Building a sustainable greenhouse gases inventory system in Macedonia

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Abstract

Purpose - The main goal of this paper is to highlight the lessons learned and good practices regarding the greenhouse inventory system in the Republic of Macedonia.
Design/methodology/approach – A comparative analysis for the preparation of the three national communications to UNFCCC in Republic of Macedonia.
Findings - The findings reveal the shift from a project-approach, based on external consultants, towards a more process-oriented-approach, where a multi-disciplinary national team has been established to prepare the inventory. Also, notable results include improvements in the technical capacity of the inventory team, communications with data sources and other stakeholders, Quality Assurance/ Quality Control procedures, documenting and archiving, regional cooperation, as well as, the reliability of data series for GHG emissions.
Practical implications - The study may serve well for countries with similar national circumstances and priorities for preparation of greenhouse inventory systems.
Originality/value - Developing national database (inventory) of greenhouse gases is an essential first step toward managing better climate change policy planning. A complete and transparent national greenhouse inventory is an essential tool for understanding emissions and trends, projecting future emissions and identifying sectors for cost-effective emission reduction opportunities. It is also a core element of National climate change reports to the UNFCCC (National Communications). This case study shows the development of a sustainable system for preparation of greenhouse gas inventories and it describes the data collection and analysis procedures within that system.
Keywords - Climate Change, Greenhouse gas, Inventory, National Communication, Global Warming
Paper type - Case study

1. Introduction

Responding to the obligations incurred by signing the UN Framework Convention on Climate Change (UNFCCC) as a non-Annex I Party, the Republic of Macedonia submitted the First National Communication on Climate Change in 2003 and the Second National Communication in 2008. The Third National Communication should be submitted by the end of 2013 (Ministry of Environment and Physical Planning, 2003, 2008).

The Ministry of Environment and Physical Planning (MOEPP) is the leading national institution responsible for the development of actions needed to fulfil the country's obligations to the UNFCCC, including the preparation of National Communications on Climate Change. As implementing agency, UNDP has supported national efforts to address and respond to climate change challenges by providing primary support in development of the National Communications, as well as comprehensive policy support for the establishment of the legal and institutional framework for implementation of the Kyoto Protocol.

The Law on Environment[*] provides the legal framework for the development of a National Inventory. As stipulated in this Law (Article 188, paragraph 3), the Minister of Environment and Physical Planning, as the managing body of the state administration responsible for the affairs of the environment, shall prescribe the details as to the conditions, manner and procedure for preparing the GHG Inventory. The National Inventory shall be prepared once in three years according to the Law on Environment, Article 188, paragraph 4 and shall be an integral part of the National Plan on Climate Change as referred to in the Law on Environment, Article 187.

A complete and transparent national GHG inventory is an essential tool for understanding emissions and trends, projecting future emissions and identifying sectors for cost-effective emission reduction opportunities, as well as for designing appropriate climate change policies – reflective to the country specifics and, at the same time, responsive to the international requirements. Recognising this, UNDP and MoEPP actively support continuity to the institutional and technical capacity strengthening process for preparation of the national GHG inventory.

Preparation of three National Communications (NCs) over a period of thirteen years enabled gathering of much knowledge on preparation of GHG inventory. Variety of challenges, from limited data availability and technical expertise to coordinating a large number of institutions had to be resolved. National team have made considerable progress in addressing these challenges using innovative approaches and have enhanced the capacity development of national professionals.

2. Methodology for preparation of GHG inventory

A greenhouse gas inventory is database of direct and indirect greenhouse gases (GHGs) emitted into or removed from the atmosphere over a certain period of time. The inventory takes into account the following six direct gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride(SF_6). The following four indirect gases are taken into account: carbon monoxide (CO), nitrous oxides (NOx), non-methane volatile organic compounds (NMVOC) and sulphur dioxide (SO_2). It comprises sectors Energy, Industrial Processes, Solvent and Product Use, Agriculture, Land Use, Land-Use Change and Forestry, and Waste.

The GHG inventory is prepared using methodology, software and guidance prescribed by the Intergovernmental Panel on Climate Change (IPCC): *the 1996 Revised IPCC Guidelines for National Greenhouse Gas Inventories, 2000 IPCC Good Practice Guidance, Good Practice Guidance for Land Use, Land-Use Change and Forestry and the 1996 IPCC Software for National Greenhouse Gas Inventories*. The non-Annex I Parties to UNFCCC (i.e. developing countries) are encouraged to use the methodologies given in the above mentioned guidelines, but furthermore are given certain flexibility in to choose other methods that suits best their national circumstances. Regardless of the chosen method it is essential to obtain comparable data for the share of GHG emissions of each country in the world aiming to support world efforts to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

GHG inventory is prepared using different levels of calculation complexity, so called Tiers. The higher the number designating the tier, the more detailed is the methodology and the

[*] Official Gazette 53/05, 81/05

more accurate are the emission estimates. Tier 1 represents the minimum, or default, methodology (IPCC, 1997). If sufficient data is available, higher tier can be applied. Tiers 2 or 3 involve more elaborate methods which could be either source category-specific or technology-based. These methods require more detailed data and/or measurements for their application.

Most of the activity data needed for preparation of national inventory are taken from official national documents such as: statistical yearbooks, energy balances, various strategies and reports from relevant institutions.

3. Case study: Macedonian GHG inventory

National greenhouse emissions in the country range between 10 000 to 14 000 kt CO_2-eq and originate mostly from the energy sector (73.41%). Total national greenhouse gas emissions and removals in the period 1990-2009 are presented on Figure 1. National emissions per capita amount to 5.6 tCO_2 -eq., which is 1.6 times lower than the EU-28 average or nearly 4 times lower than the average emissions per capita of highly industrialized countries like the USA. Due to the predominance of lignite-based power generation, national average carbon intensity[†] is 652 kg/toe, which is 4.3 times higher carbon intensity than the average of EU-28 countries.

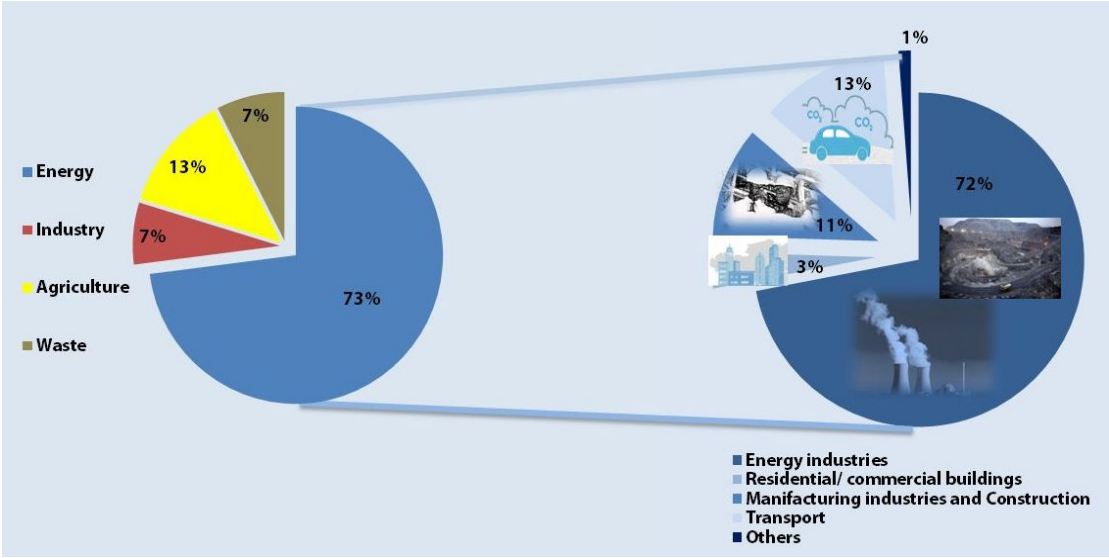

Figure 1. Summary greenhouse gas emissions by sector in CO_2-eq [Gg] for period 2003-2009

As far as specific *direct greenhouse gases* are concerned, 75–80% of emissions are CO_2 emissions (mostly from the burning of fuels in the energy sector), 12–14% are CH_4 emissions (mostly from agriculture and waste), 7–9% are N_2O emissions (from burning fuels and emissions from soils) and 1–2% are HFCs from the industrial processes sector (Figure 2).

[†] The Energy Intensity Indicator represents the ratio between the gross inland consumption of energy (kg/toe) and Gross Domestic Product (GDP in 1000 EUR/ year)

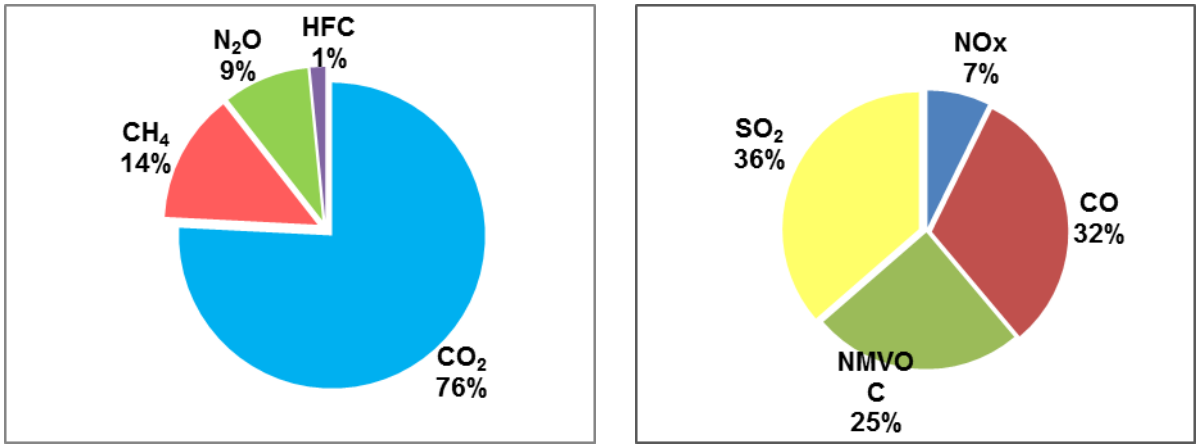

Figure 2. Direct and indirect GHG emissions in the country

Considerable progress has been achieved during the preparation of the National Communications on Climate Change, particularly in shifting from a project-approach towards a more process-oriented-approach. Notable results include improvements in the following areas obtaining more reliable data series for GHG emissions:

- the technical capacity of the inventory team
- communications with data sources and other stakeholders
- Quality Assurance/ Quality Control procedures
- documenting and archiving
- regional cooperation

4. Results and discussion

The main challenge for the preparation of GHG inventories is the sustainability of the process. It should be noted that the inventory system outlined above was project-based, established for the purpose of compiling the national GHG inventories as part of the National Communications (Markovska and Grncarovska, 2006). In order to ensure sustainability in the upgrading and maintenance of the GHG Inventory, a process of transferring knowledge and experience has begun by increasing the capacity of three new employees in the Ministry of Environment and Physical Planning.

A variety of major challenges have had to be overcome, including limited data availability, insufficient technical expertise and the need to coordinate a large number of institutions. The national team has made considerable progress in addressing these challenges, employing innovative approaches and enhancing the capacity of national professionals. Also, notable results include improvements in the technical capacity of the inventory team, communications with data sources and other stakeholders, Quality Assurance/ Quality Control procedures, documenting and archiving, regional cooperation, as well as, the reliability of data series for GHG emissions.

Below are outlined several good practices introduced during the preparation of the national GHG inventory.

4.1. Improvement of the institutional system for the preparation of GHG inventory

The preparation of the GHG inventory for the First and Second National Communications was outsourced to the Research Centre for Energy, Informatics, and Materials of the Macedonian Academy of Sciences and Arts (ICEIM-MANU). For preparation of the Third

National Communication it was decided to introduce new institutional arrangement for upgrading and maintaining the GHG Inventory in order to strengthen the institutional capacities of the MoEPP, as well as to ensure the sustainability of the project results upon its completion. For this purpose, three professionals were engaged to form a **GHG Inventory team** to assure continuous and regular updating of the national GHG database and to serve as a baseline for the introduction of a system of Monitoring, Reporting and Verification. An experienced national consultant from ICEIM-MANU was engaged as a Chief Technical Advisor to provide substantive training, guidance and support to the GHG Inventory team during the preparation of the updated GHG Inventory.

4.2. Strengthening the technical capacities of the GHG Inventory team

Participation in additional training and workshops on climate change has significantly improved the capacities of the GHG Inventory team for the preparation of improved inventory. The GHG inventory team actively participated in the preparation of a Roadmap for the introduction of a Monitoring, Reporting and Verification system under the EU Emissions Trading Scheme (Hristova, 2012). Based on the recommendations given in the Roadmap, the GHG team were nominated and accepted in the **UNFCCC Roster of Experts**. This training additionally strengthened the capacities of the GHG Inventory team for the preparation of more comprehensive inventory in line with the reporting requirements of the UNFCCC.

The team are also acquainted with the 2006 IPCC Guidelines and the corresponding new software for GHG inventory preparation. This software will be obligatory for all countries from 2014 onward and requires more detailed input for calculating national GHG emissions. Training in the use of this software further significantly raised the capacities of the national GHG team for preparing future inventory and enabled gaining first-hand knowledge on new procedures to be introduced.

4.3. Improved procedures for Quality Assurance/Quality Control

Each member of the GHG Inventory team is responsible for one or more sectors. An **Enterer** is responsible for identifying/verifying data sources, entering and documenting the input data (activity data and emission factors), while a **Checker** is responsible for checking and validating the input data and emission estimates. In this way, each team member focuses on a specific part of the inventory preparation and makes the calculations more thoroughly. This approach was introduced in the Second National Communication and was implemented again as a good practice in the Third National Communication, avoiding possible mistakes in data entry.

This set-up enables maximum possible extent of control and quality assurance of the input data and estimated emissions and involves the following entities:

- **The Ministry of Environment and Physical Planning**, responsible for supervising the national inventory process and reporting the emissions to UNFCCC
- **The National Institution (ICEIM-MANU)**, responsible for coordinating and supervising the preparation of inventories
- **The Sectoral Experts** (GHG inventory team)**:**

- the **Enterer**, responsible for identifying/verifying data sources, entering and documenting the input data
- the **Checker**, responsible for checking and validating the input data and emission estimates

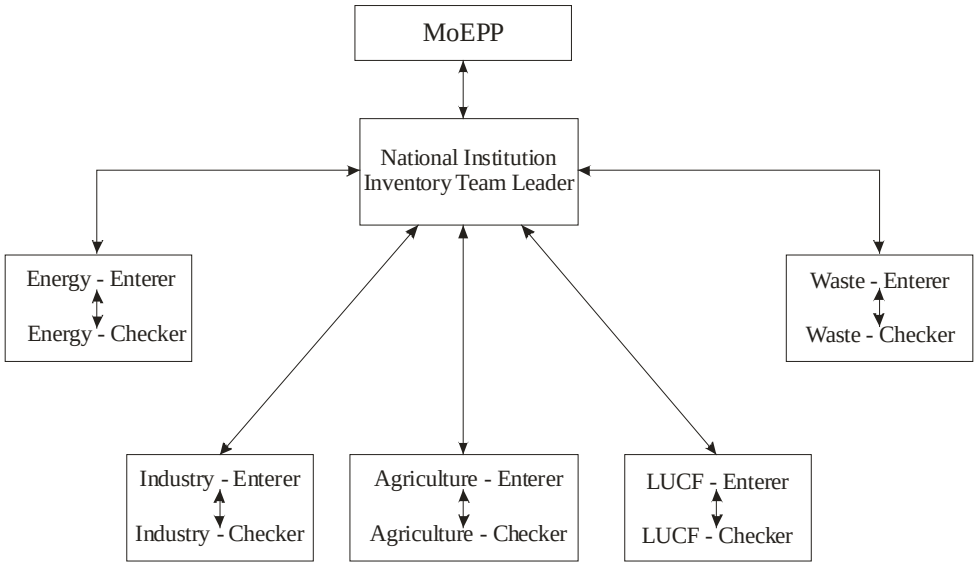

Figure 3: Structure of the national GHG inventory team for the Second National Communication

4.4. Improved institutional cooperation

National communications served as a trigger for all other strategic and policy documents and research related to national development priorities. Coordination is essential between all stakeholders working in the area of climate change to create synergies and send out coherent and consistent messages. Therefore the **National Climate Change Committee** (NCCC) was established with decision from the Government as body that has leading role in providing analytical and institutional capacity from the key national institutions to integrate climate change priorities into country development strategies and relevant sector programmes. It brings together representatives from all relevant institutions and encouraged networking, knowledge transfer and sharing of experiences related to climate change. The NCCC provides information and policy guidance as well as making use of the results and recommendations from the National Communication in sectorial plans and national strategies. The NCCC was closely involved in providing recommendations for resolving identified data gaps, thus setting a baseline for the establishment of a national system for GHG inventory data collection.

Involving all relevant stakeholders from both the public and the **private sector** in the development of the GHG inventory increased access to information, thus providing data relevant for introducing more detailed methodology and the development of highly technical components such as country-specific emission factors, particularly since major emitters of greenhouse gasses are source-point installations. Establishing **direct contact with these installations** and other national and governmental institutions, including the Chamber of Commerce and the State Statistical Office, proved essential in obtaining unpublished data collected only for internal purposes. This resulted in the introduction of several subsectors for the first time –such as aviation—and the introduction of higher Tier methodology in many sub-sectors, including the cement industry, aviation, and railway transport.

The long-term agreement for cooperation and data exchange between the Macedonian Air Navigation Services Provider M-NAV and the Ministry of Environment and Physical Planning also added value. This cooperation made it possible to disaggregate the data on

domestic and international aviation and allowed the application of higher Tier methodology in calculating emissions from the aviation subsector–a methodology that only 8 other countries in the world use at this time.

4.5. Improved documenting and archiving

The data documenting structure was reported for each activity rate, emission and conversion factor directly in the worksheets of the IPCC software[‡]. This documenting procedure increased the **long-term sustainability and transparency of the inventory process**. Below each table in the software there are links to the appropriate data source, enabling any newcomers to the inventory process or relevant stakeholders to understand the data collection process and rationale behind the selection of appropriate emission factors across the inventory. This documenting procedure might appear to create additional work; however, it resulted in a more reliable time series of high quality inventories and serves as national training material for the preparation of future GHG inventories in the country. This good practice was confirmed during the preparation of the GHG inventories for the Third National Report. Despite the fact that a new institutional arrangement was established to assure continuous and regular updating of the national GHG inventories (as described in the introduction), the new GHG inventory team were able to continue their preparation of the new inventory without difficulty on the basis of the documenting tables. In order to provide consistency in preparation of GHG inventories, the database is stored in the Ministry of Environment and Physical Planning.

4.6. Key source analysis

The identification of key source categories has a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both (Intergovernmental Panel on Climate Change, 2000). National key source categories for each inventory are identified in a systematic and objective manner by performing a quantitative analysis of the relationships between the level of each source category's emissions and total national emissions. Any source category that meets the 95% threshold in any year should be identified as a key source category. According to the last key category analysis performed for the period 2003–2009, 18 categories were considered key sources in the seven examined years. The key source with the highest contribution to national total emissions is CO_2 Emissions from Energy Industries - Coal - Lignite. The contribution of emissions from the Energy Industries to total national emissions in the last analysed year (2009) was 47.17%.

4.7. Uncertainty management

The Monte Carlo algorithm, which is the Tier 2 method for estimating uncertainties, was used for estimating uncertainty as it is suitable for detailed category-by-category assessment of uncertainty, particularly where uncertainties are significant. For every variable, random values were generated for each input used in the methodology formula to calculate the desired outputs. This process was repeated with over 40,000 iterations in order to compute multiple estimates of the model output.

In the Second National Communication estimation of the uncertainties has been conducted for the Sectoral Approach of the Energy Sector. The total uncertainty for the whole Energy sector obtained by the Monte Carlo simulation was 8.45 %, which is within the confidence-range accepted in the IPCC Good Practice Guidance (±10%).

[‡] version 1.3.2 of 1996 IPCC Software for National Greenhouse Gas Inventories

The degree of uncertainty of data in the Third National Communication to the UNFCCC was estimated only for the Industrial Processes sector. The Industrial Processes sector was particularly interesting as a subject of uncertainty assessment because the cumulative result for this sector depends on many variables with high uncertainty (Markovska *et al*., 2003). Within industrial processes there were inter-annual fluctuations as well as significant changes from one year to the next due to the introduction of new industrial production or temporary or permanent plant closures. Changes in processes, production intensity and technology can also cause significant fluctuations. Emission trends for each category and/or sub-category can be explained in terms of some type of economic or technological change. This is why this sector is so sensitive to change and why it is important to conduct an uncertainty analysis to confirm whether the results are within the confidence range. Uncertainty analysis was performed for each CO_2-emitting sub-category in the Industrial Processes category for every year in the period 2003–2009. The results of the Monte Carlo Simulation are given in Table 1.

Table 1. Summary Results of the Monte Carlo simulation of CO_2 emissions from the Industrial processes sector for the period 2003–2009

CO2- eq Emission [Gg]					
YEAR	**MAX**	**MIN**	**MEAN**	**ST.DEV**	**DEV/MEAN**
2003	727.69	452.26	579.39	63.04	**10.88%**
2004	797.36	499.91	640.72	64.01	**9.99%**
2005	891.55	552.17	705.72	73.09	**10.36%**
2006	908.02	512.59	682.02	76.31	**11.19%**
2007	824.65	521.13	662.85	65.74	**9.92%**
2008	880.3	548.07	682.28	66.23	**9.71%**
2009	609.4	295.51	424.24	68.39	**16.12%**

The results obtained from the Monte Carlo simulation are as expected. It can be seen that there is high uncertainty in the Industrial Processes emission estimates due to lack of data, though in most years the results fall within the confidence-range accepted in the IPCC Good Practice Guidance (±10%). An uncertainty outlier can be noticed in 2009 due to lack of data, especially in the HFCs consumption category.

4.8. Training materials

Training materials were prepared for *each sector*, including a step-by-step guide to the process of completing the inventory tables, explaining good practices and sources of data and emission factors. These training materials serve as a useful tool for those working on inventory for the first time.

4.9. Emission-Monitoring Inventory software

The Ministry of Environment and Physical Planning was additionally supported by the development of a new software solution for the industry sector: Emissions Monitoring in Industry. EMI is a web-based platform that gathers data directly from industrial installations about annual production, feedstock usage, and details about specific production processes in a distributed manner. EMI effectively speeds up the process of data collection for the three inventories required of the industry sector by the MoEPP, i.e. the GHG inventory, the Air Pollutants cadastres and the Cadastre of Polluters. This software provides a single user-friendly online form to be filled in once a year by appointed representatives from industries, in place of many questionnaires sent sporadically throughout the year. Moreover, the software allows experts from different departments to have access to raw data and reports using separate administrative accounts.

4.10. Modelling GHG Emissions Software

The Ministry of Environment and Physical Planning was further aided by the purchase of a new software solution for modelling GHG emissions, BREEZE AERMOD v.7 (EPA), which simulates the impacts of GHG emissions from a variety of sources: power plants, industrial facilities, farms, landfills, hazardous waste facilities and wastewater treatment plants (WWTP) and is now the most common tool for modellers throughout the world. This software produces 3D graphics reflecting real-time air pollution concerning the atmospheric conditions (temperature, wind, precipitation, etc.). The Ministry of Environment and Physical Planning was additionally provided with transfer of knowledge.

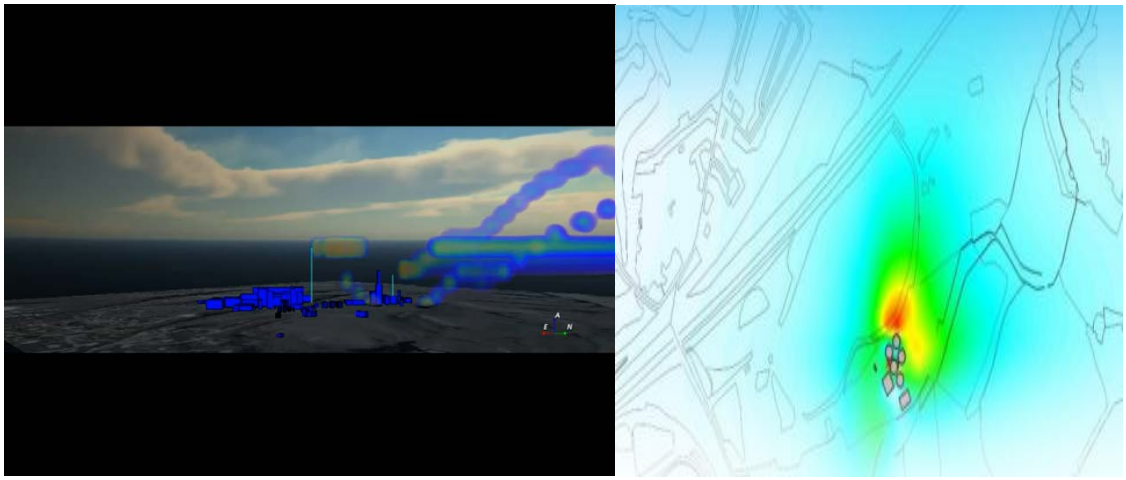

Figure 4. 3D graphics showing: air pollutant dispersion from a factory; nitrous oxide emissions from a pig farm. (Obtained with Breeze Aermod software.)

The picture on the left below shows a 3D graphic of the dispersion of NO_x emissions from a factory. The picture on the right shows nitrous oxide emissions and their dispersion from a pig farm (with high concentrations in red; medium concentrations in yellow; low concentrations in green).

4.11. Country-specific Emission Factors developed

Based on the recommendations given in the Roadmap for the Adoption of National Emission Factors and Recommendations for the Harmonization of Emission Factors between IPCC and CORINAIR methodologies and Reporting Guidance, a national company was engaged to develop country-specific emission factors for the key sources of GHG emissions. In

cooperation with the project team, the company successfully managed to develop a significant number of country-specific emission factors for key emitting sectors. The development of country-specific emission factors enabled the application of improved methodology in the calculation of GHG emissions from key sources.

4.12. Revised legal framework for inventory data collection

Data availability and the discontinuity of the time series in cases where the data does exist is general problem for preparation of GHG inventory. The results and findings therefore include a great range of uncertainty, since in many cases expert judgment was used in the absence of the necessary data.

As a step towards improvement, a separate document was produced on the 'Preparation of Legal Provisions for the GHG Inventory', exploring the possibilities for establishing a legally binding national system for the collection of data needed for developing a more detailed inventory of greenhouse gas emissions. This activity resulted in an amendment to the Law on Environment in order to establish a national system for the collection and management of data needed for the development of national GHG inventory. Improved data management will enable the application of more sophisticated methodology for obtaining emission estimates in future national communications. It is crucial that those national institutions which are obliged to collect data become more deeply involved in order to make adjustments in the data collection methodology.

4.13. Regional cooperation

The National Communication Support Programme (NCSP) added significant value, improving the quality of the inventory by providing technical support and guidelines where needed. The international conference organized by NCSP on Lessons Learned and Experiences from the Preparation of National Communications in Non-annex I Countries enabled the sharing of knowledge and good practices among countries. The Macedonian TNC coordinator presented a paper on good practices in the compilation of the country's GHG inventory (Zdraveva *et al*, 2012).

5. Conclusions

Introduction of above described good practices was significant leap forward and facilitated making the inventory preparation a continuous and sustainable process. For example, within the Third National Communication many new subsectors were included for the first time thus improving its quality. Tier 2 was applied in 7 categories (Energy Industries, Aviation, Fugitive Emissions from lignite, steel production, ferro-alloy production, Waste- Solid Waste Disposal Sites and Uncertainty Management) in comparison with the Second National Communication when tier 2 was partially applied only in the Energy sector.

There is still much room for improvement, however, in making more effective use of the results from relevant national activities related to climate change issues and in fulfilling the country's commitments under the UNFCCC.

The key for successful building of industrial GHG inventory is to provide relevant data with good quality. In order to establish a sustainable data collection it is important to develop transparent, comparable, coherent, complete and accurate measurement, reporting and verification (MRV) national system. The reporting system should be robust, flexible, transparent and most importantly country driven so it can respond to national circumstances.

On the other hand, it must be in line with the most recently adopted or recommended IPCC Guidance and Guidelines.

In addition, it is further recommended that the same approach be applied to inventory compilation at local level. This will help local governments measure the impact of mitigation actions undertaken within municipalities.

Institutional arrangements shall be based, where possible, on existing institutions (efficient usage of already existing staff), with the relation of new ones being the result of necessity.

Deeper and stronger relation and collaboration with the installations and linkages with other relevant projects should be encouraged. It is difficult, but not impossible to incorporate GHG emissions in the reporting scheme of the A and B Integrated Pollution Prevention Control (IPPC) installations.

Finally, the inventory system must seek out the most cost effective solutions at all stages and structural levels, including multifunctional approach, i.e. the reporting under different conventions (e.g. CORINAR, PRTR) should be possible with one centralized data collection.

Acknowledgement

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