Project Number 282910

ÉCLAIRE

Effects of Climate Change on Air Pollution Impacts and Response Strategies for European Ecosystems

Seventh Framework Programme

Theme: Environment

D20.2: Detailed description of model integration to establish 2050 scenarios

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Organisation name of lead contractor for this deliverable: **IIASA**

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Dissemination Level		
PU	Public	☒
PP	Restricted to other programme participants (including the Commission Services)	☐
RE	Restricted to a group specified by the consortium (including the Commission Services)	☐
CO	Confidential, only for members of the consortium (including the Commission Services)	☐

1. Executive Summary

This reports describes the activities to further extend the GAINS model covering the year 2050. External data series have been extended towards that year, and internal structures (as new technologies and revised applicabilties of control measures) have been updated to include that extension. Results have been harmonized to become applicable in a set of related project activities (ECLIPSE, PEGASOS). Changes required are described here. The identical emission set has been made available in a gridded format, and is also used in a chemical transport model (the EMEP model), from which results are further distributed to vegetation models. The same EMEP model has been used to describe, under a multitude of different input conditions (in terms of emissions) the resulting effect towards a set of pre-defined indicators. These "source receptor matrices" which are available for optimization in the GAINS model describe the effects of changing emissions on potentially ecosystem-relevant receptor indicators and allow to quantify their respective impacts.

2. Objectives:

IIASA's GAINS model provides projections of atmospheric emissions of air pollutants (SO2, NOx, NMVOC, NH3, PM including BC and OC as well as size fractions) and greenhouse gases (all Kyoto gases). The spatial resolution is the country level (for some very large countries sub-regions have been defined) and originally extended to the year 2030 in five-year time steps. Within ECLAIRE (and fitting into the related EU projects PEGASOS and ECLIPSE), GAINS model results are targeted to provide the backdrop to modelling activities within ECLAIRE. For this purpose, a specific emission scenario for the year 2050 needs to be developed. This emission scenario is the input for source receptor matrices to be produced for 2050 transport condition (downscaled climate model results of the year 2050) within WP8.

3. Activities:

3.1 GAINS updates

In order to allow an extension of GAINS (for a model overview see Amann et al., 2011), three model aspects needed to be adapted:

- Extending activity data to 2050
- Providing additional abatement options that might be available in 2050, and estimating costs of such additional measures
- Adjusting the implementation of these or other available options (measures) for the year 2050.

The activities required for that purpose have been implemented under a number of different projects, most prominently the ECLIPSE and the PEGASOS project but work has been started already under EC4MACS. The most comprehensive documentation to-date has been published by Klimont et al. (2012), with some details specifically worked out in the peer-reviewed literature (Klimont et al., 2013).

GAINS operates on a country scale. Activity data, cost estimates and implementation rate of abatement measures thus typically are provided on a country basis, even if for several countries also sub-regions have been defined. Technical measures are understood to be generally available in all countries with the same emission factors (or emission abatement efficiency), but possibly at different costs reflecting national differences in energy prices, labour costs etc. For country/region scale, GAINS allows to optimize costs for a given accepted level of effects.

In order to meet the needs of the modelling community, GAINS emission projections data have been spatially allocated to a 0.5x0.5 km² grid (longitude/latitude) with global coverage, with several layers provided for different source categories. For each source category, also temporal distribution patterns (monthly) are available. Data can be downloaded from the IIASA web site: http://www.iiasa.ac.at/web/home/research/researchPrograms/Overview2.en.html

Estimating implementation of measures estimates the future effects of currently implemented legislation ("Current legislation – CLE"). In a basic principle, the model will not allow any environmental measures adopted to be released again, in order to avoid any deterioration occurring. Measures implemented at any point in time may be replaced by more stringent ones, however.

This emission dataset in its original, spatially unresolved version (internal name: CP_WEO11_S10P50_v2) has also been transferred to EMEP for modelling use and providing output to dynamic global vegetation models (DGVMs) and dynamic soil vegetation growth models (DSVMs). This procedure allows to make sure consistent datasets are being made available.

3.2 Workshop organized

Increasing emissions of nitrogen constitute multiple environmental challenges at different spatial scales. A comprehensive assessment of these problems and their linkages to related issues requires adequate projections of nitrogen release into the environment.

For this purpose, a 'Workshop on global nitrogen scenarios in the 21st century' was organized at IIASA, Laxenburg (Austria), October 11-12, 2012 (co-hosted by ECLAIRE, INI and TFRN). The workshop allowed to review the key assumptions of the currently available nitrogen scenarios for the 21st century and to discuss our understanding of the factors that could lead to alternate future developments.

Up to now, global scenarios of future nitrogen emissions have emerged as a side-product of the global RCP greenhouse gas emission scenarios developed for the climate modelling community. However, as the RCP process focuses on GHG emissions, the current scenarios might not span the entire possible range of future nitrogen emissions, and do not explicitly address the scope – and importance – of possible policy interventions to manage nitrogen at the different stages.

The presentations invited for the workshop provided a review the key assumptions of the currently available nitrogen scenarios for the 21st century. Our understanding of the factors potentially leading to different developments such as breakpoints and options for policy interventions were discussed. Concepts to describe drivers and to establish parameters for the release of nitrogen compounds, specifically to the atmosphere, will be used in the interpretation of the scenarios derived.

3.3 Source receptor matrix

The GAINS model is able to link emissions (and changes in emissions) to effects (or changes in effects). In order not to employ a complex atmospheric chemistry and transport model for that task, results of a limited set of model runs (for which emissions are varied by countries according to a predetermined pattern) are used to derive the respective effects of emission changes onto atmospheric concentrations and depositions. We call this a “source-receptor matrix”, with the source variation being performed on a country level, while the effects are made visible by grid of the respective atmospheric model.

The concept has been generally used and described, i.a., by Kiesewetter et al. (2013). The relationship between source and receptor has been modelled using the EMEP model on a ¼° x ½° lat-lon grid scale (depending on latitude, roughly 28 x 28 km^2). A multitude of individual parameters is available from the model for each model hour, but only a very limited set of such parameters can be added up over a full year (or several years) of model runs. Thus only these pre-determined parameters are included in the matrix. For the most recent of the source-receptor matrices, ECLAIRE interest has been consulted, which resulted in a set of indicators being available as listed in Tab. 1:

Tab. 1: Source-receptor transfer indicators implemented in GAINS

	EMEP variable	Description	Emitted pollutants	Impact indicator
Sulphur deposition	DDEP_SOX_M2* WDEP_SOX	Wet deposition of sulphur, ecosystem-specific dry S deposition	SO2	Exceedance of critical loads for acidification and nutrient nitrogen
Nitrogen deposition	DDEP_OXN_M2* DDEP_RDN_M2* WDEP_OXN WDEP_RDN	Wet deposition of oxidised and reduced nitrogen, ecosystem-specific dry N deposition	NOx, NH3	
Ozone flux to vegetation	POD1_IAM_DF	Phytotoxic ozone dose (mmol/m2) above a threshold of 1 nmol/m2/s - Deciduous forest (generic)	NOx, VOC	Phytotoxic ozone dose (generic forest)
	POD3_IAM_CR	Phytotoxic ozone dose (mmol/m2) above a threshold of 3 nmol/m2/s - Agricultural crops (generic)	NOx, VOC	Phytotoxic ozone dose (generic crop)
	POD6_IAM_CR	Phytotoxic ozone dose (mmol/m2) above a threshold of 6 nmol/m2/s - generic crop	NOx, VOC	Phytotoxic ozone dose (generic crop)
Ozone	SOMO35	Annual sum of ozone over 35 ppb (daily maximum 8-hour mean)	NOx, VOC	Premature mortality due to ozone
PM2.5	PM25_RH50	Annual mean PM2.5 from anthropogenic sources (excluding dust and sea-salt)	PM2.5, SO2, NOx, NH3, VOC	Statistical loss of life expectancy

Moreover, an extended set of parameters have been stored from the EMEP model runs to be eventually implemented in GAINS. For these, no linearity checks have been performed yet. These parameters include averaged surface concentrations of compounds like ammonia as well as ammonium or nitrate aerosols, AOT40 values, as well as accumulated deposition data.

As the source-receptor matrices describe the variation in the value of an indicator based on the variation of emissions, it does not really matter that the actual scenario used to establish the matrix differs somewhat from the recommended ECLAIRE scenarios. The same quality tests that are performed to safeguard the matrix being applicable to a range of emission variations also make sure that a variation in input is likewise covered.

Source receptor matrices and their results beyond the original points of establishment have been compared successfully against the full model runs, in order to identify potential limitations of the approach. Nevertheless, as long as accessibility to computing power is not a critical issue (=low number of scenarios or optimization needs), still taking advantage of full atmospheric models in general is advisable.

4. Results:

Activity data in GAINS always are taken as externalities. For the current exercise, energy activities have been adopted from WEO until 2030, and from the POLES model (Russ et al., 2007) for the years

2035-2050. Agricultural projections (animal numbers and fertilizer use) are based on Alexandratos and Bruinsma (2012) who project current trends. For the countries of the EU, more refined information was used. Energy projections till 2050 derive from Capros et al. (2012), projections on agricultural developments are available from the CAPRI model (see Britz et al., 2007, for a model description).

Technologies have been extended to cover the period till 2050. Specifically, this includes new classifications of power plants including Integrated Gasification Combined Cycle, ultra- and supercritical steam power plants or combined cycle gas turbines. Carbon capture and storage options have been considered. In industry, industrial combustion to specific boiler types as used by industrial sectors (paper&pulp; chemical industry, cement & lime). New emission concepts for mobile sources include EURO 5 and EURO 6 sets of measures. Activities have been presented in more detail by Amann et al. (2012).

As mentioned above, resulting emission projections are available in gridded format. Grid size is 0.5° x 0.5° globally, emissions are available by source sector and pollutant for the "S10P50" scenario, a baseline scenario considering mitigation measures introduced already now ("current legislation"). At this time, no decarbonisation scenario is available. Fig. 1 provides (as an example) ammonia emissions from agriculture over Europe, while Fig. 2 shows NO_x emissions from mobile sources (same area).

Pollutants specifically available are:

- Sulfur dioxide (SO_2)
- Nitrogen oxides (NO_x)
- Methane (CH_4)
- Non-methane volatile organic compounds (NMVOC)
- Carbon monoxide (CO)
- Ammonia (NH_3)
- Particulate matter, of which the following parameters are separately accounted for:
    - Particulate matter consisting of particles smaller than 10µm aerodynamic diameter (PM10)
    - Particulate consisting of particles matter smaller than 2.5µm aerodynamic diameter (PM2.5)
    - Organic matter (OM)
    - Organic carbon (OC)
    - Black carbon (BC)

The following source sectors are specified in the dataset (note that some of these sectors are not emitting all of the pollutants listed above):

- Agriculture (animals, rice, soil)
- Agriculture (waste burning on fields)
- Residential and commercial
- Power plants, energy conversion, extraction
- Industry (combustion and processing)
- Solvents
- Surface transportation
- Waste
- Total

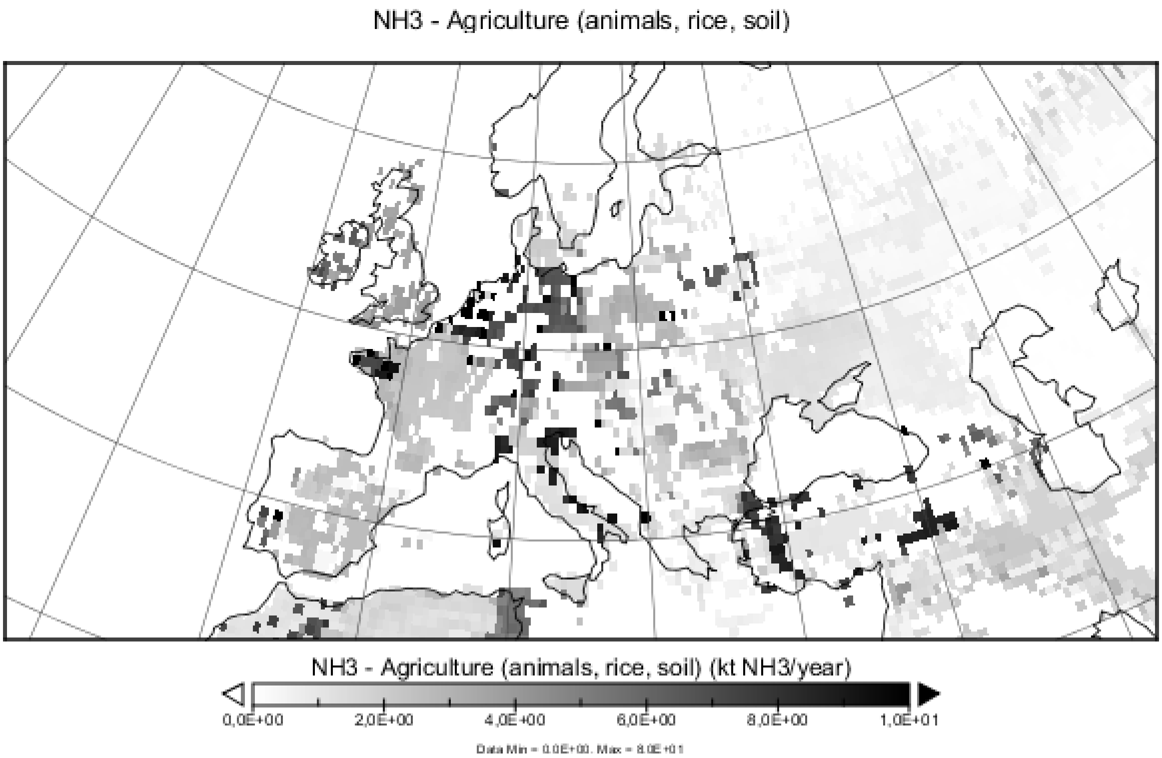

Figure 1: Gridded GAINS projections for 2050 (example: NH_3 from agriculture)

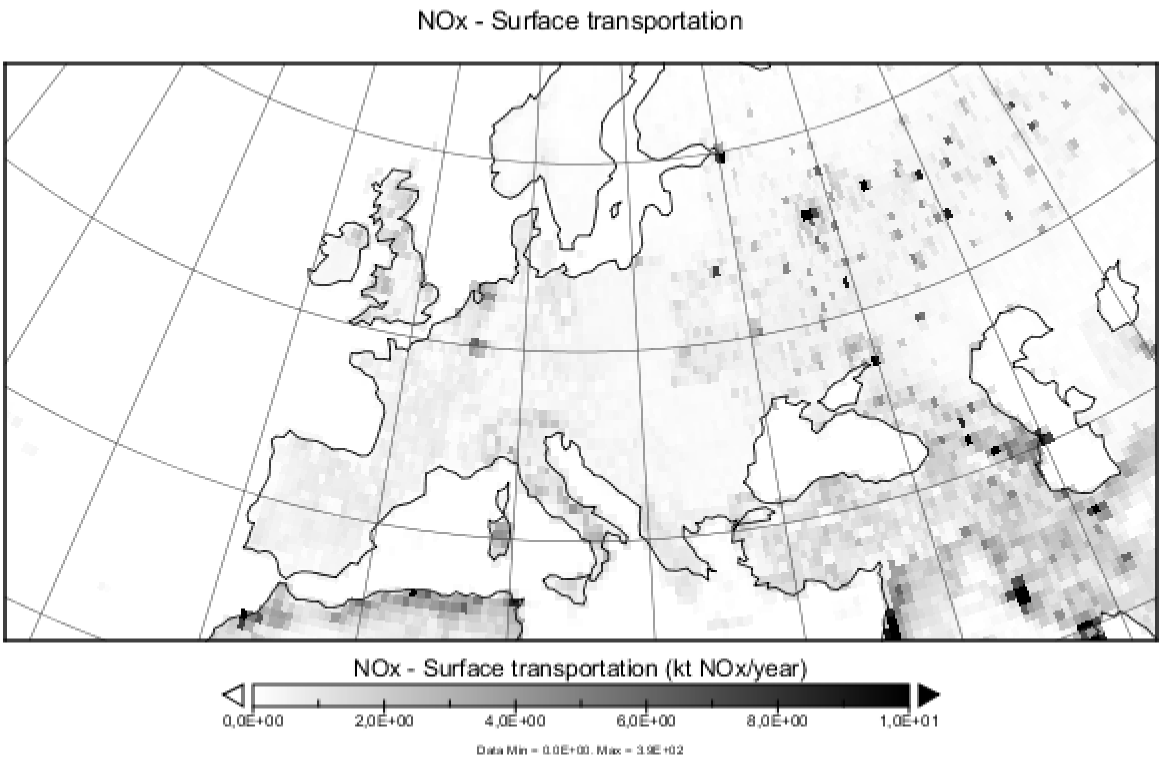

Figure 2: Gridded GAINS projections for 2050 (example: NO_x from transport)

5. Milestones achieved:

Work presented here contributed to and was discussed at the “Component 5 status workshop” (MS95) and the workshop (organized in two parts) “Setup of modelling system complete” (MS96)

6. Deviations and reasons:

The planned publication of this deliverable as a report (documentation of available results) has been moved from the original date in order to allow its joint completion with D20.3 (emission projections beyond 2050), originally scheduled for April 2013. As that date was also the foreseen deadline for the new socio-economic scenarios under IPCC (so-called SSP scenarios), it seemed useful to integrate these efforts and at the same time contribute to these scenarios. With the SSP deadlines further shifting, that link seemed not useful any more, hence completion of this deliverable is performed independent of D20.3. Underlying data have been provided to project partners as originally planned – September 2012 for gridded emission data, while data for source-receptor matrix calculations have been provided early 2013 (and EMEP results made available to partners by June 2013).

7. Publications:

- W. Winiwarter, Z. Klimont: GAINS scenarios for 2050. Workshop on global nitrogen scenarios in the 21st century, Laxenburg, October 11-12 2012.
- Wilfried Winiwarter, Markus Amann, Benjamin Bodirsky, Lex Bouwman, Frank Brentrup, Irene Cionni, Wim De Vries, Frank Dentener, Jan Willem Erisman, Günther Fischer, David Fowler, Petr Havlik, Zbigniew Klimont, Adrian Leip, Rob Maas, Michael Obersteiner, Christian Palliere, Magdalena Pierer, Shilpa Rao, Keywan Riahi, David Simpson, Steven Smith, Mark Sutton, Junyu Zheng: Developing multi-purpose global nitrogen projections. Poster presented at the IIASA 40th Anniversary Conference “Worlds within reach – from science to policy”, Vienna and Laxenburg, Oct. 24-26, 2012
- This report

8. Meetings:

- 'Workshop on global nitrogen scenarios in the 21st century’, IIASA, Laxenburg (Austria), October 11-12, 2012
- Component 5 status workshop, organized as part of the ECLAIRE 2nd General Assembly held in Edinburgh, UK from 15-18th October.
- Workshop “Setup of modelling system complete”, held in at the Copenhagen site of Aarhus University, DK, in two parts: part 1, April 11, 2013; part 2, April 25, 2013.

9. List of Documents/Annexes:

This Report does not contain Annexes

REFERENCES

Alexandratos, N., Bruinsma, J., 2012. World agriculture towards 2030/2050, the 2012 revision (No. 12-03), ESA Working Paper. World Food and Agricultural Organization, Rome, Italy.

Amann, M., Bertok, I., Borken-Kleefeld, J., Cofala, J., Heyes, C., Höglund-Isaksson, L., Klimont, Z., Nguyen, B., Posch, M., Rafaj, P., Sander, R., Schöpp, W., Wagner, F., Winiwarter, W., 2011. Cost-effective control of air quality and greenhouse gases in Europe: modeling and policy applications. Environmental Modelling and Software 26, 1489–1501.

Amann, M., J. Borken-Kleefeld, J. Cofala, C. Heyes, Z. Klimont, P. Rafaj, P. Purohit, W. Schöpp and W. Winiwarter, 2012. Future emissions of air pollutants in Europe – Current legislation, baseline and the scope for further reductions. TSAP Report #1. Version 1.0. Report to DG ENV under contract ENV.C.3/SER/2011/0009. IIASA, Laxenburg, June 2012.

Britz W., Pérez I., Zimmermann A., Heckelei T. 2007. Definition of the CAPRI Core Modelling System and Interfaces with other Components of SEAMLESS-IF, SEAMLESS Report No.26, SEAMLESS integrated project, EU 6th Framework Programme, contract no. 010036-2, www.SEAMLESS-IP.org, 116 pp, ISBN no. 90-8585-114-9 and 978-90-8585-114-1

Capros, P., Tasios, N., De Vita, A., Mantzos, L., Paroussos, L., 2012. Model-based analysis of decarbonising the EU economy in the time horizon to 2050. Energy Strategy Reviews 1, 76–84.

Kiesewetter, Gregor, Jens Borken-Kleefeld, Wolfgang Schöpp, Chris Heyes, Imrich Bertok, Philippe Thunis, Bertrand Bessagnet, Etienne Terrenoire, Markus Amann (2013). Modelling compliance with NO_2 and PM10 air quality limit values. TSAP Report #9, Version 1.0, IIASA, Laxenburg (AT), March 2013.

Klimont Z., Kupiainen K., Heyes Ch., Schöpp W., Höglund-Isaksson L. (2012). Updated GAINS database including reference emission scenario. Deliverable: D1.1, ECLIPSE (Evaluating the Climate and Air Quality Impacts of Short-Lived Pollutants) Collaborative Project, Project no. 282688 , Laxenburg, July 2012 (report restricted).

Klimont Z, Smith SJ, Cofala J (2013). The last decade of global anthropogenic sulfur dioxide: 2000-2011 emissions. Environmental Research Letters, 8(1):014003.

Russ P., Wiesenthal T, van Regemorter D, Ciscar JC, 2007. Global climate policy scenarios for 2030 and beyond. Analysis of greenhouse gas emission reduction pathway scenarios with the POLES and GEM-E3 models. Report EUR 23032 EN, European Communities, Luxembourg. Available at http://dx.doi.org/10.2791/576.