Advanced Methods for Estimating Uncertainties in National Greenhouse Gas Emission Inventories – the Case of Finland

Suvi Monni
VTT Processes
30 April 2003
Structure of the presentation

- Greenhouse gas emissions in Finland
  - national circumstances
- General on uncertainty estimates
- Input parameter uncertainties
- Combining uncertainties
- Results
- Conclusions
Finland

- Northerly located country
  - a quarter of the country lies north of the Arctic Circle
- Cold climate
  - annual mean temperature 6°C in south, less in north
  - 1/5 of final energy is used for space heating
- 2/3 of primary energy comes from imported sources
Primary energy production in Finland 1975-1999

- Fossil fuels
- Wood
- Peat
- Nuclear power
- Natural gas
- Oil
- Coal
- Net imports of electricity
- Other
Availabilty of hydropower depends on rainfall rates.

Electricity production in Nordic countries in 2000:

- Hydro: 61%
- Wind and geothermal: 18%
- Nuclear: 19%
- Condensing & CHP: 19%
- Availability of hydropower depends on rainfall rates.

Total electricity produced: 394 TWh
Lots of energy used to produce export products (metals, pulp and paper)

Industry uses half of the final energy in Finland
N$_2$O from Energy Sector: Fluidised Bed Combustion

Advantages of fluidised bed combustion:

• fuel flexibility (wet, low-grade fuels, different particle size etc)
• in-process capture of SOx
• low NOx emissions

Disadvantages:
• high N$_2$O emissions
Peat Fuel Use

- 6% of Primary Energy in 2001
- Emissions from peat combustion (CO₂, CH₄, N₂O)
- Peat production area around 55 000 ha
  - emissions: CO₂ and CH₄
- Arable peatland area around 150 000 ha
  - emissions: CO₂
- Closely related to Land Use -sector

Picture: Heikki Kokkonen
Greenhouse gas emissions from Finland in 2000

- Energy sector in total 83%
  - Centralised energy 28%
  - Transport fuels 18%
  - Heating and other combustion 10%
- Industrial fuels 22%
- Peat production 5%
- Agriculture 10%
- Industry and solvents 4%
- Waste 2%
- Other 1%
Uncertainty estimates (1)

- Required for UNFCCC and Kyoto Protocol
- Essential for emission trading and other Kyoto mechanisms
- Give information on future research priorities
  - emission inventory improvements
- IPCC Good Practice gives two different “tiers” for combining uncertainties
  - Tier 1: error propagation equations (normal distributions, symmetrical, uncertainty cannot exceed 100%, handling of correlations problematic)
  - Tier 2: Monte Carlo simulation (distributions can have all possible shapes and widths, flexible handling of correlations)
    - used in this study
Uncertainty estimates (2)

Uncertainties due to
- measurement errors
- natural variability of emission sources
- bias in expert judgement

Basis of uncertainty estimates
- measurement data
- domestic and international literature
- expert judgement
- IPCC default uncertainties
Uncertainty estimates (3)

- Fuel combustion often accurately known (IPCC 2000)
  - activity data uncertainty ±1-5% in large sources
  - emission factor uncertainty
    - \( \text{CO}_2 \): < ± 5%
    - \( \text{CH}_4 \): ± 50-150%
    - \( \text{N}_2\text{O} \): order of magnitude
- Uncertainty in industrial processes depends of plant-specific data and process conditions
- Agriculture and Waste sectors contain many highly uncertain emission sources
Input Parameter Uncertainties, Case 1: N\textsubscript{2}O Emissions from Cars with Catalytic Converters

Urban; Cold start; Cars with a new and 50 000 km used catalytic converter

Urban; Cold start; Car with a 8000 km used catalytic converter

Urban; Warm start; New catalytic converter

Urban; Warm start; Car with a 8000 km used catalytic converter

Finnish Emission Factor

Urban; Warm start

Rural road

Rural road
Input Parameter Uncertainties, Case 2: Solid Waste Disposal on Land

- Emissions from solid waste disposal on land are calculated with a First Order Decay Method (FOD)
  - takes the dynamic behaviour of waste degradation into account
  - emissions from waste disposed in landfills since year 1900 are calculated

- Uncertainties of each parameter are estimated
  - uncertainties in historical activity data are large (the waste amount in the beginning of 1900 was very small)
  - suitability of parameters in Finnish conditions (e.g. freezing and melting of land) has to be taken into account in uncertainty estimates

- Resulting uncertainty around ±30%
Monte Carlo Simulation

- Input parameters of emission calculation model are replaced with probability density functions (e.g. normal or lognormal distributions)
- Total uncertainty is obtained taking random numbers from each input distribution several thousands of times

\[
\text{Activity data} + \text{Emission factor} = \text{Emissions}
\]
Uncertainties by gas

<table>
<thead>
<tr>
<th>Gas</th>
<th>Uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO$_2$</td>
<td>-4...+6%</td>
</tr>
<tr>
<td>CH$_4$</td>
<td>-19...+20%</td>
</tr>
<tr>
<td>N$_2$O</td>
<td>-33...+40%</td>
</tr>
<tr>
<td>HFCs, PFCs and SF$_6$</td>
<td>-53...+32%</td>
</tr>
</tbody>
</table>
### Uncertainties by sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>IPCC code</th>
<th>Uncertainty in 2001 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Combustion</td>
<td>1A</td>
<td>±3%</td>
</tr>
<tr>
<td>Fugitive emissions from fuels</td>
<td>1B</td>
<td>-59...+106%</td>
</tr>
<tr>
<td>Industry</td>
<td>2</td>
<td>-27...+43%</td>
</tr>
<tr>
<td>Agriculture</td>
<td>4</td>
<td>-37...+47%</td>
</tr>
<tr>
<td>Waste</td>
<td>6</td>
<td>-28...+30%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>-5...+6%</strong></td>
</tr>
</tbody>
</table>
Key sources

Key sources identified with the Tier 2 method of IPCC Good Practice Guidance

5 most important key sources in 2001

<table>
<thead>
<tr>
<th>Source category number</th>
<th>Gas</th>
<th>Key Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>1B</td>
<td>CO₂</td>
<td>Arable peatlands</td>
</tr>
<tr>
<td>4D</td>
<td>N₂O</td>
<td>Agricultural soils</td>
</tr>
<tr>
<td>1B</td>
<td>CO₂</td>
<td>Peat production areas</td>
</tr>
<tr>
<td>1A4</td>
<td>CO₂</td>
<td>Other Sectors (commercial, institutional, residential, agriculture, forestry, fisheries,): Liquid Fuels</td>
</tr>
<tr>
<td>2B2</td>
<td>N₂O</td>
<td>Nitric Acid Production</td>
</tr>
</tbody>
</table>
Conclusions

- Total uncertainty in Finland is rather low (-5…+6%)
  - due to large share of CO₂ emissions from fossil fuel combustion, which are accurately known
- CO₂ emissions are accurately known, but other gases contain higher uncertainties
- CO₂ emissions from peat production and N₂O emissions from agricultural soils dominate the uncertainty
  - the reduction of these uncertainties would need lots of research both internationally and in Finland