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Weekly greenhouse gas emissions of municipalities: Methods and comparisons

S. Monni [a,*], S. Syri [b]

[a] Benviroc Ltd, Lekkerikuja 1 B 21, FI-02230 Espoo, Finland
[b] Aalto University, School of Engineering, Department of Energy Technology, P.O. Box 14100, FI-00076 Aalto, Finland

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ABSTRACT

Local authorities need timely information on their greenhouse gas (GHG) emissions and their causes, comparison with other municipalities and tools for dissemination of information to the citizens. This paper presents a weekly GHG emission calculation system, CO_2-report, which provides such data for citizens and local decision-makers in a timely manner, in contrast to the official emissions statistics, which are available on an annual basis 1–2 years afterwards. In this paper, we present the methodology and three main outputs of CO_2-report: (1) weekly GHG emissions; (2) advance annual emissions; and (3) final annual emissions for 2009 with comparison of 64 municipalities in Finland. We explain the reasons for the large variability of annual emissions, from 5 to 13 t CO_2-eq/capita, discuss the accuracy of advance and final emission estimates at local level, and show the weekly variability of emissions for three example municipalities with different emission profiles.

1. Introduction

As the concern on the impacts of climate change has spread from the scientific community to the general public, residents of cities and municipalities have become interested in emissions caused by their daily activities. Many tools have been developed in recent years to describe these impacts. Efficient and timely communication of the results of local GHG inventories to local decision makers and citizens is important, as the ultimate goal of emission inventories is to support the emission reduction actions. Information on local GHG emissions and their causes can be provided to citizens by developing tools for estimating real time emissions and utilizing the possibilities of present ICT to provide information for residents and decision-makers on-line.

One emission information tool that has rapidly gained popularity is the calculation of the so-called carbon footprint. Carbon footprint is based on the greenhouse gas emissions of a product or service over its entire life cycle, being an illustrative tool when different products or services or different stages in the life cycle are compared. However, carbon footprints of cities are data-intensive, and therefore city greenhouse gas (GHG) emissions have typically been quantified based on an inventory approach, which includes annual emissions occurring within the city, and the methods of treating extra-boundary activities such as material use and transportation may vary. Imports and exports of electricity and heat across city borders are also taken into account, but the methodologies for accounting such imports and exports vary (e.g. Sovacool and Brown, 2010; Kennedy et al., 2010; Ramaswami et al., 2008).

The EU energy and climate package has set goals to reduce GHG emissions by 20% by 2020, with an option to increase the reduction target to 30% if a comprehensive international agreement is reached (Council of the European Union, 2007). In addition, the EU has set targets for renewable energy use and increased energy efficiency. For Finland, the EU obligation is to reduce the GHG emissions from the sectors outside the EU emissions trading system by 16% by the year 2020 from the 2005 level. In order to achieve the EU target, the Finnish Government prepared National long-term Climate and Energy Strategy in 2008 (Ministry of Employment and the Economy, 2008). According to the strategy, Finland's emissions in 2020 would be about 20% above the 1990 levels if new climate policy measures were not carried out. Therefore, achieving the targets requires a wide array of measures in e.g. energy conservation, energy efficiency and renewable energy use in energy, industry and transport sectors. Finland's obligation to increase the share of renewable energy is from the present about 28% to 38% of final energy use by 2020. Also this target is challenging, and achieving it requires that final energy consumption is turned to a declining trend and fossil fuels are replaced by renewable energy.

Finland's ambitious emission targets cannot be achieved without local-level commitment to mitigating climate change. Municipalities are often in a position to make decisions that affect local

* Corresponding author. Tel.: +358 40 543 1476.
E-mail addresses: Suvi.monni@benviroc.fi (S. Monni), sanna.syri@aalto.fi (S. Syri).

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emissions in the short, medium and long term. In particular, municipalities are responsible for land-use and transport planning, building permits, waste management and providing local public transportation services. Some of the municipalities are major local energy suppliers or owners of energy supply companies, even though this role has changed in many cities during the last ten years due to the privatization and liberalization processes of the electricity market in the Nordic countries. The municipalities are also close to the people, and can significantly influence how residents consume, for example by information measures. The municipalities can also promote renewable energy by removing barriers through, for example, land-use planning and building permits which favor renewable energy.

In this article we present the development of a weekly on-line greenhouse gas emission monitoring system for municipalities and cities in Finland, called the CO_2-report. CO_2-report provides timely information of local emissions and their sources for citizens and decision-makers in contrast to the official emissions statistics, which are available on an annual basis 1–2 years afterwards. In Finland, the official annual emissions statistics are compiled by Statistics Finland, and they are published usually in December the following year.

In the present phase of the development of CO_2-report, the information is made available for residents via web pages, which are updated always on Mondays–Tuesdays of the following week. In addition, there are wide further development opportunities, for example using mobile applications. In addition to weekly emission estimates, the system provides an annual advance GHG estimate by municipality, and when the final annual statistics are available, the system calculates the final GHG emission figures for the municipalities. Currently the emissions of 64 municipalities are calculated in the system using the same methodology, covering 58% of population in Finland. This provides a unique dataset of GHG emissions of Finnish municipalities, facilitating understanding of the most important sources of emissions and their mitigation options.

Section 2 describes the methods, data sources and processing of data used in the modeling. Section 3 presents the calculation results, discusses the reasons for differences between municipalities and provides an analysis of uncertainties. Annual emission estimates are presented for all municipalities included and weekly estimates are shown for three examples, Helsinki, Parikkala and Kuhmoinen, which have very differing emission profiles, Helsinki being the capital of Finland, Parikkala being a typical rural community with significant agricultural activity and Kuhmoinen showing the impacts of a large amount of summer cottages in the community.

2. Methods

The calculation model "CO_2-report" calculates weekly emissions for more than 60 municipalities, who have joined to the system, out of about 340 municipalities in total in Finland. The basis of weekly GHG estimates for the year n (for example 2009) is the annual GHG estimate calculated for the latest year for which official statistics are available (year $n-1$ or $n-2$). Based on the weekly indicators described below, the weekly GHG emissions are calculated for each week of year n, which at the end of the year constitute the advance emission estimates for the entire year. When the official statistics are updated for year n (in year $n+2$), the final emission estimates for year n are calculated, and the emissions of all over 60 municipalities are compared.

The methodology corresponds at municipality-level Finland's official methodology of reporting national emissions to the UN FCCC (Statistics Finland, 2010a). The model comprises the three most important greenhouse gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). CH_4 and N_2O emissions are calculated with the global warming potential factors 21 and 310, respectively, as carbon dioxide equivalent (CO_2-eq).

Weekly greenhouse gas emissions are calculated for seven sectors, which are of particular interest for consumers and decision makers at the local level:

- District heating
- Building-specific heating
- Electric heating of buildings
- Other electricity consumption (excluding industry)
- Road transport
- Agriculture
- Waste.

Emissions of industrial activities, other transport modes and emissions and removals from land use may be included in annual reports provided to municipal authorities, but are not included in the weekly statistics.

The CO_2-report calculates the emissions of activities, which occur inside the municipality's geographical boundaries, such as consumption of transport and heating fuels, cultivation of land and animal husbandry. However, the emissions related to energy and waste are allocated to municipalities based on consumption of electricity and heat, and generation of waste and wastewater.

Main data sources, data processing steps and key assumptions by category are summarized in Table 1.

2.1. District heating

Emissions of district heating describe the emissions of production of district heat which is consumed in the municipality. The fuels consumed in district heating are based on the statistics compiled by the Finnish Energy Industries (2010a) and on direct questionnaires for the district heat providers. Emissions from combined heat and power (CHP) production are allocated to electricity and district heat based on the emissions of an alternative (separate) production of heat and electricity (European Union/Covenant of Mayors, 2010). This is a commonly used method in the Nordic countries out of several possible approaches (e.g. Graus and Worrell, 2011).

CO_2 emission factors of fuel use are those compiled by Statistics Finland, and the CH_4 and N_2O emission factors are from the Kasvener model developed at the Finnish Environment Institute (Petäjä, 2007). The fuel-specific emission factors of the Kasvener model are average emission factors by boiler type (e.g. district heat boiler) instead of technology (e.g. grate fired boiler), as in the official GHG inventory.

The weekly variation of emissions from district heating is based on the variation of heating requirement, which is measured by heating degree days. The Finnish Meteorological Institute calculates the weekly and monthly heating degree days at 20 measurement stations across Finland. The heating degree day number is calculated as the daily average difference between the outdoor and indoor temperatures, the indoor temperature being assumed as $+17\ ^{\circ}C$ (the so-called S17 heating degree day). In the CO_2-report we use the measurement station closest to the municipality in concern, and calculate the weekly heating-degree days based on the average heating demand in the municipality compared to the measurement station location.

District heating suppliers of several municipalities provide information on the monthly or annual fuel mix used for district heat production. For the rest of the municipalities, the latest fuel mix in district heating statistics is used as a basis in the weekly calculation of emissions until final statistics are available.