Annex III

Review of Regional Air Pollution Control Mechanisms-
Focus on the LRTAP Convention

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August 2016

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Abbreviations

ACAP	Asian Center for Air Pollution research
BAT	Best Available Technologies
CCAC	Climate and Clean Air Coalition
CLE	Current Legislation Emissions
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CTM	Chemistry Transport Model
EANET	Acid Deposition Monitoring Network in East Asia
EB	Executive Body of the CLRTAP
EC	European Commission
ECMWF	European Center for Medium-range Weather Forecasts
EECCA	Eastern Europe, Caucasus and Central Europe
EMEP	European Monitoring and Evaluation Programme (Cooperative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe)
EU	European Union
IAM	Integrated Assessment Modelling
IIASA	International Institute on Applied Systems Analysis
GAINS	Greenhouse Gas- Air pollution Interactions and Synergies
GAW	Global Atmospheric Watch
HM	Heavy Metal
MTFR	Maximum Technical Feasible Reduction
NEASPEC	North-East Asian Sub-regional Programme for Environmental Cooperation
NH_3	Ammonia
NMVOC	Non-methane Volatile Organic Compounds
NO_x	Nitrogen Oxides

OECD	Organisation for Economic Co-operation and Development
POPs	Persistent Organic Pollutants
PM	Particulate Matter
SLCFs	Short-Lived Climate Forcers
SO_2	Sulphur Dioxide
UNECE	United Nations- Economic Commission for Europe
WGE	Working Group on Effects
WGSR	Working Group on Strategies and Review
WHO	World Health Organization
WMO	World Meteorological Organization

1. Executive summary

The present document is a review of the win-win processes adopted by the Convention on Long-Range Transboundary Air Pollution (CLRTAP) established by United Nations Economic Commission for Europe, to develop science and policy dialogues in an efficient way to reduce background air pollution in a large geographical domain. Even if the Convention is interested in numerous air pollutants, the analysis is mainly focused on ozone and particulate matter issues because of their important adverse effects on human health. How such a process could be used as a model to develop similar dialogues between communities in North-East Asia, where the impacts of long-range transport of air pollution can be very significant, is considered as well.

The Convention on Long-Range Transboundary Air Pollution is generally considered as a remarkable example of a forum where science and policy progress together. The European Commission also considers the scientific insights from the Convention as the starting point of EU political negotiations. This is a unique framework that has been set-up to promote and develop dialogues between both communities, so that political decisions can account for the most up-to-date scientific inputs. The structure of the Convention itself with scientific and policy-oriented bodies, work plans and strategies that answer to each other. Nevertheless, dialogues exist but are not always so easy to develop. Some topics can get consensus, in terms of priorities for both science and policy communities, while some gaps remain for others. It can be due to lack of data, to incompatible temporalities between science (generally quite long) and policy responses, or to lack of resources. Air quality policies develop in Europe in a more and more constrained framework regarding financing resources. Anyway the CLRTAP is considered as an actual successful instrument to enhance dialogues between all communities and account for the various aspects of air pollution management. Moreover, it allows, thanks to its structure and the wealth of data it generates, to develop fruitful cooperation with other bodies, organizations and conventions both at the scientific and policy levels. In its long-term strategy, cooperation with other international initiatives is clearly mentioned and should develop.

The cornerstone of interactive processes between science and policy is integrated assessment modelling (IAM). IAM can give very concrete and understandable answers to policymakers on the impacts of emission control measures, regarding their costs and the benefits they bring to health and the environment. Moreover, it is supposed to provide optimised solutions to share in a fair way the burden of the cost of the control strategies between the different countries and stakeholders.

The starting point of IAM for policy decision remains the availability of emission inventories and projections (to test different future scenarios). Emission and projection data should be acknowledged by all the stakeholders as relevant and representative. Choice of one or several chemistry transport models to compute source/receptor relationships and to assess the impact of scenarios should also be endorsed by the stakeholders as the ways to evaluate the efficiency of the implemented policies (monitoring networks). Interpretation of the model results (impacts of the scenarios, sources-receptor calculation, allocation of main sources, and so on) should be accepted by all the Parties to agree on the control strategy.

The ways these steps are covered in the CLRTAP are described in detail in the present report. Available tools and projects in North-East Asia are considered as well. The conclusions of this review are very optimistic considering the maturity of tools that could allow building up such a science-policy process. They can be summarised in three points potentially useful for a future action plan:

- The priority is the establishment of an accurate and sustainable emission inventory throughout the region that will be the basis for future policy-oriented modelling work. This is a sensitive issue because it targets the economic activity of stakeholders and technically demanding. This is the reason why defining a technical framework shared by all the stakeholders, and agreed by the policy makers and implemented under regulatory constraints is certainly the most efficient. This is one of the most important lessons learnt from the implementation of the CLRTAP.
- The EANET network, already in operation to monitor acid air pollution deposition, is a great tool to develop a common understanding of long-range transport in the North-East Asian region and to assess the impact of reduction emission actions. It started to be expanded toward other relevant pollutants, like ozone and particulate matter and this effort should be encouraged. This is a good basis for air quality monitoring framework that could support evaluation of the trends and the impact of emission reduction strategies. More stringent reporting process will allow maintaining a policy-oriented database for long-range transport of air pollutants observations.
- Finally, modelling teams in North-East Asia are very active and several model experiments and tools are available to start a policy-oriented integrated assessment process. Responsibility for developing and running models should be attributed by policy bodies to dedicated scientific teams to facilitate policy dialogue and decision. The CLRTAP decided to support the development of the EMEP models by dedicated centres funded by the Convention, but other options can be investigated, with multi-models/multi-teams approaches. The main difficulty is to establish a consensus for a framework (regarding model uncertainties, evolution, and interpretation of the results, indicators simulated and so on) so that policy agreements can be reached. But the projects that already started provide an excellent basis in that perspective, taking advantage of the lessons learnt from the European Convention on Long-Range Transboundary Air Pollution.

International cooperation should also develop, especially with the CLRTAP/EMEP programme: exchanges on best practices, QA/QC, available instrumentation, trends in transboundary fluxes, and fitness of the monitoring network for modelling purposes would be good topics to initiate partnerships. A workshop between EMEP and NEASPEC focused on emission inventories and monitoring aspects could be a good instrument to start such cooperation.

2. Introduction and Context

Air pollution is one of the most sensitive environmental areas, still being responsible for great damages for human health and ecosystems. According to very recent studies from the World Health Organization (WHO), more than 80% of people living in urban areas that monitor air pollution are exposed to air quality levels that exceed the WHO limits. Moreover, while all regions of the world are affected, populations in low-income cities are the most impacted. WHO[1] estimated that in 2012 indoor and outdoor air pollution was responsible for 7 million of premature deaths in the world each year (almost 4 million attributed to outdoor air pollution). In a very recent study, OECD claimed that by 2060, the outdoor air pollution could cause 6 to 9 million premature deaths a year and cost 1% of global GDP (OECD, 2016).

All parts of the world are concerned by this burden which affects and scares general population, impacts the economy and makes policy makers highly concerned. For example, Figure 1 below shows one of the conclusions of the OECD study: the number of premature deaths due to air pollution nowadays, and its evolution by 2060. The harmful health effects could dramatically increase in certain parts of the world, especially over the Asian continent.

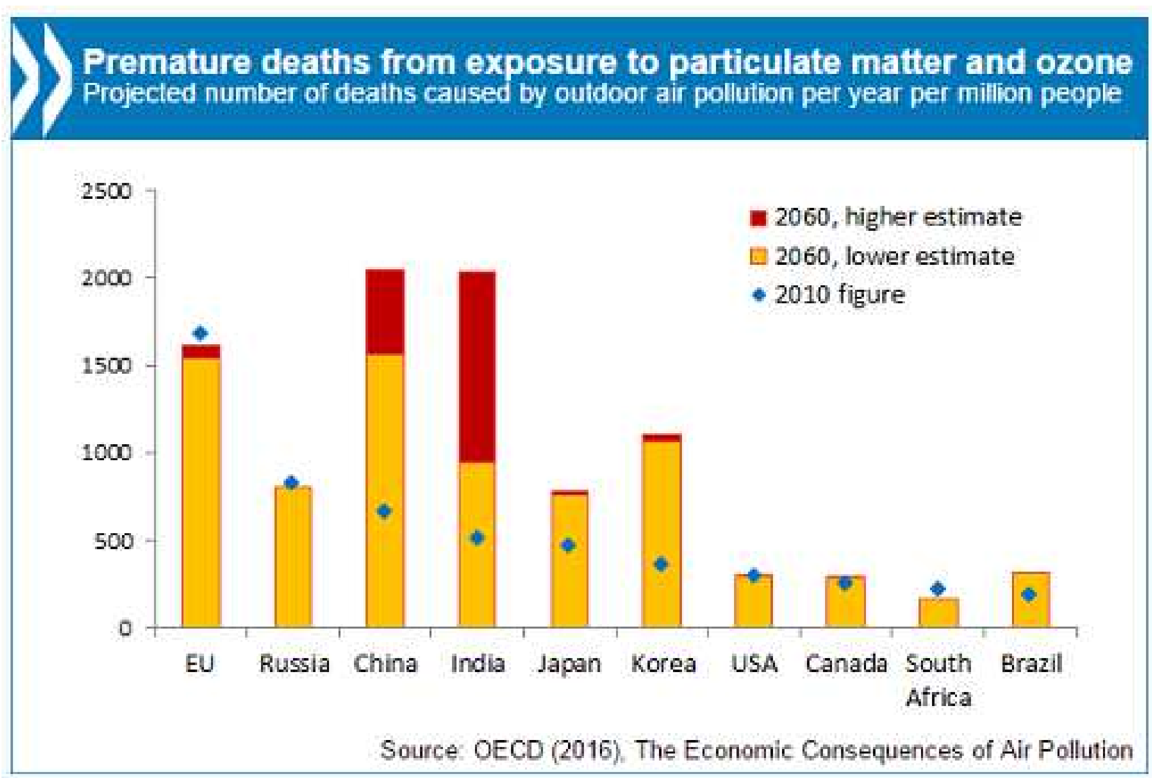


Figure 1. From (OECD, 2016), premature deaths in 2060 due to exposure to air pollution (ozone and particulate matter)

In 2012, the North-East Asian Sub-regional Programme for Environmental Cooperation (NEASPEC) started a project to address **adverse effects of long-range air pollution in East Asia**. After the first review phase, the relevance of developing coordinating actions was

[1] http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/

demonstrated, as the existence of inter-regional projects of interest targeting air pollution management in Asia: the Acid Deposition Monitoring Network in East-Asia (EANET), the Joint Research Project on Long-range Transboundary Air Pollutants in North-East Asia (LTP project), the Model-Inter-Comparison Study in Asia (MISC-Asia). Those initiatives deal with various scientific aspects of air pollution management in the NEASPEC region. The review allowed highlighting some priorities for the development of transboundary air pollution control tools and policies in North-East Asia[2]:

1. Focus on ozone and Particulate Matter (PM), Need of scientific assessment of health impacts
2. Development of Emission Inventories (EI),
3. Conception of policy scenarios and abatement technologies assessment,
4. Modelling source-receptor relationships of transboundary air pollution.

The review also considered initiatives in other parts of the world, and especially the Convention on Long-Range Transboundary Air Pollution (CLRTAP) established in 1979 by the UNECE[3]. This Convention built upon clear interlinkages between science and policy established over a large geographical domain. For a long time, it implements reporting and assessment systems, compliant with regulatory protocols that played a big role in the success obtained by the Convention. The key aspects borne by the CLRTAP strategy rely on:

- Development of a collaborative monitoring network,
- Integrated assessment of air pollution control policies including economic aspects,
- Development of dialogue tools between science and policy.

The new review that is the object of the present contract aims at presenting how all those items or questions are considered in running processes as the CLRTAP, and proposing some recommendations to implement similar and appropriate strategies in the NEASPEC domain taking into account its own specificities.

To cover those various aspects and provide NEASPEC experts with operational insights, the document will be organised as followed:

1. Introduction to the CLRTAP: history and main achievements, and links with other air pollution management frameworks and conventions,
2. Air pollutant targets and health issues: ozone and PM,
3. Emission inventories: the starting point for developing air pollution management strategies,
4. Monitoring transboundary air pollution: a basic assessment tool to evaluate the impact of air pollution control strategies,
5. Modelling source-receptor relationships: looking for an optimised cooperative framework,

[2] Source : Terms of Reference of the contract, and NEASPEC working paper, 2012, "Review of the main activities on transboundary air pollution in East-Asia"
[3] The United Nations Economic Commission for Europe

6. Policy scenarios and abatement technologies assessment: various options for various levels of ambition,
7. Integrated assessment including economic aspects: optimising the benefits and limiting the costs,
8. Policy/science dialogue: how to set-up the framework.

3. Introduction to the CLRTAP

General overview

Since 1979 the Convention on Long-Range Transboundary Air Pollution[4] of the United Nations Economic Commission for Europe (UNECE) is one of the most famous and successful mechanisms that has been implemented by a large number of states to deal with an environmental issue. The Convention currently involves 51 Parties (or countries) that agreed to develop national capacities and international cooperation for reducing the harmful effects of air pollution (and especially transboundary air pollution) on human health and ecosystems in Europe. The United States and Canada are Parties to the Convention as well. Eight international protocols have been established under the aegis of the Convention.

They relate to several aspects of air pollution (see the table below). The most recent key protocols are the following:

- The 1999 Gothenburg Protocol which entered into force on the 17 May 2005 and was revised in 2012: Its mains goal is to abate acidification, eutrophication and ground-level ozone and, and reducing exposure to fine particulate matter ($PM_{2.5}$) has been added to the revised text.
- The 1998 Protocol and Persistent Organic Pollutants (POPs) which entered into force in 2003 and was revised in 2009.
- The 1998 Protocol on heavy metals which entered into force in 2003 and were revised in 2012.

Title	Entry into force	Status of ratification
The 1999 Gothenburg Protocol to Abate Acidification, Eutrophication and Ground-level Ozone and its 2012 amended version	17 May 2005	• Signatories:31 and Parties: 26 • Amended version
The 1998 Aarhus Protocol on Persistent Organic Pollutants (POPs) and its 2009 amended version	23 October 2003	• Original protocol (Signatories : 36 and Parties : 33) • Amended version, annex Ⅰ and Ⅱ (Parties : 6) • Amended version, annex Ⅰ, Ⅱ, Ⅲ, Ⅳ, Ⅵ, Ⅷ
The 1998 Aarhus Protocol on Heavy Metals and	29	• Original protocol

[4] http://www.unece.org/env/lrtap/welcome.html

its 2012 amended version	December 2003	• Signatories : 35 and Parties : 33 • Amended version • Parties : 7
The 1994 Oslo Protocol on Further Reduction of Sulphur Emissions	5 August 1998	• Signatories:28 and Parties: 29
The 1991 Geneva Protocol concerning the Control of Emissions of Volatile Organic Compounds or their Transboundary Fluxes	29 September 1997	• Signatories : 23 and Parties : 24
The 1988 Sofia Protocol concerning the Control of Nitrogen Oxides or their Transboundary Fluxes	14 February 1991	• Signatories : 25 and Parties : 35
The 1985 Helsinki Protocol on the Reduction of Sulphur Emissions or their Transboundary Fluxes by least 30 percent	2 September 1987	• Signatories : 19 and Parties : 25
The 1984 Geneva Protocol on Long-term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP)	28 January 1988	• Signatories : 22 and Parties : 47

Regulation

The present review will be more focused on the processes that drove the elaboration and the implementation of the Gothenburg Protocol which is of high interest regarding the objectives of the NEASPEC initiative. It should be noted that this Protocol is also named "multi-pollutants/multi-effects" because it proposes integrated strategies to reduce at the same time emissions of several substances ("multi-pollutants") to get benefits in several environmental and health areas ("multi-effects").

It is very important to note that the approach adopted by the Convention to elaborate its Protocols is an "effect-oriented" approach. Emission reductions to which the Parties have to commit are set considering:

- Effect objectives: reduction of exposure to human health and ecosystem to the targeted pollutants with respect to a reference level representative of current exposure,
- Available technologies (nowadays and in the future) to reduce emissions and their costs for implementation in the EMEP region,
- Economic constraints in the Parties.

The **Gothenburg Protocol** (in its 2012 amended version) sets **national emission ceilings** for each country of the EMEP region to be respected in 2020 (for the revised 2012 protocol) for sulphur dioxide, nitrogen oxides, non-methane volatile organic compounds (NMVOC), ammonia and fine particulate matter[5] $PM_{2.5}$. Each year the Parties report emissions for the current situations and their projections for the future years. A kind of flexibility mechanism

[5] PM2.5 refers to fine particulate matter with diameter lower than 2.5 microns. PM10 refers to particles with diameter lower than 10 microns

allow them to declare adjustments in the emissions or projections they reported in the previous year if new sources or new scientific insights are likely to modify former estimations of emissions and as a consequence the reduction objectives they have to deal with in application of the Gothenburg protocol. Emissions limit values for specific control measures for sulphur dioxide, nitrogen oxides, VOCs and ammonia are also defined, as well as limit values for mobile sources and VOC content in some products. Finally, the protocol requests implementation of best available technologies (BAT) for mobile and stationary sources in accordance with respective guidance documents.

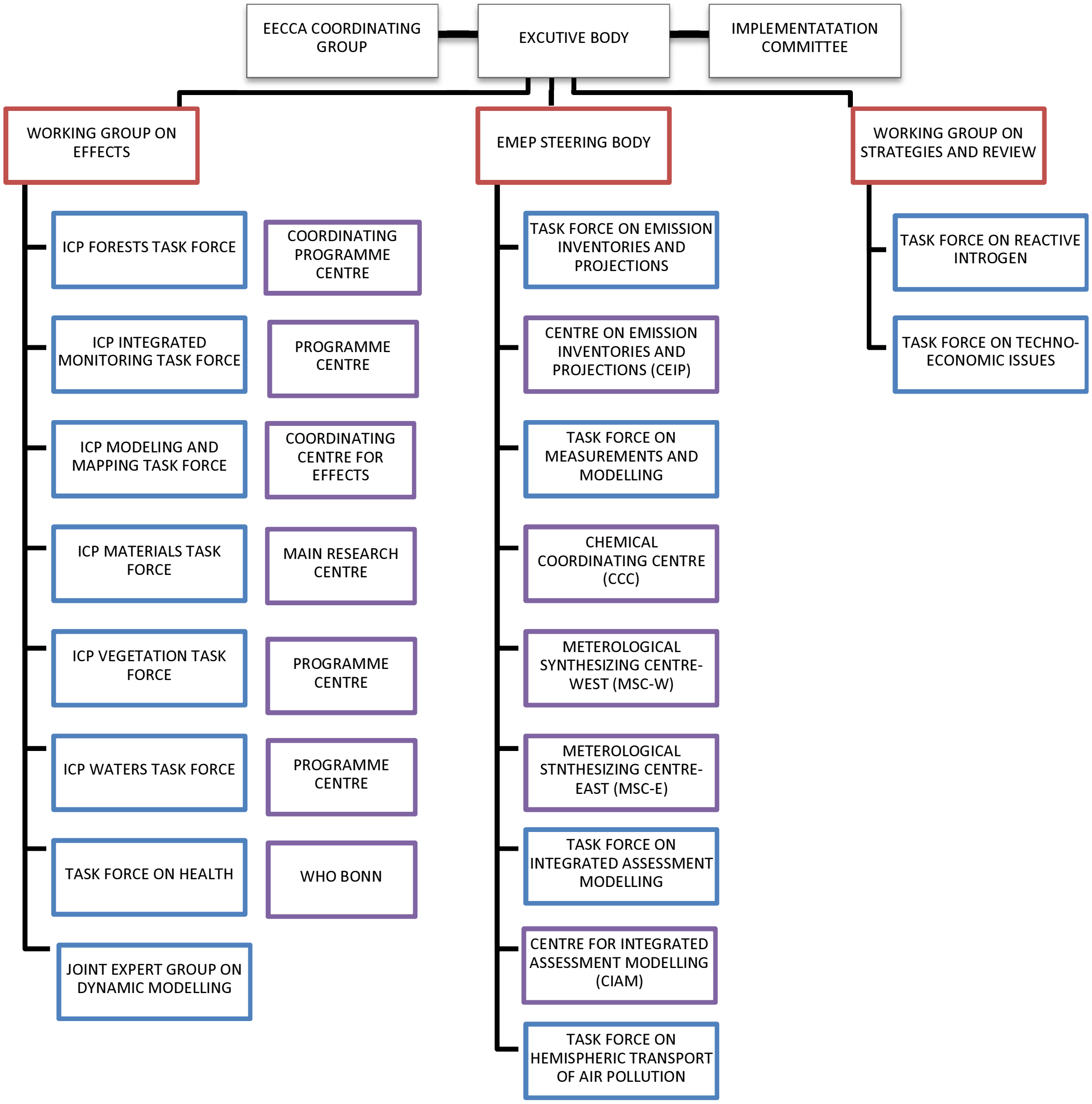
The **Protocol on Heavy Metals** (in its 2012 amended version) sets emission reduction objectives compared to a reference year for mercury, lead, and cadmium. Emissions limit values and implementation of best available technologies are set for major stationary sources and application of product control measures (as unleaded petrol, unleaded batteries) is requested as well. Yearly reporting obligations for emissions are also defined to assess progress in compliance with the emission reduction objectives. Co-operation with the UNEP Minamata Convention on mercury develops currently.

The **Protocol on Persistent Organic Pollutants** (in its 2009 amended version) sets emission reduction objectives for 4 Polycyclic Aromatic Hydrocarbons (PAHs), dioxins and furans, hexachlorobenzene, and polychlorinated biphenyls, and application of best available technologies in major sectors. It also requests elimination of production or use of 21 pesticides and use restriction for 2 industrial chemicals. Yearly reporting obligations for emissions are also defined to assess progress in compliance with the emission reduction objectives. Co-operation with the UNEP Stockholm Convention on POPs develops currently.

Structure of the Convention and the EMEP programme

The structure of the Convention on Long-Range Transboundary Air Pollution is summarised by Figure 2 below. It has already been described in detail, in the first review conducted by NEASPEC (NEASPEC, 2012), and in the present document, only aspects that illustrate interlinkages between science and policy are detailed.

The Executive Body of the Convention endorses final decisions and regulations. The Executive Secretary of the UNECE ensures the secretariat and logistic aspects of all meetings of the Executive Body and its subsidiary bodies and supports them in some actions, to reinforce compliance with the Protocols and ratification by a large number of Parties. Compliance with the Protocols is evaluated by the "Implementation Committee" a legal experts group. The EECCA Coordinating group supports and promotes the implementation of the Convention in the Eastern Europe, Caucasus and Central Asia (EECCA) regions.



Legend: Subsidiary bodies (Red boxes), Task forces (Blue boxes), Programme/EMEP Centres(Purple boxes)

Figure 2. Synthesis of the CLRTAP structure (source : CLRTAP Secretariat)

The so-called "subsidiary bodies" of the Convention allow building up a unique framework that allies **high level of science** guaranteed by the scientific-oriented bodies:

- The EMEP Programme (Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe[6])
- The Working Group on Effects or WGE[7] and **policy implementation** supported by the Working Group on Strategy and Review (WGSR).

All Parties to the Convention are invited to participate in scientific and policy relevant discussions and to the decisions adopted by the Executive Body. The activity of the

[6] www.emep.int
[7] https://www.unece.org/fileadmin/DAM//env/lrtap/WorkingGroups/wge/welcome.html

Convention is framed by a work plan established every two years which describes foreseen objectives for science, policy, compliance, capacity building, communications and outreach[8]. It is driven by the "long-term strategy" of the Convention, established by a decision from 2010[9], which sets main priorities until 2020 and perspectives until 2050.

The EMEP programme set-up by the EMEP Steering Body covers a large number of topics relevant to air pollution assessment, and identified as key topics by the first NEASPEC review: emissions, monitoring, modelling and integrated modelling. A dedicated protocol (1984) defines financing scheme to ensure sustainability of this programme. More precisely the EMEP budget, to which all Parties are supposed to contribute, covers:

- Coordination costs of monitoring activities,
- Emission data collection and quality assurance checking,
- Modelling of concentrations and depositions of air pollutants targeted by the protocols of the Conventions
- Integrated assessment modelling based on the computation of source-receptor matrices.

A large part of those scientific and technical activities are conducted by the EMEP Centres, partially supported by this budget and by the hosting countries. The EMEP centres provide national experts (who generally belong to so-called "task Forces" or "expert groups") with essential and relevant scientific background and insights. There are 5 scientific Centres supporting the EMEP programme.[10]

- **CCC: Chemical co-ordinating Centre hosted by Norway (NILU),** is the Centre in charge of coordination actions regarding the EMEP network. It proposes priorities for the EMEP monitoring strategy (currently established until 2019) and supports parties for its implementation. CCC is also responsible for QA/QC (Quality Assurance/Quality Control) aspects and published a number of guidelines for measurements and chemical analyses.[11] This is very important the Parties comply with these recommendations to get good quality and comparable observation data for assessment. CCC organises laboratory inter-comparisons to evaluate the quality of the air pollution measurement processes in the Parties. Last but not least, CCC is responsible for collecting observation data from the Parties (in-situ and data from field campaigns) and gathering them in the EMEP observation database which is now called EBAS.[12] All EMEP data are, by this way, freely available online. CCC directly supports the work of the Task Force on Measurement and Modelling (TFMM) and the Task Force on Hemispheric Transport of Air pollution (TF HTAP). It develops strong linkages with other monitoring networks and projects according to the EMEP outreach strategy.

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[8] See in annex the work plan 2016-2017 available at https://www.unece.org/fileadmin/DAM/env/documents/2015/AIR/EB/English.pdf

[9] http://www.unece.org/env/lrtap/welcome.html

[10] http://www.emep.int/

[11] http://www.nilu.no/projects/ccc/qa/index.htm

[12] http://ebas.nilu.no/

- **MSC-W: Meteorological Synthesizing Centre-West, hosted by Norway (met.no)[13]**, is the centre responsible for developing and implementing modelling tools dedicated to the simulation of transboundary fluxes of acidifying and eutrophying pollutants, ground-level ozone and particulate matter (pollutants related to the Gothenburg protocol). A key product of the MSC-W modelling work is the source-receptor matrices or the so-called "blame-matrices" which estimate the contribution of the emissions in any country to the depositions or air concentrations of sulfur oxides, nitrogen oxides, ground level ozone and PM in any other country. The chemical transport model developed at Meteorological Synthesizing Centre - West is called the EMEP/MSC-W model. The Eulerian model was released as open source code in 2008 and is under continuous development for meeting new tasks within the EMEP programme and other projects. MSC-West produces every year country reports describing air pollution in the Parties and the corresponding source-receptor matrices. All results are available and downloadable on the website. MSC-West directly supports the work of the Task Force on Measurement and Modelling (TFMM), the Task Force on Integrated Assessment Modelling (TFIAM) and the Task Force on Hemispheric Transport of Air pollution (TF HTAP).

- **MSC-E: Meteorological Synthesizing Centre-East, hosted by the Russian Federation**,[14] is the centre responsible for developing and implementing modelling tools dedicated to heavy metals (HM) and Persistent Organic Pollutants (POPs) airborne concentrations and deposition in the EMEP domain. MSC-E develops a number of tools that can be applied from the global to the national scale regarding the various fates in the environment of the targeted pollutants. MSC-E developed a strong expertise in HM and POPs emissions and supports the centre dedicated to emission activities in data collection and quality checking. All results are available and downloadable on the website. MSC-E directly supports the work of the task Force on measurement and Modelling (TFMM), the task Force on Hemispheric Transport of Air pollution (TF HTAP), the Task Force on Emission Inventories and Projections (TFEIP) and the Task Force on Integrated Assessment Modelling (TFIAM).

- **CEIP: Centre for Emission and Projections, hosted by Austria (Umweltbundesamt)[15]** , is the centre in charge of emissions data management. It covers collection of emissions and projections of acidifying air pollutants, heavy metals, particulate matter and photochemical oxidants from Parties to the CLRTAP, review of submitted inventories in order to improve the quality of reported data, preparation of data sets as input for long-range transport models and technical support to the Parties for compliance with their duties. CEIP is also responsible for

[13] http://emep.int/mscw/index_mscw.html
[14] http://www.msceast.org/
[15] http://www.ceip.at/

the EMEP emission database (WebDab)[16] which gathers all reported emissions data for the pollutants targeted by the protocols. WebDab is regularly updated and includes the official emission data and the activity data reported by the Parties, and the gridded data that are used in the EMEP models. CEIP is in charge of the implementation of complex emission review processes, proposed by the Task Force on Emission Inventories and Projections (TFEIP) and adopted by the Executive Body, that guarantee quality and inter-comparability of reported emissions. Recently, a new task has been attributed to CEIP: the review of the emissions and projections adjustments the Parties are now allowed to propose according to the revised Gothenburg protocol.

- **CIAM: Centre for Integrated Assessment Modelling, hosted by Austria (IIASA)[17]**, which elaborates all scientific and technical materials necessary for integrated assessment of transboundary air pollution control policies. This includes development and implementation of the GAINS Model[18] which evaluates cost-effective emission reductions strategies (for air pollutants but also for greenhouse gases) optimising the balance between the cost of the control measures and their benefits for human health and ecosystems. The European version of GAINS uses the source-receptors matrices developed by MSC-W as basic input data. CIAM supports the work of the Task Force on Integrated Assessment (TFIAM) which brings together information from the Parties, from the EMEP technical centres and from other bodies of the Convention to assess the expected impact of current and future regulations and to identify future priorities and stakes.

Main achievements and analysis

The CLRTAP is based on strong interlinkages between scientific and policy bodies. It is considered in Europe as the only one policy tool that develops appropriate scientific studies to bear policy decisions. The decision and regulatory processes that develop under the Convention follow two-ways trips between scientific subsidiary bodies (EMEP and WGE) and policy bodies (WGSR, EB). They can be summarised as followed:

1. The strategy is driven by scientific knowledge and evaluation: what are the impacts of transboundary air pollution on human and ecosystems, which pollutants should be regulated, what are the variables and parameters needed to characterize air pollution trends and their responses to air pollution control strategies.
2. Policy framework allows implementation of monitoring networks in the countries with common technical rules to ensure quality, and comparability. It sets the level of national emission ceilings relevant for controlling and limiting harmful effects of air pollution and defines reporting obligations for emissions, airborne concentrations, and deposition to assess progress in this objective.

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16 http://www.ceip.at/ms/ceip_home1/ceip_home/webdab_emepdatabase/

17 http://www.iiasa.ac.at/web/home/research/researchPrograms/MitigationofAirPollutionandGreenhousegases/CLRTAP---EMEP---CIAM.en.html

18 http://www.iiasa.ac.at/web/home/research/researchPrograms/air/GAINS.en.html

3. Science also helps understanding trends and potential unexpected behaviours (for instance if the impact of emission reductions on air pollutant concentrations is not as significant as expected) and new stakes.
4. Policy framework takes into consideration of such issues and proposes appropriate evolutions of the legislation or strategy: for instance, reducing PM exposure was introduced in the revised Gothenburg Protocol in 2012 but was not covered in the former one; need for developing more cooperation with the climate community to conceive win-win control strategies and focus on short-lived climate forcers (SLCFs) raised quite recently.

Figure 3 below gives a schematic and simplified presentation of the strong interlinkages tied between science and policy in the CLRTAP framework. The proposed examples are not exhaustive but give a good illustration of the type of activities that can develop in both fields. This set-up is one of the main strengths of the Convention and one of the reasons of its success.

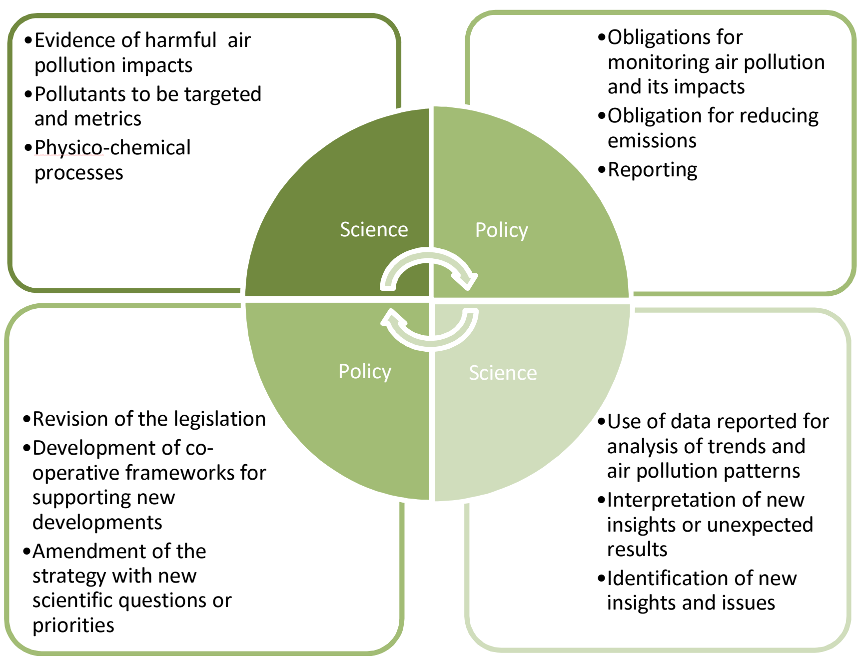


Figure 3. Schematic representation of policy-science interactions in the CLRTAP processes

Main achievements of more than 30 years of active work within the CLRTAP are synthesized in a very recent and important document "the 2016 "CLRTAP Assessment Report" that was published by the end of May 2016 (CLRTAP, 2016). This report gives a certain number of key insights and messages considering several decades of intensive work of the Convention. At the same time, the two scientific subsidiary bodies of the Convention published two reports on the trends over the past 20 years on air pollutant concentrations and depositions and the associated effects on health and ecosystems in *Air pollution trends in the EMEP region between 1990 and 2012*and *Trends in ecosystem and health responses to long-range transported atmospheric* *pollutants* respectively. Obviously results from those reports[19] were used to establish the conclusions of the main assessment report. Some of them can be of high relevance for NEASPEC, for instance:

- The success stories: drastic reduction of emissions of some pollutants that allowed reduction of exposure to atmospheric concentrations and deposition (e.g. sulphur emissions). The avoided harmful impacts for the European domain have been quantified.
- The importance of long-range transport of air pollution and thus of international cooperation to achieve such goals.
- The role played by local air pollution (at the city level) and the need to define good interlinkages between local, national and international policies.
- The co-benefits with other environmental policies for climate change, energy, agriculture and even water.

Follow-up given to the scientific assessment report illustrates the duality between science and policy that characterises the work of the Convention. The results of this report have been represented and acted by the Executive Body which mandated a working group with national policy experts to highlight, from those results, important policy key messages that will be used to elaborate a mid-term evaluation of the long-term strategy and to set new priorities for scientific work.

If the benefits and the successful results of the Convention are unquestionable, some issues likely to slow down or limit the running processes exist as well. They relate to:

- **Economic constraints for the convention bodies**: the budget allocated to EMEP activities (according to the 1984 Protocol on EMEP activities funding) is very limited compared to the actual cost and some priorities need to be established. They limit the ambition of the scientific projects and oblige the bodies and the parties to the Convention to look for new resources (national funding, application to international projects, cooperation with other Conventions, etc).
- **Economic constraints for the Parties**: some countries have important difficulties to mobilise the necessary budget to implement relevant monitoring network, gather essential information for emission inventories, implement QA/QC processes, build up databases, etc. They also have to make some priorities between various regulatory frameworks and in some cases the obligations of the CLRTAP are not in the forefront of their priorities.
- **Heterogeneity in national infrastructures and need for capacity building**: obviously large differences between monitoring (for emissions, concentrations and deposition) infrastructures are observed in the 51 Parties. This is a direct consequence of the economic aspects mentioned above and of political choices. There is a need for training and capacity building in several Parties, especially in the EECCA region. Promoting the work of the Convention, intensifying ratification of the protocols and

[19] In the following paragraphs going deeper into scientific details, some results from those reports will be presented as illustrations

supporting the implementation of the monitoring and reporting processes in those countries in one of the current main priorities of the Executive Body and its subsidiary bodies.

Other international mechanisms dealing with transboundary air pollution

The UNECE Convention on Long-Range transport of Air Pollution is one of the most ambitious and achieved mechanisms to deal with this issue. The United States and Canada take part to the Convention (even if they are not covered by the "EMEP domain"), but those countries have also specific co-operative frameworks that target the American continent. There are bi-lateral agreements including:

- The US-Mexico Border 2012 Programme addressing PM and ozone according to the La Paz Agreement
- The US-Canada air quality bilateral agreement addressing PM and ozone and some POPs
- The North-American Commission for Environmental Cooperation, an organization established by the USA, Canada and Mexico in 1994 with the aim of "improving understanding of trade-environment linkages; promoting citizen engagement and increasing government accountability regarding enforcement". It is led by Environmental Ministers of the three countries. This structure is driven by citizen's involvement to fix its main priorities and support data gathering. Amongst relevant achieved projects, one should note the AirNow, an air quality forecasting system for the US and Canada, and the North-American **B**lack Carbon Emissions Estimation Guidelines.

Another relevant framework which has to deal with transboundary issues is the Arctic Council[20] created 20 years ago by 8 Member States[21] of the Arctic region to develop cooperation for environmental protection. The Arctic Monitoring and Assessment Programme (AMAP) and the Arctic Contaminant Action Programme (ACAP) focus on long-range transport of air pollutants, in particular, mercury, POPs and black carbon. In this framework emission inventories and monitoring and modelling facilities are developed and implemented to assess transboundary fluxes, their impacts, and the best approach to avoid or limit them. This structure is quite close, regarding its organisation, to the Convention, with high-level policy involvement (Environment Ministers of the 8 Member States) and scientific programmes funded by the Member States to support the policy decision.

In Asia, where air pollution raises as a big environmental concern, international co-operation develops as well, and becomes more and more active, especially under the NEASPEC initiative. As mentioned in the introduction and in the terms of reference framing the present review, some on-going projects are already well-identified as follows (NEASPEC, 2012).:

[20] http://www.iiasa.ac.at/web/home/research/researchPrograms/air/GAINS.en.html

[21] Canada, Denmark, Finland, Iceland, Norway, Russian Federation, Sweden, USA

- EANET (Acid Deposition Monitoring Network in East Asia)[22] involves 13 countries and defines a common technical framework to characterize acid deposition status and its effects in East Asia. Mobilization of high-level policy makers in the member countries allowed developing a robust and reliable framework to assess levels and trends of not only acidifying pollutants but also ozone and PM. Capacity building, training, exchange of experiences, establishments of common QA/QC rules for monitoring are the main achievements of this project. In 2015, a review on the status of air pollution in Asia has been published.[23] This complete report covers a large range of air pollutants (including heavy metals and POPs) and several aspects of management issues (emissions, monitoring and modelling, mitigation strategies, and link with climate change). It proposes a sounding scientific basis for supporting the policy decision. EANET is coordinated by the Asia Center for Air Pollution Research (ACAP) in Japan.
- LTP, the Joint Research Project on Long-range Transboundary Air Pollution in North-East Asia is a 20 years old tripartite project involving China, Japan and Republic of Korea. Work is based on scientific and technical expert groups which develop monitoring and modelling tools and provide an assessment of long-range transport of air pollution in the targeted area. The objectives remain research-oriented, and the project, which is now in its fourth development stage, currently focuses on fine particulate matter issues.

This short review shows the uniqueness of the CLRTAP on one side the way it works, and on the other side its objectives, its legal, its regulatory achievements, the scientific results and tools it brought. As a conclusion, it should be noted that an important driver of the CLRTAP strategy is the international cooperation to enhance. This is the reason why a specific Task Force on Hemispheric Transport of Air pollution (TFHTAP) was created in 2005 under the EMEP programme. This task force has the mandate to develop international cooperation for a better assessment and management of air pollution taking into account intercontinental issues.

4. Air pollutants targets and health issues: ozone and PM

One of the conclusions of the first NEASPEC review was the need to focus on ozone (O_3) and PM (PM_{10} and $PM_{2.5}$), and the development of a policy and scientific framework to deal with transboundary air pollution.

This recommendation is first justified by the adverse effects of those air pollutants on human health. Recent publications by the World Health Organization (WHO) and the Organization for Economic Co-operation and Development (OECD), consider that reduction of life expectancy of population (or premature deaths) is essentially due to exposure to fine particulate matter ($PM_{2.5}$) and ozone. They use a large number of epidemiological studies that demonstrate those effects, considering mortality (number of premature deaths,

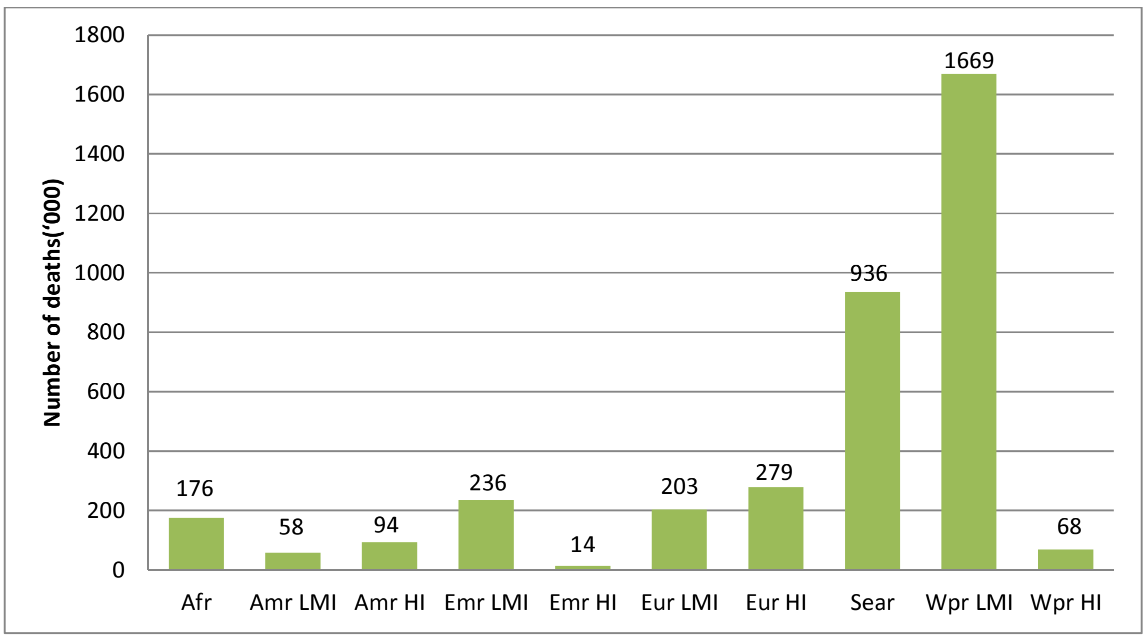
[22] http://www.eanet.asia/

[23] http://www.eanet.asia/news/17_index.html

reduction of life expectancy) and morbidity (chronic bronchitis, asthma, cardiovascular and respiratory accidents, and so on) indicators.

WHO and OECD recent studies present new insights on the linkages between exposure to ozone and PM air concentrations and health issues and the cost of air pollution for our societies. The "Review of Evidence of Health Aspects of Air Pollution" (REVIHAAP) and the project on "Health Risks of air pollution in Europe" (HRAPIE) published in 2013 (WHO and WHO, 2013a,b) must be considered to get updated data and clues. They include methodological information and recent figures.

In a more global perspective, WHO published in 2014 that an evaluation of the burden of disease from outdoor and indoor air pollution that would represent almost 7 million of premature deaths in the world, among which 3.7 million can be attributable to outdoor air pollution[24], Western Pacific and South East Asian regions bearing most of this burden (see the figure below from WHO). This important point was confirmed in the very recent paper from *Ambient air pollution exposure estimation for the global burden of disease* (Brauer et al, 2016) presenting the global burden due to air pollution exposure.



AAP: Ambient air pollution, Amr: America, Afr: Africa, Emr: Eastern Mediterranean, Sear: South-East Asia, Wpr: Western Pacific; LMI: Low-and middle-income; HI: High-income

Figure 4. Evaluation of the number of premature deaths attributable in 2012 to outdoor air pollution Source : WHO[25]

The reasons for premature deaths due to outdoor air pollution have been summarized by the WHO in a very explicit scheme proposed in Figure 5.

[24] http://www.who.int/phe/health_topics/outdoorair/databases/en/

[25] http://www.who.int/gho/phe/outdoor_air_pollution/burden/en/

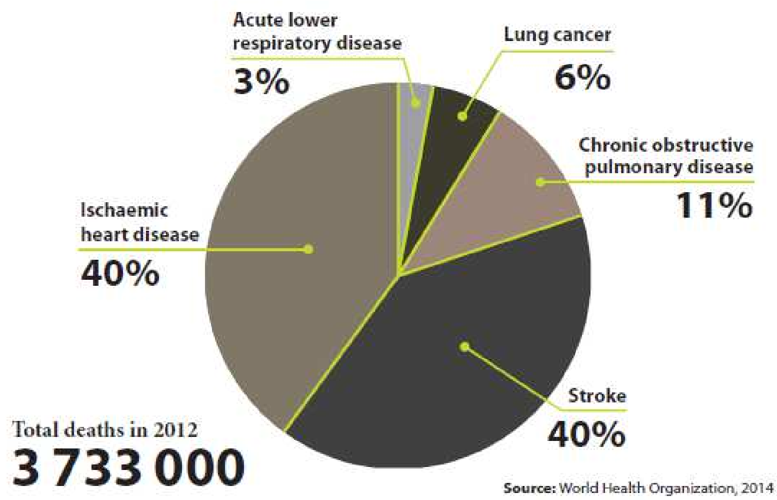


Figure 5. Reasons for premature deaths due to air pollution (Source: WHO)

WHO publishes guidelines to define limit values (or air quality objectives) regarding air pollutant concentrations that should not be exceeded to avoid adverse effects on human health.[26] For ozone, a limit value of 120 g/m^3 for the 8-hours average is the recommended value[27]. But for PM, no guideline is proposed by the WHO because "*available information for short- and long-term exposure to PM_{10} and $PM_{2.5}$ does not allow* ***a judgement to be made regarding concentrations below which no effects would be expected***". WHO recommends avoiding exposure to annual concentrations of $PM_{2.5}$ larger than 10 µg/m^3 (annual average). According to WHO, 96% of the European citizens are still exposed to PM levels exceeding this value, and 98% are exposed to ozone levels exceeding the WHO guideline! Therefore, even in the regions where significant improvements in terms of air pollution have been monitored, some efforts are remained to be done.

In Asia, a number of studies provide interesting insights about the exposure of Asian citizens to PM and ozone, which include studies on *Health impact assessment of PM_{10} and $PM_{2.5}$ in 27 Southeast and East Asian cities* and *Evaluation of premature mortality caused by exposure to PM2.5 and ozone in East Asia.* The first study was conducted in 27 cities of Southeast and East Asia and showed that decreasing $PM_{2.5}$ and PM_{10} concentrations (annual average) would reduce mortality due to PM exposure by 8 to 9 %. The second one was based on modelling results for East Asia and showed that premature deaths due to exposure to ozone and PM in this region were about 316,000 and 520,000 cases for the years 2000 and 2005 respectively.

Another justification to consider ozone and particulate matter to develop new international control strategies is their transboundary nature. Evolution of air concentration patterns are ruled by complex physico-chemical processes that lead to the development of large scale (continental and sometimes hemispheric) phenomena. Long-range transport drives air pollution background levels which should be reduced as a priority (long term exposure).

[26] http://www.euro.who.int/__data/assets/pdf_file/0005/74732/E71922.pdf

[27] Note that this value corresponds to the limit value set in the European legislation on air quality, 2008/50/EC Directive on ambient air quality and cleaner air for Europe

5. Emission inventories: the starting point

General overview

The first step for consolidating a management strategy for long-range transport of air pollution relies on emissions. The knowledge of air pollutant emission sources is essential to conceive control strategies and limit the amount of air pollutant emission. All anthropogenic activities (industry, residential heating, cooking, road and off-road traffic, agriculture, etc) are likely to be responsible for air pollutants emissions. Some pollutants (biogenic volatile organic compounds, dust, vegetation debris…) come from natural sources. Controlling national anthropogenic emissions is the very first step in the elaboration of a co-operative framework that aims at controlling with a limitless phenomenon.

Emission inventories provide decision makers with an evaluation of the total of air pollutants emitted each year by each activity sector (anthropogenic and biogenic). They allow monitoring emission reduction efforts and trends for a given country and its neighbours. Therefore, this is an excellent tool for policy support, providing simple metrics and allowing negotiations between stakeholders regarding compliance with agreed objectives. Emission inventories are used in many environmental fields: air pollution, climate change, water pollution, etc. They are generally based on a nomenclature reflecting the classification of the emitting activities or sources (SNAP[28], NFR[29], or the CRF[30] of the UNFCCC). "Gridded" emission inventories describe the geographical distribution of emissions and in some cases their temporal variability. They are generally used to present maps of emissions that facilitate communication towards the public or to feed chemistry-transport models that calculate airborne concentrations and deposition taking into account transformation of emissions through very complex physicochemical processes. However, building up gridded emission inventories requires much more work than compiling annual totals.

In principle, emission estimations result from the product of an emissions factor per pollutant and per sector at a given time by the amount of activity in the corresponding sector and at the same time. Emissions factors are the quantity of pollutant emitted for 1 unit of activity in the considered sector:

$$E(P,S,t) = EF(P,S,t) * A(S,t)$$

With *P= Pollutant, S= activity sector, t= time, EF= emission factor, A= activity*

To derive gridded emissions this equation is estimated in the geographical domain taking into account the location of the activity sectors and the sources.

It is possible to sort objectives of emissions inventories between policy and scientific goals, as presented in the table below.

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[28] Selected Nomenclature for Sources of Air pollution (1985 to 1998)
[29] Nomenclature for Reporting (2001)
[30] Common Reporting Format (1997)

Objective of the inventory	Policy goals	Scientific goals
Qualifying the activity sectors, especially the largest emitters, or those that influence the most local and regional air pollution patterns	• Allow identifying largest emitters for potential control measures • Allow checking compliance with emission limit values legislation	• Allow to understand air pollution episode situations when they are influenced by specific sector
Following emission trends over the time and assessing the impact of control strategies	• Assess the impact of legislation	
Providing information support for raising awareness of the general public (especially maps of gridded emissions that are generally very illustrative)	• Communication on air pollution	
Checking compliance with ceilings objectives set by international or national laws and agreements	• Implementation of the legislation	
Comparing and assessing the impact of different emission reduction options	• Looking for most cost-effective emission control strategies	• Understanding responses to emissions reduction accounting for the chemical regime, the distribution of source, etc.
Providing inputs to chemistry-transport models that simulate air quality (gridded emissions)	• Drawing maps of concentration for air pollution management or communication • Feeding air quality forecasting systems	• Scientific studies to improve understanding of the influence of the main drivers of air pollution and how air pollution patterns behave • Input for air quality forecasting experiences to evaluate chemistry-transport models

Therefore, each country that aims at implementing air pollution policies needs to develop a national emission inventory and to maintain it for operational use. Such a tool can be used as an input for scientific activities. A number of parameters characterise the inventory:

- **Update frequency**: emission inventories rely on a given year. But sources may change from year to year and, especially for policy purposes, it is essential to update the tool. It is a heavy and costly task, difficult to conduct on a yearly basis. Generally, an appropriate frequency is defined by the emission inventory administrator (every 3 or 5 years for instance) for a formal update based on a new evaluation of activity sectors and associated emission factors, and in-between, a simple upgrade is proposed, "extrapolating" activity data.
- **Temporal resolution**: for policy purposes and trends analysis, a yearly resolution is sufficient. But for modelling purposes, including analysis if air pollution episodes and forecasting, much higher resolution (the hour) is requested. Generally, modellers

use time distribution tables predefined for each sector. The highest the resolution is where the highest uncertainty is.

- **Spatial resolution** (for gridded data): building up very high resolved emission inventory (for instance with a 1km*1km resolution) can be very difficult and very expensive because it requests drastic work to describe activities with the requested resolution. In some situations, for instance, to develop "local emission inventories" that focus on the largest cities is essential. In 2017, the CLRTAP will request its Parties to report gridded emissions with a 0.1°*0.1° last-long resolution which is an excellent compromise to deal with both policy and scientific purposes. Now it requests a new and significant effort from the Parties.
- **Sectoral distribution:** the number of sectors and their qualification used to describe the activities is important when the emission inventory helps in defining control strategies that aim at targeting a limited number of sectors. A fine distribution allows evaluation of the relative weight of various activities and can be very useful to support decision making. Sectoral distribution is described by a standardized nomenclature (see above).

Within the perspective of dealing with transboundary air pollution, an international agreement to reduce the impacts of long-range transport of air pollutants could require from each stakeholder, objectives of reduction of emissions for a number of air pollutants. Emissions inventories are the appropriate tool to check whether the involved Parties comply with those objectives but this approach raises potential sensitive issues: equity of the effort requested, compliance, quality of the data reported, and so on.

This is the reason why in such a framework, Parties to the agreement will elaborate emission inventories with respect to 3 basic properties (or criteria):

- **Comparability**
  Inventories should be built up following the same methodological approach regarding the sectoral distribution, the variables used to describe the activity, the emission factors.

- **Transparency**
  Inventories should be correctly documented with data and assumptions chosen and are likely to be challenged by national or international experts.

- **Accuracy and Completeness**
  Gaps in estimations should be avoided, all agreed targeted pollutants and sectors should be considered and emissions provided with the best estimates.

Dealing with those criteria supposes that a methodological reference framework is established. This framework must be a part of the agreement after negotiation between the Parties, and consequently results from compromises accounting for economic, scientific and political constraints. The national emission inventory resulting from this process, provided that it complies with the three basic criteria, which can be considered as **an official emissions inventory reported under the agreement**. But as the result of some compromises in the methodology, it may not be as accurate as it could be and not directly be applicable for scientific evaluations (use in chemistry-transport models). This duality between policy-oriented and scientific emission inventories is a real issue, more and more visible with the increased use of air quality models for assessment, scenarios analysis, and decision making. In that perspective, it should be carefully considered in the elaboration of a new cooperative framework for transboundary air pollution.

The CLRTAP framework on emissions

The CLRTAP managed to define a framework to deal with the three basic criteria discussed above. Each year the Parties report their national emissions of nitrogen oxides (NO_x), sulphur dioxide (SO_2), volatile organic compounds (VOCs), ammonia (NH_3) and fine particulate matter ($PM_{2.5}$). In 2015, for the first time almost 20 Parties reported black carbon emissions (on a voluntary basis) as well.

The framework document

The Task Force on Emission Inventories and Projections (TFEIP) helped by the Centre on Emission Inventories and Projections (CEIP) elaborates the methodological framework (compilation of activity data by sector, the definition of emission factors…) to support and frame the work of the national experts. The agreed methodology is described in details in a framework reference document, called the ***EMEP/EEA Emission Inventory Guidebook***. The last available version is from 2013[31] and the guidebook should be updated this year. It is important to note that the document is elaborated by national experts from the Convention and is formally adopted first by the EMEP Steering Body and finally by a decision from the Executive Body. Emissions are categorised according to the NFR nomenclature (Nomenclature for Reporting) which is based on 6 main classes: energy, industrial processes and product use, agriculture, waste, other sources and natural sources. Figure 6 below is an extract of the nomenclature table and illustrates how those categories are specified in the guidebook.

Source categories to be assessed in key category analysis		Special considerations
Category code	**Category title**	
1.A.3.b. vi	Road transport: automobile tyre and brake wear	
1.A.3.b. vii	Road transport: automobile road abrasion	
1.A.3.c	Railways	
1.A.3.d. ii	National navigation (shipping)	Disaggregate to main fuel types
1.A.3.e	Pipeline compressors	Disaggregate to main fuel types
1.A.4.a. i	Commercial/institutional: stationary	Disaggregate to main fuel types
1. A.4.a. ii	Commercial/institutional: mobile	Disaggregate to main fuel types
1. A.4.b. i	Residential: stationary plants	Disaggregate to main fuel types
1. A.4.b. ii	Residential: household and gardening (mobile)	Disaggregate to main fuel types
1. A.4.c. i	Agriculture/forestry/fishing: stationary	Disaggregate to main fuel types

Figure 6. Extract of the NFR Nomenclature as described in the EMEP/EEA emission inventory guidebook

[31] http://www.eea.europa.eu/publications/emep-eea-guidebook-2013

The TFEIP is also a forum for the exchange of views and experience between the experts of all the countries, with expert panels that investigate some topics, workshops and internet forum. The Secretariat of the Convention is also deeply involved in capacity building activities for the less advanced countries, especially the so-called EECCA countries (Eastern Europe, the Caucasus and Central Asia).

Reporting

The reporting process is framed by guidelines revised in 2013 and formally adopted by the EB.[32] Full time-series of emissions should be reported for the year N-2 by the 15th February of year N. Gridded emissions reporting is expected for the first time by the 1st May 2017 and should be repeated every 4 years. It is important to note that according to the Gothenburg Protocol, the parties should report their projections as well every four years for the years 2020, 2025, 2030 and if possible 2040 and 2050. Finally, Parties provide annually in March so-called "Informative Inventory Reports" (IIR) that describe data reported and facilitate the review process. Data are collected, gathered, checked and processed by the Centre on Emission Inventories and Projections (CEIP). An example shows the status in last May of the 2016 reporting process concerning emission data from 2014. The principle of "Transparency" should be guaranteed by the documentation reported (IIR in particular).

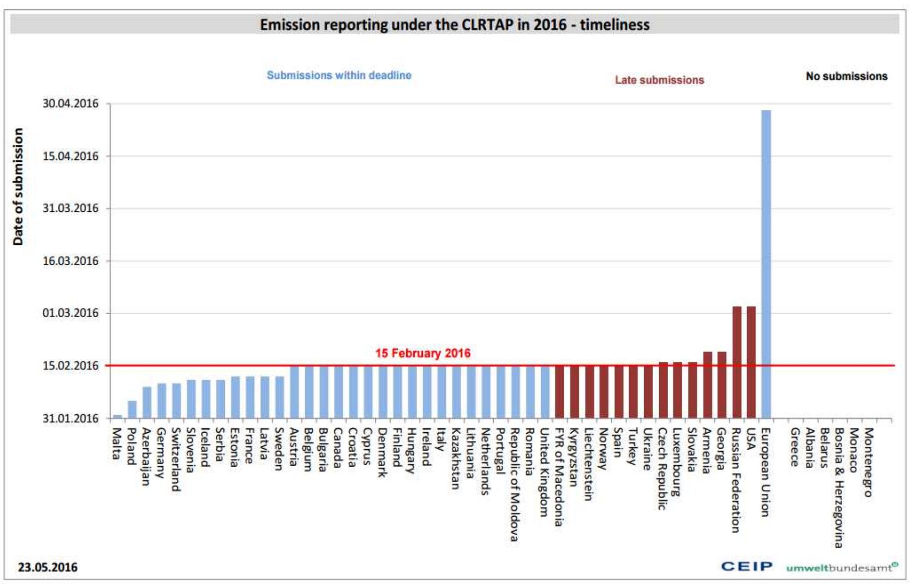

Figure 7. Status of emissions reported under the CLRTAP in 2016[33]

CEIP also checks quality and completeness of submitted emission inventories, iterates with national experts in case of questions or problems and ensures gap filling when inventories are not complete. This task is obviously extremely time-consuming which requests a high level of expertise but essential to consolidate emission inventories likely to be used for modelling and air pollution assessment. So far very few countries provided gridded emission data (it will be mandatory only in 2017). Therefore, CEIP was also in charge of the

[32] http://www.unece.org/env/lrtap/executivebody/eb_decision.html - decisions 2013/3
[33] www.ceip.at

elaboration of gridded data from data reported. Figure 8 shows what has been achieved by CEIP for $PM_{2.5}$ emissions in 2011, for all sectors in Europe.

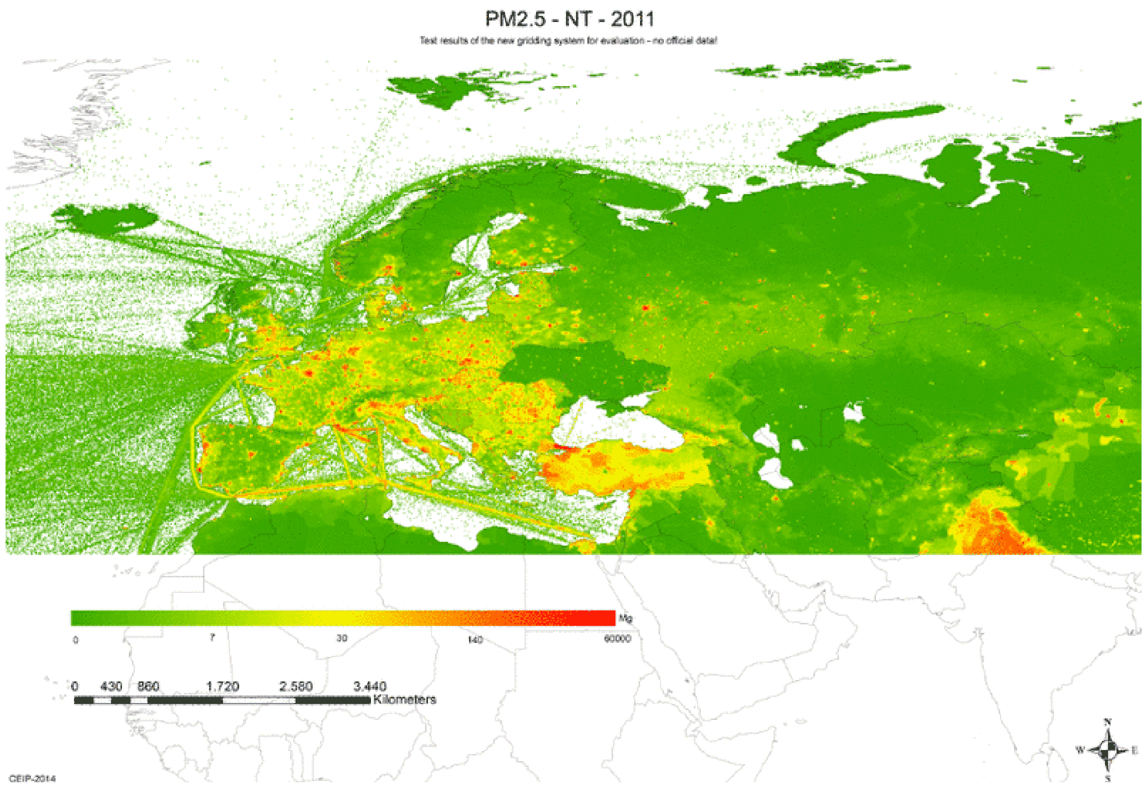

Figure 8. Gridded $PM_{2.5}$ emissions in 2011 elaborated by CEIP[34]

Review

In the manner of Greenhouse Gases (GHG) inventories, CLRTAP air pollutant reporting process includes peer-review steps to assess the quality of the reported data according to the state of the art, the methodological requirements of the Convention and available data. It should be noted that reporting "good" emission data is mandatory for Parties to the Convention. The Executive Body adopted in 2007 a number of decisions to define and frame the review process for emission inventories[35].

The technical review of national inventories checks and assesses Parties' data submissions with a view to improving the quality of emission data and associated information reported to the Convention. The review process is aiming at inventory improvements by checking transparency, consistency, comparability, completeness and accuracy of submitted data. The technical review of submitted emission data is carried out in three stages:

- *Stage 1*: Initial check of submissions for timeliness, completeness and formats. It is generally based on automated tests and country reports are made quickly available;

[34] http://www.ceip.at/ms/ceip_home1/ceip_home/new_emep-grid/01_grid_data_2011/
[35] http://www.ceip.at/fileadmin/inhalte/emep/review/RevGuid_ece.eb.air.ge.1.2007.16.e.pdf

- *Stage 2*: Synthesis and assessment of all national submissions with respect to consistency, comparability, trends with recommendations for data quality improvement; results are published in country reports in May;
  Stage 3: In-depth reviews of selected inventories, by pollutant, country or sector, as in the workplan agreed by the Executive Body. Up to 10 countries are checked annually by 2 review teams. Each country is supposed to get a centralized review of quantitative and qualitative information of selected inventories by pollutant and sector annually.

The review is performed by CEIP (stages 1 and 2) and by national experts (stage 3) proposed by the Parties. The countries always have a chance to analyze the review reports, to bring additional inputs or justifications, and even to re-submit new datasets. This is an iterative process until the presentation of the conclusions during the annual EMEP Steering Body meeting in September, where they are adopted.

This set-up allowed improving significantly the quantity and the quality of officially submitted emission inventories, at least for emissions targeted by the Gothenburg Protocol. Experience shows that there are more difficulties for heavy metals and POPs, and that there is still space for improvement through capacity building actions, especially in the countries of the EECCA region. However, the annual budget necessary to maintain this system is high as the level of involvement of the Parties which provides national experts for the methodology and reviews. Currently, some actions aim at revising the review process for a better allocation of financial resources, without lightening the quality objectives. An idea could be to focus stage 3 in-depth reviews only on countries for which reported data seem the most uncertain. This aspect will be discussed in the future annual meetings of the EMEP Steering Body.

Application to the NEASPEC framework

For NEASPEC, the challenge will be to set-up **the cooperative and reporting framework** which will allow sharing emission information and developing an integrated air pollution management strategy. Most of the countries already developed emission inventories (gridded or not). But there is a need to check the coherence of the methodological approaches, consistency of the formats (for instance the nomenclature to sort activity data), and availability of basic data collected to calculate emissions. This first step is essential to develop a common framework for estimating emissions and galvanizing dialogue between national experts.

However, scientific initiatives provided a starting point. In particular, the MIX Asia Emission Inventory supports two scientific projects: the Model Inter-Comparison Study for Asia (MICS-Asia) and the evaluation of source-receptor matrices at the hemispheric scale realised in the framework of the EMEP Task Force on Hemispheric Transport. Results and methodologies are published in (Li et al, 2015). The authors summarize it as followed (extract from the paper) and on Figure 9:

"*Five emission inventories are selected and incorporated into the mosaic inventory, as listed in the following: REAS inventory version 2.1 for the whole of Asia (referred to as REAS2 hereafter,* *Kurokawa et al., 2013), the Multi-resolution Emission Inventory for China (MEIC) developed by Tsinghua University*[36]*, a high resolution NH3 emission inventory by Peking University (referred to as PKU-NH3 inventory hereafter, Huang et al., 2012), an Indian emission inventory developed by Argonne National Laboratory (referred to as ANL-India hereafter, Lu et al., 2011; Lu and Streets, 2012), and the official Korean emission inventory from the Clean Air Policy Support System (CAPSS) (Lee et al., 2011).* "

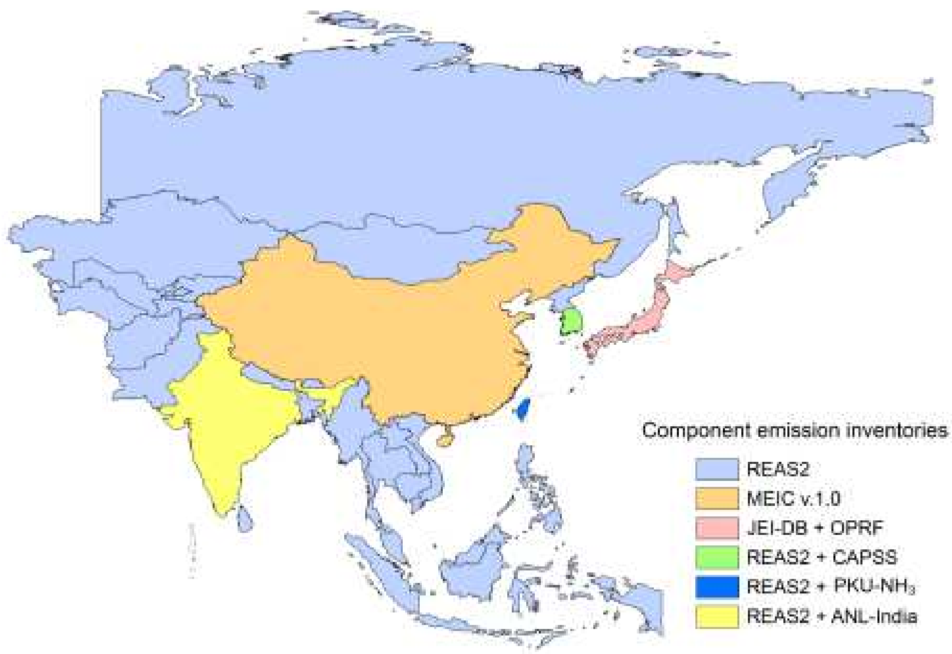

Figure 9. Domain and component of the MIX emission inventory (Source : Li et al, 2015)

The inventory is largely based on the REAS inventory (Regional Emission Inventory in Asia) developed since 1997 and compiling data for the years 2000 to 2008 (Kurokawa, 2013).[37] The approach to improving most updated data was complex and required a lot of work to build up a new consistent emission inventory for Asia, for the years 2008 and 2010 available for modelling studies (so scientific purposes). Main difficulties include::

- Dealing with various references and nomenclatures that characterize activity sectors, to elaborate a consistent list of pollutants (especially for VOCs which can include several hundreds of chemical species),
- Selecting the best estimates in areas where several inventories overlapped,
- And dealing with boundary areas where two or more emission inventories meet.

The other initiative that should be mentioned in this report is the LTP project which aims at assessing the impacts of long-range transport of air pollutants in East Asia and involves three

[36] http://www.meicmodel.org
[37] https://www.nies.go.jp/REAS/

countries: China, Japan and Republic of Korea. This project started in the early 2000s' with the objective of computing and analysing source-receptor matrices, first for sulphur and nitrogen compounds and in its next stages for ozone and PM. Emissions inventories for the years 1998 and 2006 have been elaborated on the basis of national emission tools, but seems that no more recent data are available. This initiative was very promising because 1) national scientific capacities were mobilised, 2) the objective was to enhance dialogue with policy makers.

More recently a new initiative to elaborate an emission inventory for modelling in East Asia led to the CREATE tool (Comprehensive Regional Emissions Inventory for Atmospheric Transport Experiment). This project is leant to the GAINS-Asia project which is an integrated modelling platform for air pollution management policies developed by IIASA.

As the MIX-Asia and LTP emission inventory, CREATE includes up-to-date data and relevant methodologies to elaborate emissions datasets for modelling long-range transport and scenarios. Data are consistent through the domain because they have been compiled by experts more or less the same methodologies. But they do not reflect national and "official" contributions that would be the starting point of negotiations for reducing emissions. Recommendations for an action plan would cover the following items as priorities:

- Definition of the reference framework for the elaboration of emission inventories with the elaboration of guidelines that could be adopted by the 6 countries of the NEASPEC region. Experience developed in each country (especially China, Japan, Republic of Korea) should be used to define a common basis for sectoral nomenclature, minimum requirements for activity data, emission factors, methodologies;

- Identification of necessary capacity building actions to support the elaboration of national emission inventories; an evaluation of the associated economic costs (and perhaps benefits) would be welcome. The existing scientific emission inventories (MIX-Asia, LTP, CREATE) can provide approximations for missing data or be a starting point for national inventories;

- A systematic comparison of existing inventory (MIX-Asia, LTP, CREATE) would be necessary to prepare future policy discussions on the modelling results and scenario analyses obtained with those inventories

- Implementation of a reporting system, that could be very simple in a first stage (common emission database) with rules for updating;

- Elaboration of a mid-term strategy to secure QA/QC aspects, dissemination and use for both policy and scientific purposes. Note that comparison with existing inventories is an excellent verification tool.

6. Monitoring transboundary air pollution

The EMEP monitoring strategy

Main principles

Monitoring transboundary fluxes was one of the first objectives of the CLRTAP. Historical measurements at relevant observation sites allow qualifying main fluxes and quantifying the evolution of air pollution levels while emission reductions strategies develop. The monitoring strategy of the EMEP programme is published on the Convention website. [38] The last version revised in 2012 relates to the 2010-2019 period and complies with a number of principles of the EMEP strategy. The monitoring programme should ensure:

a) *Sufficient ongoing long-term monitoring of concentrations and deposition fluxes to test the effectiveness of the Convention's protocols as well as other European policies;*

b) *Adequate spatial coverage in new EMEP areas as well as in areas that have been insufficiently covered up to now;*

c) *Sufficient temporal resolution that will allow investigation of atmospheric processes and model improvements as well as analysis of individual pollution events important in relation to human health and ecosystem impacts;*

d) *Co-located and concurrent monitoring of all relevant components and adoption of standard methodologies and adequate quality assurance procedures;*

e) *Conduct of monitoring in an affordable way for all Parties, particularly those with economic limitations, but at the same time in a way that takes advantages of the scientific development and emerging capabilities at the national level.*

Several key points are hidden behind those principles

- Location and number of monitoring stations in each country must allow to the evaluation of transboundary fluxes and background air pollutant concentrations and deposition. They depend on the considered pollutant (see below);
- Long historical sets of observation data are essential to catching signals representatives of the impact of emissions control strategies. In that perspective, the Parties are encouraged to keep operational their EMEP monitoring sites as long as possible. Some sites can provide data over 30 years;
- Selection of measured parameters should be driven by scientific needs to better support understanding of atmospheric processes and anticipate air pollutant behavior;
- Quality assurance and comparability of the measurements is essential to building up confidence in the network and use the data for policy negotiations. As a consequence,

[38] http://www.unece.org/fileadmin/DAM/env/documents/2009/EB/ge1/ece.eb.air.ge.1.2009.15.e.pdf

EMEP and its Chemical Coordinating Centre (CCC) defined a stringent framework that should be applied by all the Parties;

- If capacity building actions are necessary to develop the monitoring network, they are identified as priorities in the work plan.

The EMEP network is considered as one of the most robust and relevant regarding its capacity to catch trends in air pollution patterns in Europe and the length of its historical datasets (more than 20 years in some cases) with a high degree of quality. It is developed upon a graduate strategy. Monitoring networks are classified from level 1 and 2 with mandatory parameters, mandatory measurement and analytical devices and protocols and a number of stations fixed with respect to the size of the country, to level 3 which corresponds to scientific networks that can usefully complement level 1 and 2 ones with new parameters and new instrumentation.

Level 1 site (mandatory) should provide **long-term basic chemical and physical measurements of the EMEP** parameters. Those should be the first priority when extending the network to areas that are not correctly covered. A target density of at least **1 or 2 level 1 site per 100,000 km²** is recommended. The level 1 parameters are synthesised in the table (Figure 10) below (issued from the Annex of the EMEP Monitoring Strategy 2010-2019).

Programme	Parameters	Minimum time resolution
Inorganic compounds in precipitation	SO_4^{2-}, NO_3^-, NH_4^+, $H^+(pH)$, Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, (cond)	Daily
Heavy metals in precipitation	Cd, Pb $(1st\ priority), Cu, Zn, As, Cr, Ni$ $(2nd\ priority)$	Daily/ weekly
Inorganic compounds in air	$SO_2, SO_4^{2-}, NO_3^-, HNO_3, NH_4^+, NH_{3+}, (sNO_3, sNH_4), HCl, Na^+, K^+, Ca^{2+}, Mg^{2+}$	Daily
NO_2 in air	NO_2	Hourly/Daily
Ozone in air	O_3	Hourly
PM mass in air	$PM_{2.5}$, PM_{10}	Hourly/Daily
Gas particle ratios of N- species	$NH_3, NH_4^+, HCl, HNO_3, NO_3^-$ (in combination with filtre pack sampling)	Monthly
Meteorology	Precipitation amount(RR), temperature(T), wind direction(dd), wind speed(ff), relative humidity(rh), atmospheric pressure(pr)	Daily (RR), Hourly

Figure 10. Level 1 parameters in the EMEP monitoring strategy *39*

Level 2 sites (mandatory) provide **additional physicochemical speciation of relevant components** to assess long-range transport. Generally, they are defined by the party itself, according to a topic particularly sensitive in its own monitoring strategy. Parties with a land area larger than **50,000 km² are expected to operate at least 1 level 2 sites**, and those with a

39 http://www.unece.org/fileadmin/DAM/env/documents/2009/EB/ge1/ece.eb.air.ge.1.2009.15.e.pdf

land cover area larger than **100,000 km² are expected to operate level 2 sites at least for more than one topic** chosen in the list presenting in Figure 11.

Programme	Parameters	Minimum time resolution	Notes
Acidification and eutrophication Observations contribute to the assessment of nitrogen chemistry, influence by local emissions and dry deposition fluxes (see also para. 18b)			
Gas particle ratio	$NH_3/NH_4^+, HNO_3/NO_3^-$ (artifact-free methods)	Hourly/Daily	
Ammonia in emission areas (optional)	NH_3	Monthly	Optional low cost alternative to provide high spatial resolution information in emission areas, where desired.
Photochemical oxidants Observations contribute to the assessment of oxidant precursors (see also paragraph 18b)			
$\boldsymbol{NO_x}$	NO, NO_2	Hourly	In the EU Directive 2008/50/EC, WMO GAW
Light hydrocarbons	$C_2 - C_7$	Hourly	In the EU Directive 2002/3/EC and benzene in 2008/50/EC, WMO GAW
Carbonyls	Aldehydes and ketones	8 hourly twice a week	In the EU Directive 2002/3/EC
$\boldsymbol{CH_4}$	Methane	hourly	WMO GAW
Heavy metals Observations contributes to the assessment of mercury and heavy metals fluxes (see also paragraph 18b)			
Mercury in precipitation	Hg	Weekly	In the EU Directive 2004/107/EC
Mercury in air	$Hg\ (TGM)$	Hourly/Daily	In the EU Directive 2004/107/EC
Heavy metals in air	$Cd, Pb\ (1st\ priority), Cu, Zn, As, Cr, Ni\ (2nd\ priority)$	Daily/Weekly	In the EU Directive 2004/107/EC for As, Cd, Ni, and 2008/50/EC for Pb
Persistent organic pollutants Observations contribute to the assessment of persistent organic pollutants (see also paragraph 18b)			
POPs in precipitation	$PAHs, PCBs, HCB, chlordane, HCHs, DDT/DDE$	Weekly	PAG in EU Directive 2004/107/EC. POP is included in UNEP Stockholm Convention
POPs in air	$PAHs, PCBs, HCB, chlordane, HCHs, DDT/DDE$	Daily/Weekly	PAH in EU Directive 2004/107/EC. POP is included in UNEP Stockholm Convention
Particulate matter Observations contribute to the assessment of particulate matter and its source apportionment (see also paragraph 20(c)).			
PM mass in air	PM1	Hourly/Daily	
Mineral dust in PM10	*Si, Al, Fe, Ca*	Daily/Weekly	Chemical speciation included in WMO/GAW recommendation for the aerosol network, GAW report No 153 and No 172

EC and OC in PM10	*Elemental and Organic Carbon*	Daily/Weekly	Chemical speciation included in WMO/GAW recommendation for the aerosol network, GAW report No 153 and No 172
Aerosol absorption	*Light absorption coefficient*	Hourly/Daily	Included in WMO/GAW recommendation for the aerosol network, GAW report No 153/172. Core parameter
Aerosol size/number distribution	*dN/dlogDp*	Hourly/Daily	Included in WMO/GAW recommendation for the aerosol network, GAW report No 153/172. Core parameter
Aerosol scattering	*Light scattering coefficient*	Hourly/Daily	Included in WMO/GAW recommendation for the aerosol network, GAW report No 153/172. Core parameter
Aerosol Optical Depth	*AOD at 550 nm*	Hourly	Included in WMO/GAW recommendation for the aerosol network, GAW report No 153/172. Core parameter
Tracers Observations contribute to the assessment of individual long-range transport events and their source apportionment (see also paragraph 18b)			
Carbon Monoxide	*CO*	Hourly	In the EU Directive 2004/107/EC, WMO GAW report No 172
Halocarbons	*CFCs, HCFCs, HFCs, PFCs, SF6*	Hourly	WMO GAW report No 172

Figure 11. Level 2 parameters in the EMEP monitoring strategy[40]

Level 3 sites are fully research-oriented. They are implemented by the Parties on a voluntary basis with the objective of improving scientific understanding of physico-chemical processes. They are undertaken by research groups and included as well field campaigns. Level 3 sites are nominated by EMEP supersites. New instruments can also be tested on these sites.

The EMEP monitoring strategy integrates collaborations with other atmospheric chemistry monitoring networks and collocated measurements with other programmes such as OSPAR[41], HELCOM[42], AMAP[43] or GAW[44] can develop.

Since 2006, measurement field campaigns (or Intensive Observation Periods -IOP) have been organized by the CCC and the Task Force on Measurement and Modelling to get complementary data necessary to document specific topics: for instance, nitrogen and eutrophying compounds, chemical speciation of particulate matter, etc. The added-value of such initiatives comes from the interest of new data collected during the campaigns and the

[40] http://www.unece.org/fileadmin/DAM/env/documents/2009/EB/ge1/ece.eb.air.ge.1.2009.15.e.pdf

[41] Convention for the protection and conservation of North East Atlantic and its resources

[42] Baltic Marine Environment Protection Commission

[43] Arctic Monitoring and Assessment Programme

[44] Global Atmospheric Watch from WMO

strong collaboration between national experts and research groups that develop to conceive and run intensive observation periods.

The EMEP network

The EMEP network is currently made of **338 sites located in 42 countries. 409 physico-chemical parameters are measured by 80 instruments** approved by the CCC (to ensure quality assurance and comparability of the measurements). Since 1970, 30,500 datasets have been issued from the EMEP network and that makes the EMEP database as one of the biggest ones in Europe to characterize long-range transport. Figure 12 presents the EMEP monitoring network in 2013 for nitrogen, sulphur compounds, and ozone. National interactive maps of EMEP monitoring networks are proposed on the website of the CCC.[45]

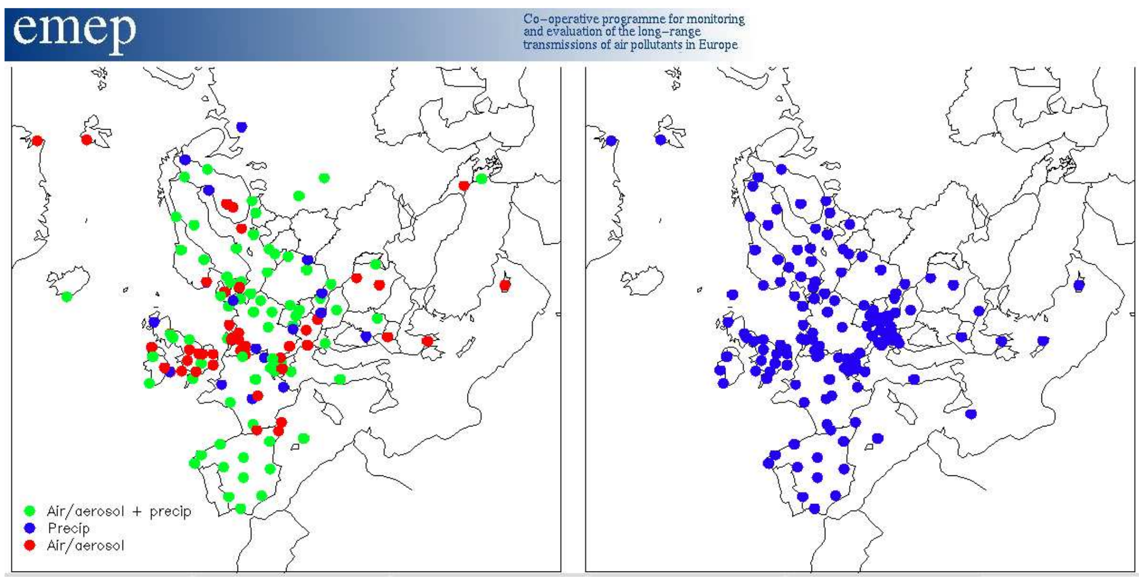

Figure 12. EMEP measurement network for main component (left) and ozone (right) in 2014[46]

Observation data are reported to the CCC by the Parties each year on the 31st July for data of the previous years. A simple but common reporting format has been to facilitate compilation, quality checking, and integration in the database. Thanks to recent project supported by EMEP budget and Norway, the CCC developed a new database, called EBAS. It gathers all EMEP data but also observations from other programmes and projects relevant for understanding long-range transport of air pollution[47] (AMAP, OSPAR… and **EANET see Figure 13**[48])

[45] http://www.nilu.no/projects/ccc/sitedescriptions/index.html
[46] http://www.nilu.no/projects/ccc/network/index.html
[47] The database is easily accessible on http://ebas.nilu.no/
[48] Actually only historical data from 2001 to 2005 from the EANET network are proposed on the EBAS web site

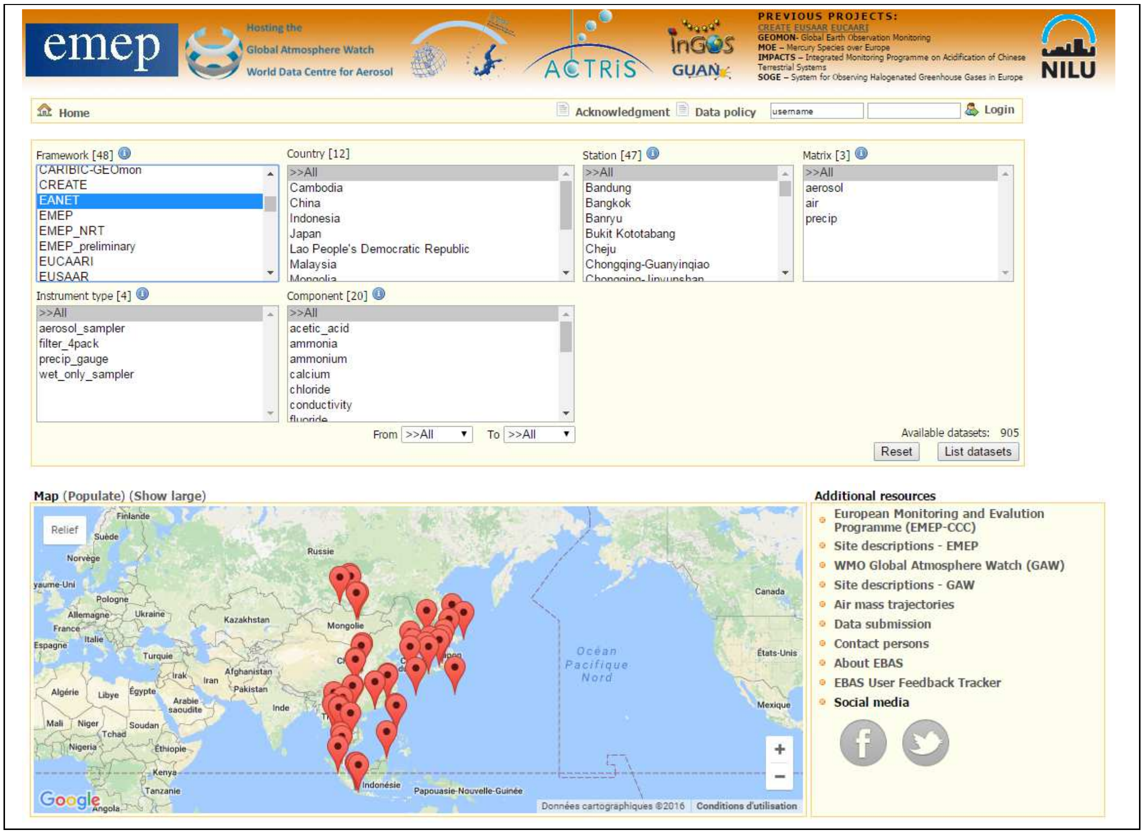

Figure 13. Snapshot of the the EBAS webpage for the selection of monitoring stations

Contribution to the EMEP monitoring network and reporting observations are obligations for the Parties to the Convention. However, their involvement to comply with them requests important financial resources and varies from a country to another. Therefore, policy makers support and mobilization are essential for encouraging the development of the network especially in less documented areas (and in the EECCA countries) and keeping under operational conditions the existing sites to get long historical time series. Figure 14 presents very instructive information: this is a representation of the level 1 compliance index regarding the "national EMEP networks" implemented in the countries. The value 100 means that all the level 1 requirements (as set in the EMEP monitoring strategy) are implemented. The graph proposes a comparison between the years 2000, 2005 and 2013. The value 100 was reached by only one country (the Netherlands) in 2013. The index improved in most of the countries between 2000 and 2005. But it is interesting to note that this is not systematically the case between 2005 and 2013. Some countries decided to decrease the level of ambition and quality of their EMEP network, generally because of budgetary constraints. **This is one of the highest current concerns the Convention has to face to nowadays.**

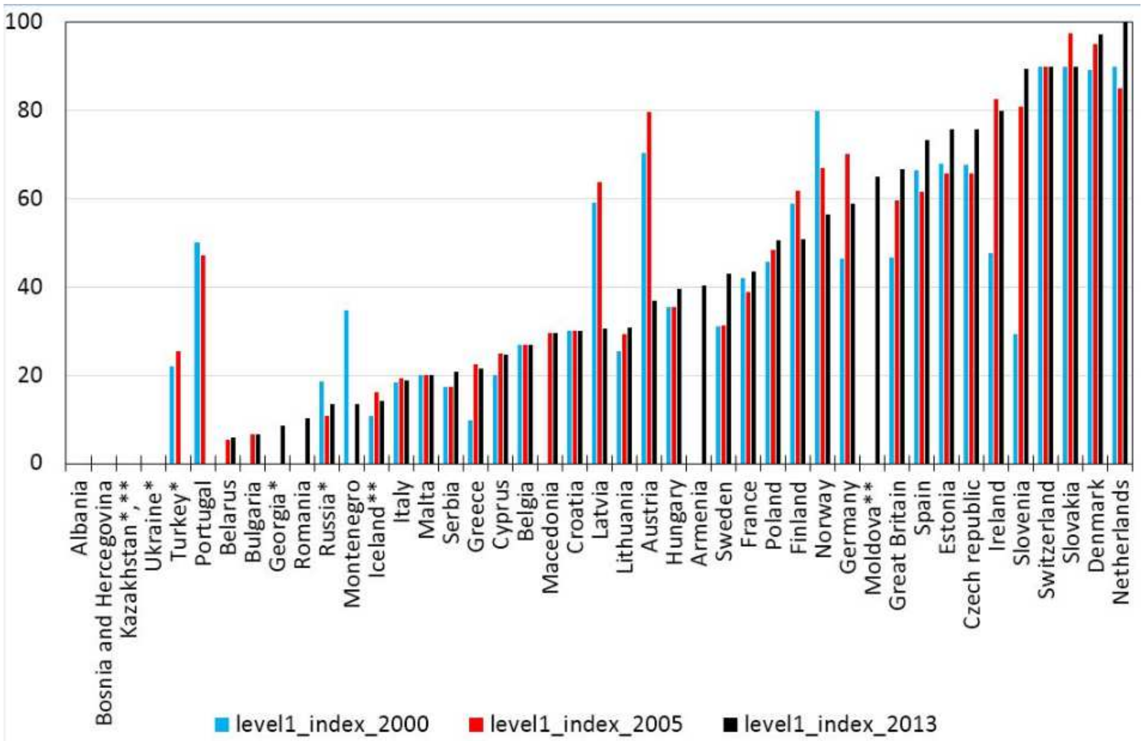

Figure 14. Evaluation of the level1 compliance index, for the network implemented in EMEP countries in 2000, 2005 and 2013

The quality of the EMEP monitoring network is acknowledged by both the scientific and the policy communities thanks to the stringent QA/QC framework that has been defined and that is guaranteed by the support provided by the Chemical Coordinating Centre (CCC). This Centre:

- Defines guidelines for measurements and chemical analyses.[49]
- Sets data quality objectives (DQO) regarding detection limits and precisions of measurements[50]
- Proposes a reference flagging system to qualify submitted data
- Organizes regularly laboratories and fields inter-comparison campaigns to check quality control processes implemented in the parties and the performance of the measurements.
- Organizes workshops and training sessions can also help the national experts to improve their practises. Moreover, the task Force on Measurement and Modelling allows exchanges of views and experiences between national experts and contributes to the definition of new monitoring activities.

What we learn from the EMEP network

In 2015, national experts and the EMEP technical centres performed an analysis of the trends in air pollutants concentrations and deposition in the EMEP domain over the 20 past years.

[49] For access to the reference manual: http://www.nilu.no/projects/ccc/manual/index.html
[50] http://www.nilu.no/projects/ccc/qa/index.htm

This study was possible thanks to the long time series available at the EMEP monitoring sites and the scientific and technical EMEP framework that guarantees quality and comparability of the observations available everywhere in Europe. The report (EMEP, 2016) is available on the website of the Convention.[51] It presents a number of key messages, some of them are reported below to illustrate our analysis:

- *European emissions of ozone precursors NOx and NMVOCs have substantially decreased since 1990. This decrease in reported emissions is corroborated by atmospheric measurements, which likewise show a substantial decrease in ambient NO_2 and NMVOC concentrations;*
- *Annual mean ozone levels measured at EMEP stations was increasing in the 1990s, and shows a slight decreasing trend starting in 2002;*
- *Summertime peak ozone measured at EMEP stations showed a flat trend in the 1990s, and a decline starting in 2002. This decline is consistent with reductions in European precursor emissions;*
- *Decreases of measured oxidised nitrogen are determined both by emissions and atmospheric chemistry. Particulate matter (PM) composition has shifted from ammonium sulphate to ammonium nitrate hence changing the atmospheric lifetime of both reduced and oxidised nitrogen. The consequence of this is that reductions in emissions are not directly transferred to decreases in concentrations;*
- *Reduced nitrogen remains a major area for concern as there are no-trend or increasing trends observed at the majority of sites;*
- *PM_{10} and $PM_{2.5}$ mass measurements were only monitored extensively enough to assess trends after 2001. Over the 2002-2012 period, decreases of 26% and 34% were observed at the sites assessed for PM_{10} and $PM_{2.5}$ respectively*;

To be used by policy makers, those scientific conclusions must be completed by key messages such as:

- Strategies to reduce emissions, and the protocols of the Convention had a positive impact on long range air pollution over the 20 past years, especially on concentrations of ambient acidifying and eutrophying compounds, but the monitored decreases in concentrations are not always in the same proportions as the emission decreases:
  - Emission control strategies should be reinforcing
  - Ambient concentrations are not only driven by emissions, but also by other parameters like nonlinear chemical processes in the atmosphere, meteorology, climate warming, and hemispheric transport… Science should give new answers
- Ozone trends illustrate those issues with decline of ozone summer peaks in Europe but a slower and lower response to annual average, which shows that ozone is still a concern in Europe;
- PM trends are very encouraging, but they need to be confirmed (the network is relatively recent).

[51] http://www.unece.org/env/lrtap/welcome.html

- There is a need to extend the monitoring network in the far Eastern parts of Europe which are not correctly covered and where analysis of the impact of control strategies would be essential.

Those results are confirmed by the trends analysis realised by the Working Group on Effects of the Convention (WGE, 2016) that presents a synthesis of measurements of the effects on ecosystems. The operational development and implementation of effects monitoring networks for vegetation, forests, freshwater, to complement to the traditional air and deposition monitoring network are quite unique and one of the strengths of the Convention. However, the effect activities are funded only by countries contributions, and it is more and more difficult to get the appropriate budget to maintain them. This is one of the key and difficult issues the Convention has to face within the current period. **Envisaged solutions could require a revision of the monitoring strategy (including air concentrations and effects) to deal with budgetary constraints. New priorities will certainly have to be set by the policy makers in the coming years**.

Need to develop outreach activities

Another strategic aspect of the monitoring strategy of the Convention is the development of active cooperation with other networks and programmes. First it should facilitate access to complementary data, second it should help in optimising resources (a country could develop a supersite that serves several objectives and networks). Close co-operations develop for years with the Global Atmospheric Watch Programme from WMO, with the European ACTRIS network focused on the composition of atmospheric aerosols.[52]

A missing aspect in the EMEP monitoring strategy is Earth observation. Satellite observations of atmospheric composition are more and more developed, and even if the parameters (generally integrated columns of concentrations, measurements of aerosol optical depth also named AOD) are not directly operational for policy assessment. **The main added-value of satellite observation is the potential coverage of areas where there are no or very few in-situ measurements**. NASA in the USA, EUMETSAT, ESA in Europe derive new products from Earth observations that could be of high interest for policy applications (see Figure 15 for instance $PM_{2.5}$ map elaborated from MODIS[53] measurement for the 2001-2006 period). In 2015, the European Commission has launched, after 10 years of preparation, the Copernicus services[54] - dedicated to environment monitoring and based on a large set of data from in-situ and satellite observations and modelling. The Copernicus Atmosphere Services (CAMS)[55] are dedicated to atmospheric composition and promote the use of satellite information with services that aims at using those data to elaborate comprehensive maps of air pollution at the global scale. They are operated by the European Center for Medium-range Weather Forecasts (ECMWF) helped by a panel of European laboratories which developed high-level expertise in the field of atmospheric monitoring and modelling.

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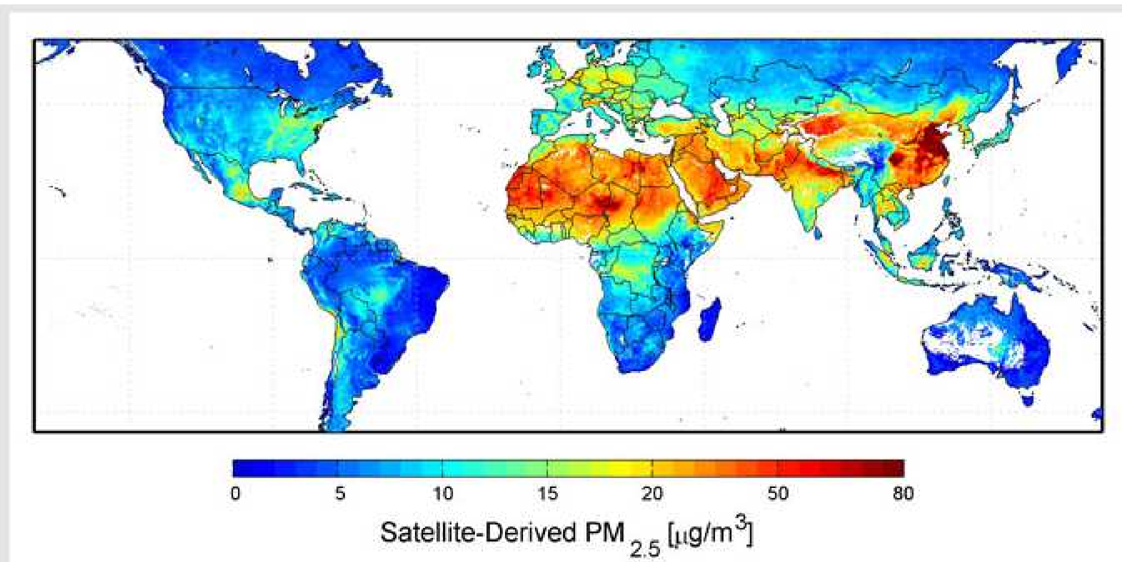
[52] http://www.actris.eu/
[53] MODIS= Moderate Resolution Imaging Spectroradiometer http://modis-atmos.gsfc.nasa.gov/MOD04_L2/index.html
[54] http://www.copernicus.eu/
[55] http://atmosphere.copernicus.eu/

In the coming years cooperation with Copernicus and satellite data providers should develop to complement the EMEP monitoring strategy with new and relevant datasets. It will start through scientific partnerships because data should be evaluated and analysed, but policy decisions will be necessary to formalise the process.

Another aspect is the international collaboration with non-European networks. The established partnership with the GAW network has been previously mentioned as the fact that EBAS database compile historical (until between 2001 and 2005) EANET data. It would be definitely worthwhile to develop exchanges of monitoring data to evaluate the impact of hemispheric transport of air pollution and to develop exchanges of expert views regarding practises, QA/QC, instrumentation, etc.

- ➔ To start, a workshop could be organised between EMEP and other international air quality monitoring communities (especially in Asia region).



› View larger
Global satellite-derived map of $PM_{2.5}$ averaged over 2001-2006. Credit: Dalhousie University, Aaron van Donkelaar

Figure 15. PM2.5 map for the 2001-2006 period derived from MODIS observations[56]

[56] http://www.nasa.gov/topics/earth/features/health-sapping.html

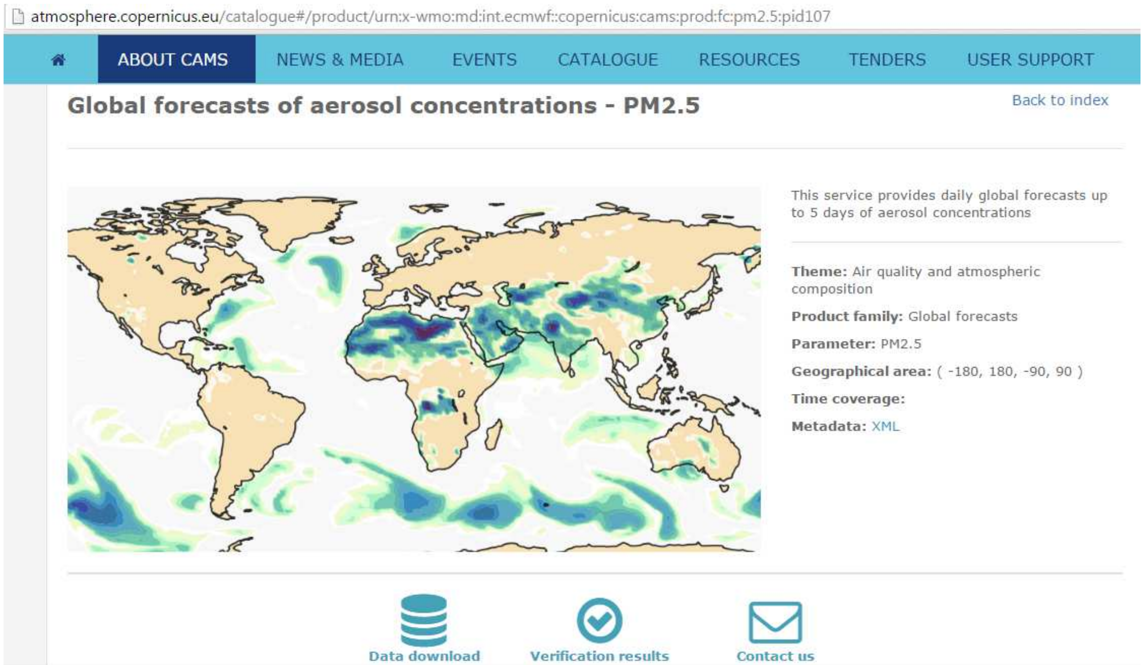


Figure 16. Snapshot of the CAMS webpage presenting global aerosol concentration forecasts[57]

Monitoring activities in NEASPEC region

Regarding international cooperation in this region, EANET, the Acid Deposition Monitoring Network in East Asia[58], operated under the technical coordination of the ACAP is an excellent example. It covers four environmental media (wet deposition, dry deposition, soil and vegetation, inland aquatic environment). It involves 13 countries and is based on 46 and 54 dry and wet deposition monitoring sites respectively. This network is complemented by 19 "ecological sites" that monitor the effects of acid deposition.

This network results from a successful organisation based on policy and science interactions as it is done within the CLRTAP. Decisions are taken by the Intergovernmental Meeting with official representatives of the countries, advised by the Scientific Advisory Committee and its task forces. Secretariat is ensured by the UNEP Regional Office for Asia Pacific. QA/QC and capacity buildings are important priorities of the project and inter-laboratory comparison projects, reporting procedure and training sessions are implemented on a regular basis. The concept is very close to what is implemented within the CLRTAP for monitoring objectives.

[57] http://atmosphere.copernicus.eu/catalogue#/product/urn:x-wmo:md:int.ecmwf::copernicus:cams:prod:fc:pm2.5:pid107
[58] http://www.eanat.asia/

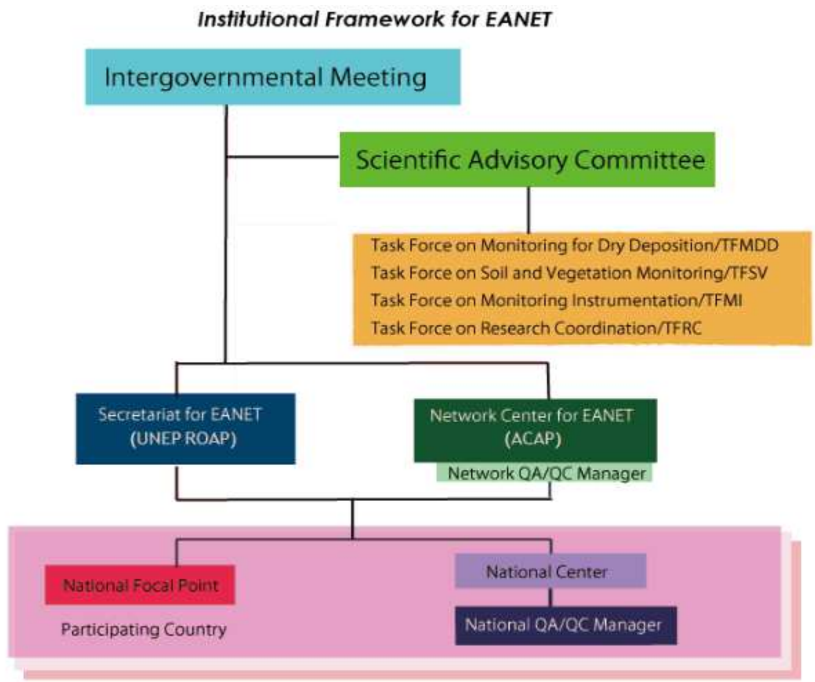


Figure 17. Organization of the EANET network[59]

The LTP project previously mentioned for emission issues contributed to the development of monitoring capacities as well. It focused on SO_2, NO_x, PM and ozone monitoring and the sites implemented in the three participating countries do not necessarily belong to EANET.

Therefore, solid frameworks are currently running in East Asia for air pollution monitoring. Historically acid deposition and its effects on the environment were the priorities, the networks should now expand to better assess transboundary fluxes of ozone, nitrogen oxides and particulate matter. For both EANET and LTP initiatives policy-science interactions exist. QA/QC issues are well-developed within the EANET and development of the network will take advantage of this situation. The observation data should be promoted and used for policy support, to assess the impact of emission control strategies and for scientific objectives, to better understand atmospheric processes and support the development of chemical transport models in the region. Trends analysis would help in the policy perspective and new linkages with modelling groups would support the other one.

- International cooperation should also develop, especially with the CLRTAP/EMEP programme: exchanges on best practises, QA/QC, available instrumentation, trends in transboundary fluxes, and fitness of the monitoring network for modelling purposes would be good topics to initiate partnerships. As concluded in the previous paragraph, a workshop between EMEP and NEASPEC focused on monitoring aspects to deal with these subjects would be a good instrument to start.

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59 http://www.eanet.asia/eanet/org.html

7. Modelling for policy purposes

General overview

Modelling is the basic tool to elaborate maps and projection of future situations. Transboundary air pollution is generally modelled by regional chemistry-transport models (CTM) that allow simulation of a large number of complex physic-chemical processes governing the atmospheric chemical composition. Most of those models developed for several decades and reached a degree of maturity compatible with policy applications.

Several CTMs are developed in the world: from the USA, one can mention CMAQ, CAMx, WRF-Chem and from Europe, EMEP (from the EMEP programme), CHIMERE (FR), LOTOS-EUROS (NL), MATCH (SE), and so on. There are some experiments in Asia based on the implementation of American models: (Zhang et al, 2007), (Kim et al, 2014), (Gao et al, 2014), (Zhong et al, 2016). Other projects that deal with the development and evaluation of CTM propose an evaluation of the model MRI-PM/c against measurements collected by the EANET network (Kajimo et al, 2012). In North-East Asia, the work of the Japan Meteorological Agency for developing a new regional CTM for ozone (NHM-Chem) should be mentioned, as their results for simulating inorganic aerosols. Finally, the MISC-Asia projects and especially its second phase allowed to run several CTMs over the Asian domain and to assess the capacities of current tools in this specific region. A number of articles have been published on the results[60].

The papers mentioned, as examples, above refer generally to scientific studies focused on the development and performance evaluation of regional chemistry-transport models applied over the East-Asia domain. Air quality models are used for four mains purposes with two sides' aspects: policy and science. The table below synthesises this point of view:

Objective for modelling	Policy use	Science use
Production of air pollutant concentration and deposition maps	Assessment and trends of air pollution fields • *Assessment maps issued from CTM scan be significantly improved with the assimilation, in the model results of observation data. Data assimilated maps of air pollution should be preferred for policy applications*	• Improved understanding of air pollution patterns
Air quality forecasting	• Information and communication to the general public • Support for air pollution episodes' management	• Evaluation of the model performances on a day per day basis

[60] A special issue in Atmospheric Environment (2008, Vol 42) has been published under the supervision of G.R.Charmicheel (university of Iowa), and H. Ueda (Acid deposition and Oxydant research Center)

Scenario analysis	• Evaluation of the impact of emission reduction scenarios seeking for best emission control strategies	• Evaluation of the model sensitivity to variability in emissions • Understanding of nonlinear physico-chemical processes
Source-receptor calculations	• Evaluation of the impact of emission sources to identify and reduce the most influent one	• Understanding of nonlinear physico-chemical processes
Evaluation of emission inventories	• Evaluation of reported or estimated emissions with regard to their modelled impact on concentrations • Inverse modelling based on complex mathematical approaches ("adjoint modelling") could be useful in the perspective of emission inventories evaluation	• Evaluation of model and emission uncertainties • Development of inverse modelling and "adjoint" models

The EMEP models

The EMEP programme supported the development of its own model suites. In the CLRTAP Convention framework, the MSC-W and MSC-E modelling teams have their own fields of application for modelling: MSC-W is in charge of modelling acidifying and eutrophying compounds, ozone and particulate matter while MSC-E is responsible for modelling heavy metals and POPs. Both teams developed a global version of their modelling system to be able to simulate the fate of atmospheric pollutants at the hemispheric scale, in particular in support to the work of the EMEP Task Force on Hemispheric Transport of Air Pollutant (TF HTAP), and to develop international cooperation. The EMEP models development is supported by the EMEP budget allocated by the Convention and its Parties. Therefore, they are the reference and official modelling tools that support the work of the Convention and all policy assessments discussed in this framework. Of course, for domestic use, Parties are free to 1) use the EMEP models results, 2) implement national versions of the EMEP models with the support of the centre MSC-W and MSC-E, and 3) develop their own model of capacities. But the results provided by the EMEP modelling teams as considered as references for the policy negotiations.

In the present paper we will focus more on the EMEP model developed by MSC-W which deals with ozone and PM. The very first version of the models was dedicated to the simulation of sulphur and nitrogen deposition (for acid rain issues).[61] It was a lagrangian model. The first results of the EMEP Eulerian photo-oxidant model were presented in 1997 for the first time. A version dedicated to the simulation of particulate matter has been developed at the same time and in 2002, MSC-W presented a unified version of the EMEP

[61] http://www.emep.int/mscw/mscw_models.html

models computing airborne concentrations and deposition of acidifying, eutrophying chemical compounds, ozone and PM (PM_{10} and $PM_{2.5}$) and their chemical composition. The Unified EMEP model code (version rv3) was released as open source under the GPL license v3 in February 2008. The release of the code included also a full input data set for 2005 and model results for comparison.

During the development of the models, the grid resolution has changed from the EMEP grid for the Lagrangian model (150x150 km^2) to the one for the Eulerian model (50x50 km^2 and now 10x10 km^2).

The EMEP/MSC-W eurlerian model is now used for a number of applications with respect to policy needs of the Convention. Actually, this is the official and reference modelling tool for the work on the Convention:

Its first and most famous application is **the calculation of source receptor (S/R) matrices** that give the response in a given area and in terms of air pollutant concentrations, to a change a given change in emissions in another area. Those S/R matrices (or "blame" matrices) are used for integrated assessment modelling in the GAINS model to seek for optimised emissions reduction strategies based on national emission ceilings, and country to country or country to grid SR matrices are computed by the EMEP centre. They are provided to IIASA as an input of the GAINS model, but are also published on the website.[62] The source-receptor (SR) relationships give the change in air concentrations or depositions resulting from a change in emissions from each emitter country. For each country, reductions in six different pollutants have been calculated separately: with an emission reduction of **15% for SO_x, NO_x, NH_3, NMVOC, $PPM_{2.5}$[63] or PPM $_{coarse}$[64]** respectively. Both maps and numerical files are available. Figure 18 shows an example of a graphical map of blame matrices (based on countries to grid SR matrices), established for 2013, and presenting the influence of emissions in France on $PM_{2.5}$ concentrations elsewhere. This kind of map and the corresponding numerical files in *txt* format are calculated and available (see Figure 19) for all the Parties, all the targeted pollutants with various exposure indicators and for all years since 1997 to 2013 (currently). Operation production and maintenance of this precious database represents a huge amount of work but is essential for policy discussions and their traceability. Moreover, EMEP MSC-W model calculations are changing with time, not only because of EMEP MSC-W model updates, but also due to modifications of the input data (e.g. revised emission data and meteorology). It means that the SR matrices should be recalculated as well. For transparency, types of model results can be distinguished and are available on the websites:

- Type 1) Model results that have been *officially reported* in the annual EMEP status reports, based on model simulations using the best available input data (emissions, meteorology, etc.) at the time of reporting.

[62] http://www.emep.int/mscw/
[63] Primary PM2.5
[64] Primary coarse particle means PPM10 minus PPM2.5 concentrations

- Type 2) Model results from *later re-calculations*, using updated input data which were not available at the time of reporting (e.g. revised and improved emission data for the past, meteorological data on finer resolution, etc.)

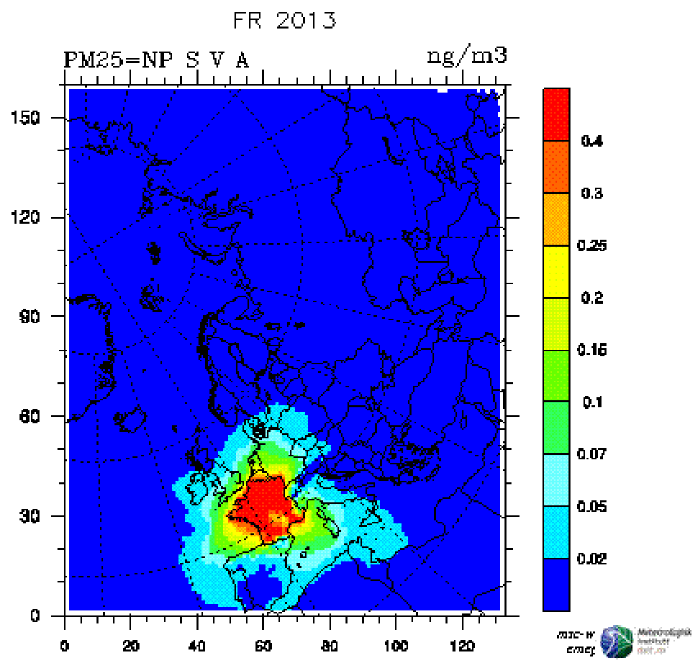


Figure 18. Graphical map of blame matrices for 2013, showing the influence of emissions from France on $PM_{2.5}$ concentrations and computed with EMEP/MSC-W

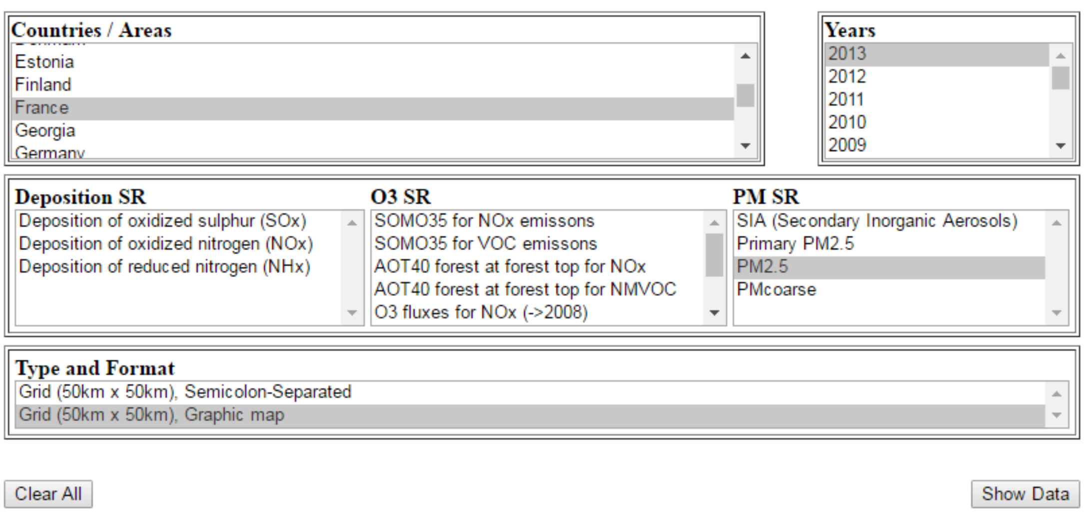


Figure 19. Snapshot of the MSC-W website: selection of the available option for downloading or drawing S/R country to grid data

Another policy-oriented application of chemistry transport models is the provision of air quality assessment maps which means maps of concentrations, deposition or exposure indicators (human health and ecosystems) throughout the EMEP domain or for each Party to the Convention. Those calculations allow a simple and attractive presentation of levels of concentrations everywhere, to check (if relevant) compliance with air quality legislations (for instance limit values or quality objectives for health and ecosystems protection) and assess trends (the assessment is performed every year). These calculations are used to elaborate on a yearly basis official country reports downloadable on the MSC-W website (Figure 20).

Assessment maps issued from CTM can be significantly improved with data assimilation techniques, which correct model results with observation data from in-situ monitoring networks (for instance the EMEP network), and sometimes with satellite information. Such methods provide very relevant information (often the best estimate of air pollutant concentration fields) but require significantly high resources (human and computational). This is the reason why, so far, they are not very developed for policy purposes. The EU Copernicus project CAMS for atmosphere monitoring coordinated by ECMWF[65] proposes now such kind of services for near-real-time applications (episodes monitoring) and past re-analyses of air pollution patterns in Europe and at the global scale. But this is quite new and not yet considered in the Convention modelling framework.

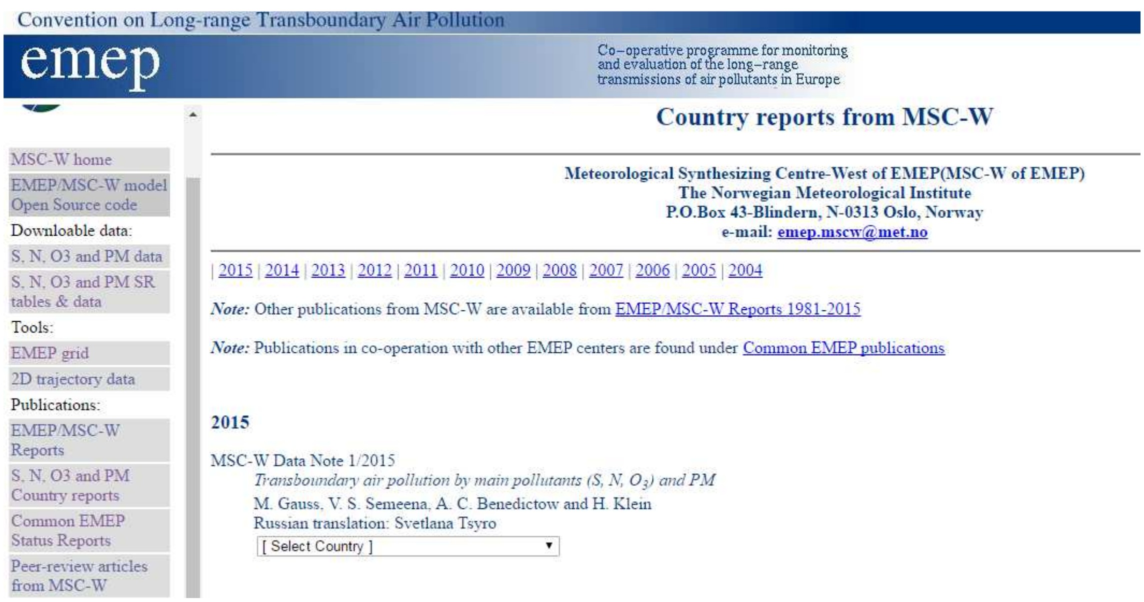


Figure 20. Snapshot of the MSC-West website: access to the yearly country reports

The last type of policy application of the EMEP/MSC-W model is the simulation of the impact of emission reduction scenarios on concentration and deposition fields. Emissions are reduced for some pollutants and some sectors according to the scenario to be tested, and the model is run with this new emission inventory to compute health or ecosystem impacts indicators. Those evaluations are generally used for integrated assessment works when the most cost-effective options are sought.

[65] http://www.ecmwf.int/en/about/what-we-do/copernicus/copernicus-atmosphere-monitoring-service

However, when policymakers use results of air quality models to support decision making, it is essential that the reliability and the quality of those results could be demonstrated. Within the EMEP framework, the Task Force on Measurement and Modelling (TFMM) bears this important question. The experts of this task force, together with those of the centre MSC-W assess the performance of the EMEP model, comparing its results to both observations and other models results (model-intercomparison). Challenging a model against other models, especially for application related to responses to emission changes (source-receptor matrices, scenario simulations), is the only one way to assess its robustness, its intrinsic uncertainties, and its quality. Actually, to build up confidence in EMEP model results for the policy decision, a number of evaluation tasks are conducted on a regular basis:

- **Model evaluation against observations** from the EMEP monitoring network and other networks (for instance the AQ-reporting regulatory database from the European Union). The results are published by the EMEP Centres every year in status and performance reports (see for instance EMEPa and EMEPb, 2015);
- **Model inter-comparisons against other model results** that are developed in the countries. The so-called EURODELTA projects, conducted under the aegis of the task force on Measurement and Modelling aimed at the EMEP model evaluation through this way. The last phase of the project (EUREDELTA3) focused 1) on the evaluation of the physio-chemical processes using results of the EMEP field campaigns 2) on modelled responses to emission changes. This last question is one of the most difficult for model evaluation because the truth (actual response) is general unknown. In this project, a retrospective analysis of the impacts of emission changes in the EMEP domain over the 20 past years was performed. Therefore, observations exist and can be used to assess model responses. This phase of the project is still on-going. EURODELTA3 mobilised the capacities of almost 10 European research teams (with their own models) mandated by their countries, which shows the big interest of policy makers for model evaluation and verification. Results related to the objective 1 (comparison against field campaigns) have been published in an EMEP report in 2014 (EMEP, 2014) and another peer-review paper is under review.
- **Peer-review** which refers to acknowledgement of the relevance and quality of the model by the scientific community. A number of peer-review papers (more than 20 per year) have been published by MSC-West in that perspective (available on).[66]

Modelling activities in the NEASPEC region

In 2015, the NEASPEC agreed for a project dedicated to the simulation of long-range transport and source-receptor relationship in the North-East Asia region. It involved the Scientific Research Institute for Atmospheric Air Protection (SRI, Russian Federation), but also the Chinese Research Academy of Environmental Sciences (CRAES, China) and the Pusan National University (PNU, Republic of Korea). The project is based on the implementation of the US WRF-CMAQ models. It is conceived with policy-support objectives and in 2016, delivery of source-receptor calculations should occur. At the time of writing this report, results are not available yet for discussion.

[66] http://www.emep.int/mscw/

But other relevant initiatives should be mentioned.

The LTP project (involving China, Japan and republic of Korea) was conceived for computing source-receptor matrices among the three countries. At the same time, this project has performed model evaluation (at least for SO_2 and sulphur compounds) since experts of each country were running their own models: Model3/CMAQ for China, RAQM for Japan and RADM for Korea. SR relationships exist for SO_2 and NO_x and should developed, in the next stages of the project for PM and ozone using CMAQ source-tagging facilities.

The MICS-Asia projects are a suite of a model inter-comparison project. The second phase ended in 2008[67] and provided a lot of results regarding the capacities of CTM to reproduce air pollution patterns in Asia (Charmicael et al 2008). A new phase is currently on-going and will develop strong linkages with the work of the EMEP task Force on Hemispheric transport of air pollution (TF HTAP). Evaluation of about 10 models results of about thirty model species characterizing atmospheric composition (with a focus on PM) run by research teams in China, Japan, Korea, Taiwan and the USA will be evaluated against an extensive set of observation data (EANET network, satellite observation).

Therefore, operational and evaluated modelling tools are now available in the Asian region. Science is here and tools exist for developing a modelling framework for policy decision regarding long-range transport of air pollution in the NEASPEC region. Policy agreements should be implemented among between the countries using these tools such as SR matrices, scenario analyses, air quality assessment. To define reference modelling results, that can be accepted by all the stakeholders.

Some countries can consider that their own modelling capacities are more relevant (more representative of their situation, etc.) than the common ones, and this is a key point for policy negotiations, especially because the model results will highlight some responsibilities and contributions from a country to air pollution in other countries. The question of the development or implementation of unique reference model (as EMEP is) makes sense. Indeed, the added-value of availability of air quality evaluations realised with a set of several models is obvious considering that the range of model responses is a representation of the intrinsic modelling uncertainty. The development of so-called "Ensemble" approaches which build up model results resulting from the combination of the results of several individual models should be more carefully considered in policy frameworks.

8. Policy scenarios, abatement technologies and integrated assessment

Modelling is the only one way to assess the potential impacts of future policy scenarios and emission reduction strategies that are conceived but the policy-makers, with regard, for instance, to source-receptor relationships. But once the model is considered as "operational"

[67] http://www.acap.asia/adorc/mics.html

for such a policy-oriented use (see the previous paragraph) relevant policy scenarios should be defined. Integrated assessment modelling (IAM) allows the evaluation of the impact of various emission reduction scenarios on air pollution exposure indicators taking into account the cost of implementation of control measures and the associated benefits for human health and ecosystems. IAM is also used to assess the co-benefits accounting for interlinkages between various environmental policies, for instance air pollution with climate change policies. We describe and comment on first issues related to the elaboration of air pollution control scenarios and in a second step, the IAM approach.

Building-up policy scenarios

Policy scenarios reflect future political choices of the countries regarding energy, urban development, industrial development, population growth and account for their economic development. They also take into account progress in the development and implementation of new technologies suited to limit emissions of air pollutants. The so-called "best available technologies" (BAT) are supposed to reflect the most advanced techniques available. Such techniques can rely on their own industrial or combustion processes, or on system that trap pollutants before they are emitted (filters for example). Future policy scenarios and their impacts are analysed considering a reference state often called the "Business As Usual" (BAU) scenario and corresponds at a situation for the same date in the future but only reflecting population growth and economic development without any additional environmental consideration and/or reinforcement of the legislation. In the framework of the negotiations of the EU NEC Directive, the term "Current Legislation Emissions "(CLE) scenario was generally used.

More ambitious policy scenarios are built up considering several key aspects, among which:

- Energy policies
- Maximum feasible technical reductions
- Non-technical measures

Each of them is discussed below:

Country's energy policies

The country's energy policy describes for the current and future situations, the assumptions taken by a country to cover its energy needs. This is a very sensitive subject, directly connected to economic development; "*moving toward a low carbon economy*" supposes that some substantial efforts are made to reduce the environmental footprint of energy consumption. Country's energy mix depends on its own resources, economic capacities and policy choices regarding renewable energies. The climate negotiations lead to more pressure for their development and for reducing energy consumption. A recent communication from the European Commission[68] sets that by 2030, a reduction by 40% of greenhouse gases compared to 1990 should be achieved, as a 27% share of renewable energy[69] consumption

[68] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS A policy framework for climate and energy in the period from 2020 to 2030 /* COM/2014/015 final

[69] 20% share of renewable energy is expected for 2020

and 27% energy savings compared to BAU scenario. Obviously, energy production and use does not impact only greenhouse gases emissions but also air pollutants emissions (as NO_x, SO_x and even PM), and the impact on air quality is high. It concerns power plants and mobile sources.

Maximum Feasible Technical Reduction and emission limit values

The easiest concept to deal with air pollution control is to define ambitious targets regarding emission limit values that could be reasonably set for main sources. The sectoral environmental legislation defines such values that are generally framed by technological constraints. In the European Union, for instance, the Industrial Emissions Directive sets emission limit values for a large panel of industrial activities considering best available technologies and their implementation costs.[70] Those are discussed by all the Member States and stakeholders (representatives of industrial sectors, and NGOs) with the European IPPC[71] Bureau of the European Commission[72] and reported in guidelines called the Best Available Techniques reference documents or BREFs.[73]

The Convention on Long Rang Transboundary Air Pollution created an expert group, which became recently a Task force of the policy working group on Strategies and Review (WGSR), called Task Force Technico-Economic issues[74], to deal with these questions. Issues discussed are a bit different than those considered by the European Union because of larger diversity in capacities of the countries to assimilate and implement high technological ambition level. However, compromises are generally found and the annexes of the protocols of the Convention include objectives for emission limit values for the main sources. This collaborative work is very efficient to support EECCA countries, in particular, in the implementation of ambitious policies. Experts from the Convention assess the Maximum technical feasible reductions (generally translated as the so-called "MTFR" scenario), provide technical support for capacity building to progress towards this objective and evaluate the potential for further improvement in the future regarding economic development of the countries.

Another sensitive sector for where emission limit values are essential is the road transport sector, the main source of NO_x emissions! Road transport activity increases logically with population growth and economic development. In the European Union, so-called Euro 5 and 6 Regulation (715/2007/EC[75]) sets the emission limits for cars for regulated pollutants, in particular, nitrogen oxides (NO_x, i.e. the combined emissions of NO and NO_2) of 80mg/km. The implementation of these limit values is set-up in the regulation 692/2008/EC which has been amended on 10th march 2016 by the regulation 2016/427 for Euro6 light passenger and commercial vehicles after the "Volkswagen scandal" occurred. This story showed strong weaknesses in the implementation of type-approval rules for motor vehicles in the European Union, and large discrepancies between emissions measured in laboratories and those

70 IED 2010/75/EU, http://ec.europa.eu/environment/industry/stationary/ied/legislation.htm
71 Integrated Pollution Prevention and Control
72 http://eippcb.jrc.ec.europa.eu/
73 http://eippcb.jrc.ec.europa.eu/reference/
74 TFTEI, http://tftei.citepa.org/en/
75 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:171:0001:0016:EN:PDF

measures in real-world driving conditions. It highlighted the fact that finally emission limit values for road transport sector generally used in policy scenarios are certainly too optimistic. The European Commission tried to reinforce legislation regarding estimation and control of actual road transport emissions following a gradual process. It must be correctly transpose in the policy-scenarios to avoid to large uncertainties in their impact estimates.

Non-technical measures

This term gathers all emission control measures that cannot be implemented through technological improvement. They refer to measures that will lead changes in the citizens' behaviors because of taxes or high prices of services, or because of raise of awareness that will motivate greener behaviors, or because of structural changes in life in the city etc. … Such measures mainly target emissions from urbanized areas (residential heating, road transport). For instance, they refer to policies that aim at promoting green driving, and use of green public transports, or encouraging pedestrian trips or use of bicycles, modal shift to rail… They link with mobility and urban planning adopted by the city (for instance avoiding housing in highly air pollution exposed areas). They can play a very important role in air pollution control strategies but their impact, in terms of emission reduction is usually very difficult to quantify. Therefore, this is the same when evaluating their added-value against air pollution exposure. Quite few studies in Europe investigated this class of measures (UmweldtBundesAmt, 2013), (D'Elia, 2009) which are still too rare.

Conceiving policy scenarios

The Convention LRTAP (and the European Union for the National Emission Ceilings Directive[76]) decided to adopt an effect-oriented approach for the definition of emissions control scenarios. This approach is based on the following question: **given environmental and health targets, which level of ambition in terms of emission reductions, is required to reach them**?

Considering the opportunities linked to technology, and future policies for energy, urban development, agriculture likely to be implemented in the countries, various assumptions can lead to various future scenarios to be tested in the models. Burden sharing between the countries (in the perspective of reducing background air pollution levels and long-range transport) can result from "theoretical optimisation" regarding source-receptors relationships, but is also hardly driven by political negotiations. The very recent negotiations that ended in late June 2016 for the revision of the National Emission Ceilings Directive are very instructive in that perspective. After several months of discussions between the three political instances of the European Union (European Parliament, European Commission, and European Council) an agreement has finally been found to define new emissions ceilings for the Member States:

- By 2020, and until 2029, the EU Member States will have to comply with national emission ceilings objectives set in the CLRTAP Gothenburg Protocol for SO_2, NO_x, NMVOC, ammonia and $PM_{2.5}$;

[76] National Emission Ceilings Directive (NECD) – 2001/81/EC, currently under revision. The objectives of the revised version will be consistent with the objectives of the 2012 revised Gothenburg Protocol of the CLRTAP

- In 2030, those ceilings will be more stringent to ensure that impacts of air pollution on human health will be reduced by 50% compared to the 2005 situation.

A large part of the negotiations (and disagreements) was related to this effect objective (reduction of health impacts by 50%). Some stakeholders requested a higher level of ambition (-52%) while others wanted to limit the efforts to a reduction of the impacts by 48%. Integrated Assessment Modelling allows recommending strategies to achieve such objectives with acceptable costs.

The final decisions on the level of ambition of emission reduction scenarios were political (with insights from science) but the implementation of the agreement will require scientific work and IAM approaches.

Integrated Assessment Modelling (IAM)

IAM has several objectives:

- Evaluation of the costs and the impacts (regarding ecosystems and human health) of emission control measures or scenarios,
- Cost-effectiveness analysis to look for least cost sets of measures that will be the most well-suited to deal with environmental objectives defined by policy makers,
- Cost-benefits assessments to maximize net benefits of control strategies.

In the CLRTAP framework, the Task Force on Integrated Assessment Modelling (TFIAM) helped by the Centre on Integrated Assessment modelling (CIAM hosted by IIASA), are the most natural bridges between science and policy. The GAINS integrated assessment models developed by IIASA[77] for the needs of the Convention and the European Commission integrates scientific knowledge on air pollutant emissions (current and projections), atmospheric chemistry-transport, and economy, to define and test various policy scenarios and to select the most appropriate ones for implementation. The final decision is taken by the policy bodies: the Working Group on Strategy and Review (WGSR) and, of course, the Executive Body (EB). The reports published by the CIAM to support the revision process of the Gothenburg Protocol in 2012 are available on the website.[78] IIASA also provided a number of studies to support the implementation of the European Thematic Strategy on Air Pollution (TSAP) and the National Emission Ceilings Directive (NECD) revision process.[79] As an illustration, few results are given and commented below.

The table and the graph proposed in Figure 21 are issued from *Environmental Improvements of the 2012 Revision of the Gothenburg Protocol* (CIAM, 2012) and present an estimation of the impacts on health and ecosystems of different scenarios: proposed revised Gothenburg Protocol commitments, the Current Legislation Emissions (CLE) scenario extrapolated in 2020 and the Maximum Technical Feasible Reduction (MTFR) scenario. The level of ambition of the negotiated Gothenburg Protocol for 2020 is lower than the one estimated for a full implementation of the current legislation in Europe. This is a political decision that gives a

[77] http://gains.iiasa.ac.at/models/
[78] http://www.iiasa.ac.at/web/home/research/researchPrograms/air/policy/Gothenburg-revised_2012.en.html
[79] http://www.iiasa.ac.at/web/home/research/researchPrograms/air/policy/TSAP-reports.html

bit of flexibility to the Parties and should encourage wider ratification. **The EB estimated that it was worthwhile to get as many countries as possible on board, ratifying the protocol**, and more efficient than to set too strict emission reduction objectives that may not be achieved. The stringent compliance evaluation process that supports the implementation of the objectives of the Convention can slow down the ratification steps in the countries, and avoid a political priority.

The GAINS[80] model also integrates strategies to reduce greenhouse gases to seek for win-win approaches regarding both air pollution and climate issues. In particular, in the framework of the TSAP in Europe and within cooperation with UNEP and the Climate and Clean Air Coalition (CCAC), IIASA considered the potential benefits of strategies focused on the reduction of emission of Short-Lived Climate Pollutants (SLCPs). Black Carbon and Methane are the most famous compounds in these categories. Black carbon is well-known for its adverse effects on human health and its warming properties for the atmosphere. Methane is a precursor of ozone, which has also harmful impacts on health and ecosystems and is one of the main greenhouse gases. Integrated assessment modelling (and GAINS) allowed evaluating the co-benefits for air quality and climate of control strategies for methane and black carbon emissions. The results are published in and UNEP/WMO report (UNEP, 2011). This work was conducted with global atmospheric chemistry models and provided an assessment of the impact on health indicators of such mitigation strategies. Figure 22 is one of the results presented in the report and shows their potential important benefits for Asia.

		2000	2020, with emission reduction commitments	2020, GAINS estimate for Current legislation	MFR
Health impacts from PM (million years of life lost)	**Total**	306.0	224.9	204.0	159.0
	EU-27	204.0	132.1	116.0	101.0
	Non-EU	102.0	92.8	88.0	58.0
Health impacts from ozone (# of premature deaths/year)	**Total**	32449	29031	24697	21183
	EU-27	22707	18927	17375	15082
	Non-EU	9742	10104	7322	6101
Acidification of forests (thousand km^2 of forest area with acid deposition above critical loads)	**Total**	328.5	138.7	110.8	39.8
	EU-27	280.3	110.7	89.6	37.5
	Non-EU	48.2	28.0	21.2	2.3
Freshwater acidification (thousand km^2 of catchment area with acid deposition exceeding critical loads)	**Total**	82.2	36.0	34.1	22.7
	EU-27	54.0	22.7	21.7	13.7
	Non-EU	28.2	13.4	12.3	8.9
Acidification (average accumulated exceedance of critical loads, $eq^{-1}\ ha^{-1}\ year^{-1}$)	**Total**	53.1	12.7	9.9	3.1
	EU-27	128.0	24.3	19.4	5.8
	Non-EU	10.3	2.9	2.0	0.4
Eutrophication	**Total**	1988.9	1583.1	1408.1	847.5
	EU-27	1197.9	1005.1	950.3	596.2

[80] GAINS means Greenhouse gas – Air pollution Interaction28.2s and Syn13.4ergies12.38.9

(Total ecosystems area with nitrogen deposition exceeding critical loads, thousand km^2)	Non-EU	790.9	578.0	457.8	251.4
Eutrophication (average accumulated exceedance of critical loads, $eq^{-1}\ ha^{-1}\ year^{-1}$)	**Total**	182.8	106.4	95.3	37.7
	EU-27	334.0	185.1	168.8	63.6
	Non-EU	77.8	49.6	43.0	14.1

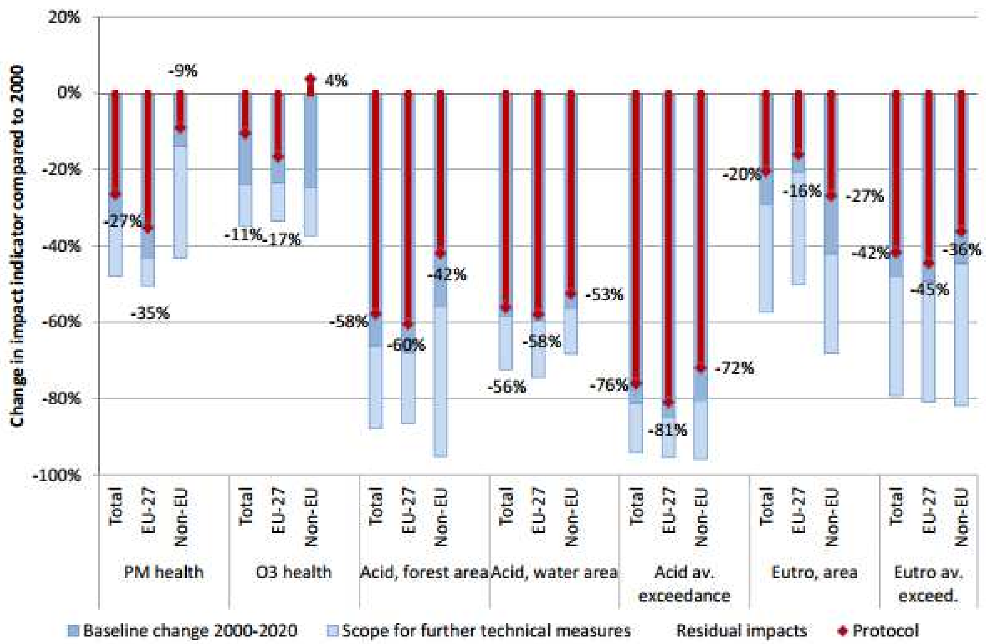
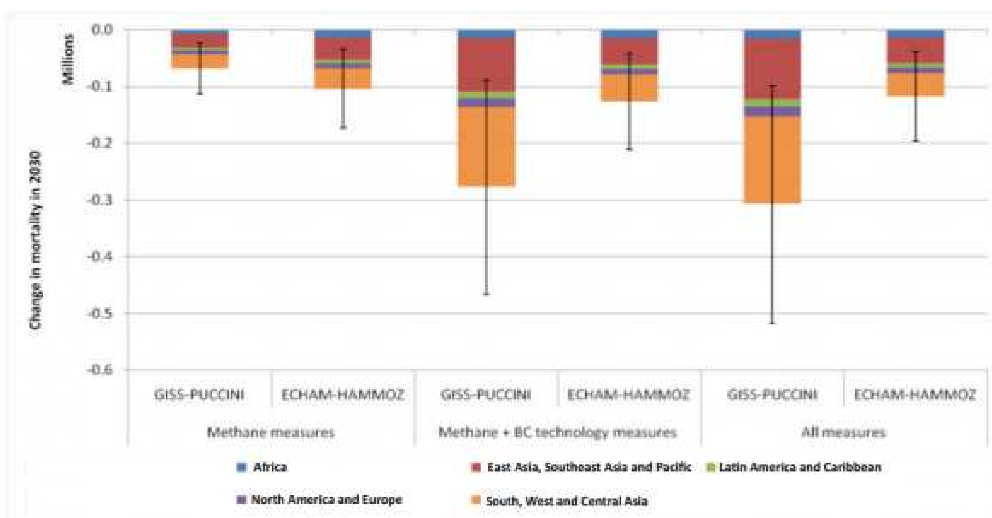


Figure 21. Impacts on health and ecosystems of various emission reduction scenarios discussed within



the Gothenburg Protocol revision process (Source: CIAM, 2012)

Figure 22. Changes in mortality indicator due to methane and black carbon emission control measures compared to the expected 2030 situation. GISS-PUCCINI and ECHAM-HAMMOZ are global atmospheric chemistry models (source: UNEP, 2011)

Collaboration already started between IIASA and the Asian Center for Air Pollution research (ACAP) on co-benefits of SLCPs strategies in Asia (Akimoto et al, 2015). Other reviews, like *Emission trends and mitigation options for air pollutants in East Asia* (Wang et al, 2014), propose possible emission control strategies for reducing air pollutant emissions in Asia accounting for various assumptions for energy, industry, and transportation policies and development. GAINS-Asia is developed by IIASA to support research projects on mitigation strategies for long range transport of air pollution in Asia. And national initiatives, like the development of the model GAINS-Korea, should also be mentioned as an example of the implementation of a policy framework, scientifically driven, to reduce air pollution impacts in the country.

A number of tools and experiences for developing integrated assessment modelling in North-East Asia are available. Linkages with the CLRTAP and its technical and scientific bodies could help in the assessment of these tools for specific North-East Asia questions, and in their appropriation by the stakeholders to define a common policy framework. First experiments show relevant and promising results but they still need to develop a policy framework to guarantee effective implementation.

9. Conclusion: Policy/science dialogue: how to set-up the framework

A number of scientific tools are now available to support the development of air pollution control strategies applicable at a large scale and focused on transboundary effects. This results from several decades of scientific research in the atmospheric field that aims at conceiving efficient and reliable devices for measuring air pollutants and its compounds and precursors, understanding very complex physico-chemical processes that drive air pollutant concentrations, and developing numerical models to simulate those processes. Tools are definitely mature enough to support the policy decision, and are widely used, but not always in a full integrated way. Moreover, the dialogue between scientific communities and policy makers is often too tight to allow efficient interactions. Consequently, scientists develop more and more research that is not always understood by the policy makers which finally take decisions more driven by policy and economy than by science. This could be an even more sensitive issue considering management of long-range transport of air pollution which involves several countries with various views and objectives.

The Convention on Long-Range Transboundary Air Pollution is generally considered as a remarkable example of a forum where science and policy progress together. The European Commission also considers the scientific insights from the Convention as the starting point of EU political negotiations. This is a unique framework that has been setup to promote and develop dialogues between both communities, so that political decisions can account for the most up-to-date scientific inputs. The structure of the Convention itself with scientific and policy-oriented bodies, work plans and strategies that answer to each other. Nevertheless, dialogue exists but is not always so easy to develop. Some topics can get consensus, in terms of priorities for both science and policy communities, while some gaps remain for others. It can be due to lack of data, to incompatible temporalities between science (generally quite long) and policy responses, or to lack of resources. Air quality policies develop in Europe in a more and more constrained framework regarding financing resources. However, the CLRTAP is considered as an actual successful instrument to enhance dialogue between all communities and account for the various aspects of air pollution management. Moreover, it allows, thanks to its structure and the wealth of data it generates, to develop fruitful cooperation with other bodies, organizations and conventions both at the scientific and policy levels. In its long-term strategy, cooperation with other international initiatives is clearly mentioned and should develop.

The cornerstone of interactive processes between science and policy is integrated assessment modelling (IAM). IAM can give very concrete and understandable answers to the policymakers on the impacts of emission control measures, regarding their costs and the benefits they bring to health and the environment. Moreover, it is supposed to provide optimised solutions to share in a fair way the burden of the cost of the control strategies between the different countries and stakeholders.

The starting point of IAM for policy decision remains the availability of emission inventories and projections (to test different future scenarios). Emission and projection data should be acknowledged by all the stakeholders as relevant and representative. Choice of one or several chemistry transport models to compute source/receptor relationships and to assess the impact of scenarios should also be endorsed by the stakeholders as the ways to evaluate the efficiency of the implemented policies (monitoring networks). Interpretation of the model results (impacts of the scenarios, sources-receptor calculation, and allocation of main sources) should be accepted by all the Parties to agree on the control strategy. This means keeping under control inherent uncertainties of the approach. Uncertainties exist at the various levels of the decision process:

- In emission inventories and projections: but they could be limited by the definition of a clear methodology, adopted by all the countries. If uncertainties hold in these methodologies, they should impact all the stakeholders. However, discrepancies could develop because of lack of data to describe activities and sources. This is the reason why within the CLRTAP's significant efforts are dedicated to capacity building in emissions, especially for the countries of the EECCA region.
- In chemistry-transport modelling: The Parties to the CLRTAP decided to support the development of reference models borne by the EMEP programme, implemented and run by a technical centre which provides assessments for the whole domain. The EMEP models are freely available for the country experts and their national implementation (which may request specific adjustments to reduce uncertainties) can be supported by the EMEP centres. Performances of the models are presented and reviewed by the country experts and priorities for their evolution are adopted at the policy level (Executive Body of the Convention). Stakeholders may challenge the

results or performances of the models and this is the reason why model inter-comparison projects are organised, involving national modelling capacities. These are also a great scientific forum for air quality modelling and contribute to uncertainty control in modelling. So-called "ensemble" approaches based on the combination of several model results can be a good way to conciliate policy and science: ensemble models results are generally more robust than individual models ones and they allow to use model capacities and skills from several stakeholders' teams.

- In monitoring: air pollution measurement devices have their own intrinsic uncertainties, linked to the instrumentation and the way it is used. Getting comparable monitoring data from a country to another is essential for policy purposes. This is the reason why the Convention CLRTAP established a stringent QA/QC framework for monitoring the long-range transport of air pollutants where site location, and recommended monitoring devices are clearly described. Laboratory inter-comparison field campaigns allow evaluating practises, the quality of the chemical analyses and uncertainties in measurements.
- In integrated assessment modelling: there are huge uncertainties, by nature, in the assumptions made for economic development, implementation of emission control measures and best available technologies, in their costs that should be borne by the country or the concerned industrial sector, in the monetisation process of their impacts. This is another reason why it is worthwhile to give this responsibility to a technical centre (like CIAM in the CLRTAP) that works for all the Parties, provided that there is enough transparency in the assumptions, and the models used by this centre, and a permanent dialogue with the stakeholders. This is not so easy to establish, but essential to building up confidence in the process.

The analysis of the capacities and the project currently run or planned in North-East Asia shows that in each of these fields, there are relevant tools and experiences already conducted by scientific teams in some countries. We noted that several projects dedicated to long-range air pollution management are on-going, and they are based on cooperation between scientific teams: new NEASPEC initiative on modelling, LTP project, MICS-Asia project, EANET network… and some of them are endorsed by policy bodies, which is an essential step to initiate policy-science dialogue.

This dialogue should increase for the establishment of an accurate and sustainable emission inventory throughout the region that will be the basis for future policy-oriented modelling work. As explained in this document, this is a sensitive issue, because it targets the economic activity of the stakeholders and this is the reason why technical framework, agreed by the policy makers and implemented under regulatory constraints is certainly the most efficient. This is one of the most important lessons learnt from the implementation of the Convention LRTAP.

The EANET network, the already operation to monitor acid deposition, is a great tool to develop a common understanding of long-range transport in the North-East Asia region and to assess the impact of reduction emission actions. It started to be expanded toward other relevant pollutants, like ozone and particulate matter and this effort should be encouraged.

The basis for an air quality monitoring tool exists. More stringent reporting process will allow maintaining a policy-oriented database for long-range transport of air pollutants observations.

Finally, modelling teams in North-East Asia are very active and several model experiments and tools are available to start a policy-oriented integrated assessment process. Responsibility for developing and running models should be attributed by policy bodies to dedicated scientific teams to facilitate policy dialogue and decision. The Convention LRTAP decided to support the development of the EMEP models by dedicated centres funded by the Convention, but other options can be investigated, with multi-models/ multi-teams approaches. The main difficulty is to establish a consensus for a framework (regarding model uncertainties, evolution, interpretation of the results, indicators simulated…) so that policy agreements can be reached. But the projects that already started provide an excellent basis in that perspective, taking advantage of the lessons learnt from the European Convention on Long-Range Transboundary Air Pollution.

Therefore, international cooperation should also be developed, especially within the CLRTAP/EMEP programme: exchanges on best practises, QA/QC, available instrumentation, trends in transboundary fluxes, and fitness of the monitoring network for modelling purposes would be good topics to initiate partnerships.

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