The Salut’air–Project:
Assessment of European Air Quality in 2050 in the Context of Climate Change

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The Salut’air project

- **Salut’air**
  - Evaluation of strategies mitigating long-range transboundary air pollution in the context of climate change *
- **Funded by the French research programme PRIMEQUAL**
  - financed by the French Ministry for Ecology and ADEME
  - bringing together different scientific communities concerned with air pollution and its impacts
- **Project tasks**
  - downscaling of global climate and chemistry fields to regional scale (Europe)
  - modelling of air pollution scenarios under climate change
  - assessment of impacts on air quality and health in 2050
  - cost-benefit analysis for 2050

=> presentation of preliminary results

* Evaluation des StrAtégies de LUTte contre la pollution de l'AIR à longue distance dans le contexte du changement climatique
Institutes involved

Project partners

• INERIS
  - Bertrand Bessagnet, Augustin Colette, Frédéric Meleux (MOCA - Atmospheric Modelling and Environmental Mapping Unit)
  - Simone Schucht (EDEN - Economics and Decision for the Environment Unit)
  - Laurence Rouil (DECI – Environmental Modelling and Decision Department)

• Laboratoire des Sciences du Climat et de l’Environnement
  - Sophie Szopa, Robert Vautard, Gaëlle Clain (LSCE/IPSL/CEA/CNRS)

• Laboratoire de Météorologie Dynamique
  - Laurent Menut (LMD/IPSL/CNRS)

Further collaboration with

• IIASA
  - Shilpa Rao, Keywan Riahi, Peter Kolp (ENE – Energy Program)
  - Zig Klimont, Wolfgang Schöpp (MAG - Mitigation of Air Pollution & Greenhouse Gases)

• EMRC
  - Mike Holland
The project setup - regional air quality and climate impact assessment

- **Radiative Forcing**
  - RCP/AR5

- **Atmosphere/Ocean General Circulation Model**
  - IPSLcm5A: CMIP5 (IPSL)

- **Regional Climate Model**
  - WRF: Euro-Cordex (INERIS/IPSL)

- **Regional Chemistry Transport Model**
  - CHIMERE (INERIS/IPSL)

- **Health Impact Assessment**
  - Alpha-RiskPoll-France (INERIS, collaboration with EMRC)

- **Cost/Co-benefit Analysis**
  - (INERIS)

- **Global Chemistry Model**
  - INCA: ACCMIP (IPSL)

- **Air Pollutants**
  - (IIASA: GEA Emissions and Costs)

Developed and/or performed within the framework of Salut’air
The modelling chain allowing to compare costs and benefits of emission reduction strategies

**Impact pathway approach**

- Emissions
- Dispersion and deposition
- Exposure
- Impacts
- Monetisation

**Models used**

- Integrated assessment model GAINS and energy model MESSAGE
- Climate and regional air quality modelling chain
- Alpha-RiskPoll-FR (developed with EMRC at INERIS)

**Comparison of costs and benefits**

- Costs of measures
- Comparison of costs and benefits
- Benefits (avoided damage)
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Two emission scenarios from GEA used for AQ and health impact assessment

- Match RCPs in terms of global radiative forcing
- Revised handling of air pollutant emissions
  - detailed assumptions on air pollution abatement in 2030 provided by the integrated assessment model GAINS and fed into the global energy model MESSAGE
- Through collaboration with IIASA access to
  - spatial pollution maps for NOx, VOCs, NH3, SO2, PM2.5, CO, BC and OC
  - global CO2 trajectories for the two climate contexts (REF and MIT)
  - expenditures (investment and O&M costs) for air quality and climate/energy policy
  - data for MESSAGE regions WEU & EEU

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Policies</th>
<th>Climate context</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Air pollution</td>
<td></td>
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<tr>
<td></td>
<td>Climate change</td>
<td></td>
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<tr>
<td></td>
<td>Energy efficiency</td>
<td></td>
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<td></td>
<td>Energy access</td>
<td></td>
</tr>
<tr>
<td>CLE-1 Reference case (climate policy) with current air pollution legislation</td>
<td>all current and planned air quality legislation implemented by 2030; further improvement of emission factors with economic growth</td>
<td>no climate change policy</td>
</tr>
<tr>
<td>CLE-2 Sustainable climate policy with current air pollution legislation</td>
<td>limit on temperature change to 2°C in 2100</td>
<td>annual energy intensity reduction of 2.6% until 2050</td>
</tr>
</tbody>
</table>

**GEA:** Global Energy assessment, coordinated by IIASA, [http://www.iiasa.ac.at/Research/ENE/GEA/index_gea.html](http://www.iiasa.ac.at/Research/ENE/GEA/index_gea.html)

**GAINS:** Greenhouse gases – Air pollution INteractions and Synergies model (IIASA, MAG team)

**MESSAGE:** Model for Energy Supply Strategy Alternatives and their General Environmental impact), model selected for producing the AR5 RCP8.5 (IIASA, ENE team)

Salut’air project, Simone Schucht, INERIS
NOx, SO2 and PM2.5 emissions in kt/year – WEU&EEU

Emission scenarios

Air pollution policy
- CLE in 2030
- further improvement of emission factors with economic growth until 2050

Climate change policy
- reference scenario (CLE1)
- mitigation scenario (CLE2)
Energy/climate and air pollution mitigation expenditure in the GEA scenarios

MIT (CLE2) relative to REF (CLE1)

Energy costs
- ambitious energy/climate policy increases energy expenditure $\approx 110$ billion € ($\approx 30\%$)
- increase in energy efficiency; reduction in energy demand
- lower investment costs on energy supply side; higher investment costs on energy demand side

AP costs (NOx, SO2, PM2.5)
- cost savings $\approx 42$ billion €
- same air pollution objectives require less emission reduction measures
- structural changes between energy types; reduction of final energy demand

Net aggregate costs
- increase in costs $\approx 65$ billion € (decrease for AP costs, increase for energy/climate policy costs)
The modelling chain allowing to compare costs and benefits of emission reduction strategies

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Comparison of costs and benefits

- Costs of measures
- Comparison of costs and benefits
- Benefits (avoided damage)
Assessment of health impacts from air pollution

- **Implementation of Alpha-RiskPoll-France (ARP-FR) at INERIS**
  - collaboration with Mike Holland (EMRC)
  - ARP-FR designed for taking pollution data generated by CHIMERE model
  - approach coherent with the one used by the EC and UN/ECE
  - impact pathway approach

- **Health effects taken into account**
  - exposure to fine particles
  - exposure to ground level ozone
  - mortality (adults, children)
  - morbidity (different indicators)

**Alpha/RiskPoll Models**: developed by M. Holland & J. Spadaro, used by AEA & EMRC (for CAFE / CLRTAP)
Indicators and monetary values used to quantify health impacts

Core indicator

<table>
<thead>
<tr>
<th>End point</th>
<th>Population</th>
<th>Impact</th>
<th>Pollutant</th>
<th>Exposure metric</th>
<th>Valuation (€, 2005)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute Mortality median VOLY</td>
<td>all ages</td>
<td>Premature deaths</td>
<td>O3</td>
<td>SOMO35</td>
<td>57 700</td>
</tr>
<tr>
<td>Respiratory Hospital Admissions over 65 years</td>
<td>all ages</td>
<td>Cases</td>
<td>O3</td>
<td>SOMO35</td>
<td>2 220</td>
</tr>
<tr>
<td>Minor Restricted Activity Days (MRADs)</td>
<td>15 - 64 years</td>
<td>Days</td>
<td>O3</td>
<td>SOMO35</td>
<td>42</td>
</tr>
<tr>
<td>Respiratory medication use over 20 years</td>
<td>all ages</td>
<td>Days</td>
<td>O3</td>
<td>SOMO35</td>
<td>1</td>
</tr>
<tr>
<td>Chronic Mortality LYL median VOLY</td>
<td>all ages</td>
<td>Life years lost</td>
<td>PM</td>
<td>PM2.5 annual average</td>
<td>57 700</td>
</tr>
<tr>
<td>Infant Mortality median VSL</td>
<td>0-1 years</td>
<td>Premature deaths</td>
<td>PM</td>
<td>PM2.5 annual average</td>
<td>1 635 000</td>
</tr>
<tr>
<td>Chronic Bronchitis over 27 years</td>
<td>all ages</td>
<td>Cases</td>
<td>PM</td>
<td>PM2.5 annual average</td>
<td>208 000</td>
</tr>
<tr>
<td>Respiratory Hospital Admissions</td>
<td>all ages</td>
<td>Cases</td>
<td>PM</td>
<td>PM2.5 annual average</td>
<td>2 220</td>
</tr>
<tr>
<td>Cardiac Hospital Admissions</td>
<td>all ages</td>
<td>Cases</td>
<td>PM</td>
<td>PM2.5 annual average</td>
<td>2 220</td>
</tr>
<tr>
<td>Restricted Activity Days (RADs)</td>
<td>15 - 64 years</td>
<td>Days</td>
<td>PM</td>
<td>PM2.5 annual average</td>
<td>92</td>
</tr>
<tr>
<td>Respiratory medication use 5-14 years</td>
<td>all ages</td>
<td>Days</td>
<td>PM</td>
<td>PM2.5 annual average</td>
<td>1</td>
</tr>
<tr>
<td>Respiratory medication use over 20 years</td>
<td>all ages</td>
<td>Days</td>
<td>PM</td>
<td>PM2.5 annual average</td>
<td>1</td>
</tr>
<tr>
<td>LRS symptom days</td>
<td>5-14 years</td>
<td>Days</td>
<td>PM</td>
<td>PM2.5 annual average</td>
<td>42</td>
</tr>
<tr>
<td>LRS among adults with chronic symptoms</td>
<td>over 15 years</td>
<td>Days</td>
<td>PM</td>
<td>PM2.5 annual average</td>
<td>42</td>
</tr>
</tbody>
</table>

Sensitivity analyses

- Ranges for mortality valuation data
  - acute mortality (ozone), chronic mortality (PM), infant mortality (PM)
- Additional indicators for sensitivity analyses
  - ozone: minor restricted activity days; respiratory symptoms
  - PM\(_{2.5}\): restricted activity days; asthma consultations; consultations for upper respiratory diseases

Salut’air project, Simone Schucht, INERIS
Exposure to fine particles and life years lost from chronic exposure to PM$_{2.5}$

Important reduction in exposure between 2005 and 2050 (CLE 1 vs. 2005) due to atmospheric policy (and despite climate change);

Additional reduction brought about by climate policy (CLE 2 vs. CLE 1)

Similar results for Life Years Lost
Exposure to ozone and premature deaths from acute exposure to ozone

Small reduction of exposure between 2005 and 2050 (CLE1 vs. 2005) – effects of atmospheric policy counterbalanced by climate change & hemispheric transport;

Important reduction brought about by climate policy (CLE 2 vs. CLE 1)

Health effects from ozone increase between 2005 and 2050 (CLE 1 vs. 2005) despite a low reduction in exposure => effect of population increase;

Important reduction brought about by climate policy (CLE 2 vs. CLE 1)
Health damage (monetised)

WEU & EEU - core indicator - €M/year

≈ 60% reduction in health damage between 2005 and 2050 due to atmospheric policy (CLE 1 vs. 2005);

Additional reduction (≈ 50%) brought about by climate policy (CLE 2 vs. CLE 1);

Health damage dominated by PM2.5 effects; partly opposing development for ozone overcompensated.
The modelling chain allowing to compare costs and benefits of emission reduction strategies

Impact pathway approach

- Emissions
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- Monetisation

Models used

- Integrated assessment model GAINS and energy model MESSAGE
- Climate and regional air quality modelling chain
- Alpha-RiskPoll-FR (developed with EMRC at INERIS)

Comparison of costs and benefits

- Costs of measures
- Comparison of costs and benefits
- Benefits (avoided damage)
Comparison of costs and benefits of the policies

Assessment of the health effects of one air pollution reduction strategy under two climate/energy policy contexts

- No assessment of benefits relative to costs of air pollution policy in monetary terms
  - we do not have CLE costs in 2005, nor the costs for less ambitious AP policies
- Classical benefit/cost ratio not applicable
  - requires comparison of air pollution mitigation policies differing in their ambition levels
- Rather a co-benefits/cost ratio
  - increase of energy/climate policy costs versus decrease of AP policy cost and health damages

=> Preliminary results
Comparison between costs and co-benefits of an ambitious climate policy (incremental analysis)

Moving from the scenario without to the scenario with climate policy:

- additional costs for climate/energy measures ≈ 107 billion €/year in 2050
- co-benefits of the energy policy per year in 2050:
  - air pollution reduction costs decrease relative to the scenario without climate policy (savings ≈ 42 billion €)
  - avoided health damage (= benefits) from reduced air pollution ≈ 79 billion €
- co-benefits for the AP policy and for health impacts exceed the additional energy costs
- AP costs only NOx, SO2, PM2.5
- further benefits from the reduction of greenhouse gases not taken into account
Attribution study to understand what drives the results shown in the maps

- Analysis of the impact of different processes playing a role in the future evolution of air quality
  - the global and regional climate
  - air quality mitigation policies (=> emissions)
  - chemical background changes (contribution of long-range AP transport)

- The question
  - do regional (European) AP policies attain the expected effects or are these counterbalanced by long-range AP or climate change?

- Isolation of the contribution of each driving factor to the overall projected change
  - disentangling the main factors through sensitivity decadal simulations
  - replication of the decadal simulations, keeping two factors constant and varying the third
  - e.g. to investigate the impact of climate change use constant present day AP emissions and boundary conditions but change the climate forcing
  - 12 * 10 runs to analyse the impacts of all drivers
Results of the attribution study

- **Ozone**
  - confirmation of the climate penalty (cf. literature) - not very strong, decreasing in the future
  - a strong penalty (REF) or benefit (MIT) comes from chemical background
  - air pollution policies (emission reductions) are effective

- **PM$_{2.5}$**
  - weak impact of long-range transport
  - air pollution policies (emission reductions) dominate the overall result
  - climate has a negative contribution - weak but statistically significant climate benefit

⇒ no consensus in literature on whether climate penalty or benefit for PM (model dependent) - uncertainty
⇒ impact of aerosols on climate change more often analysed than that of climate change on aerosols
⇒ advocates for attribution studies to be done by other modelling teams
⇒ results might be used in health impact assessment/CBA?
Average PM2.5 exposure (2005) per capita from the Climate Cost & Salut’air projects

- Is there natural dust in the Climate Cost project concentrations (GAINS using EMEP SRMs)?
- How to deal with this in health impact assessment?
  - WHO advice for CBA (NECD): “exclude particles from natural sources as they are not controllable using the measures considered in the setting of emission ceilings” (TSAP Report 10, EMRC)

• CHIMERE exposure slightly higher than Climate Cost exposure
• Possibly due to a PM composition issue
=> CHIMERE might have more natural dust in the PM$_{2.5}$ concentrations than the Climate Cost data
Summary & conclusions

• The Salut’air project uses
  • most recent model runs of global and regional climate and atmospheric chemistry model inter-comparisons under IPCC/AR5
  • up-to-date projections for air pollutants and greenhouse gases
• The Salut’air analysis found important co-benefits of climate policy for air pollution policy and health impacts
• The attribution study disentangling the relative impact on PM$_{2.5}$ and ozone concentrations of climate change, atmospheric policies and chemical background changes
  • confirmed the climate penalty for ozone; major influence of long-range transport
  • found a weak climate benefit for PM$_{2.5}$ (uncertainty!), and a strong impact of air pollution policies
• More modelling teams performing attribution studies would be helpful to reduce uncertainty about the climate impact on PM$_{2.5}$
• There might be a point in comparing particle composition across different models & analyses
  • develop a template for modellers to complete?
  • composition of PM$_{2.5}$, origin of emission data, information on scenario development ...
Thank you for your attention!

Publication on the air quality modelling results

Acknowledgements
• The **Salut’AIR** project supported by the French Ministry in charge of Ecology and ADEME
• The **Global Energy Assessment** and specific collaboration with **IIASA**
• The collaboration on health impact assessment with **EMRC**
• The EU FP7 **CityZen** and **ATOPICA** projects
• The **European Environmental Agency** through its support to the European Topic Centre on Air Quality and Climate Mitigation
• The **CCRT** supercomputing centre
Annex
The project setup - regional air quality and climate impact assessment

- **Air Pollutants** (IIASA: GEA Emissions and Costs)
  - Close collaboration with IIASA
  - Implementing air pollutant emission scenarios
  - Documentation of scenarios
  - Cost analysis
  - Collaboration with M. Holland for the development of a climate-air quality HIA interface
  - Monetisation of health impacts

- **Radiative Forcing**
  - RCP/AR5
  - Atmosphere/Ocean General Circulation Model
    - IPSL/CM5A/MR: CMIP5 (IPSL)
  - Regional Climate Model
    - WRF: Euro-Cordex (INERIS/IPSL)
  - Regional Chemistry Transport Model
    - CHIMERE (INERIS/IPSL)
  - Health Impact Assessment
    - Alpha-RiskPoll-France (INERIS, collaboration with EMRC)
  - Cost/Co-benefit Analysis
    - (INERIS)

- **GHG+SLCF**
  - RCP/AR5
  - Global Chemistry Climate Model
    - LMDz-OR-INCA : ACCMIP (IPSL)
  - Adapted to use
    - Climate forcing from RCM
    - Boundary conditions from GCTM
    - Emissions scenarios of IIASA
  - Exposure products
    - Relevant for HIA
  - Analysis of the cost of AP measures
    - (INERIS)

- Development of the dynamical regional climate downscaling of the IPSL AOGCM model
  - Experimental production of historical and 2 projections
  - Operational production of Euro CORDEX

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Data for MESSAGE regions WEU & EEU

Western Europe
- Andorra, Austria, Azores, Belgium, Canary Islands, Channel Islands, Cyprus, Denmark, Faeroe Islands, Finland, France, Germany, Gibraltar, Greece, Greenland, Iceland, Ireland, Isle of Man, Italy, Liechtenstein, Luxembourg, Madeira, Malta, Monaco, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom

Central & Eastern Europe
- Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, The former Yugoslav Rep. of Macedonia, Latvia, Lithuania, Hungary, Poland, Romania, Slovak Republic, Slovenia, Yugoslavia
O$_3$ concentrations in Europe - SOMO35 (sum of O$_3$max $>$ 35ppb)

**Historic climate model 2005**

**GEA CLE1–REF (~RCP8.5) 2050**

**GEA CLE2–MIT (~RCP2.6) 2050**

**Difference to historic**

- status quo for CLE1 (climate reference scenario) (joint effect of global climate & hemispheric transport $=>$ global ozone increases under RCP8.5)
- large decrease for CLE2 (climate mitigation scenario)
PM$_{2.5}$ concentrations in Europe (annual mean)

Projections:
- significant decrease under both scenarios

Air quality results feeding into the health impact assessment
Contribution of different impacts to overall health damage (monetised) in 2050

Health costs dominated by PM2.5 effects, especially:
- chronic mortality (≈ 66%)
- chronic bronchitis (≈ 13%)
- restricted activity days (≈ 10%)

Health costs from ozone amount to:
- ≈ 1.5 % in 2005
- ≈ 4.6 % in CLE 1 2050 (=> effect of climate change & long range transport)
- ≈ 2.1 % in CLE 2 2050 (=> ambitious climate policy)

Model run with climate correction and urban increment (decrement)
Attribution study for SOMO35

- Climate penalty confirmed, decreasing in the future
- Effective air quality legislation
- Major chemical background penalty (REF)

Source: A. Colette, EGU 2013, session AS3.7, Air pollution modelling
Attribution study for PM$_{2.5}$

- Weak impact of long-range transport
- Air quality legislation dominates
- Slight climate benefit (not robust – cf. literature)

Source: A. Colette, EGU 2013, session AS3.7, Air pollution modelling