D5.4: Guidance document on maintaining transparency in higher Tier inventories

WP5: Improving national emission inventories and projections

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Introduction - Purpose of this document

Activities in the MELS project strive for improving the knowledge background on the release of environmentally relevant components from animal husbandry sources to the environment, specifically the atmosphere. Scales range from an individual farm (to devise appropriate individual abatement measures) to a country (for a national inventory and policies/measures to attain policy targets), and compounds covered are ammonia, methane, and nitrous oxide.

Guidance documents are available to support the establishment of emission inventories, both for air pollutants like ammonia (EMEP/EEA, 2019) and for greenhouse gases such as methane and nitrous oxide (IPCC, 2019). These guidance documents provide detailed instructions to create such inventories. In order to make use of resources in an optimal way, emission sources that are not important should be estimated with fairly simple methods, while most effort should be directed towards significant sources. Thus, these guidelines provide methodologies for different levels of detail (tiers) in which emissions need to be reported. The simple "tier 1" approach seems sufficient for small sources of little general relevance – typically consisting of a generic emission factor to be multiplied with easily available statistical information. For more significant sources (contributing a certain fraction of total emissions or contributing to the trend or to the uncertainty of emissions: IPCC, 2006), taking advantage of higher level tiers (tier 2 or tier 3) that depend on specific national or regional information is required.

The above-mentioned MELS activities have focused on developing and supplying data for improving the accuracy of more complex inventory methodologies. MELS has developed functional relationships between emission factors and underlying parameters (MELS deliverable D3.1) and parameterizes these into functional models (MELS deliverable D3.3). In order to understand and analyze the value of these functional models, the current document provides some theoretical foundations that describe the added value provided by applying such models, the available options to remain transparent, to allow comparison across methods (and also across regions, using benchmarking approaches), and to validate whether results are fit for purpose.

The challenge of multi-purpose inventories

Using more complex algorithms, in general, is considered to provide better results that more closely resemble real fluxes. Such algorithms are expected to represent the true

conditions of a process more closely than simplified approaches, and hence they also would be able to better reflect the cause-effect chain. A change in an underlying cause (an input parameter to the model) would then also be correctly represented in the consequences, the model output. This is especially the case for situations where underlying models are adequately validated. Yet, it is all but clear whether models have been validated fit for purpose, with multiple purposes of emission models becoming prevalent. These purposes include:

Quantifying emissions: the most obvious quantity to be obtained from emission inventories (including from the agricultural sector, i.e. animal husbandry and treatment of agricultural cropping area) is the quantity of emissions. Emission inventories thus are tailored to fit this purpose.

Assessing patterns (spatially and temporally): spatial variability as well as temporal trends and cycles characterize the release of compounds into the atmosphere. Spatial and temporal variability determine both the distribution and the behaviour of compounds in the atmosphere, and they may become relevant for subsequent effects or at least observable concentrations. Hence any validation also depends on the pattern, and on the proper identification of such patterns.

Sources (causes) of emissions: Before emission reduction measures can be adequately taken, it is essential to understand not only the total of emissions of a given compound in an area (including its pattern), but also to know about the specific pathway for its release. Once this pathway is identified, adequate measures can be taken to resolve an issue. Both technical and legal measures set to avoid/minimize release require such identification as precondition.

Emission abatement: in order to understand the potentials of emission reductions (and subsequently, the impact of any measure) it is essential to quantify the effect of an abatement measure. A model that is able to adequately describe the release of compounds under normal conditions not necessarily would also predict the behaviour under measures. Validation here is particularly relevant as factual evidence may be quite small (even while being one of the focus targets of MELS).

Abatement costs: Economic reasons often help prioritize action. Marginal cost curves may be used to identify the most cost-efficient way to improve the environmental quality – these require not only emission abatement measures, but also their costs properly understood. An emission model, ideally, also needs to properly cover the costs

of emission abatement (which also needs to reflect technology available at a given time, i.e. cost curves require continuous updates).

As tier 1 methodologies are available to address all of these purposes, an open question remains to which extent a tier 2 or tier 3 methodology (which may be an improvement over the simple methodology in only a few aspects) is able to provide improved responses to just one (often: the emission quantity) or several of the purposes. Here full transparency is needed whether or not a higher tier methodology provides the same or a different response than the lower tier result. Facilitating such transparency requires to systematically reorganize output of emission models (higher tier methods) so they can be directly compared to tier 1 results.

Normalization

The central element of all comparisons is to establish a common level to compare to. Different approaches to assess emissions (or any other parameter to satisfy the purposes of emission inventories) will lead to results that refer to different entities, depending on how the underlying calculation has been set up. At whatever detail certain results are being developed, aggregation is required to arrive at such a common level. Ideally, only a comparison "like-with-like" is valid, relating to the identical system boundaries. In practice all kind of comparisons will be needed and may provide guidance. In order to come as close as possible to the "like-with-like" theorem, some kind of normalization may need to be applied.

Direct comparison can only be performed in situations when emissions have been quantified for the same area, time period and source sector using two or more levels of complexity. Resulting calculated emissions then can be evaluated and compared, in order to identify the reasons for any apparent discrepancies and to attribute their causes, with consequences for improvement cycles (see e.g. Amon et al., 2021, who compared the consequences of applying updated IPCC emission guidelines to the situation of Austria). Similarly, comparing a common (yet simplified) tool available for many countries may provide guidance in the quality and accuracy of emission data provided by individual countries taking advantage of a wealth of locally specific information (see Klimont et al., 2022, who compared national inventories with the results of a harmonized tool, the GAINS model). Such comparisons can be regarded a general strategy in the validation of national emission inventories.

If not comparing the identical situation with different methods, but across similar situations, e.g. in different countries, further normalization will be required to compensate for structural differences. Such normalization may take account of (i) population numbers, (ii) area, (iii) economic production values such as GDP, (iv) economic activities such as agricultural production or animal numbers, or (v) any other potentially relevant numerator.

Using normalization as a way to assign emissions to a given underlying metric implicitly connects emissions with that metric. The strategy becomes meaningful only if the metric (directly or indirectly) has a role in the generation of the emissions. E.g., when using population numbers, there is an underlying assumption that each individual person is responsible for the same amount of emissions. This can be directly (persons cause emissions in their metabolic processes or during their daily activities, such as transport to and from work or generating waste) or indirectly (e.g., everybody needs food, emissions are due to food production on a similar level for each person). Comparably, scaling by area assumes that emissions are due to certain area sources (could also be agricultural area only, as e.g. caused by constant addition of fertilizer leading to ammonia emissions). When attributing emissions to economic activity in general, GDP may be a good indicator, but if we assume a more specific source of economic activity to be made responsible, such as animal husbandry, it can be useful to use production numbers or stock as a metric.

Whatever the metric chosen for normalization to compare emissions between units of different size, it is important to note that it reflects an entity that is somehow considered to represent an emission generating activity.

Comparing partial inventories

As pointed out above, direct comparison of results is possible and meaningful when extending different approaches to the same dataset. As soon as different approaches are being applied to different datasets (or even using the identical approaches to these different datasets), comparison needs to rely on assumptions. This refers in particular to partial inventories, where the full data set is restricted to one or more levels:

- *observation region:* whether comparing a part of the area with the area total, or two independent areas, size and structure of that region may characterize emissions and hence have to be taken account of in a comparison.

- *time period and extent of observation:* while emission inventories typically are provided for a full year, it is instructive to observe emissions over a given time (emission trends), as well as to understand the temporal pattern within a given year. In both cases, means to develop an understanding of such a behaviour may take advantage of surrogate data that reflect the temporal behaviour of underlying activities.
- *economic sector (subsector):* especially when it comes to taking responsibility for emissions and attributing measures of emission reduction, it is important to identify the sources and source sectors responsible. Comparisons can be useful across sectors (which sector is more important for total emission?), within sectors (how do different methods of emission assessment compare for a specific sector?), or also within a sector in different areas/time periods (for benchmarking: are there examples demonstrating that a better solution is feasible?). When comparing economic sectors, a detailed understanding of system boundaries is decisive. Do emissions from cattle include grazing cattle or just the indoor manure management chain? Would emissions caused by mineral fertilizer be covered? How is energy distributed across sectors, is a combustion engine to generate electricity on an anaerobic digestion plant considered an agricultural activity (part of the manure management chain) or a power plant? Here it is essential to take advantage of existing guidance (see below).
- *specific emitted compound:* multiple chemical species are being released into the atmosphere, most often classified into air pollutants and greenhouse gases. Accounting often is done for an individual substance (e.g., CO_2 or SO_2), but may also cover two (NO_x as the sum of NO and NO_2) and a compound class (such as NMVOC, the non-methane volatile organic compounds; or F-gases, fluorinated gases covering perfluorocarbons, hydrogenated fluorocarbons and sulfur-hexafluoride). Emission models may describe their release, or just the relationship of their release to that of another compound. Any comparison needs to make sure to use appropriate and harmonized units.

For each of these partial inventories, in addition to the inherent need of properly identifying and harmonizing system boundaries, consideration of the respective purposes to establish such inventories remains relevant. Allocating emissions to sectors, in order to also allocate responsibility for emission reductions, necessarily comes with an identification of emission abatement potentials and abatement costs. In such a specific case, abatement measures and their effectivity would need to be assessed on a source

sector level. Partial inventories hence maintain to be purpose-oriented, and they may also need normalization for comparing.

All of the above are subsets of the total release of compounds into the atmosphere. The total release (at least when focusing on one specific compound) is needed to compare against independent datasets such as ambient measurements (as in inverse modelling, where atmospheric transport models and tower or satellite measurements help to establish an emission inventory that is at least in part independent of an inventory based on statistical inputs; see e.g. Bergamaschi et al., 2015). A complete inventory, ready for comparison with inverse modelling results, needs to include all fluxes into and out of the atmosphere. In addition to anthropogenic activities (typically used in national emission inventories) also emissions from natural sources need to be covered.

Key elements of existing guidance

Both for greenhouse gases (GHG's) and air pollutants, standardized procedures are available that form the basis of emission assessment and reporting. These guidelines also describe methods of benchmarking between inventories of different origin.

For GHG's, guidance has been provided in IPCC (2006), as part of the quality guidance (Vol. I, Ch. 6 "QA/QC"). This guidance puts an emphasis on the "CCCA" principles (Completeness, Consistency, Comparability, and Accuracy) in a manner resembling scientific criteria. An overarching "Transparency" principle is added, as also (in terms of the overall QA/QC cycle) an "Improvement" principle to be used in any QA/QC plan.

Complex emission models and their transparent use have been established for the update of that document, the 2019 refinement (IPCC, 2019). Again in its Vol. I, Ch. 6, a checklist can be found ensuring good practice in using complex, higher tier models in inventories (section 6.12.7). Going into considerable detail, this checklist also supports quantitative comparisons with other (less detailed) datasets. Methodological guidance towards transparency includes checks and model evaluation (on an inventory level, without providing specific methodology).

The respective guidance document for air pollution, valid for Europe as created under the European Convention on Long-Range transboundary Air Pollution, has been compiled as EMEP/EEA (2019). Its Chapter 6 covers the "Use and reporting of models" and also focusses on model transparency, specifically referring to the guidance presented by IPCC (2019).

This overview shows that the problem of transparency (and lack of transparency in complex models) is well understood and that appropriate guidance is provided to deal with it in the framework of quality considerations. The guidance, however, may not be fully meeting all practicalities for a meaningful and ready-to-use comparison of inventories of different tiers.

Here national guidance may help out. In the framework of their reporting obligations to the UNFCCC, countries routinely publish national inventory reports, also providing (in different levels of detail) guidance how their own inventories have been prepared. E.g., as a notable initiative, the New Zealand Ministry of Primary Industries maintains and regularly updates a methodology guidebook on the national GHG emissions (MPI, 2022).

Quantification via implied (emission) factors

As outlined above, numerical methods are still amiss that could support transparency considerations, for the purpose of comparing and benchmarking results of emission estimation done at different complexity levels. Guidance has been published, however, and can be used to extend towards quantitative representation.

We have also described the importance and the potential of normalization of emission data. When using, as normalizing factor, an entity that we consider matching most closely the emission generating principle, we arrive at an emission factor. Normalizing the result of a complex emission calculation yields an implied emission factor, a factor that mimics the performance of a complex model, such that using the factor would arrive at the identical result. The implied emission factor (for transparency reason, clearly identified as such) provides a level of comparison of emission calculation of different complexity, for different regions, or across different sectors. Using an implied emission factor allows transparent comparison – obviously still requiring explanations for observed differences.

Also, we have identified a number of related results to emissions – emission abatement, or emission costs. Again, the same principle applies. We can derive implied entities that allow us to render results comparable. E.g., for emission abatement, an emission reduction factor (as the fraction of emission removed, in percent) can be given. Or for emission costs, a cost factor (per mass unit pollutant removed) will yield results

comparable across different detail levels, allowing for transparent comparison, for benchmarking between models, sectors, spatial units, and methods generally.

Comparing variability and uncertainty

Whatever the method chosen to quantify emissions, it will only partially be able to address irregularities that are the result of multiple impacts, too many to be addressed in any methodology. It is essential to separate variability and uncertainty. Variability refers to fluctuations in time and/or space, of emission fluxes. It can be handled by identifying its magnitude and by focusing on aggregate information (averages). Uncertainty is more tricky and difficult to cover. One way to deal with uncertainty in emission inventories is to move over to more complex (higher tier) methods that are understood to have lower uncertainty. In fact, comparison of two emission estimates with known uncertainties allows to assess whether or not observed differences are statistically significant.

Guidance documents (IPCC, 2006) provide detailed information how inventory uncertainty can be assessed, taking advantage of differences in reported underlying information. Uncertainty is a reporting obligation in inventories submitted to the UNFCCC. Some early scientific approaches on GHG uncertainty have been published for the Austrian emission inventory (Winiwarter and Rypdal, 2001; Winiwarter and Muik, 2010). Uncertainty information is understood to improve quality of information provided to policy makers, to identify robust solutions of suggested emission reduction measures, and to guide towards much needed improvement of certain elements of an inventory.

Distinguishing between variability and uncertainty is important, but in practice often remains challenging. It has been argued (Leip et al., 2011) that the well-known order-of-magnitude uncertainty associated with N_2O emissions from soil (IPCC, 2006) in fact is the result of most possible situations already being measured, and hence reflecting variability rather than uncertainty. That would imply that the overall emissions, using an average of the available highly variable data, match the real situation much better than expected from the uncertainty numbers provided. This assumption is supported by encouraging results of inverse models (Bergamaschi et al., 2015).

Examples of application

The idea of using implied factors, even while not systematically developed, has been applied successfully in the past already. Literature references used above provide clear evidence. Implied factors have proven to be practical, and practicability is a prerequisite of their being used.

With respect to emissions, the national inventory reports submitted under the UNFCCC in some parts are specifically providing results as implied emission factors. For methane emission from dairy cattle, IPCC (2006) provides a complex algorithm to take advantage of metabolic feed conversion to estimate methane emissions. The resulting CRF tables (also shown in the national inventory report, the NIR – e.g. see Anderl et al., 2022, for Austria) provide the implied emission factor, the resulting emission per dairy cow.

Also, emission reduction (as the fraction of removed emissions, in percent) has been used before in the GAINS model. Using the term reduction efficiency, Amann et al. (2011) describe the fraction not being emitted due to the introduction of an emission reduction measure – fully independent of the underlying model to estimate emissions.

Examples for implied costs (here as specific costs in EUR/kg pollutant abated) have been shown provided by Klimont and Winiwarter (2015). Implied costs conveniently show different abatement measures in comparison, they provide the foundation of a cost curve (used to optimize an abatement strategy. In MELS, the results provided by Rychła et al. (2023) are the practical result of this concept.

Conclusion

Complex algorithms to estimate emissions or parameters related to emissions tend to make the generation process difficult to trace. Methods are needed to create transparency into this process, such that results derived from different detail level can be made comparable. Comparability can stretch over different areas, time slices, sectors, or even chemical compounds. We show here that the use of “implied factors”, simplified parameters that can be extracted from complex models while representing elements of much simpler models, can serve as an element creating such transparency. At the same time, that element would also permit a core element for benchmarking and comparison more generally. The proposed elements of implied emission factors, reduction efficiencies and specific costs have already been used in the literature and seem to be useful and practical for the purpose of creating transparency.

References

Amann, M., Bertok, I., Borken-Kleefeld, J., Cofala, J., Heyes, C., Höglund-Isaksson, L., Klimont, Z., Nguyen, B., Posch, M., Rafaj, P., Sandler, 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.

Amon, B., Çinar, G., Anderl, M., Dragoni, F., Kleinberger-Pierer, M., Hörtenhuber, S. (2021). Inventory reporting of livestock emissions: the impact of the IPCC 1996 and 2006 Guidelines. Environ. Res. Lett. 16, 075001.

Anderl, Michael, Angela Friedrich, Marion Gangl, Martin Kriech, Verena Kuschel, Christoph Lampert, Nicole Mandl, Bradley Matthews, Simone Mayer, Erwin Moldaschl, Katja Pazdernik, Stephan Poupa, Maria Purzner, Anne Karina Rockenschaub, Wolfgang Schieder, Carmen Schmid, Günther Schmidt, Barbara Schodl, Elisabeth Schwaiger, Bettina Schwarzl, Gudrun Stranner, Peter Weiss, Manuela Wieser, Andreas Zechmeister (2022). AUSTRIA'S NATIONAL INVENTORY REPORT 2022. Submission under the United Nations Framework Convention on Climate Change and under the Kyoto Protocol. REP-0811, Umweltbundesamt, Vienna.

Bergamaschi, P., Corazza, M., Karstens, U., Athanassiadou, M., Thompson, R.L., Pison, I., Manning, A.J., Bousquet, P., Segers, A., Vermeulen, A.T., Janssens-Maenhout, G., Schmidt, M., Ramonet, M., Meinhardt, F., Aalto, T., Haszpra, L., Moncrieff, J., Popa, M.E., Lowry, D., Steinbacher, M., Jordan, A., O'Doherty, S., Piacentino, S., Dlugokencky, E. (2015). Top-down estimates of European CH_4 and N_2O emissions based on four different inverse models. Atmos. Chem. Phys. 15, 715–736.

EMEP/EEA (2019). EMEP/EEA air pollutant emission inventory guidebook 2019. Technical guidance to prepare national emission inventories. EEA Report No 13/2019. European Environment Agency - Publications Office of the European Union, Luxembourg.

IPCC (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, prepared by the National Greenhouse Gas Inventories Programme, Intergovernmental Panel on Climate Change. Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). IGES, Hayama, Kanagawa, Japan.

IPCC (2019). 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, prepared by the National Greenhouse Gas Inventories Programme,

Intergovernmental Panel on Climate Change. Calvo Buendia, E., Tanabe, K., Kranjc, A., Baasansuren, J., Fukuda, M., Ngarize, S., Osako, A., Pyrozhenko, Y., Shermanau, P. and Federici, S. (eds).). IGES, Hayama, Kanagawa, Japan.

Klimont, Z., W. Winiwarter. Estimating costs and potential for reduction of ammonia emissions from agriculture in the GAINS model. Chapter 9 in: S. Reis, C. Howard and M. Sutton, eds., Costs of ammonia abatement and the climate co-benefits, pp. 233 – 261. Springer, Dordrecht (2015)

Klimont, Z., Gregor Kiesewetter, Katrin Kaltenegger, Fabian Wagner, Younha Kim, Peter Rafaj, Sabine Schindlbacher, Chris Heyes, Bruce Denby, Mike Holland, Jens Borken-Kleefeld, Pallav Purohit, Hilde Fagerli, Toon Vandyck, Laura Warnecke, Agnes Nyiri, David Simpson, Adriana Gomez-Sanabria, Rob Maas, Wilfried Winiwarter, Leonidas Ntziachristos, Maria Georgakaki, Albert Bleeker, Peter Wind, Lena Höglund-Isaksson, Robert Sander, Binh Nguyen, Stephan Poupa, Michael Anderl (2022). Support to the development of the third Clean Air Outlook. Specific Agreement 13 under Framework Contract ENV.C.3/FRA/2017/0012. Final Report. International Institute for Applied Systems Analysis (IIASA), Laxenburg (Austria).

Leip, A., Busto, M., Winiwarter, W. (2011). Developing spatially stratified N_2O emission factors for Europe. Environmental Pollution 159, 3223–3232.

MPI (2022). Methodology for calculation of New Zealand's agricultural greenhouse gas emissions. Version 8. Ministry for Primary Industries, Wellington, New Zealand. Available at https://www.mpi.govt.nz/dmsdocument/13906-detailed-methodologies-for-agricultural-greenhouse-gas-emission-calculation

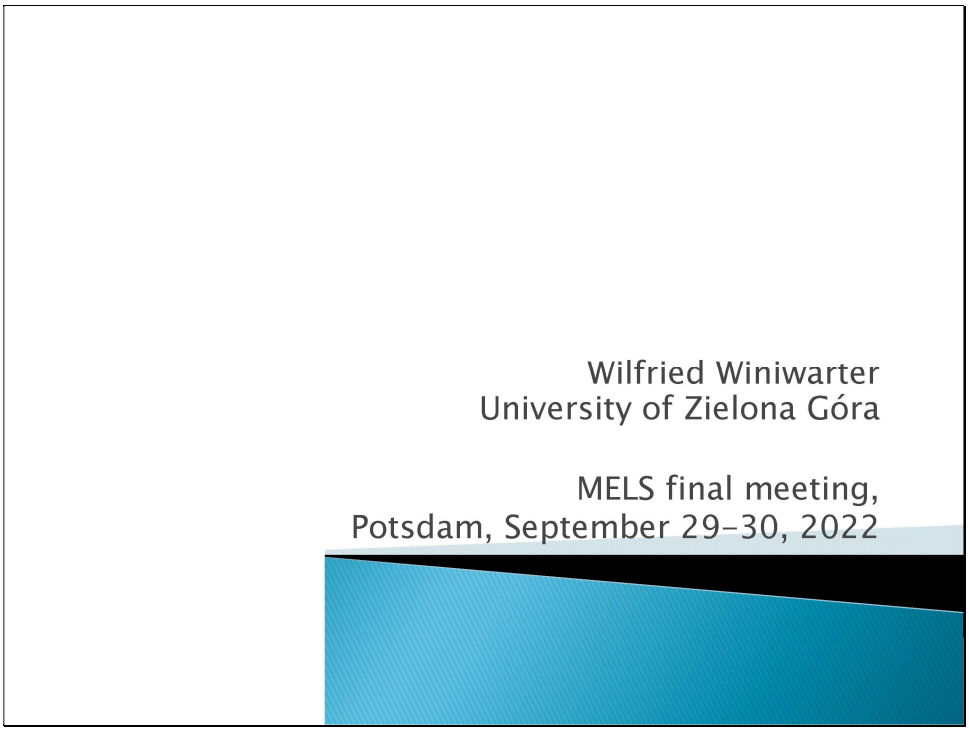
Rychła, A., et al. (2023). Costs of strategies measures to reduce of ammonia emissions from livestock production: A multi-country assessment. Manuscript for submission.

Winiwarter, W., Muik, B. (2010). Statistical dependence in input data of national greenhouse gas inventories: effects on the overall inventory uncertainty. Climatic Change 103, 19–36.

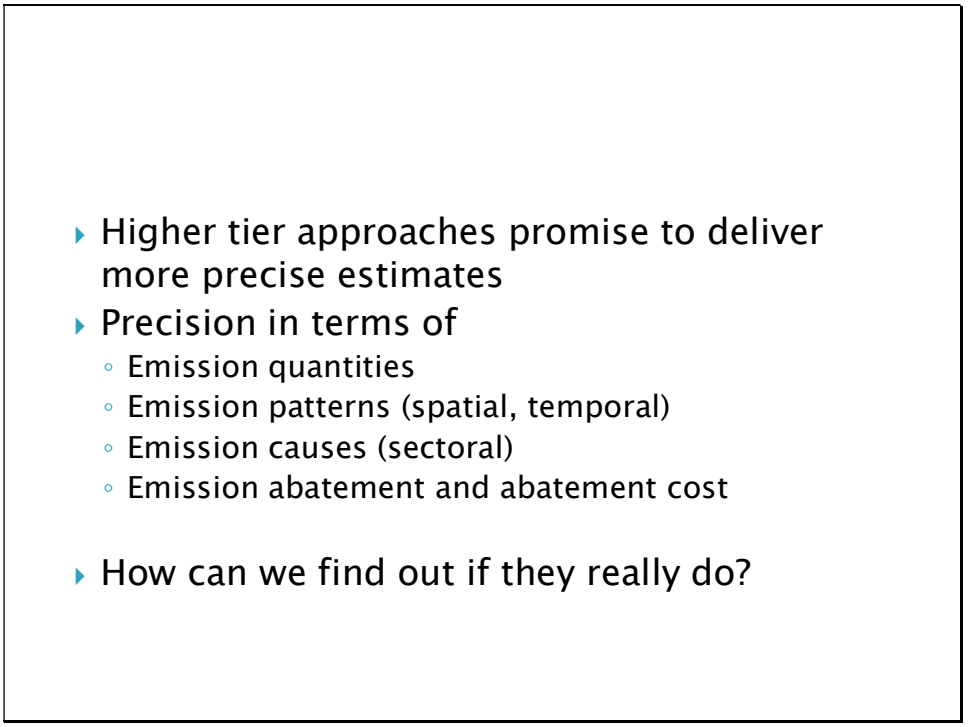
Winiwarter, W., Rypdal, K. (2001). Assessing the uncertainty associated with national greenhouse gas emission inventories: a case study for Austria. Atmospheric Environment 35, 5425–5440.

Appendix: Presentation slides shown at the MELS final meeting

Slide 1



Slide 2



Slide 3

- Methods for benchmarking have been developed
  - IPCC 2006 national GHG inventory guidelines (Vol. 1 Ch. 6 QA/QC)
  - EMEP/EEA air pollutant emission inventory GB 2019 (Chapter 6.6 Use and reporting of models)
- Comparing between methods (different tiers) is similar as comparison between countries
  - Normalization required to account for different size, pattern, …

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Slide 4

- Compare like with like (e.g. emissions for identical spatial and sectoral system boundaries)
- Compare differences accounting for the differences (normalizing), e.g.
  - By population numbers
  - By area
  - By economic indicators
- Assess and understand uncertainties (normalizing adds to uncertainty)

Slide 5

- Total emissions for full spatial extent (most general, least meaningful)
- Sectoral split (spatial split)
- Most typically available:
  Split between activity data and emission generating process → implied emission factor
- Separate between situations of different emission characteristics
  - By practice (e.g. mineral fertilizer type; stage in manure management)
  - By abatement technology

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Slide 6

- Taking into account model results
- Implied default emission factor:
  emissions per activity unit
  (e.g.: kg NH_3 per animal)
- Implied reduction efficiency (as a consequence of abatement method):
  100 x (1 – Ea/Ed) (%)
- Implied abatement costs
  costs per abated emissions
  (e.g.: €/kg NH_3)

Slide 7

- Model as “black box” just produces the result, no details
- Write-out interim results that may provide disaggregation needed
- Inverse approach: vary input to identify model sensitivity

Slide 8

- Is higher tier model able to respond to a given research/policy question?
- Is lower tier (emission factor) approach also providing this response?
- Do different tier methods provide comparable results (considering uncertainties)?
- Where do differences occur?
  - total emissions
  - sectoral emissions
  - emission factors
  - emission reductions
  - abatement costs

Slide 9


is better than a more complex one
KHAM'S RAZOR
"Non sunt multiplicanda entia
sine necessitate"
UNIWERSYTET
ZIELONOGÓRSKI