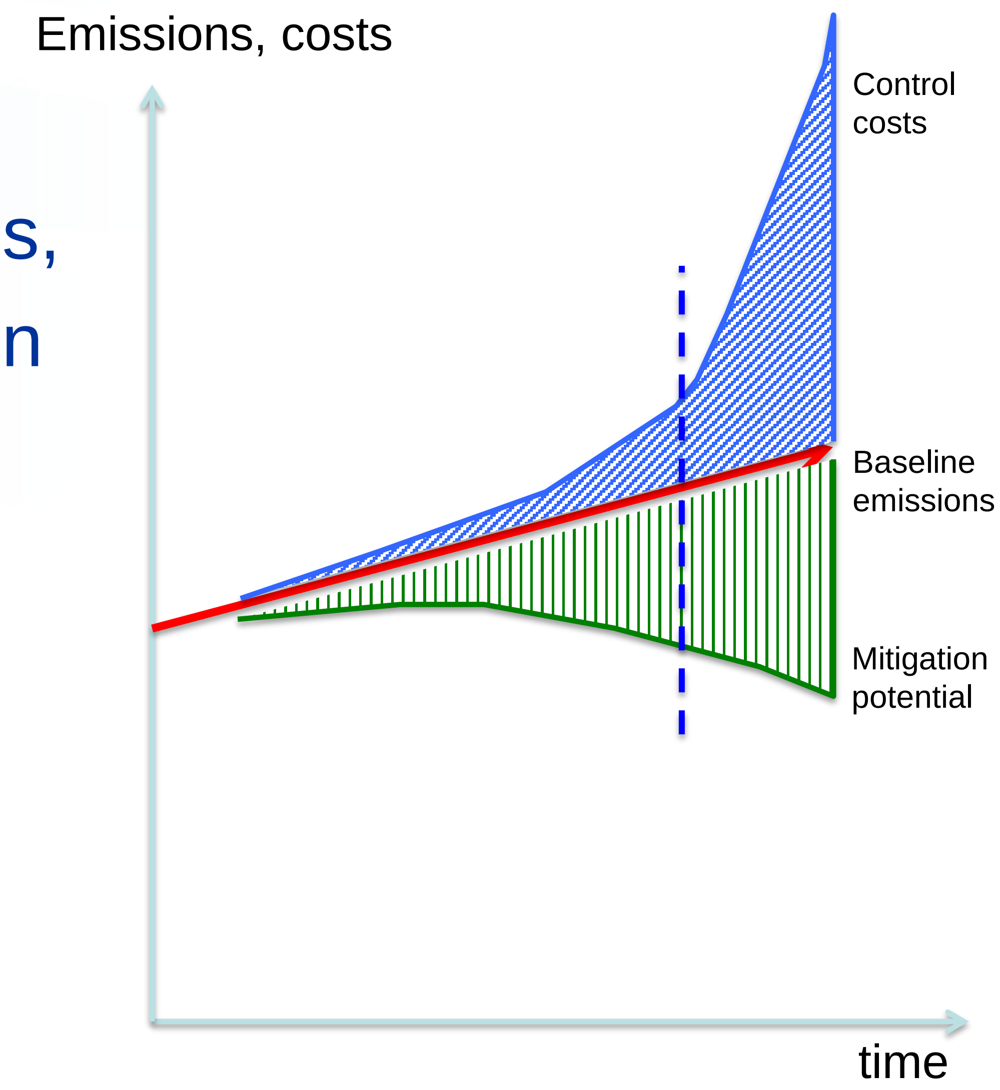
GAINS model and emission inventories

- GAINS is not an emission inventory model
- We are not reviewing the inventories but use them (and other sources) to validate GAINS estimates
  - We try to understand and reproduce the inventory (with GAINS resolution)

Why?

We are interested in:

- projecting emissions,
- Assessing mitigation potential,
- calculating control costs,
- searching for cost-optimal strategies considering constraints/targets



The cost-effectiveness approach

Models help to separate policy and technical issues:

Decision makers	Models
Decide about •Ambition level (environmental targets) •Level of acceptable risk •Willingness to pay	**Identify cost-effective and robust measures:** • Balance controls over different countries, sectors and pollutants • Regional differences in Europe • Side-effects of present policies • Maximize synergies with other air quality problems • Search for robust strategies

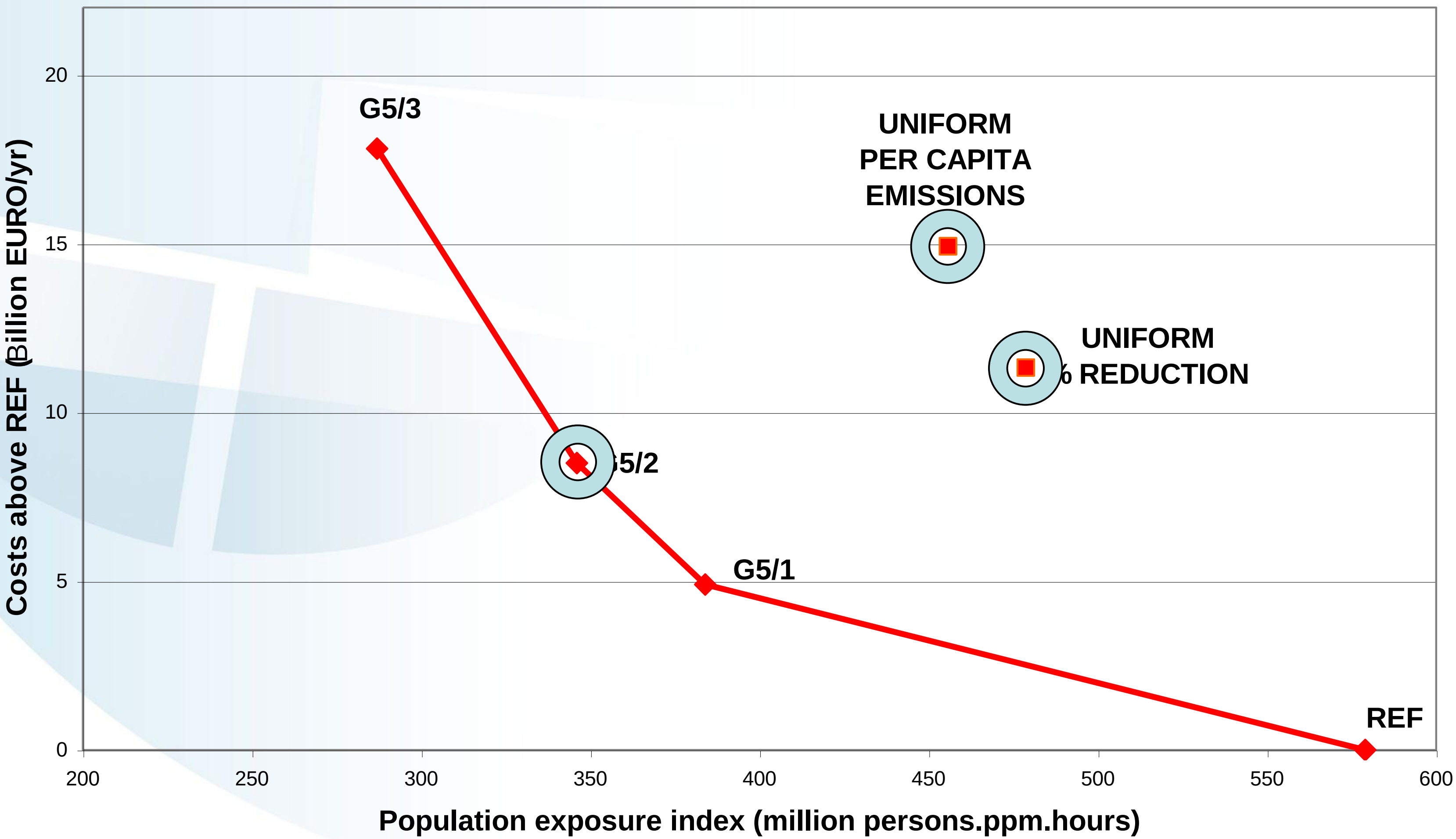
Air pollution policy processes in Europe

- Regional air quality policy process initiated by signature of the LRTAP Convention (1979)
- Change in approach with the LRTAP SO_2 protocol (1994) where models were used for the first time
- Multi-pollutant/multi-effect approach introduced in Gothenburg Protocol (1999) and EU acidification strategy (1997-2001)

- Lessons learned so far (policy-science perspective)
  - Move towards regional policy triggered by e.g., ‘destruction’ of common good
  - Science has a role helping to separate policy and technical issues
  - Building trust in science results takes time
  - Robustness of results often more important than presentation of uncertainties
  - Cost-effectiveness approach has been accepted but will be always confronted with equality/fairness of burdens
  - Involving stakeholders from industry, NGOs essential

Uniform or effect-based scenarios?

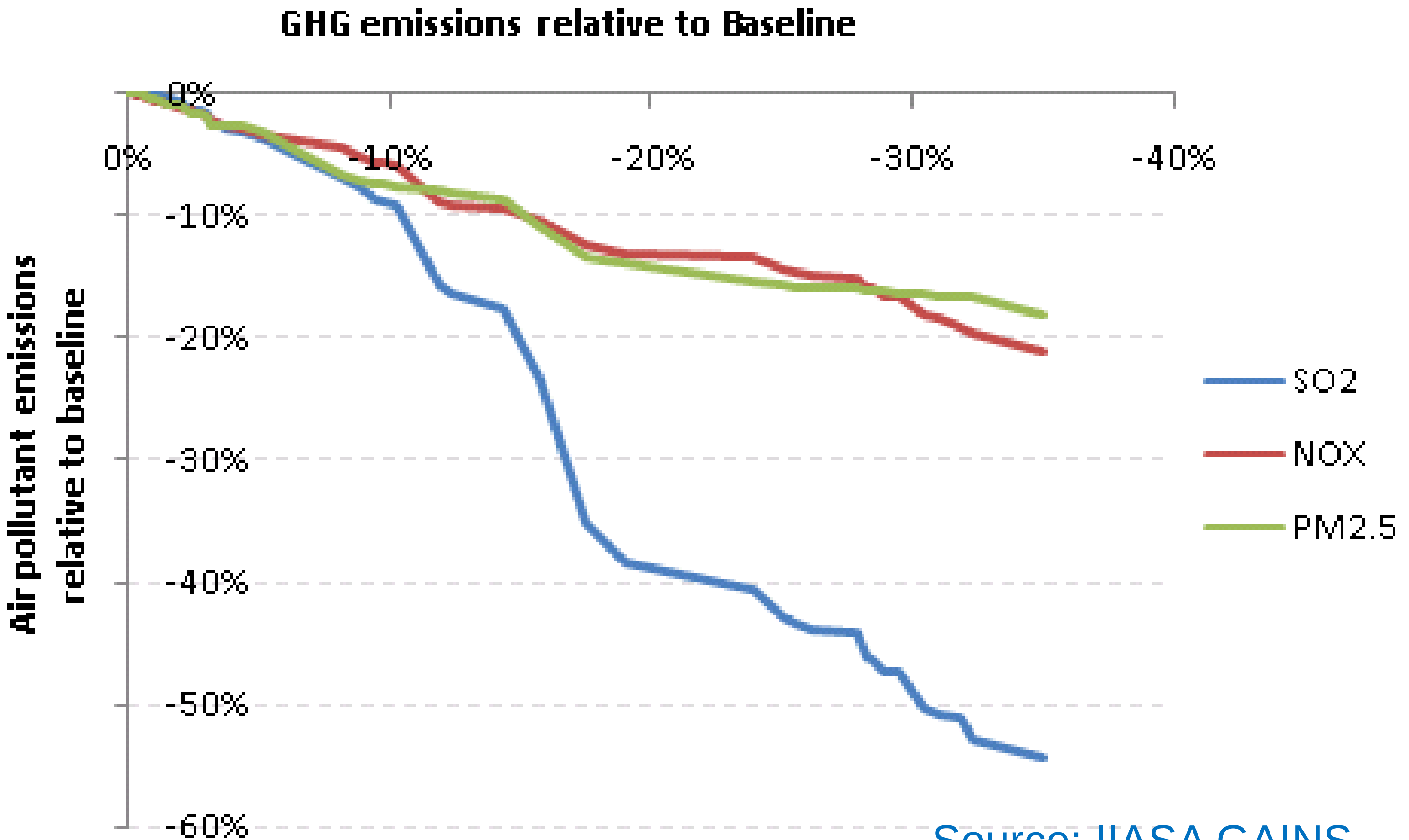
Example from discussion leading to Gothenburg Protocol (1999)



Scope for optimization...

- Some sources are more strongly linked than others via the atmosphere to sensitive receptors
- Some sources are cheaper to control than others

Co-control of GHGs and air pollutants

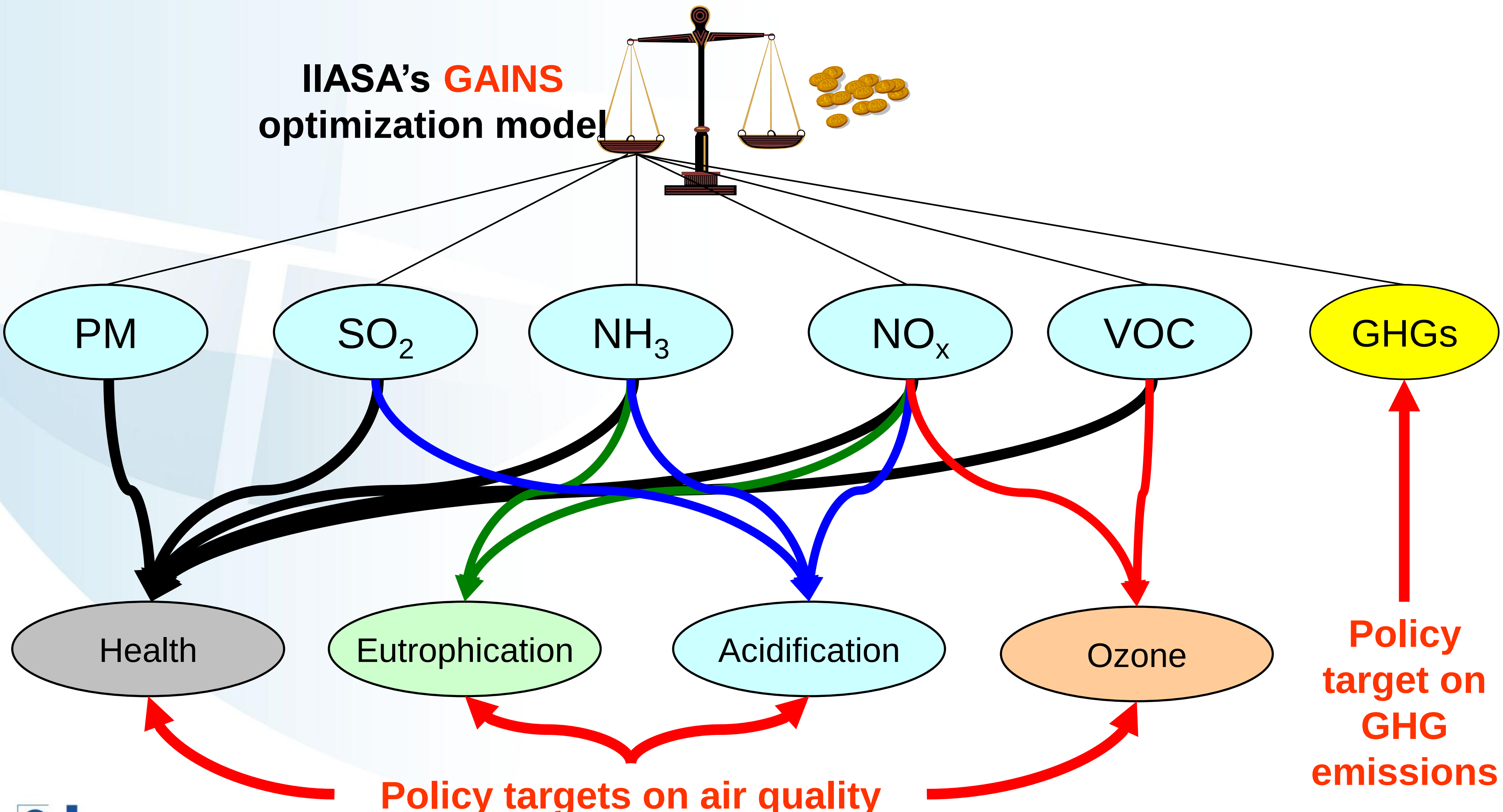


Source: IIASA GAINS
http://gains.iiasa.ac.at

The **GAINS** approach

for identifying cost-effective emission control strategies

(**G**HG-**A**ir pollution **IN**teractions and **S**ynergies)



Extension of the GAINS multi-pollutant/multi-effect framework to include near-term climate impacts (http://gains.iiasa.ac.at)

	PM (BC, OC)	SO_2	NO_x	VOC	NH_3	CO	CO_2	CH_4	N_2O	HFCs PFCs SF_6
Health impacts: PM (Loss in life expectancy)	√	√	√	√	√					
O_3 (Premature mortality)			√	√		√		√		
Vegetation damage: O_3 (AOT40/fluxes)			√	√		√		√		
Acidification (Excess of critical loads)		√	√		√					
Eutrophication (Excess of critical loads)			√		√					
Climate impacts: Long-term (GWP100)							√	√	√	√
Near-term forcing (in Europe and global mean forcing)	√	√	√	√	√	√				
Black carbon deposition to the arctic	√									

Method – ***emission factors***

- “Unabated” emission factors for anthropogenic sources only
- Country/region specific factors taken into account wherever possible, i.e.:
  - For SO2: fuel characteristics
  - For PM: fuel and installation characteristics
  - For NH3: N-excretion and volatilization, production efficiency, housing period
  - For NMVOC: climatic conditions, volatility of fuels, solvent content of products

Method – ***abatement techniques***

- Economic and technical information for "technical" measures
- For most techniques efficiency assessed from literature and communication with experts, however, country/region specific factors taken into account when necessary and available, i.e.:
  - For NH3: geophysical conditions, feeding strategies
  - For NMVOC: sector "composition", solvent content of products
- Introduction of "applicability" parameter, i.e., maximum technically feasible application rate of control option
- Actual and projected penetration rate of control technology

What is the origin of GAINS data?

[activities and activity parameters]

- **Historical (1990,1995,2000, 2005)**
  - Statistics (IEA, Eurostat, FAO, IFA, EFMA)
  - Communication with national experts (consultations)
  - UNECE and UNFCCC submissions,
  - Industrial data (consultations CEPE, EFMA, other)
  - Models (PRIMES, TREMOVE, CAPRI),
  - Literature studies, and
  - Own assessments
- **Forecasts (until 2030)**
  - Communication with national experts (consultations)
  - UNECE and UNFCCC submissions,
  - Industrial data (consultations),
  - Models (PRIMES, TREMOVE, CAPRI, FAO, EFMA),
  - Literature studies

What is the origin of GAINS data?

[emission factors and ef parameters, reduction efficiencies and costs of abatement]]

- Guidebooks (CORINAIR/EMEP, AP-42, BUWAL)
- UNECE Expert Groups
- National submissions (consultations)
- International databases, e.g., CEPMEIP
- Industrial associations
- Peer-reviewed literature
- Grey literature
- Own expertise

UNECE
Long-Range Transboundary Air Pollution Convention

GAINS APPLICATION IN REVIEW OF GOTHENBURG PROTOCOL

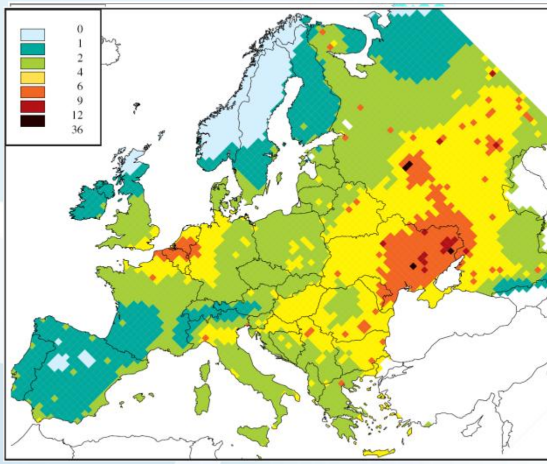
Central question for policy makers

To what level should the emissions of air pollutants be reduced in the year 2020?

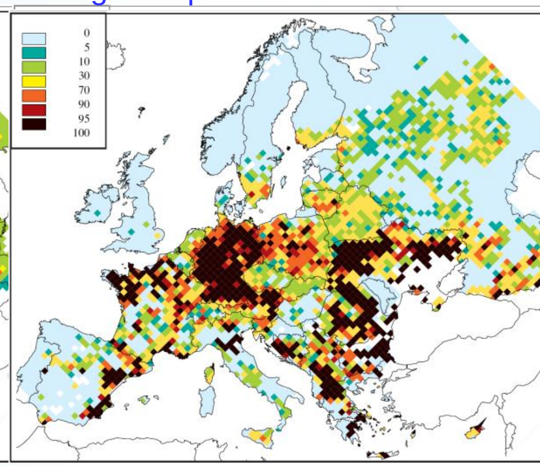
- Where will emissions and effects be in 2020 without further policies?
- What reductions are technically feasible?
- How much do they cost? – optimal/non-optimal
- Who (which countries) pay(s)?
- How much are they willing to pay?
- Who benefits?
- Is it enough?
- Is it fair?

Integrating over different effects:
Air quality impacts in 2000 and policy for 2020

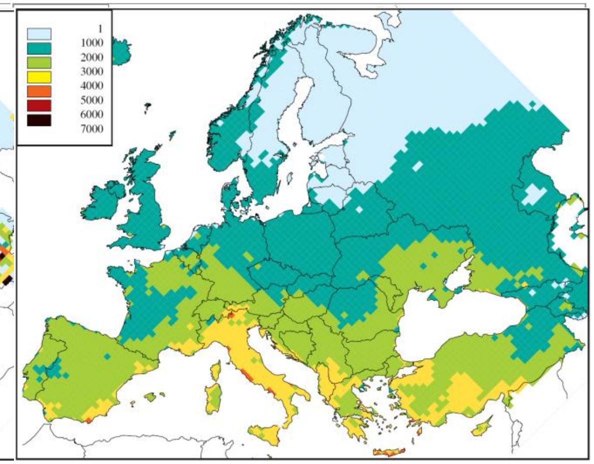
Health impacts from fine PM

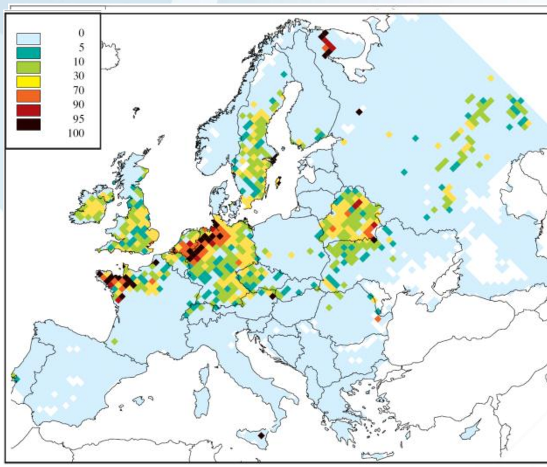


Biodiversity threat from excess nitrogen deposition

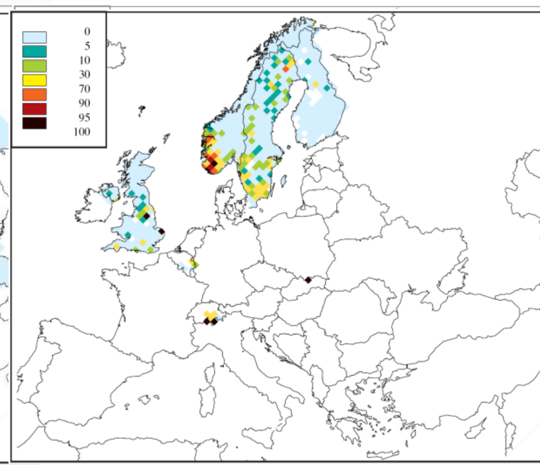


Health impacts from ozone

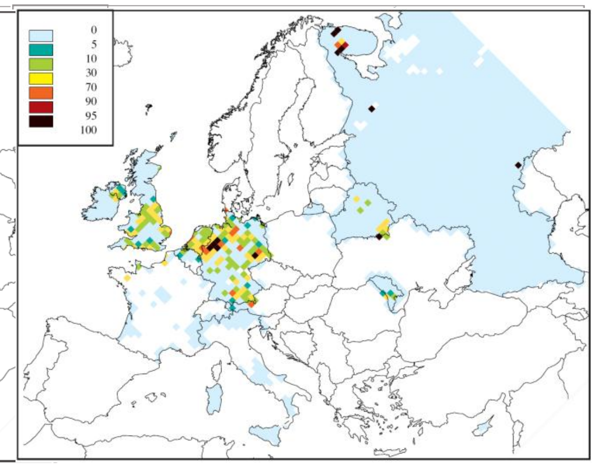




Acidification of forest soils



Acidification of rivers and lakes



Acidification of nature protection areas

Central question for policy makers

To what level should the emissions of air pollutants be reduced in the year 2020?

- Where will emissions and effects be in 2020 without further policies?
- What reductions are technically feasible?
- How much do they cost? – optimal/non-optimal
- Who (which countries) pay(s)?
- How much are they willing to pay?
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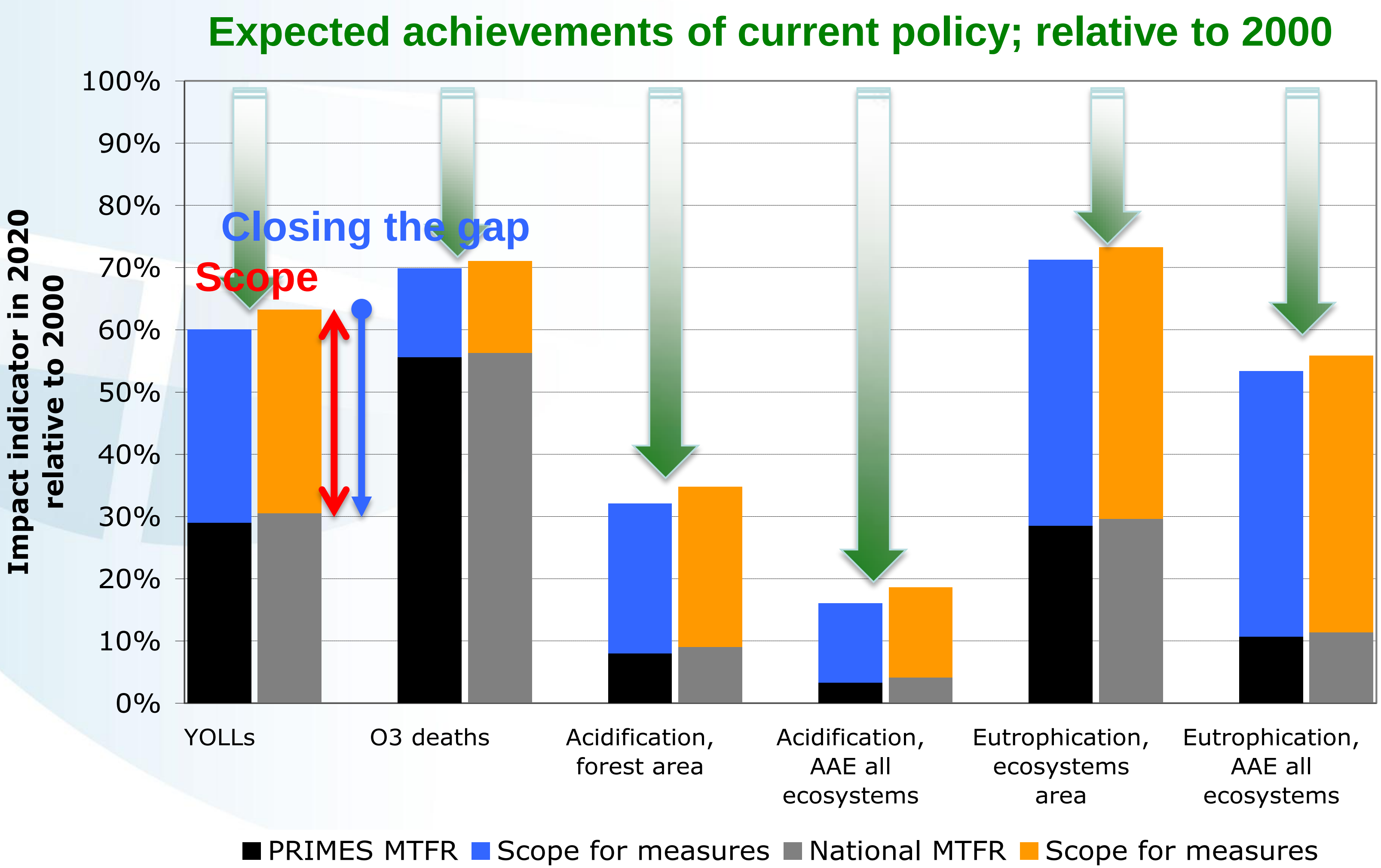
Scope for further environmental improvements in the UNECE area: 4(6) effects



Four options for target setting

Where do we want to go by 2020?

Environmental targets for a cost-effectiveness optimization

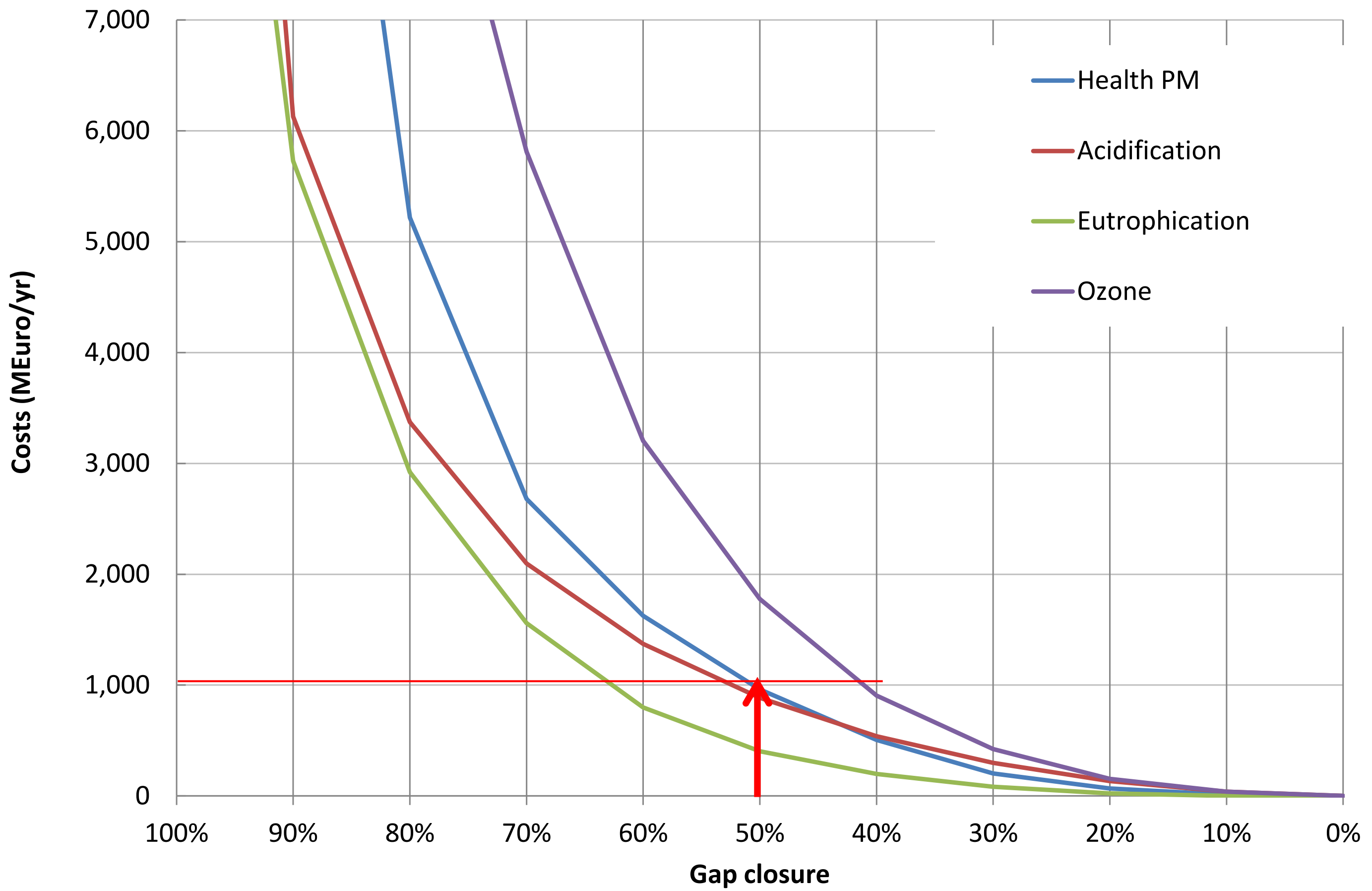
- must be achievable in all countries,
- should result in internationally balanced costs and benefits.

Four options have been analysed with GAINS:

1. Uniform absolute targets (‘caps’) on environmental quality (in terms of impact indicators)
2. Equal relative change (‘gap closure’) in impact indicators compared to a base year
3. Equal portions of the possible improvements in each country (equal ‘gap closure’ between Baseline and Maximum Technically Feasible Reduction)
4. Europe-wide improvements at least cost

Choosing an ambition level

Costs for improving individual effects



100% means: impact is reduced from
Baseline to Maximum Technically Feasible Reduction

Discrete options for ambition levels

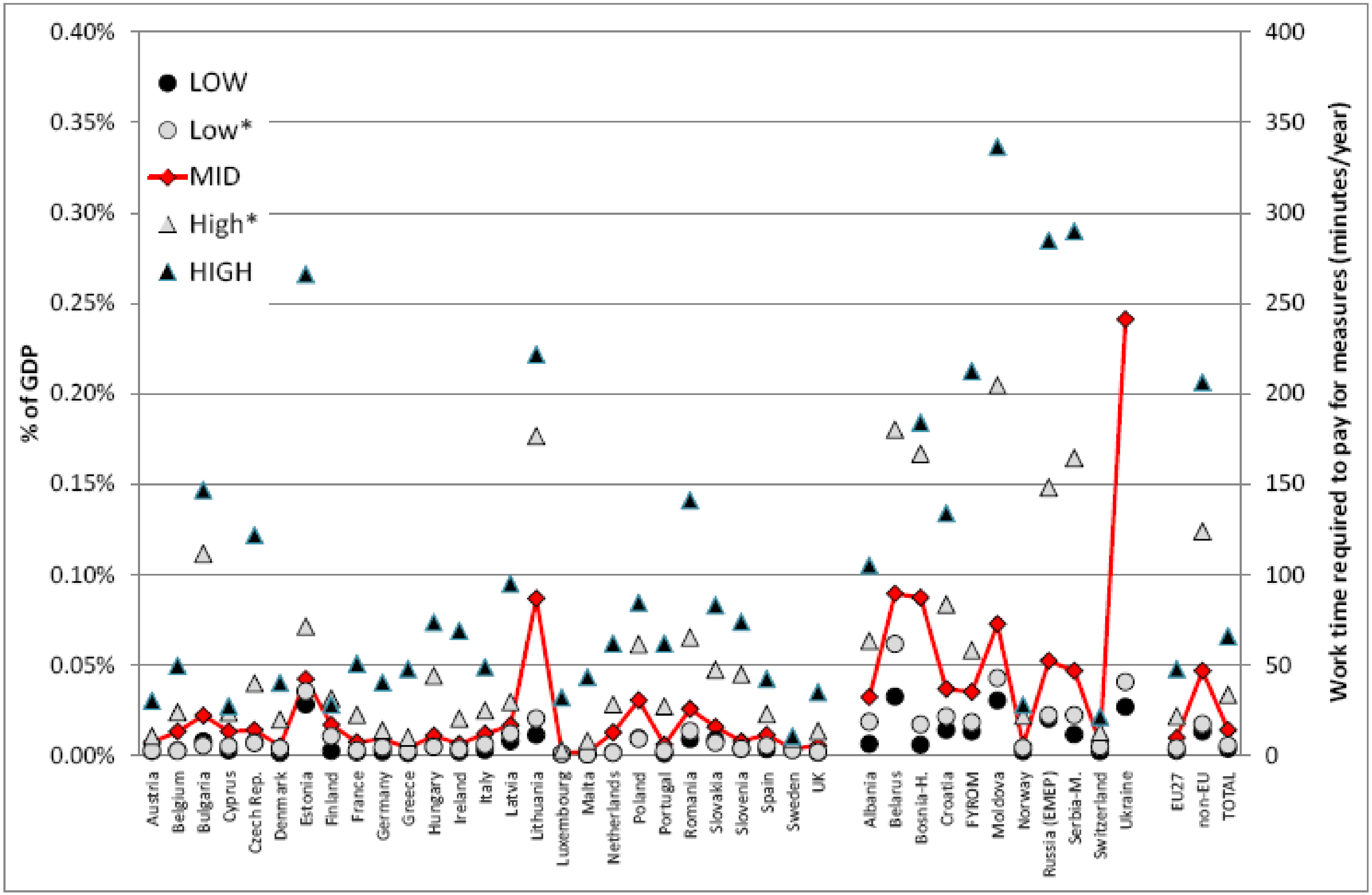
Closing the gap

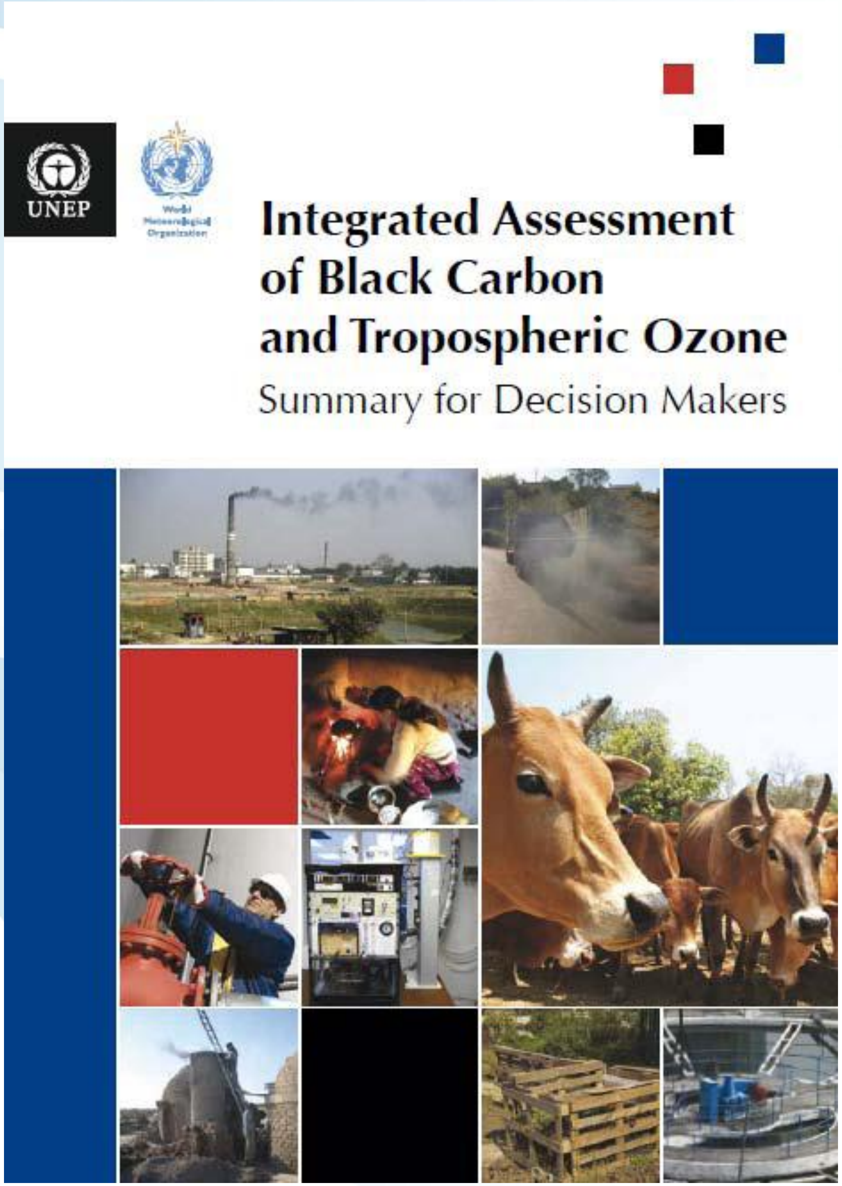
	Health-PM	Acidification	Eutrophication	Ozone
HIGH	75%	75%	75%	75%
High*	75%	75%	75%	50%
Mid	50%	50%	60%	40%
Low*	25%	25%	50%	25%
LOW	25%	25%	25%	25%

100% means: impact is reduced from Baseline to Maximum Technically Feasible Reduction

Additional air pollution control costs

as a percentage of GDP in 2020





GAINS IN UNEP BC AND O_3 ASSESSMENT

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Scenario development: Approach

From Baseline scenario towards RF mitigation and climate impacts

1. Develop emission projections for all substances
   (IEA 2009 World Energy Outlook Baseline and 450ppm, GAINS model technology db)

2. Determine future RF by sector and gas
   (Literature GWP values)

3. Rank mitigation measures by their net impact on warming of their CH_4/BC/OC/CO/SO_2/NMVOC/NO_x emission changes
   (GAINS technology db)

4. Choose a set of efficient measures
   (representing ~90% of potential)

5. Estimate climate impacts and co-benefits (NASA-GISS, ECHAM)

Small number of measures addresses most of the reduction potential

- Methane
  - About 40% reduction (relative to 2030 baseline), at a global level, can be achieved by only 7 measures in 3 key sectors:
    - Fossil fuel industry,
    - Waste management,
    - Agriculture
- Black carbon
  - About 80% reduction (relative to 2030 baseline), at a global level, can be achieved by only 9 measures in 4 key sectors:
    - Domestic combustion
    - Transport
    - Small industry
    - Agriculture
- Simultaneously significant reductions of other air pollutants

Global benefits from full implementation of measures in 2030 compared to the reference scenario; *UNEP/WMO, 2011*

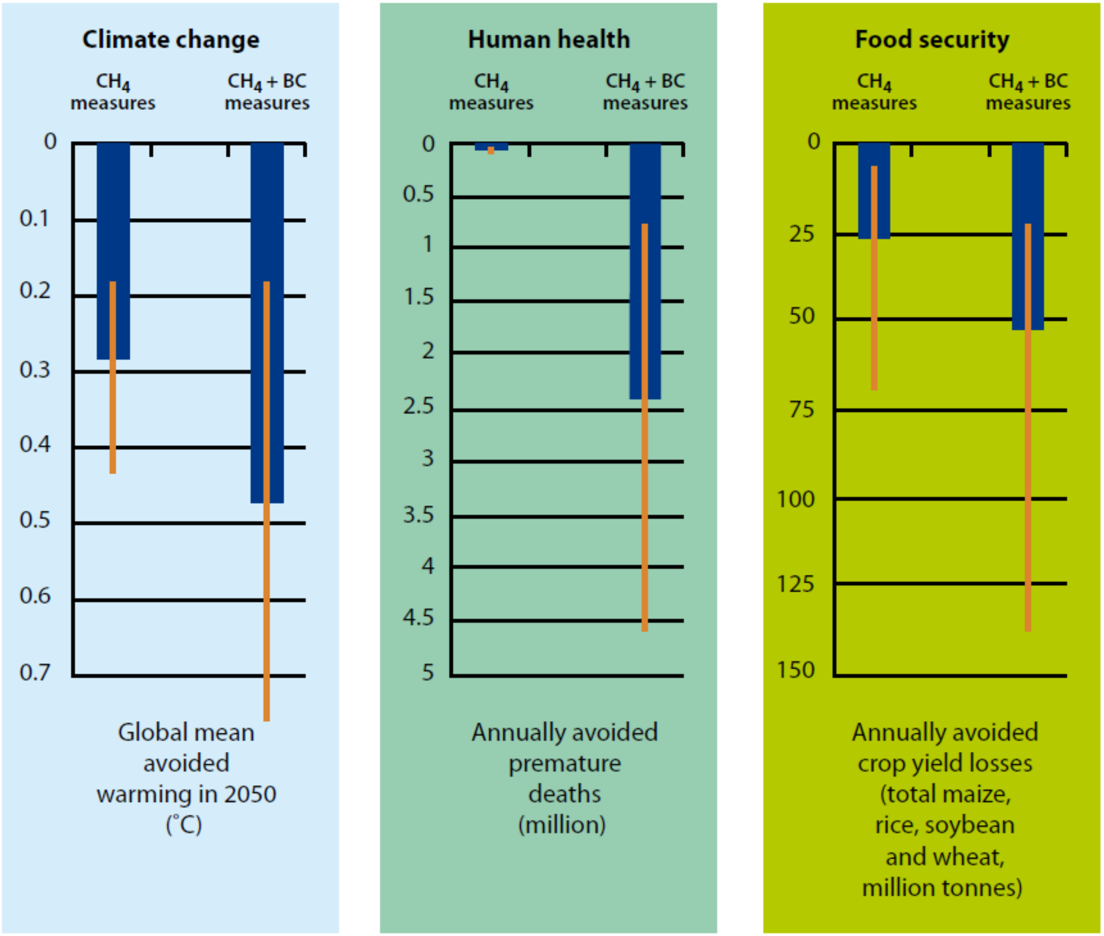
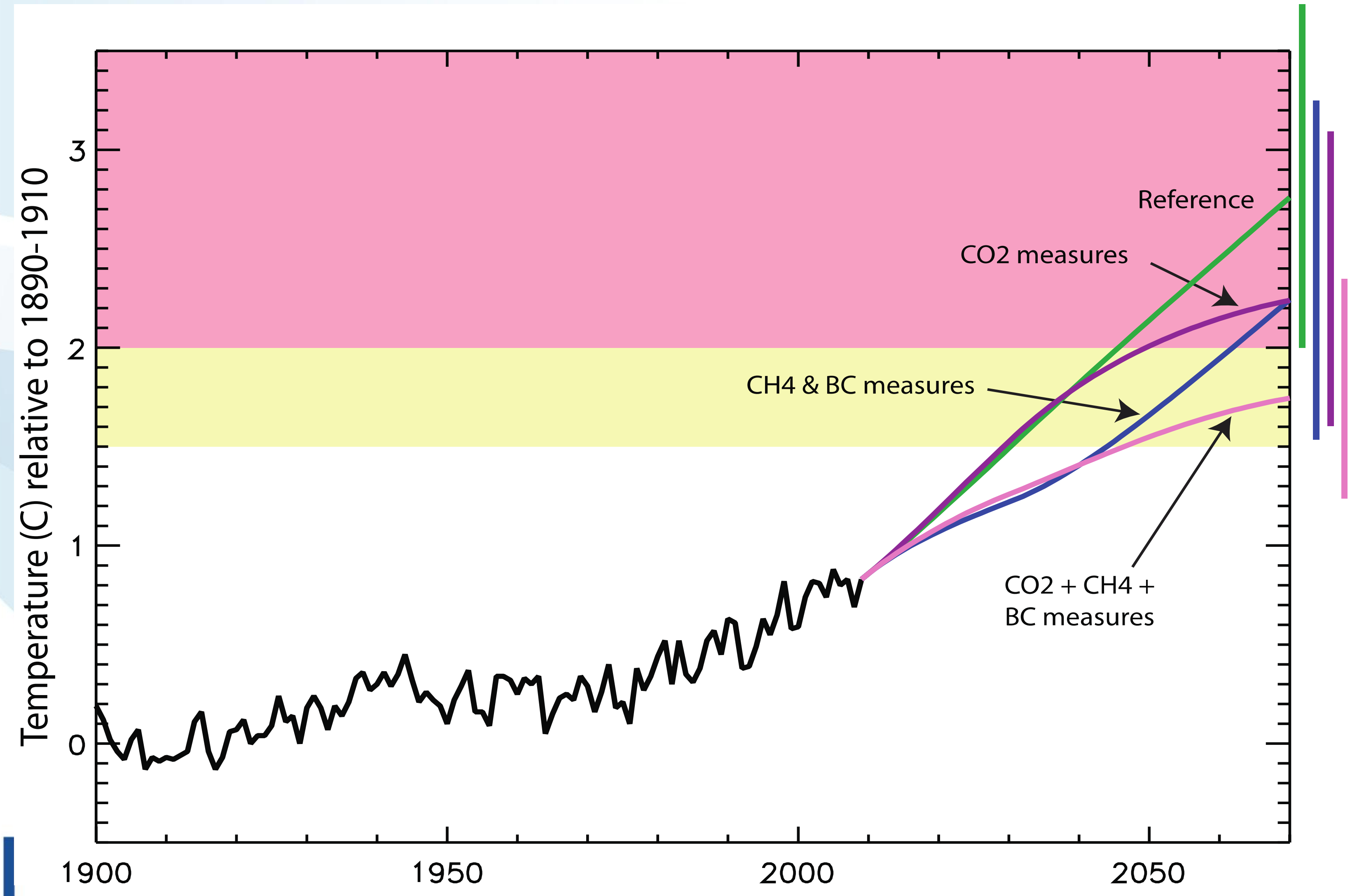
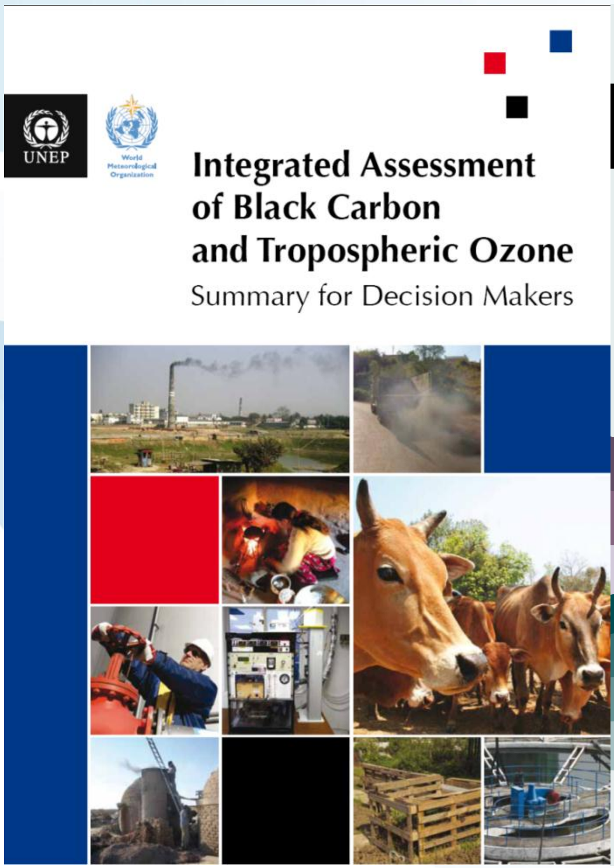


Figure 1. Global benefits from full implementation of the identified measures in 2030 compared to the reference scenario. The climate change benefit is estimated for a given year (2050) and human health and crop benefits are for 2030 and beyond.

Observed deviation of temperature to 2009 and projections under various scenarios; *UNEP/WMO, 2011; Shindell et al., 2012 (Science)*



Recent UNEP Assessments



More details and background available from:

- UNECE Gothenburg Protocol revision work
  - http://gains.iiasa.ac.at/index.php/policyapplications/gothenburg-protocol-revision
  - GAINS model: http://gains.iiasa.ac.at
- UNEP related work:
  - *UNEP/WMO, 2011*. Integrated Assessment of Black Carbon and Tropospheric Ozone.: http://www.unep.org/dewa/Portals/67/pdf/BlackCarbon_report.pdf
  - *UNEP, 2011*. Near-term Climate Protection and Clean Air Benefits: Actions for Controlling Short-Lived Climate Forcers - A UNEP Synthesis Report.: http://www.unep.org/publications/ebooks/SLCF
  - *Shindell et al., 2012*. Simultaneously Mitigating Near-Term Climate Change and Improving Human Health and Food Security*. Science* 335, 183; DOI: 10.1126/science.1210026

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