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Cost-benefits of Greenhouse Gas (GHG) activity-based and automated data-gathering

CTT2.0 Carbon Track and Trace

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Table of Contents

Preface

About LoCaL

This report was written through support from Low Carbon City Lab (LoCaL). LoCaL aims to reduce 1Gt of CO2 and mobilize €25 billion of climate finance for cities annually by 2050. It is an innovation platform aiming to provide cities with better tools for assessing greenhouse gas emissions, planning, investing and evaluating progress. Started in 2015, LoCaL is a growing community of more than 20 organisations dedicated to unlocking climate finance for cities. This report was realized as part of the project Closing the Gap through Transformative LoCaL Action (CGTLA) under LoCaL.. LoCaL is a Climate-KIC flagship programme.

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About Climate KIC

Climate-KIC is the EU's largest public private partnership addressing climate change through innovation to build a zero carbon economy. We address climate change across four priority themes: urban areas, land use, production systems, climate metrics and finance. Education is at the heart of these themes to inspire and empower the next generation of climate leaders. We run programmes for students, start-ups and innovators across Europe via centres in major cities, convening a community of the best people and organisations. Our approach starts with improving the way people live in cities. Our focus on industry creates the products required for a better living environment, and we look to optimise land use to produce the food people need. Climate-KIC is supported by the European Institute of Innovation and Technology (EIT), a body of the European Union.

About Carbon Track and Trace

The Carbon Track and Trace (CTT) project is intended to provide cities with real-time greenhouse gas (GHG) measurement capability. Traditional methods of building and maintaining municipal GHG emission inventories are expensive, time-consuming, and are of questionable utility for mitigation decision and planning support processes. CTT couples low-cost, open source sensors to a Big Data analytics platform that provides cities and regions with a unique capacity to directly measure the impacts of their policy and planning decisions and to develop a semi-autonomous system for building, maintaining, and reporting their annual GHG emissions.

CTT Project website: www.carbontrackandtrace.com

Executive summary

This study was produced within the framework of the Carbon Track and Trace (CTT) project as part of the Climate-KIC Low Carbon City Lab (LoCaL) initiative, which is supported by the European Union. CTT provides a sound empirical basis for the development of more advanced greenhouse gas (GHG) emissions inventory methods, including the eventual deployment of autonomous sensors and automated software to reduce the cost and complexity of conducting GHG inventories. Additionally, the project develops improved methods of decision-support and planning-support for municipal mitigation-planning through the integration of cost-benefit assessment and geo-spatial databases.

The purpose of this study is to help close the information gap for cost-benefit analyses, comparing activity-based data with automated, sensor-based emission inventories, both in a short- and long-term perspective. Following this aim, a questionnaire was developed to capture all major costs related to an activity-based GHG inventory corresponding to the "BASIC" level requirements of the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC). Secondly, structural information on data access, reliability and availability per energy sector were collected to develop a picture of the status of real-time versus activity-based data use for municipal inventories and decision-making processes. Thirdly, the questionnaire helps to understand present perceptions and future expectations for the scale of benefits and co-benefits when applying activity- or sensor-based systems to specific energy sectors.

A qualitative survey was conducted with a selection of leading inventory experts from local governments (LGs), energy agencies, LG associations, regional and national authorities, as well as consultancies across Europe, through 16 interviews. The main findings are as follows:

Determining total costs of activity-based inventories

According to this study, in the majority of cases (67%) municipal emission inventories are outsourced in parts, or as a complete package, including the development of Sustainable Energy Action Plans (SEAPs) or Sustainable Energy and Climate Action Plans (SECAPs) as the main planning instruments recommended by the Covenant of Mayors.

Regardless of who conducts a Baseline Emission Inventory (BEI) or Monitoring Emission Inventory (MEI), cities are commonly unable to determine the total costs of such activities. When not outsourced to a third party, the exact use of internal capacities and resources are difficult to identify as specific for BEIs or MEIs. Meanwhile, outsourced inventories still require extra in-house activities and costs, in particular for municipal activity-data gathering and coordination. According to the sample from this survey, the costs of an in-house inventory range from a minimum of 1,000 to a maximum of 20,000 EUR, with an average cost of 12,400 EUR, whereas the costs of an outsourced inventory range from 5,000 to 60,000 EUR.

Internal costs related to municipal technical staff and coordination effort involved in the development of either in-house or outsourced BEIs/MEIs are not specifically tracked and therefore remain an educated guess. About 63% of interviewees could provide estimates on all major internal cost items, while 37% were not able to make monetary specifications.

The development of GHG emission inventories and SEAPs were seen as separate activities, though they share interrelated steps within the overall cyclical process of local energy analysis, action and acceleration. Therefore the separation and distinct determination of municipal technical capacities, and particularly coordination efforts, for each step remain difficult even for those public officials directly involved. About two-thirds (⅔) of the energy experts interviewed approach both activities, and their related costs, in a unified way, but allocate a share of costs exclusively to the activity-based inventory between 52% and 58% of the overall costs, on average.

Technical and coordination efforts for activity-based data gathering depend on the LG's ambition for quality and consistency of BEIs/MEIs. Additional costs are also determined by the political importance and engagement of politicians and other stakeholders. Commonly, at least one (1) politician is involved within an average of eight (8) to fifteen (15) internal meetings for the development of BEIs/MEIs. According to this survey, about four (4) public consultations, with an overall average cost of 3,500 EUR, also take place, serving a complementary purpose to the internal meetings. BEI/MEI-related costs depend on the respective regional, national and/or European funding landscape. With higher-level financing and/or co-financing, there is typically less use of nationally aggregated activity-data to be scaled down to the local level, and instead more municipal GHG emission-data repositories are individually built, maintained and validated.

Depending on the business model for outsourced inventories, total costs might be factored in, and therefore can be fully accounted for only on a medium-term basis, i.e. potentially on a 10 year timeframe. Very related to the type of third party gathering the data, the business model and approach could be categorized as scientific, exploitatory or intrinsic. Though the scientific approach applied commonly by research institutes or local energy agencies is typically the most time- and cost-intensive, it results in an inventory of high quality with bottom-up statistics and is able to be used in a neutral manner. The exploitive approach can be taken by a consultant offering a competitive price at the expense of bottom-up quality by relying on statistical downscaling methods – however, it should be noted that some consultancies still may offer higher quality assessments, thereby seeking to profit from subsequent contracts for services or the implementation of infrastructural measures. Similarly, profit-oriented public utilities may fall into the third category, using detailed statistics due to easier access to their own data (despite deregulated energy markets), and therefore either able to offer data for an inventory at a competitive price, or even for free, in order to maintain/achieve customer loyalty and/or sustain/gain concessions.

Within the sample, almost 40% needed to purchase data to finalise their inventory. The average cost related to such data acquisition was about 775 EUR, with large differences among different countries, for example ranging from 200 EUR in Greece to 2,000 EUR in Spain. Another important point to highlight is the fact that if emission inventories are outsourced, then subsequent monitoring of implemented SEAP (or SECAP) measures is also likely to eventually become a repetitive expense for a LG.

Quality of activity-based data and identifying the potential for sensor-based data collection

Two cities reflected in this survey reported to have used different tools to calculate their emissions over the course of the past years, resulting in major changes to some sectors (e.g. transport), as well as overall. To some extent, this high variability of results compromised the reliability and value of measuring emissions, as well as possibly degrading the possibility of an inventory to be used as a reliable political decision-support tool. Respondents explained the variability of their results as being not only due to the use of different algorithms, but also the input of different datasets into the tool.

Interviewees assessed the level of objectivity of measuring emissions from stationary and waste sectors as high, by 80% and 62% respectively. The transport sector, with 38% evaluated accuracy, received almost the lowest level of objectivity in data measurement, with only the industry and agriculture sectors scoring lower.

According to the sample of this survey, LGs currently have only negligible real-time data availability. Consequently, they are not able to build up neither relevant inventories nor the technical and political decision-making processes related to them. Moreover, the perceived added value and benefit of real-time data availability is considered to be low on average, but with the tendency to obtain a fair potential in residential and commercial buildings for electricity or in institutional buildings and facilities for electricity, heating and cooling.

Outlining monitored benefits and co-benefits of inventories

The majority of LGs quantify and track benefits of implemented measures from activity-based inventories in terms of reduced CO_2 emissions, energy consumption and energy cost savings, as well as the use of renewable energy sources. However, since LGs are having difficulties to precisely determine the total costs of inventories, their total benefit related to the triggered mitigation actions are neither systematically traced nor fully monitored.

Consequently, LGs' assessment of costs and benefits of an activity-based (or sensor-based) inventory is often dominated by uncertainty, and is driven by a political framework and funding conditions rather than by economic analyses and argumentation. This uncertainty can perpetuate itself in the political willingness and ability of LGs (as well as nations) to take ambitious and appropriate climate and energy action. Making such appropriate short- to mid-term decisions could allow LGs to more closely correspond to the pathway of decarbonisation recommended by the *Intergovernmental Panel on Climate Change* (IPCC) in order to have a higher likelihood than a fifty-fifty chance to achieve the target of the Paris Agreement: "Holding the increase in the global average temperature to well below 2°C above pre-industrial […].” This translates into an emission target of 80-95% by 2050, which the European Union has committed to, but also urges for an immediate cut of at least 25 - 40% by 2020.

Only a few LGs monitor the established and added-value chains from increased energy efficiency and/or local renewables, tracking them according to both potential and implemented measures. A financial flow analysis of energy imports/exports as well as expenses/revenues in relation to the BEI and intended actions is conducted only when national funding programmes allow (third parties to cover) this type of assessment. Also, the benefits and co-benefits of realized sustainable energy investments of LGs are rarely quantified, even just for only some levels of a local value chain: production and trade, planning and construction, services and crafts, and operation and refurbishment. Finally, municipal tax revenues from trade, income or rental are not included in overall cost-benefit analyses and monitoring.

Expected benefits and use-cases of sensor-based inventories

According to this survey, the appliance of a comprehensive sensor-based system striving to fully replace activity-based data collection for an entire inventory seems unrealistic to LGs at the moment. However, there is currently a real potential for automated systems to play a complementary or supporting role in specific sectors. For one thing, activity-based inventories are conducted with comparably low costs, according to the survey no higher than 70,000 EUR. Secondly, total costs of fully automated inventories corresponding to the GPC’s "BASIC" level requirements are fairly unknown to most surveyed energy experts, who currently conduct inventories. Furthermore, benefits and co-benefits of activity-based inventories and related measures are neither systematically quantified nor monitored, and so they remain unidentified and miss out on the opportunity to provide arguments in favour of investments not only for more ambitious climate and energy measures, but also for a more advanced data collection system. Finally, only a few LGs in Europe have implemented automated data systems, and even when they do exist, then they data is only fragmentally gathered. Therefore, there remain limited experience with and little consideration given to the potential added value and benefits of concrete use-cases.

Nonetheless, interviewed inventory experts still did find that the most promising and immediate use-cases for complementary automated data gathering are to be found within the transport sector (by 77%) and in residential buildings (by 38%). This is explained due to the non-availability of robust, reliable, local sets of data for on-road transport, while for the building sector, the establishment of an automated system and/or real-time optimisation can result in a high potential for energy savings (up to 20% beyond building energy management schemes), as well as the possibility to gain load flexibility beneficial for the integration of sustainable energy.

In general, the use-cases for a sensor-based solution are perceived as being able to increase, especially since prices for sensors are expected to decrease, while infrastructure more and more combines with and integrates other appliances which are relevant for other issues important to LGs, such as noise, particulate matter or traffic counting.

Introduction

This study is part of a research collaboration between the City of Trondheim, the Norwegian University of Science and Technology (NTNU), and ICLEI – Local Governments for Sustainability. Funding was provided within the framework of the **Carbon Track and Trace (CTT)** project by the Climate KIC Low Carbon City Lab (LoCal) initiative, which is supported by the European Union.

The Carbon Track and Trace project is intended to provide sound empirical basis for the development of more advanced greenhouse gas (GHG) emissions inventory methods, including the eventual deployment of autonomous sensors and automated software to reduce the cost and complexity of conducting GHG inventories. Additionally, the **project helps develop better methods of decision-support and planning support for municipal mitigation planning through integration of cost-benefit analysis and geo-spatial databases**.

Moreover, **CTT aims to develop an automated system for GHG emissions monitoring and reporting**. The system shall enable local governments (LGs) to automatically log and analyse calibrated measurements of their direct GHG emissions from buildings, transport, energy generation, and waste. This data will for the first time **allow cities and communities to develop evidence-based policy for mitigation strategies, linking specific actions and strategies to measured reductions unlocking the potential for significant increases in private capital investments in GHG emission reduction measures**.

The CTT project is divided in two phases. In CCT 1.0, a gap analysis was conducted comparing recommended Global Protocol for Community-Scale Greenhouse Gas Emissions (GPC) inventory methods to current practice in Trondheim Municipality (Driscoll et al. 2016). To address the identified gaps, a general workflow process was produced and evaluated to support the subsequent development of a scalable software platform to automate many of the GHG emission inventory steps, reducing the cost and complexity of city or regional level GHG emissions inventories.

Figure 1: Determined workflow for the development of an automated GHG emission platform in CTT 2.0

CTT 2.0 is developing a network and software system and ran field trials of various types of emissions data collection devices

The CTT project has sub-national governmental entities such as cities, city-regions, and regional governments as main target groups, with **Trondheim Municipality (Norway), South Trondheim Country (Norway) and Vejle Municipality (Denmark)** as local partner, test beds and source of expertise.

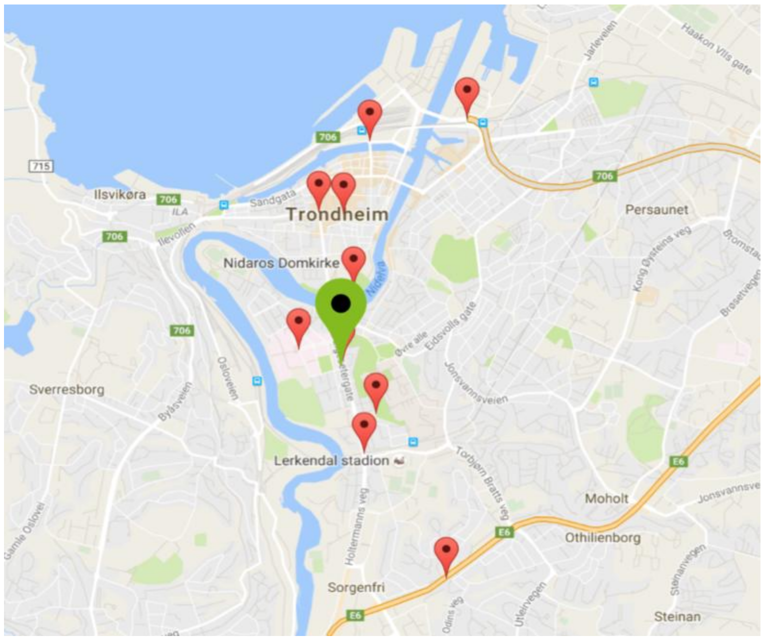

Figure 2: Different measuring points in Trondheim Municipality, Norway

The challenge

We need to wait for the new industry and the Internet of Things to develop it.
(Budapest's 11th District, Újbuda, Hungary)

Since the early 1990s, cities and communities around the world have been pursuing ambitious climate mitigation targets. Unprecedented initiatives like the European ***Covenant of Mayors for Climate and Energy*** and the global ***Compact of Mayors***, bring together local and regional authorities voluntarily committing to implementing climate and energy objectives on their territory. Today the Covenant of Mayors, which started in 2008, counts over 7,100 signatories that committed to reduce CO_2 emissions by at least 20% by 2020 and seek to renew their pledge towards 40% by 2030. Moreover, since 2015 signatories adopted an integrated approach by decarbonising their cities and communities and making them resilient at the same time, providing citizens with access to secure, sustainable and affordable energy.

On 1st January 2017 the ***Global Covenant of Mayors*** was officially launched by merging with the global Compact of Mayors, to capitalise on both initiatives' experience and build upon the key success factors: its **bottom-up governance and reporting, its multi-level cooperation model and its context-driven framework for action**.

However, setting a course towards a low-carbon and resilient city with significant reductions in greenhouse gas emissions demands a precise overview of current emissions to first identify the priority areas for interventions and second to track the success of the interventions over time. The way to formally achieve this overview is to use methods of greenhouse gas accounting to build an accounting inventory of emissions on a city or community level.

The ***Global Protocol for Community-Scale Greenhouse Gas Emissions*** (GPC) seeks to guide GHG accounting by defining a standardized way for cities and regions to calculate and report their GHG emissions in a comprehensive and comparable way. It allows local and regional governments using this consistent standard to:

- Set emission reduction targets,
- Track performance, responding to regulations and requirements of local GHG programmes,
- Build and report GHG inventories which are compatible with international standards,
- Allow horizontal aggregating and vertical integrating city GHG data,
- Provide solid proof of GHG developments for carbon financing.

GPC accounting methods are based upon principles of **relevance, completeness, consistency, transparency, accuracy, and measurability**. With the application of these principals, data quality of the sourced activity data shall be ensured amongst other purposes.

While the GPC provides clear guidance and answers a great part of the accounting challenges, the **CTT project focused particularly on aspects of data quality** concerning fitness for use in terms of accuracy, correctness, and completeness, with a lower interest in timeliness, currency, and provenance in order to **provide options and solutions for the remaining challenges related to individual data gathering, processing and evaluation**.

Moreover, municipal alias bottom-up GHG emission data repositories are resource-intensive and time-consuming to build, maintain, validate, and evaluate. The common **absence of detailed cost-benefit calculations for ex-ante, ex-durante, and ex-post appraisal** means that local and regional governments often **lack a precise and timely understanding of projected or outturn costs and benefits of their mitigation strategies and implemented measures**. Consequently, the political framework drives decisions, but since decisions lack the reflections of financial arguments fed by an added value and cost-benefit analysis of applying energy efficiency measures and increasing the use of local renewable, they are often less ambitious and structurally changing.

The main issues are uncertainty, the **gap between top-down** (downscaling national level statistical data) **and bottom-up** (local and/or real-time data) data, and the data sourcing issue.

Data sets that are collected with inaccuracy or that are not complete become an **obstacle to set up local cost-effective strategies and prioritise resources** for implementing measures aimed at reducing both emissions and costs as well as the related externalities.

The actual method used to measure and assess emissions at local government scale are by large based on an "activity-based" approach i.e. the collection and accounting of data about activities that generate emissions.

CTT has the expectation that the automation of both sensor data and analytics - if and when well built - is able to provide significant scope for cost savings and opens new products and services markets in GHG emissions inventories.

The **purpose of this study is to help close the information gap for the cost-benefit analysis comparing activity data and automated sensor-based emission inventories in the short- and long-term perspective**. Furthermore, the study seeks to capture relevant expertise that allows a more detailed assessment on current and future cost savings due to new products and services for GHG emissions inventories.

Methodology for assessing cost-benefits of activity- and sensor-based inventories

The purpose of this study is to help close the information gap for the cost-benefit analysis comparing activity data and automated sensor-based emission inventories in the short- and long-term perspective.

The methodology of the CTT **cost-benefits study is based on the following documents and chronological stepping-stones** of which some are detailed further on:

1. The GPC served as reference standard to relate costs to a comparable frame for inventories and guide on aspects of data quality and activity-based data gathering (for the second part of this qualitative survey).
2. The "Gap analysis of greenhouse gas (GHG) emissions inventory methods for Trondheim municipality" (Driscoll et al. 2016) of CTT 1.0 already identified the main challenges of activity-based and automated inventories which this study could prioritize in its analysis.
3. Within CTT 2.0 a desktop research was conducted and costs for inventories in Germany, Italy, and Spain were analysed including calls for tender.
4. A pre-survey on cost estimates of BEIs and MEIs was carried out with energy and climate experts renowned within the Covenant of Mayors who are directly involved in activity-based emission inventories in several European countries.
5. Subsequently, a survey was developed to verify and validate the indicative cost estimates with a comprehensive set of questions as well as to capture information on current and future benefits of activity- and sensor-based inventories.
6. Complementary energy experts in Europe were identified and selected with the aim to cover all types of organizations involved in GHG emission inventories and broaden the geographical scope further.
7. Finally, the survey was conducted and its quality assured by feedback loops with the interviewees.

Gap analysis and understanding challenges in municipal greenhouse gas emission inventories

The "Gap analysis of greenhouse gas (GHG) emissions inventory methods for Trondheim municipality", released in January 2016, identifies the gap between the GPC and current GHG inventory methods for the example of Trondheim. The GPC as a benchmark served to identify the main challenges within on-road transportation and residential/commercial energy consumption. Furthermore the gap analysis shows that costs and benefits of inventories remain to some extend unidentified, meaning that commonly cities are neither able to determine the total costs of inventories nor can quantify the direct benefits of mitigation action.

Furthermore the analysis concludes that since emission inventories in Europe are mostly voluntary commitments, decision-making processes on implementing climate action are often cost- and not benefit-driven. Cities also struggle in calculating the investment in terms of time and staff involved. The benefits of implementing mitigation action such as costs savings from energy efficiency and renewable energy are usually calculated up-front, but not measure-specific and introduced as a standard in the monitoring process.

Developing and structuring of the questionnaire

Following the findings of the gap analysis as well as the desktop research and pre-survey, a questionnaire was developed to:

1. Capture all major costs related to an activity based GHG inventory corresponding to the "BASIC" level requirements of the *Global Protocol for Community-Scale Greenhouse Gas Emission* (GPC).
2. Structure information on data access, reliability and availability per energy sector as well as to picture the status of real-time versus activity based data use for municipal inventories and decision-making processes.
3. Understand the present perception and future expected scale of benefits and co-benefits when applying activity or sensor based systems to specific energy sectors.

Capturing total cost for activity based GHG inventories

In its first part, the survey sought to capture from experts the total costs for developing a GHG inventory by gathering information amongst others on the number of municipal climate/energy manager(s) involved, number of other municipal technical staff involved (internal coordination, data sourcing etc.) and number of political leaders involved (council meetings, coordination etc.). The time effort of these three types of categories engaged was measured in person months.

Furthermore the survey was structured to collect also figures about internal meetings, number of external meetings (stakeholder workshops etc.) and logistical costs of internal and external meetings (room, catering etc.) that LGs and/or consultants deemed necessary to develop a solid GHG inventory. Additionally, other costs such as software costs (for accounting, calculation tool etc.) or for acquiring data sets were included in order to map and cover the complete range of relevant aspects with monetary implications.

Moreover, the survey mapped out and differentiated activities related to GHG emission inventories according to in-house and outsourced tasks. Since the activities of developing GHG inventories and SEAPs are closely linked in terms of work effort, the questionnaire sought to separate both steps. Finally, the qualitative study wished to collect the evaluating judgments related to the quality and thus reliability of the inventory produced within the scale of 1 (lowest quality) to 10 (highest quality).

Quality and accessibility of data

The quality and accessibility of data for inventories that are in accordance to the GPC was explored per energy sector, namely: Residential buildings, Commercial buildings, Institutional buildings and facilities, Transportation, Waste, Industrial processes and product use (IPPU) as well as agriculture, forestry and land use (AFOLU), and Other.

For each of the aforementioned categories a set of information was required: Availability of data, Coordination effort needed to collect them, Time intensity to access/calculate data in hrs/person, Data quality, Data source, Real-time data currently available, Real-time data currently used for instant decision-making and inventories, Added value/benefit of real-time data availability and reason. The information had a quality assessment scale for 0 (low quality) to 3 (high quality).

Moreover, the second part of the survey had also three questions that enabled the analysis to reflect the quality of answers by understanding the self-assessed and perceived soundness of the collected data within (each) local government:

- Which activity data can be regarded as objectively measured?
- Did you rely on estimates and educated guesses?
- Where would the installation of sensors be most beneficial to efficiently and accurately measure (direct) emissions?

Benefit of activity based versus sensor based inventories

The third and last part of the survey dealt with the benefits and co-benefits of activity based data collection compared with the expected benefits and co-benefits of a sensor based data gatherings. The analysis covered reflections about energy savings and potential staff effort savings because of sensor based procedures, and focused on the following areas:

- Public and private mobility;
- Private Residential, Commercial, Industrial and Institutional Buildings;
- ICT management;
- Energy grid management.

Selection of interviewees

The developed questionnaire was a means to verify and validate the indicative cost estimates obtained in the pre-survey. The comprehensive set of questions that additionally captured information on current and future benefits of activity and sensor based inventories was targeting participants of the pre-survey, but extending the list of interviewees to reach a broader geographical spread.

The qualitative survey conducted by ICLEI Europe selected 16 leading inventory experts from local governments (LGs), energy agencies, LG associations, regional and national authorities as well as consultancies from 13 different European countries (see Table 1).

Expert	Country	LG	Energy Agency	LG association	Regional	National	Consultancy
Ina Karova	Bulgaria		EA Plovdiv				
Simon J. Loveland	Norway	Trondheim					
Emanuele Cosenza	Italy						SOGESCA
Svante Sjöstedt	Sweden	Gothenburg					
Evi Tzanakaki	Greece					CRES	
Imre Rimóczi	Hungary	Újbuda, BP11					
Marika Rošā	Latvia						Ekodoma
Miguel Morcillo	Spain			Climate Alliance			
Patrycja Plonka	Poland						PNEC
Florin Andronescu	Romania		ALEA				
Luigino Acquaviva	Italy			S.G. Vesuviano			
Carme Melcion	Spain				OTCCS		
Boris Schønfeldt	Denmark	Vejle					
Erika Meynaerts	Belgium				VITO		
Kostas Komninos	Greece		Ios Aegean EA				
Petteri Huuska	Finland	Helsinki					

Table 1: Experts involved per type of organization and geographical spread

Survey and quality check

The survey was conducted mostly through a present or phone interview. The completed questionnaire was subsequently shared with the interviewee to confirm, correct or extend captured answers. Through this second review, the quality of the survey, deemed of primary importance for the most accurate and reliable results, was assured. The applied process and quality check helped not only to strengthen the validity of the results and ensured transparency, but also emphasized the qualitative character of this survey which due to the smaller amount of interviewed persons cannot be used for statistical purposes, but gives a qualified overview of the state-of-the-art on the possible transition from activity based to automated GHG inventory systems.

Determining total costs of activity-based inventories

Cost knowledge samples

First, basic knowledge about occurring costs for conducting an inventory and developing a SEAP was gathered through a sample analysis of local and regional offers for service as well as calls for tenders on inventories that were issued in 2013 and 2014. Basic elements of the latter are briefly outlined here under.

Funding contributions given by regional and other intermediate public bodies to local governments to develop inventories and/or SEAPs vary considerably, as the following overview shows:

First, the tender (DDG 2013) in **Regione Sicilia**, Italy, outlines that LGs receive different contributions according to the number of inhabitants:

- For municipalities with less than 5,000 inhabitants a flat rate contribution of 7,500 EUR plus 1.00 EUR per inhabitant applies;
- For municipalities with a population between 5,000 and 30,000 a flat rate contribution of 10,500 EUR plus 0.90 EUR per inhabitant applies;
- For municipalities with a population between 30,000 and 100,000 a flat rate contribution of 12,500 EUR plus 0.80 EUR per inhabitant applies;
- For municipalities with a population higher than 100,000 inhabitants a flat rate contribution of 15,500 EUR plus 0.70 EUR per inhabitant applies.

With this approach, small municipalities (max 5,000 inhabitants) received contributions of 7,000 to 12,500 EUR, small to mid-sized municipalities (5,000 to 30,000 inhabitants) 14,500 to 76,500 EUR, big-sized municipalities (30,000 to 100,000 inhabitants) 37,500 to 76,500 EUR and cities (more than 100,000 inhabitants) 97,000 to 474,000 EUR to develop an activity based inventory and a SEAP.

A tender (DGR 2014) in the same country, in North Italy for Regione Emilia Romagna granted contributions to local governments to support the development of inventories and SEAPs using the following categories:

- Number of inhabitants < 10,000: 3,000 EUR;
- Number of inhabitants between 10,001 and 30,000: 5,000 EUR;
- Number of inhabitants > 30,001: 7,000 EUR.

In Spain the provincial government **Diputacion Provincial de Zaragoza**, issued a tender (AL 2014) for supporting four groups consisting of overall 60 municipalities in the development of activity based inventories and SEAPs with the overall budget of 51,405.64 EUR (incl. VAT) based on the following quantitative elements:

- Assessment of the number of hours needed to finalise the work for municipalities with less than 3,001 inhabitants: 47 hours;
- Assessment of the hourly rate: 28 EUR (excluding VAT);
- Assessment of expenses for each municipality: 71 EUR (excluding VAT);
- Assessment of documentation, material, phone costs etc. for each of the four batches: 225 EUR.

In addition to these cost samples, a pre-survey on cost estimates of BEIs and MEIs was carried out with energy and climate experts during the course of a workshop on “Local Energy Data Collection for SEAP development” organized by the Covenant of Mayors on 17 June 2016. The experts that participated are directly involved in activity based emission inventories in various European countries. They were asked to provide cost estimates for an activity based BEI and MEI for a city of 50.000 inhabitants. Table 2 summarises their estimation.

Country	Italy	Slovenia	Italy	Spain	Greece	France	Bulgaria
Single, some or multiple experienced... of previously built inventories (benefiting from scale)	Multiple (consultant)	Some (energy agency)	Some (public authority association)	Multiple (regional authority)	Multiple (national authority)	Multiple (regional authority)	Multiple (consultant)
Baseline Emission Inventory (Complete inventory according to CoM) (estimated €)	5.000,00 €	8.000,00 €	5.000,00 €	6.000,00 €	15.000,00 €	30.000,00 €	10.000,00 €
Monitoring Emission Inventory (emission inventory of implemented actions only - according to CoM) (estimated €)	10.000,00 €	8.000,00 €	9.000,00 €	3.500,00 €	5.000,00 €	10.000,00 €	12.000,00 €

Table 2: Activity based inventory cost estimates for a city of 50.000

Main cost findings of survey

According to this study, in the majority of cases (67%) municipal emission inventories are outsourced in parts or as a complete package including the development of *Sustainable Energy Action Plans* (SEAPs) or *Sustainable Energy and Climate Action Plan*s (SECAPs).

Respective costs were classified in five categories: in-house activities (overall municipal staff effort), activity data purchase, outsourcing of the inventory, logistical and other costs, software purchase (Figure 3). All identified costs outlined hereunder relate to an initial Baseline Emissions Inventory. The time needed to complete this type of inventory ranges from 3 to 12 months. It is worth noting that if emission inventories are outsourced, monitoring of implemented SEAP (or SECAP) measures becomes eventually a repetitive external cost for a LG.

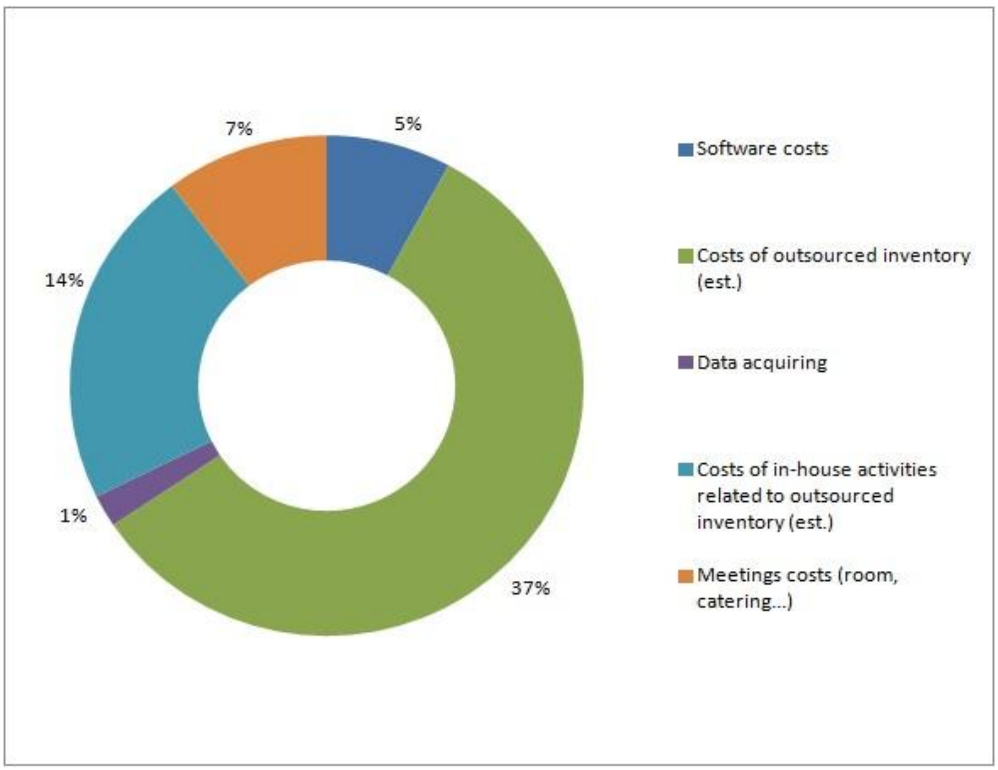

Figure 3: Overall costs shares of an outsourced BEI

The development of GHG emission inventories and Sustainable Energy Action Plans were seen as separate, but interrelated steps within the overall cyclical process of local energy analysis, action and acceleration. Therefore the distinct separation and determination of municipal technical and in particular coordination efforts for each step remain difficult even for public officials directly involved. About two-thirds (2/3) of the energy experts interviewed approach both activities and related costs in a unified way, but allocated the percentage of costs connected exclusively to the activity based inventory on average between 52 to 58% of the overall costs.

Commonly and due to the procurement process, cities are able to determine the total costs of a *Baseline Emission Inventory* (BEI) or *Monitoring Emission Inventory* (MEI) when outsourced to a third party.

Outsourcing inventories requires extra costs for in-house activities and in particular for municipal activity data gathering and coordination. These costs add up to an average of about 12,500 EUR for a BEI/MEI, but with a major spread among different countries starting with 1,000 EUR in Latvia to 35,000 EUR in Norway.

According to the sample of this survey, the costs of an inventory entirely produced by municipal staff can range from a minimum of 1,000 to a maximum of 20,000 EUR, with an average cost of 12,400 EUR, whereas the costs of an outsourced inventory range from 5,000 to 60,000 EUR.

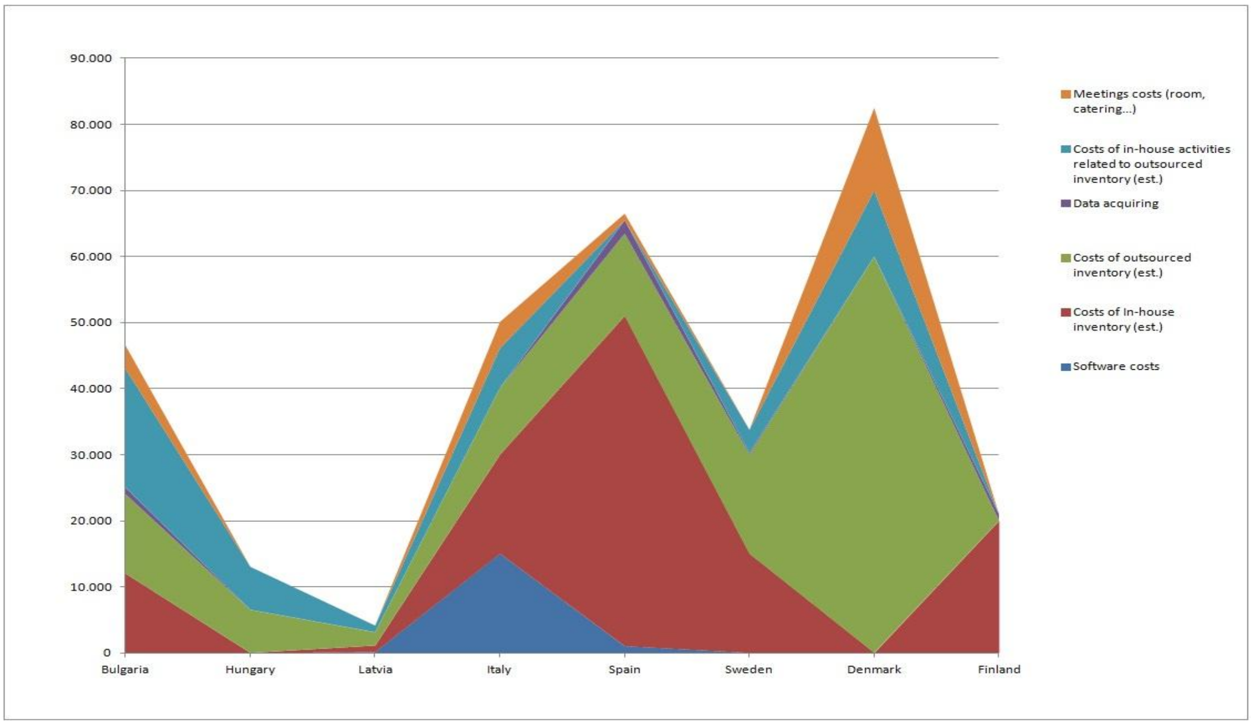

Figure 4: Variety of outsourced inventory costs for selected countries

Figure 4 illustrates the variety of overall costs for an outsourced BEI, as gathered in the surveys and reported in the legend. Results show plainly that the cost for acquiring data is minimal or nil. Indeed the average costs for data purchasing have been accounted to 775 EUR, although few of the surveyed samples had the need of acquiring data. Another clear element is that there are LGs that use outsourcing with little to no costs for in-house activities and LGs that have significant costs both for in-house and outsourced activities (eg. Spain). Software costs incur only in one case out of the sample. There are only slight cost difference for conducting an BEI in Northern Europe and Southern Europe cities, whereas these costs are considerably lower in eastern Europe countries (with big differences depending on country).

Internal costs related to municipal technical staff and coordination effort involved in the development of either in-house or outsourced BEIs/MEIs are not specifically tracked and therefore remain an educated guess. About 63% of interviewed could provide estimates on all major internal cost items, while 37% were not able to make monetary specifications.

The average amount of allocated of staff (technical staff, municipal coordinators and politicians effort) to generate a GHG emission inventory was identified. The average of two (2) persons of the municipal technical staff is involved with on overall engagement of 3.3 person months. The average number of municipal staff engaged in the coordination of the activity data gatherings and related activities are about 3.5 and aggregate staff capacity of about 2.7 person months. It is apparent there is a higher need for coordinators than for officers to develop a local GHG emission inventory, although with less active involvement. The average number of political staff involved seems high at 2.5 persons, but binds overall less than one (1) person month. Municipal staff data shows an even distribution across the countries surveyed, with the exception of Gothenburg who had higher shares for coordination.

Technical and coordination efforts for activity based data gathering depend on the LG's ambition for quality and consistency of BEIs/MEIs. Additionally, costs are also determined by the political importance and thus engagement of politicians as well as stakeholders. Commonly, at least one (1) politician is involved within the average of eight (8) to fifteen (15) internal meetings for the development of BEIs/MEIs. According to this survey, about four (4) external meetings with the overall average costs of 3,500 EUR take place with the same purpose.

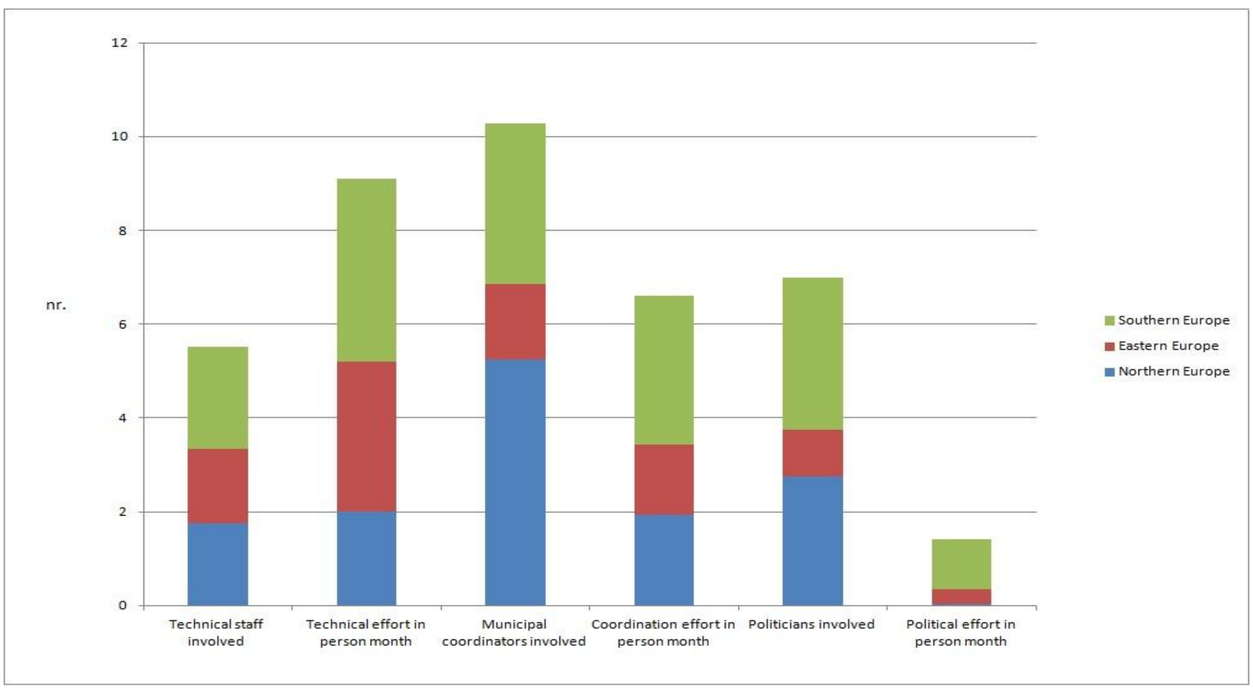

Figure 5: Technical staff, municipal coordinators and politicians' effort involved in a BEI on average

The aggregation of geographical areas (Southern, Eastern and Northern Europe) in Figure 5 helps to differentiate characteristics according to territorial level. A relatively higher number of politicians are involved in the process in Southern Europe compared to Northern Europe, but the time effort in both areas is similar. A lower number of politicians are engaged in Eastern Europe.

Municipal coordinators engage at significantly higher numbers in Northern countries, indicating that different departments are involved more intensively than in the other geographical areas of Europe.

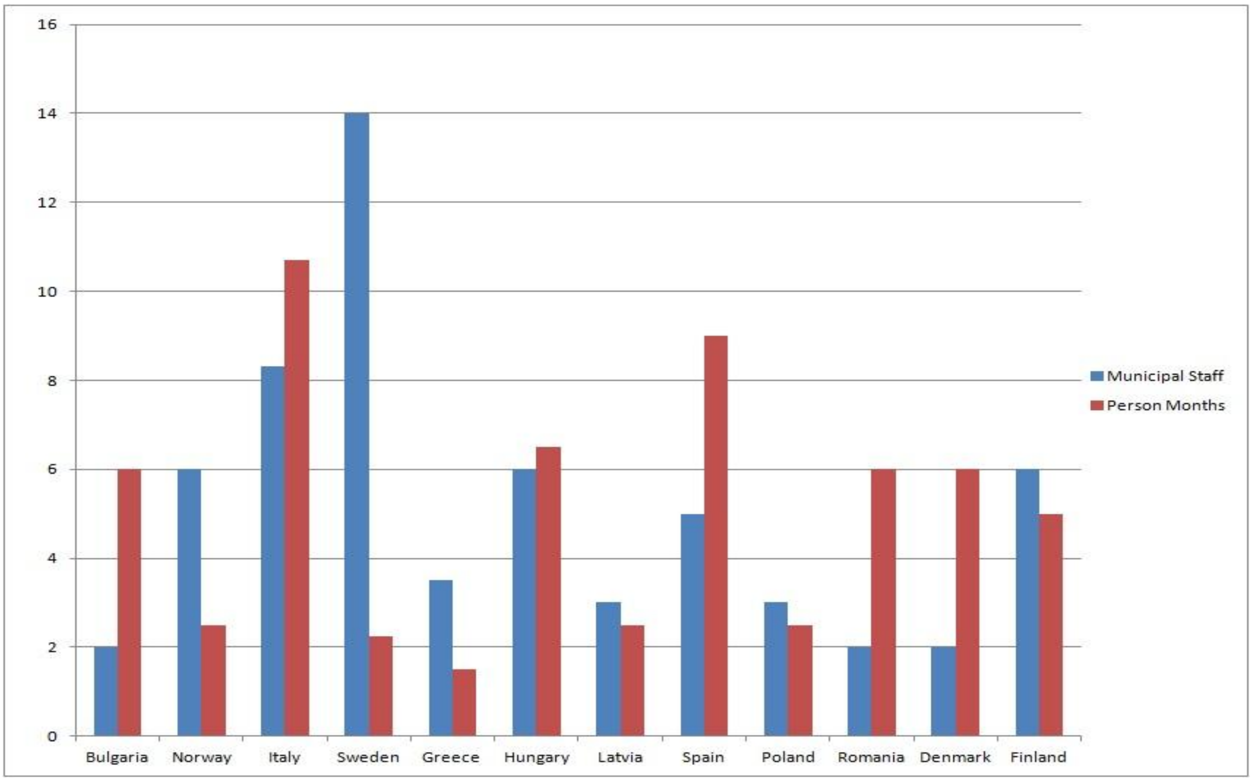

Figure 6: Municipal staff (technicians and coordinators) effort in person months per country

Figure 6 reports the municipal staff involved, both technical and with coordinating roles. Results indicate a balance between countries that engage a high number of staff (defined as more than 4), but with less time effort, and those that involve a lower amount of staff, but with a higher dedicated time.

Figure 7 shows the number of persons - and the relative effort in person month - involved in the development of a BEI, separated between technical staff, municipal coordinators and politicians and disaggregated between the surveyed nations. The figure illustrates that there is a considerable variation in the staff effort engaged across nations. A common trend can nevertheless be highlighted: the amount of technical staff allocated is lower than of municipal coordinators as well as politicians, however, the effort charged to the technical staff is higher. Municipal coordinators are involved in high numbers, but with lower time intensity if compared to the other two categories.

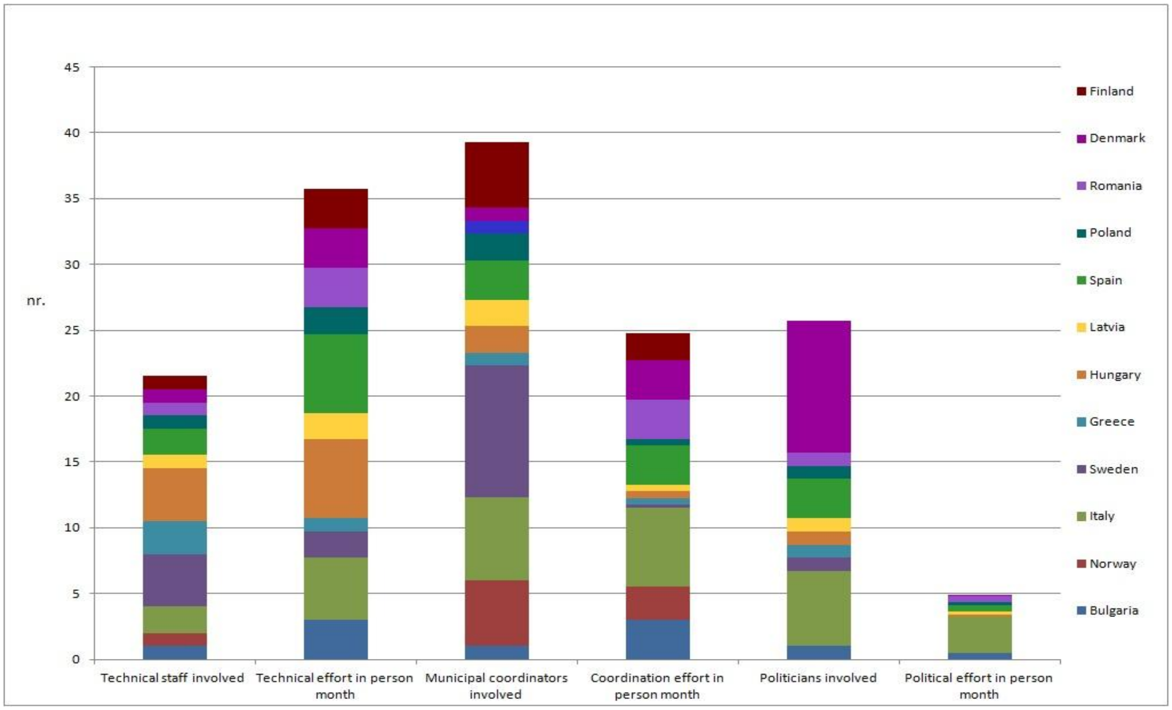

Figure 7: Technical staff, municipal coordinators and politicians' effort accumulated per country

BEI/MEI related costs depend on the respective regional, national and/or European funding landscape. The higher the finance and co-finance, the less Budapest's 11th District, Újbuda merely nationally aggregated activity data is scaled down to the local level and the more municipal GHG emission data repositories are individually build, maintained and validated.

Depending on the business model for outsourced inventories, the total costs might be factored in and therefore can be fully accounted only on a mid-term basis. Very related to the type of third party conducting the data gathering, the business model and approach could be categorized into scientific, exploitatory or intrinsic. The scientific approach applied by e.g. a research institute or local energy agency is typically the most time and cost intensive, while resulting in an inventory of good quality with bottom up statistics and neutral use. The exploitive approach can be taken by a consultant that seeks to offer a competitive price, but at the expense of bottom-up quality and reliance on statistical downscaling. However, some consultancies offer high quality, but seek to profit from the contract of subsequent services or implementing infrastructural measures. Similarly, public but profit-orientated utilities may fall into the third category, using local statistics due to easier access to data (despite deregulated energy markets) and putting forward a competitive price for an inventory or even providing energy data for free in order to maintain or achieve customer loyalty and sustain concessions.

The quality of GHG emission inventories produced entirely through municipal staff or consultants was assessed as similar and both were well ranked with an overall 7.5 out of 10 points (being 0 the lowest and 10 the highest ranking).

Quality of activity-based data and identifying the potential for sensor-based data gathering

The most important sector for real time data is the residential, in particular with its heating component, because it is there we pay more.
(Budapest's 11th District, Újbuda, Hungary)

Two cities reflected in this survey reported to have used different tools to calculate their emissions over the course of the past years. This resulted in changes in the overall emission figures as well as in specific sectors like transportation. The experience of the high variability of results compromised to some extent the reliability and value of measuring emissions as well as the possibility of an inventory to be used as a reliable political decision support tool. Responders explained the variability of results due to not only the use of different algorithms, but also the input of different data sets into the tool.

Interviewees assessed the level of objectivity of measuring emissions from stationary and waste sectors as high and good by respectively 80% and 62%. The transportation sector with 38% evaluated accuracy received the lowest level of objectivity in data measurement except for industry and agriculture (see Table 3).

	Which activity data can be regarded as objectively measured? (%)	**Did you rely on estimates and educated guesses?** (% of positive responses)	**In which sector would the installation of sensors be most beneficial to efficiently and accurately measure direct emissions?** (%)
Residential buildings – Electricity	69%	40%	38%
Residential buildings - Heating	62%	50%	38%
Commercial buildings - - Electricity	85%	40%	23%
Commercial buildings - - Heating	77%	50%	23%
Institutional buildings and facilities - Electricity	92%	25%	31%
Institutional buildings and facilities - Heating	85%	38%	31%
Transportation	38%	80%	77%
Waste	62%	50%	8%
Industrial processes and product use(IPPU)	15%	60%	8%
Agriculture, forestry and land use (AFOLU)	15%	83%	n.a.
Average	60%	52%	31%

Table 3: Responses of interviewed energy experts on data reliability and potential for direct measuring

The use of aggregated data and consequently the appliance of estimates and educated guesses vary between emission sources. While interviewed experts on average relied to about 80% on estimates in the transportation sector, electricity in institutional buildings and facilities were subject to estimated calculations of about one-fourth only. In regards to the overall development of a BEI about 52% of the activity data involved some estimations.

77% of the interviewees expressed their desire to install sensors in order to measure direct emissions and acquire more accurate data for the transport sector. The second highest score was allocated to the building sector. However, in general the perceived need for sensors was assessed with overall 31% as moderate.

*none (0), low (1), medium (2), high (3)	Availability of data*	Coordination effort needed*	Time intensity to access/ calculate data (in hours)	Data quality according to GPC*	Real-time data currently available *	Real-time data currently used for instant decision-making and inventories*	Added value/ benefit of real-time data availability*
Residential buildings - Electricity	2,62	2,08	14	2,00	0,31	0,18	1,83
Residential buildings – Heating	2,31	2,25	45	1,92	0,23	0,18	1,75
Commercial buildings - - Electricity	2,69	2,17	15	2,15	0,46	0,36	1,75
Commercial buildings - - Heating	2,38	2,25	20	2,00	0,38	0,36	1,75
Institutional buildings and facilities - Electricity	2,77	2,08	20	2,69	0,62	0,55	1,92
Institutional buildings and facilities - Heating	2,62	2,17	32	2,62	0,38	0,36	1,83
Transportation	2,15	2,33	45	1,85	0,15	0,18	1,73
Waste	2,45	2,27	30	2,64	0,38	0,30	1,75
Indutrial processes and product use(IPPU)	1,30	1,90	55	1,17	0,29	0,33	1,17
Agriculture, forestry and land use (AFOLU)	1,36	1,70	44	1,29	0,29	0,33	1,00
Average	2,27	2,12	32	2,03	0,35	0,31	1,65

Table 4: Average scoring of activity and sensor based data gatherings on selected aspects

Currently, according to the sample of this survey, LGs have real-time data available close to zero (see Table 4). Consequently, they are not able to build up related inventories or technical and political decision-making processes. Moreover, the perceived added value and benefit of real-time data availability is considered to be on average low, but with the tendency to obtain a fair potential in e.g. residential and commercial buildings for electricity or in institutional buildings and facility for electricity, heating and cooling.

The availability of activity data is assessed to be high for the stationary energy and waste sectors, and is considered medium for the transportation sector and is reported low for Industrial Processes and products Use (IPPU) and the Agriculture, Forestry and Land Use (AFOLU). In spite of the high availability of activity data, nearly 30% of sampled don´t measure GHG emissions from waste.

The average time intensity to access and calculate emissions from provided activity data for each category is 32 hours. Data from commercial and institutional buildings require the least time-intensive process, while other sectors such as transportation and industry need more effort. A possible comparison to the Workflow analysis of greenhouse gas (GHG) emission inventory methods for Trondheim municipality - which contains some details about possible workflow for sourcing, estimating, processing activity data - can be foreseen.

Data quality according to the GPC is considered average in stationary and waste sector and low in mobility, IPPU and AFOLU.

Monitored benefits and co-benefits of inventories

In Poland the public discussion is not on GHG. It is not a political priority. The priority is air quality.

(Polish Network Energie Cités)

Still too few LGs have conducted a thorough analysis to understand the full set of direct and indirect benefits associated with the development of GHG emission inventories, and identified and prioritized measures outlined in the SEAPs/SECAPs. This situation is reflected by the level of detailed responses from the interviewees who were in most cases not able to provide specific and quantified answers to neither the activity nor sensor based approach. In general, LGs seek to identify and monitor benefits of implemented measures due to activity based inventories in terms of reduced CO_2 emissions, energy and energy cost savings as well as use of renewable energy sources.

Moreover and in particular related to automated systems, there is a general lack of awareness, experience and information about the potential opportunities that automated systems can generate for BEIs/MEIs and climate and energy policies. According to this survey, skepticism on potential automated inventories for guiding local governments' policies exist in particularly in the Northern parts of Europe, where the discussion on automated data has started earlier in comparison to Southern Member States of the Europe.

Activity based inventories have a timeframe of one (1) year and are performed once every 2-4 years. The possibility of having real-time automated data is assessed as potentially useful for the stakeholder involvement process and access to data, but not as a political tool.

Costs and opportunities of activity based data collection versus automated data gatherings are still far from being entirely understood by LGs and thus the latter is not yet part of the technical process of BEI/MEI development. Therefore potential benefits could hardly be assessed in monetary or even energetic terms.

There are both pros and cons to activity based and automated based inventories. Developed experiences of municipal technical staff, but also technological and budgetary limitations of LGs have led to the current and dominating type of inventory that is conducted based on activity data. Automated data managed in a centralized way is assessed as most beneficial for the monitoring of the transportation sector and even more so when combined with other data gatherings such as traffic counts, level of noise or air quality measurements. Secondly, the building sector was perceived as the most promising sector to apply automated systems. While in the transportation sector benefits are associated mainly with an increase of data quality and reliability, in the building sector the high potential for energy savings through instant and automated regulation is the dominating benefit.

Conclusion

Real time data availability supports the reduction of consumption… and more than this, it opens data sharing.

(City of Thessaloniki, Greece)

The majority of LGs quantify and track benefits of implemented measures from activity-based inventories in terms of reduced CO_2 emissions, energy consumption and energy cost savings, as well as the use of renewable energy sources. However, since LGs are having difficulties to precisely determine the total costs of inventories, their total benefit related to the triggered mitigation actions are neither systematically traced nor fully monitored.

Consequently, LGs' assessment of costs and benefits of an activity-based (or sensor-based) inventory is often dominated by uncertainty, and is driven by a political framework and funding conditions rather than by economic analyses and argumentation. This uncertainty can perpetuate itself in the political willingness and ability of LGs (as well as nations) to take ambitious and appropriate climate and energy action. Making such appropriate short- to mid-term decisions could allow LGs to more closely correspond to the pathway of decarbonisation recommended by the *Intergovernmental Panel on Climate Change* (IPCC) in order to have a higher likelihood than a fifty-fifty chance to achieve the target of the Paris Agreement: "Holding the increase in the global average temperature to well below 2°C above pre-industrial […]." This translates into an emission target of 80-95% by 2050, which the European Union has committed to, but also urges for an immediate cut of at least 25 - 40% by 2020.

Only a few LGs monitor the established and added-value chains from increased energy efficiency and/or local renewables, tracking them according to both potential and implemented measures. A financial flow analysis of energy imports/exports as well as expenses/revenues in relation to the BEI and intended actions is conducted only when national funding programmes allow (third parties to cover) this type of assessment. Also, the benefits and co-benefits of realized sustainable energy investments of LGs are rarely quantified, even just for only some levels of a local value chain: production and trade, planning and construction, services and crafts, and operation and refurbishment. Finally, municipal tax revenues from trade, income or rental are not included in overall cost-benefit analyses and monitoring.

Expected benefits and use cases of sensor based inventories

According to this survey, the appliance of a comprehensive sensor-based system with the purpose to fully replace an activity-based data gathering and a complete inventory seems unrealistic to LGs at the moment, but with room for complementary or supporting approaches and in specific sectors. This is mainly due to four facts:

1. Activity based inventories are conducted with low costs and (in case of the survey) not higher than 70,000 EUR.
2. Total costs of potentially fully automated inventories corresponding to the "BASIC" level requirements of the GPC are fairly unknown to the energy experts currently conducting inventories.
3. Benefits and co-benefits of activity based inventories and related measures are not systematically quantified and monitored, remain unidentified and therefore don't provide arguments for investments not only for more ambitious climate and energy measures, but also for a more advanced data gathering system.
4. Only a few LGs in Europe have implemented automated data systems and if so, only fragmentally. Thus there is limited experience and reflection about the added value and benefit of concrete use cases.

However, inventory experts that were interviewed did see the most promising and immediate use cases for automated data gathering by 77% within the transport sector and by 38 % in residential buildings. This is explained due to the non-availability of robust, reliable, local sets of data for particularly on-road transport, while at the same time emissions from this sector are the fastest growing and in most urban areas can account for one-fourth to one-third of the overall GHG emissions. Moreover, the recent scandals about the manipulation of exhaust gases from vehicles by several car manufactures, together with studies quantifying that the gap between official and real-world CO_2 emission has increased from 9% in 2001 to 42% in 2015 in Europe (ICCT 2016), may encourage a number of LGs to establish very soon their own measuring infrastructure.

Secondly, automated systems are likely to be increasingly established in the building sector, because of the high potential for energy savings and the possibility to gain load flexibility for sustainable energy, when an automated system is established and real-time optimization can take place. Today the building sector is responsible for about 42% of the European energy consumption, but at the same time, has the potential to save energy by appropriate building operation management from 5 – 30% (Building EQ Report). This applies particularly to the public building stock. Moreover, recent piloting of web-based integrated energy data systems in cities like Sant Cugat, Savona, and Zanstaad demonstrated that short-term decision-making on energy planning is able to reduce energy consumption, CO_2 emissions, and energy cost beyond Building Energy Management Schemes up to 15 – 20% (OPTIMUS 2016).

In general, the use-cases for a sensor-based solution are perceived as being able to increase, especially since prices for sensors are expected to decrease, while infrastructure more and more combines with and integrates other appliances which are relevant for other issues important to LGs, such as noise, particulate matter or traffic counting.

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